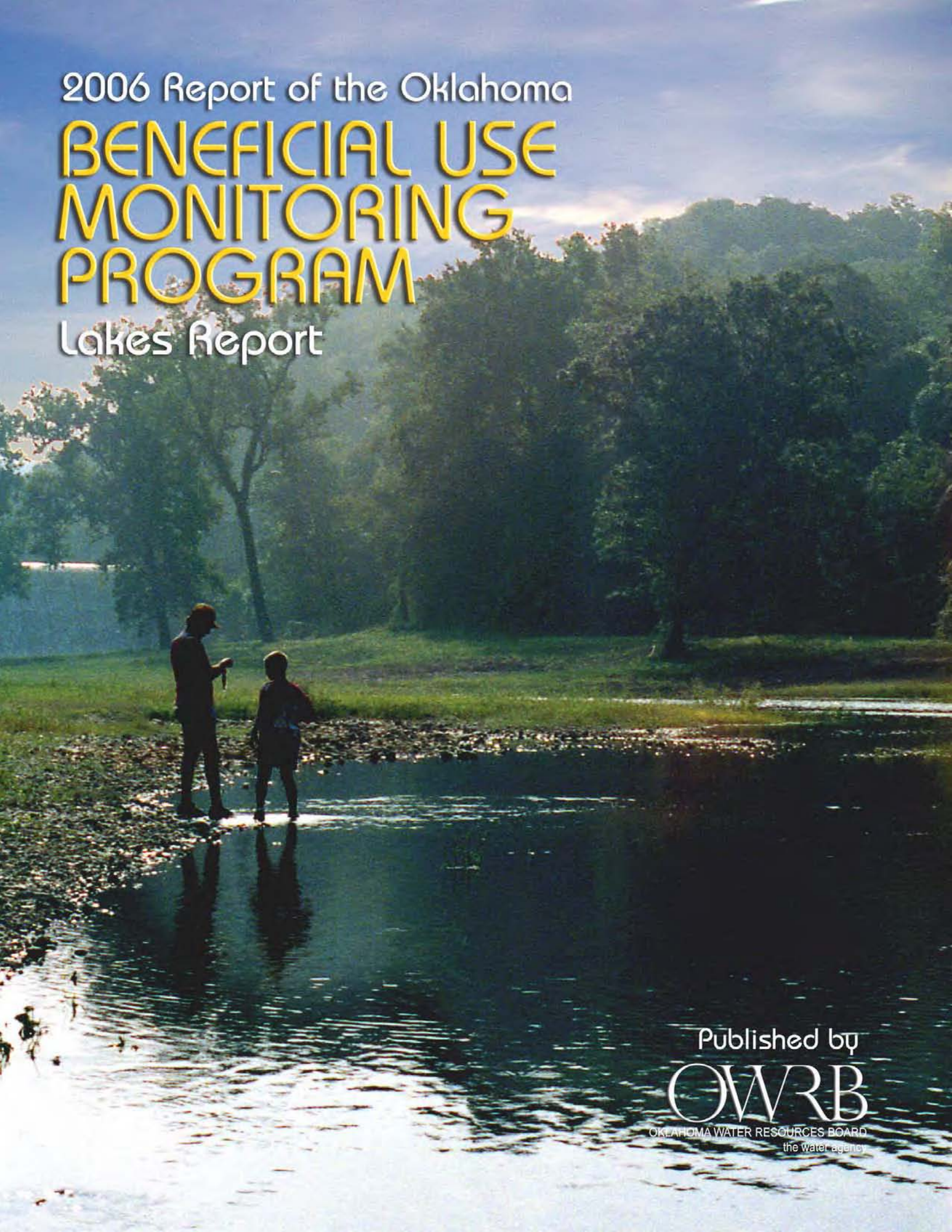
2006 Report of the Oklahoma

BENEFICIAL USE MONITORING PROGRAM

Lakes Report



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EXECUTIVE SUMMARY

Beneficial Use Monitoring Program Goal:

The goal of the Beneficial Use Monitoring Program is to document beneficial use impairments, identify impairment sources (if possible), detect water quality trends, provide needed information for the WQS, and facilitate the prioritization of pollution control activities.

The Beneficial Use Monitoring Program exists as a result of the vital economic and social importance of Oklahoma's lakes, streams, wetlands, and aquifers and the associated need for their protection and management. The data contained in this report is scientifically defensible and has been collected and analyzed following procedures outlined in Use Support Assessment Protocols (USAP), developed by Oklahoma Water Resources Board with input and concurrence of Oklahoma's other environmental agencies. Specifically, USAPs establish a consistent method to determine if beneficial uses assigned for individual waters through Oklahoma Water Quality Standards (WQS) are being supported. The legitimacy of data analyzed following protocols other than those outlined in the USAP (or the Oklahoma Continuing Planning Process (CPP) document where the USAP is silent) for use support determination is not appropriate. If the BUMP report indicates that a designated beneficial use is impaired, threatened, or otherwise compromised, measures must be taken to mitigate or restore the water quality.

The Oklahoma Water Resources Board (OWRB) has worked diligently to follow the guidelines outlined in the USAP. Recommendations in this report should be consistent with recommendations for the state's 303(d) list. Although certain inconsistencies do exist, every effort has been taken to assure compatibility between the BUMP Report and the 303(d) list. Issues regarding stream/lake segmenting additional data from non-BUMP sources and unique non-representative conditions all affect the impairment decision-making process

Traditionally, the State of Oklahoma has utilized numerous water monitoring programs conducted by individual state and federal agencies. In general, each environmental agency designs and implements its own program with only limited participation from with other state, municipal, or federal entities. These programs collect information for a specific purpose or project (e.g., development of Total Maximum Daily Loads, WQS process, lake trophic status determination, water quality impact assessments from non-point and point source pollution, stream flow measurement, assessment of best management practices, etc.). Therefore, the information is specific to each project's data quality objectives (DQOs) and is often limited to a very small geographic area.

To synchronize Oklahoma's monitoring efforts related to water quality, the State Legislature appropriated funds in 1998 to create the Beneficial Use Monitoring Program under the direction of the Oklahoma Water Resources Board, who promulgates the WQS and WQS Implementation Rule. The BUMP brings the OWRB's overall water quality management program full circle. From the promulgation of WQS, to permitting and enforcement of permits stemming from WQS-established criteria, to non-point source controls, all agency water quality management activities are intended to work in concert to restore, protect, and maintain designated beneficial uses.

The specific objectives of the BUMP are to detect and quantify water quality trends, document and quantify impairments of assigned beneficial uses, and identify pollution problems before they become a pollution crisis. This report interprets current Oklahoma Lake data collected as part of the comprehensive, long-term program. As the program has matured, the BUMP report has become one of the most important annually published documents in Oklahoma.

BENEFICIAL USE MONITORING PROGRAM COMPONENTS

- **Monitoring Rivers & Streams** - The OWRB is currently monitoring approximately one hundred thirty (130) stations on a monthly basis. These sites are segregated into two discrete types of monitoring activities. The first monitoring activity is focusing on fixed station monitoring on rivers and streams and the second monitoring activity focuses on a number of sample stations whose location rotate on an annual basis. The two monitoring components are explained below.

    - **Fixed Station Monitoring on Rivers & Streams** - - Fixed station monitoring is based largely upon the sixty-seven (67) United States Geological Survey 8-digit hydrologic unit code (HUC) basins present in Oklahoma. In general, at least one (1) sample station was located in all of the HUC watersheds with the exception of some of the smaller HUC watersheds adjacent to the state line or in a HUC that does not contain a free flowing stream at some point during the year. After consultation with the other state environmental agencies and over time the OWRB has identified one hundred seventeen (117) fixed stations of which one hundred (100) are currently being monitored.

    - **Rotating Station Monitoring on Rivers & Streams** - Over the life of the BUMP, rotational sampling has occurred on over two hundred twenty (220) stream segments. Sample stations and variables monitored are based upon Oklahoma's 303(d) list and input from other state environmental agencies on their monitoring needs. Variables monitored as part of this program component are specific for each stream segment monitored

- **Fixed Station Load Monitoring** – The OWRB is currently working with several partners including the USGS, US Army Corp of Engineers, Grand River Dam Authority, and National Weather Service to conduct flow monitoring on all of our fixed station sites that are not part of the Oklahoma/USGS Cooperative Gaging Network. This cooperative effort will allow for loadings to be calculated, trends to be assessed statewide, and provide much needed data for the Use Support Assessment process.

- **Fixed Station Lakes Monitoring** - Quarterly sampling (approximately once every 90 days) of approximately 40-45 lakes annually is currently occurring. In general, a minimum of three stations per reservoir, representing the lacustrine zone, transitional zone, and riverine zone, are designated for sampling at each lake, with additional sites sampled as needed. Additional water quality parameters and lake sites were added to the lake sampling program in 2001 to aid in making use support determinations.

- **Fixed Station Groundwater Monitoring** - Limited monitoring as part of this task has occurred in the program. Results of monitoring are presented in this report. OWRB staff has

made recommendations in this report related to the scope and magnitude of groundwater monitoring activities that the state should pursue in the future. Any proposed groundwater monitoring efforts will be coordinated with the Oklahoma Department of Environmental Quality (ODEQ).

- **Intensive Investigation Sampling** - Although no funding was made available for this element of the program, it is important that waters identified as impaired be restored. If routine monitoring identifies impairment, then an intensive study will be undertaken to document the source of the impairment and recommend restorative actions if possible. This task will not be conducted in year one or year two of the program, but thereafter, intensive investigations will be conducted as warranted. If water bodies are not identified for intensive study as part of this task, then monies will be reallocated to Tasks **1** and **3**. Other entities (i.e., tribal or governmental units outside of Oklahoma) are involved as circumstances dictate or allow.

PROGRAM HISTORY/OVERVIEW

Sampling of the numerous lakes, streams, and rivers across this state was initiated in the summer and fall of 1998. Lake sampling in connection with the Beneficial Use Monitoring Program began in July of 1998. Sampling on numerous streams and rivers began in earnest in November of the same year. The two sampling programs, one for lakes and one for streams, had separate starting dates for a number of reasons. First, the OWRB has been conducting a lake-sampling program during the warmer summer months since 1990 as part of the Federal Clean Lakes Program. This historical lake sampling program was funded through federal dollars with the express purpose of determining lake trophic status. The trophic status of a reservoir can range from oligotrophic (low biological productivity) to hypereutrophic (excessive biological productivity). In general, the more productive a reservoir, the more water quality problems it is likely to experience. Federal dollars to fund this trophic state assessment of our state's lakes were discontinued in 1994. At that time, the OWRB searched for other funding sources, and through working with the Secretary of the Environment and the Oklahoma Conservation Commission, the Water Board was able to obtain a one time federal 319 non-point source grant to continue the lake trophic state assessment program. The OWRB subsequently initiated a quarterly lake sampling program in the spring of 1998 and was able to roll the existing lake program into the BUMP.

The OWRB has developed Use Support Assessment Protocols (USAP) for lakes and streams, which are essential if the state is to be consistent in identifying waters that are not meeting their assigned beneficial uses or are threatened. The Water Resources Board has incorporated the USAP into Oklahoma Administrative Code (OAC) 785:46 to ensure that consistent determinations for impairments are made by the all of the monitoring agencies.

The state must follow consistent procedures for listing waters as impaired. Using the OWRB Use Support Assessment Protocols, it has been possible for OWRB staff to assess whether threats or impairments are present in our waterways. With continued funding, identification of impaired waters will be accomplished on additional waters.

59% of all surface acres sampled were eutrophic, 2% were mesotrophic, 25% were hypereutrophic, and 14% were oligotrophic. Two of the largest reservoirs sampled in 2005-2006 were classified as eutrophic (Grand and Tenkiller), which skewed the surface acres percentages heavily towards the eutrophic category. In general, the larger reservoirs in the state have more extensive watersheds and are generally deeper than smaller lakes, which increase the likelihood of beneficial use impairments being present since a larger surface area is available. During stratification, the larger/deeper reservoirs have a greater portion of the water column that becomes anoxic for long periods of time, which also increases the potential for nutrient release from sediments. It is obvious that many reservoirs in Oklahoma are experiencing adverse environmental impacts. However, with the available data it is not possible to adequately assess if lakes are meeting their assigned beneficial uses as they relate to nutrients. At this time, 24 lakes have been identified by the OWRB as "Nutrient-Limited Watersheds" (NLW) in the WQS and efforts should be taken to definitively determine if NLW waters are meeting their uses through initiation of a Nutrient Impairment Study to definitively determine the presence or absence of nutrient impairments in our NLW lakes. NLW are lakes with a TSI ≥ 62, based on Carlson's trophic state classification system and using chlorophyll-a as the trophic state indicator. Lakes sampled as part of the BUMP, their trophic status, and potential threats or impairments are listed in Table 1.

Table 1. Lakes Sampled by the BUMP with Associated Use Attainment Status.

Lake Name	County	W.Q. Segment #	Last Year Sampled	FWP	PPWS	PBCR	AG	AES
American Horse	Blaine		2003-2004	D.O.				
Arbuckle	Murray	310800	2004-2005	D.O.				
Arcadia	Oklahoma	520710	2004-2005					
Ardmore City	Carter	310800	2004-2005					
Atoka	Atoka	410400	2003-2004	Turbidity D.O.				True Color
Bellcow	Lincoln	520700	2003-2004	D.O.				
Birch	Osage	121300	2004-2005					
Bixhoma	Wagoner		2005-2006	D.O.				
Bluestem	Osage	121300	2005-2006	D.O. Turbidity				
Boomer	Payne	620900	2004-2005	Turbidity				
Broken Bow	McCurtain	410210	2005-2006	pH D.O.				
Brushy Creek	Sequoyah	220200	2003-2004	pH		Ent.		
Burtschi◘	Grady		2005-2006	pH				NLW
Canton	Blaine	720500	2005-2006	Turbidity				
Carl Albert	Latimer	410310	2003-2004					
Carl Blackwell	Payne	620900	2004-2005	Turbidity				
Carter	Marshall	310800	2003-2004					
Cedar (Mena)	LeFlore	410210 410300	2005-2006	D.O. pH				
Chandler	Lincoln	520700	2004-2005					

LAKE NAME	COUNTY	W.Q. SEGMENT #	LAST YEAR SAMPLED	FWP	PPWS	PBCR	AG	AES
CHICKASHA◘	CADDO	310830	2004-2005	TURBIDITY				NLW
CLAREMORE	ROGERS	121500	2005-2006					NLW
CLEAR CREEK	STEPHENS	310810	2004-2005					
CLEVELAND CITY	PAWNEE		2003-2004	D.O.				
CLINTON◘	WASHITA	310830	2003-2004	TURBIDITY		ENT.		TRUE COLOR
COALGATE CITY	COAL	410400	2003-2004	D.O. TURBIDITY				TRUE COLOR
COMANCHE	STEPHENS	311300	2004-2005					
COPAN	WASHINGTON	121400	2004-2005	TURBIDITY D.O.				TRUE COLOR
CROWDER	WASHITA	310830	2005-2006					NLW
CUSHING MUNICIPAL	PAYNE	620900	2003-2004	TURBIDITY				TRUE COLOR
DAVE BOYER (WALTERS)	COTTON	311300	2003-2004	TURBIDITY				TRUE COLOR
DRIPPING SPRINGS	OKMULGEE	520700	2004-2005	TURBIDITY D.O.				TRUE COLOR
DUNCAN	STEPHENS	310810	2004-2005					
EL RENO◘	CANADIAN		2004-2005	TURBIDITY				TRUE COLOR NLW
ELK CITY	BECKHAM	311500	2005-2006					NLW
ELLSWORTH	COMANCHE	311300	2003-2004	TURBIDITY D.O.				
ELMER THOMAS	COMANCHE	311300	2004-2005					
ETLING, CARL◘	CIMARRON	720900	2003-2004	TURBIDITY pH				NLW
EUCHA●	DELAWARE	121600	2004-2005	D.O.				NLW
EUFAULA	HASKELL	220600	2004-2005	D.O. TURBIDITY				TRUE COLOR
FAIRFAX CITY	OSAGE	621200	2003-2004	D.O.				
FORT COBB	CADDO	310830	2005-2006	TURBIDITY				NLW
FORT GIBSON	CHEROKEE	121600	2003-2004					NLW
FORT SUPPLY†	WOODWARD	720500	2005-2006	TURBIDITY				NLW
FOSS	CUSTER	310800 310810 310820 310830 310840	2004-2005					
FREDERICK	TILLMAN	311310	2004-2005	TURBIDITY				TRUE COLOR
FUQUA	STEPHENS	310810	2004-2005					
GRAND LAKE	MAYES	121600	2005-2006	D.O.				
GREAT SALT PLAINS	ALFALFA	621010	2005-2006	TURBIDITY			SULFATES & CHLORIDES	NLW
GREENLEAF	MUSKOGEE	120400	2005-2006	D.O.				
GUTHRIE◘	LOGAN	620910	2005-2006					NLW

LAKE NAME	COUNTY	W.Q. SEGMENT #	LAST YEAR SAMPLED	FWP	PPWS	PBCR	AG	AES
HEALDTON CITY	CARTER	311100	2005-2006					
HEFNER	OKLAHOMA	520520 520530	2005-2006	D.O.				
HENRYETTA ♦	OKMULGEE	520700	2004-2005	TURBIDITY				TRUE COLOR
HEYBURN	CREEK	120420	2004-2005	D.O. TURBIDITY		ENT.		TRUE COLOR
HOLDENVILLE	HUGHES	520800	2001-2002	D.O.		ENT.		
HOMINY MUNICIPAL	OSAGE	121300	2003-2004	D.O.				
HUDSON	OSAGE		2005-2006	D.O.				
HUDSON	MAYES	121600	2004-2005					
HUGO	CHOCTAW	410300	2004-2005	TURBIDITY				TRUE COLOR
HULAH	OSAGE	121400	2004-2005	TURBIDITY				NLW
HUMPHREYS	STEPHENS	310810	2004-2005					
JEAN NEUSTADT	CARTER	310800	2004-2005					
JOHN WELLS	HASKELL	220200	2005-2006					
KAW	OSAGE	621210	2004-2005	TURBIDITY D.O.				
KEYSTONE	TULSA	621200 620900	2005-2006	TURBIDITY			SULFATES & CHLORIDES	
KONAWA	SEMINOLE		2004-2005					
LANGSTON	LOGAN	620900	2003-2004					
LAWTONKA	COMANCHE	311300	2003-2004					
LIBERTY	LOGAN	620910	2005-2006	TURBIDITY				
LLOYD CHURCH	LATIMER	220100	2005-2006	D.O. pH				TRUE COLOR
LONE CHIMNEY	PAWNEE	621200	2003-2004					
LUGERT-ALTUS	GREER	311500 311510	2004-2005	TURBIDITY				
MAYSVILLE/WILEY POST	MCCLAIN		2004-2005	TURBIDITY				TRUE COLOR
MCALESTER	PITTSBURG	220600	2004-2005					TRUE COLOR
MCGEE CREEK	ATOKA	410400	2003-2004	D.O. pH				
MCMURTRY	NOBLE	620900	2004-2005	TURBIDITY				
MEEKER	LINCOLN	520700	2005-2006	TURBIDITY				
MURRAY	LOVE	311100	2005-2006	D.O.				
NANIH WAIYA	PUSHMATAHA		2004-2005					
NEW SPIRO ◘	LEFLORE	220100	2005-2006	pH				NLW
OKEMAH	OKFUSKEE	520700	2004-2005	D.O.				TRUE COLOR
OKMULGEE	OKMULGEE	520700	2004-2005	D.O.				TRUE COLOR

LAKE NAME	COUNTY	W.Q. SEGMENT #	LAST YEAR SAMPLED	FWP	PPWS	PBCR	AG	AES
OOLOGAH	ROGERS	121510	2004-2005	TURBIDITY D.O.				
OVERHOLSER ◘	OKLAHOMA	520520 520530	2005-2006	TURBIDITY				NLW TRUE COLOR
OZZIE COBB	PUSHMATAHA	410300	2004-2005	PH				NLW
PAULS VALLEY CITY	GARVIN	310810	2004-2005	TURBIDITY				TRUE COLOR
PAWHUSKA	OSAGE	121600	2004-2005					
PAWNEE	PAWNEE	621200	2003-2004					
PERRY	NOBLE	621200	2004-2005	TURBIDITY				TRUE COLOR
PINE CREEK	MCCURTAIN	410210	2003-2004	D.O. TURBIDITY PH				
PONCA	KAY	621200	2004-2005	D.O.				
PRAGUE CITY	LINCOLN	520510	2004-2005					
PURCELL	MCCLAIN	520610	2004-2005	TURBIDITY				
RAYMOND GARY	CHOCTAW	410300	2004-2005	D.O. TURBIDITY				TRUE COLOR
R.C. LONGMIRE	GARVIN	310810	2004-2005	D.O.				
ROBERT S. KERR	SEQUOYAH	220200	2004-2005	TURBIDITY				
ROCK CREEK	CARTER	310800	2004-2005	D.O.				
ROCKY (HOBART) ◘	WASHITA	311500	2003-2004	TURBIDITY		ENT.		NLW
SAHOMA	CREEK	120420	2005-2006	D.O.				
SARDIS	PUSHMATAHA	410310	2004-2005	D.O. TURBIDITY				TRUE COLOR
SHAWNEE TWIN # 1	POTTAWATOMIE	520510	2005-2006	D.O.				
SHAWNEE TWIN # 2	POTTAWATOMIE	520510	2003-2004					
SHELL	OSAGE	120420	2005-2006	D.O.				
SKIATOOK	OSAGE	121300	2004-2005	D.O.				
SOONER	PAWNEE		2004-2005					
SPAVINAW ●	MAYES	121600	2004-2005	D.O.				NLW
SPORTSMAN	SEMINOLE	520500	2004-2005	TURBIDITY				TRUE COLOR
STANLEY DRAPER	CLEVELAND		2005-2006	D.O.				
STILWELL CITY	ADAIR	220200	2005-2006	D.O.				
STROUD	CREEK	520700	2005-2006	D.O.			SULFATES & CHLORIDES	
TALAWANDA # 1	PITTSBURG	220600	2004-2005	D.O. PH				
TALAWANDA # 2	PITTSBURG	220600	2004-2005	PH				
TAYLOR (MARLOW)	GRADY	310840	2004-2005					NLW
TECUMSEH	POTTAWATOMIE	520510	2003-2004					

Results of Lakes Sampling Efforts

Data was collected by the OWRB on a quarterly basis for 36 lakes in 2005-2006. Forty-three lakes were selected for monitoring, however due to drought conditions, staff was unable to launch a boat on 7 of the lakes. For the current sample year, data was collected from the October of 2005 through August of 2006. The results of the sampling efforts are summarized below. As shown in Figure 1, 28% of lakes sampled were determined to have serious water quality nutrient concerns based upon their classification as hypereutrophic reservoirs. Lakes classified as hypereutrophic have the potential for beneficial use impairments due to low dissolved oxygen concentrations, taste and odor problems, nutrient inputs, excessive productivity, and general lake aesthetics. Hypereutrophic waters are adversely impacted primarily by excessive nutrients and primary productivity and should be monitored intensively in the future to document the presence or absence of "beneficial use impairments." Thirty-nine percent of the lakes sampled were classified as eutrophic, characterized by high primary productivity and nutrient rich conditions. A eutrophic lake also has the potential for beneficial use impairments, though the potential is less than for hypereutrophic waters. Mesotrophic waters have a small potential for beneficial use impairments and overall are representative of good water quality, low to moderate levels of nutrients, and productivity. Of the lakes sampled, 25% were classified as mesotrophic. Oligotrophic waters have very low levels of primary productivity and usually low concentrations of nutrient constituents. In Oklahoma, oligotrophic waters are either very clear waters with little nutrient inputs and genuinely good water quality conditions, or the waters are very turbid with poor water clarity with the absence of sufficient ambient light inhibiting lake productivity. Only three of the 36 lakes sampled were classified as oligotrophic. Based on the results for trophic state index calculations, 66% of the waters sampled were exhibiting high to excessive levels of primary productivity and nutrient rich conditions characteristic of eutrophic and hypereutrophic waterbodies.

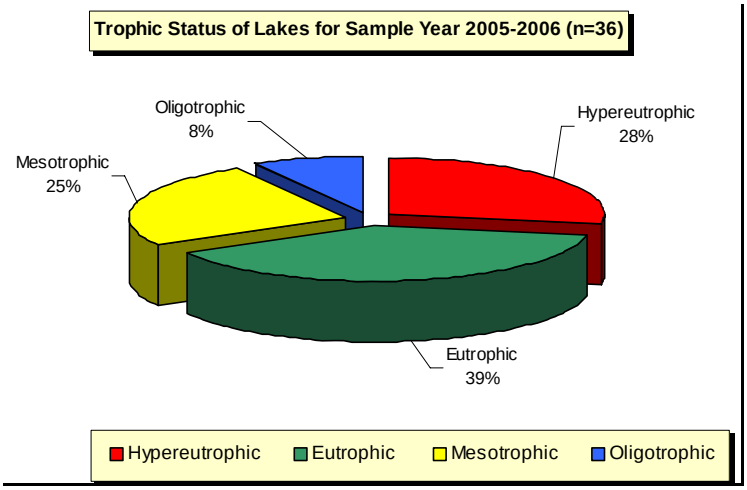


Figure 1. Trophic Status of Lakes Sampled in 2004-2005

The distribution changes somewhat when the lake surface acres for each reservoir are classified into the corresponding trophic status. Results in Figure 2 are different than Figure 1, indicating the lakes classified as eutrophic were larger in surface acres than the lakes classified as mesotrophic and hypereutrophic. When you look at lake trophic status broken out by the number of lake surface acres in each trophic state category,

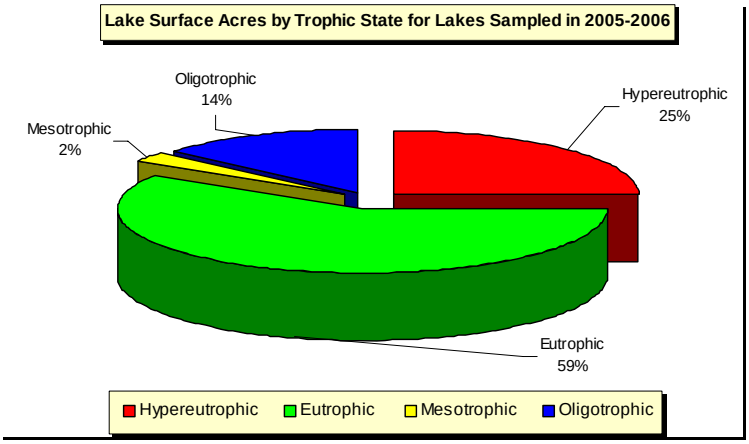


Figure 2. Lakes surface acres segregated by trophic state.

LAKE NAME	COUNTY	W.Q. SEGMENT #	LAST YEAR SAMPLED	FWP	PPWS	PBCR	AG	AES
TENKILLER FERRY◘	SEQUOYAH	121700	2005-2006	D.O.				NLW
TEXOMA	BRYAN	311100 310800	2004-2005	D.O. TURBIDITY				TRUE COLOR
THUNDERBIRD◘	CLEVELAND	520810	2003-2004	TURBIDITY				NLW
TOM STEED◘	KIOWA	311500	2004-2005	TURBIDITY				NLW
VANDERWORK	WASHITA	310830	2003-2004					NLW
VINCENT, LOYD	ELLIS	720500	2004-2005	D.O.				
W.R. HOLWAY	MAYES		2004-2005					
WAURIKA	JEFFERSON	311210	2004-2005	TURBIDITY				
WAXHOMA	OSAGE		2005-2006	D.O.				
WAYNE WALLACE	LATIMER	220100	2004-2005					
WEBBERS FALLS	MUSKOGEE	121400	2005-2006					
WES WATKINS	POTTAWATOMIE	520510	2005-2006					
WETUMKA	HUGHES		2003-2004	D.O.				
WEWOKA	SEMINOLE	520500	2003-2004					
WISTER♣	LEFLORE	220100	2004-2005	D.O. TURBIDITY				NLW TRUE COLOR
YAHOLA●	TULSA	121300	1998-1999					

† Lake Listed Based Upon 1995 U.S. Army Corps. Of Engineers Intensive Study

♣ Lake Listed Based Upon OWRB Phase I Clean Lakes Study

♦ Lake does not fit classic definition of oligotrophy. Inorganic particulates are limiting biological productivity

● Lake was not assessed through the BUMP, but through another OWRB project

◘ These Lakes will be recommended for NLW listing as part of the next WQS revision process

IMPAIRMENT CODES		
NS = NOT SUPPORTING	PS = PARTIALLY SUPPORTING	

ACRONYMS	
NLW = NUTRIENT LIMITED WATER	D.O. = DISSOLVED OXYGEN
ENT. = ENTEROCOCCI BACTERIA	

ASSIGNED WQS BENEFICIAL USES	
FWP = FISH & WILDLIFE PROPAGATION	AES = AESTHETICS
PPWS = PUBLIC & PRIVATE WATER SUPPLY	AG = AGRICULTURE
PBCR = PRIMARY BODY CONTACT RECREATION	

INTRODUCTION

Protecting Oklahoma's valuable water resources is essential to maintaining the quality of life for all Oklahomans. Used for a myriad of purposes, such as irrigation, hydropower, public/private water supply, navigation, and a variety of recreational activities, the state's surface and ground waters provide enormous benefits to Oklahoma from both an economic and recreational standpoint.

The National Recreation Lakes Study Commission (NRLSC) estimates that 32,100 people in Oklahoma are employed in support of activities related to our numerous man-made lakes. Also according to the NRLSC, 18,718,000 visitor days are spent on Oklahoma lakes each year and recreation in and around these lakes contributes approximately $2.2 billion each year to Oklahoma's economy. Of additional value are the recreational benefits associated with our smaller municipal/watershed projects, Oklahoma Department of Wildlife lakes, and rivers and streams throughout the state, which infuse millions into state coffers through fishing, hunting, camping, and related activities. (In 1987, the Oklahoma Comprehensive Outdoor Recreation Plan estimated that approximately $10.7 million was realized through camping and $15.2 million through hunting/fishing.[1]) According to a 2001 federal study, fishing activities alone contribute $476,019 dollars to Oklahoma's economy, not including the substantial ancillary costs associated with that extremely popular sport.[2]

In addition to surface waters, abundant ground waters also fuel the state's economy, serving as supply for thousands of municipalities, rural water districts, industrial facilities, and agricultural operations. According to the 1995 update of the *Oklahoma Comprehensive Water Plan*, groundwater represents the primary water supply for approximately 300 cities and towns and comprises 60 percent of the total water used in the state each year.[3] Groundwater resources also supply approximately 90 percent of the state's irrigation needs.

Oklahoma works to protect and manage its water resources through a number of initiatives, with the Oklahoma Water Quality Standards (WQS) serving as the cornerstone of the state's water quality management programs. The Oklahoma Water Resources Board (OWRB) is designated by state statute as the agency responsible for promulgating water quality standards and developing or assisting the other environmental agencies with implementation framework. State agencies are responsible for implementing the WQS as outlined by the OWRB through development of Implementation plans. Protecting our waters is a cooperative effort between many state agencies, and because the WQS are utilized by all agencies and represent a melding of both science and policy, they are an ideal mechanism to assess the effectiveness of our diverse water quality management activities.

The WQS are housed in OAC 785:45 and consist of three main components: beneficial uses, criteria to protect beneficial uses, and an anti-degradation policy. An additional component, which is not directly part of the WQS but necessary to water resource protection, is a monitoring

[1] Oklahoma Statewide Comprehensive Outdoor Recreation Plan (SCORP), 1987.
[2] U.S. Department of Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. *2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.*
[3] Oklahoma Water Resources Board, *Update of the Oklahoma Comprehensive Water Plan, 1995*.

program. A monitoring program is required in order to ensure that beneficial uses are maintained and protected. If uses are not being maintained, the cause of that impairment must be identified and restoration activities should be implemented to improve water quality such that it can meet its assigned beneficial uses.

All state agencies are currently required to implement Oklahoma's Water Quality Standards within the scope of their jurisdiction through the development of an Implementation Plan specific for their agency. This process, called WQS Implementation, allows the WQS to be utilized by other state agencies in the performance of their regulatory (statutory) responsibilities to manage water quality or to facilitate best management practice initiatives.

With the development of the BUMP, the need for protocols to determine beneficial use impairment was identified. Development of these protocols would facilitate state agencies in directing their time and money to the areas in most need of protection or remediation. The OWRB, working in close concert with other state environmental agencies and concerned parties, developed Use Support Assessment Protocols (USAP) to be used by all parties for assessing if waters were meeting their assigned beneficial uses. In addition, protocols were developed that could be coupled with a trend monitoring system to detect threatened waters before they become seriously impaired. Data collection efforts connected with protocol development and/or implementation also serves a vital purpose in refining numerical criteria currently included in the WQS and in developing appropriate numerical and narrative criteria for future WQS documents. It is essential that our waters meet their assigned uses and that WQS implementation protocols are appropriate. Please see Appendix A for the applicable Oklahoma Administrative Code (OAC) 785:46 related to the USAP. Final approval of the USAP occurred in 2000, and the OWRB has constantly worked every year since then to refine the existing protocols and pursue the addition or modification of USAP protocols to further enhance its utility and effectiveness.

Work to be performed towards development and implementation of the critical fourth component of the WQS program, monitoring, is the subject of this report. All sampling activities described and conducted as part of this program were consistent with the Oklahoma USAP. It is also important to note that they are consistent with Environmental Protection Agency (EPA) reporting requirements for the "*Integrated Water Quality Monitoring and Assessment Report" [305(b) Report and 303(d) list]*, §319 Non-point Source (NPS) Assessment, and §314 Lake Water Quality Assessment (LWQA).

BACKGROUND & PROBLEM DEFINITION

The State of Oklahoma has historically had numerous monitoring programs conducted by several state and federal agencies. In general, each environmental agency conducts their monitoring programs with some degree of integration and coordination with other state, municipal, or federal programs. Most water quality monitoring programs in Oklahoma are designed and implemented by each agency to collect information for one specific purpose or project (i.e., development of Total Maximum Daily Loads, the WQS process, lake trophic status determination, determining water quality impacts from point source dischargers, stream flow measurements, documenting success of best management practices, etc.). Information of this type is very specific to each individual project's data quality objectives (DQOs) and is often limited to a very small geographic area. This document describes sampling activities the OWRB has historically conducted for lakes and efforts that are currently ongoing for lakes and streams across Oklahoma as part of a comprehensive, long-term, statewide Beneficial Use Monitoring

Program (BUMP). The goal of the BUMP is to detect and quantify water quality trends, document and quantify impairments of assigned beneficial uses, and identify pollution problems before they become a pollution crisis.

BENEFICIAL USE MONITORING PROGRAM (BUMP) OVERVIEW

The overall goal of the Beneficial Use Monitoring Program is to document beneficial use impairments, identify impairment sources (if possible), detect water quality trends, provide needed information for the WQS, and facilitate the prioritization of pollution control activities.

BENEFICIAL USE MONITORING PROGRAM COMPONENTS

- **Monitoring Rivers & Streams** - The OWRB is currently monitoring approximately 180 stations on a monthly basis. These sites are segregated into two discrete types of monitoring activities. The first monitoring activity focuses on fixed station monitoring on rivers and streams, and the second monitoring activity focuses on a number of sample stations whose locations rotate on an annual basis. The two monitoring components are explained below.

    - **Fixed Station Monitoring on Rivers & Streams** - Fixed station monitoring is based largely upon the 67 United States Geological Survey (USGS) 8-digit hydrologic unit code (HUC) basins present in Oklahoma. In general, at least one sample station was located in all of the HUC watersheds with the exception of some of the smaller HUC watersheds adjacent to the state line or in a HUC that does not contain a free flowing stream at some point during the year. After consultation with the other state environmental agencies and over time the OWRB has identified 119 fixed stations of which 99 are currently being monitored.

    - **Rotating Station Monitoring on Rivers & Streams** - Over the life of the BUMP, rotational sampling has occurred on 200 stream segments. Sample stations and variables monitored are based upon Oklahoma's 303(d) list and input from other state environmental agencies on their monitoring needs. Variables monitored as part of this program component are specific for each stream segment monitored.

- **Fixed Station Load Monitoring** - The OWRB is currently engaged in a cooperative effort with the USGS to conduct flow monitoring at fixed station BUMP sites that do not currently have an existing USGS flow gage. This effort focuses on collecting both water quality and quantity information in order to calculate pollutant loads, which will provide OWRB staff with the data necessary to make a use support determination. This initiative is facilitated through the OWRB's Cooperative Agreement with USGS and various Compact Commission activities. The USGS cost share program, Oklahoma's 319 program, Oklahoma's 314 program and the 303(d)-process will drive sample site locations associated with this task.

- **Fixed Station Lakes Monitoring** - Fixed station lakes monitoring goal is designed to facilitate sampling on the 130 largest lakes in Oklahoma every other year. To accomplish this task, the OWRB is currently sampling approximately 40 to 45 lakes on a quarterly basis. Under this scenario, repeat sampling on a lake will occur approximately every 2-3 years, with the inclusion of lakes data collected by other sources, like the Corps of Engineers, to

meet the goal of 130 lakes every two years. Data collected consists primarily of water chemistry, nutrients, and chlorophyll-a information. In general, three stations per reservoir, representing the lacustrine zone, transitional zone, and riverine zone are sampled. On many reservoirs, additional sites are monitored, including major arms of the reservoir as appropriate. Water quality parameters have been added to the lakes sampling effort over the years to enhance our ability to make use support determinations.

- **Fixed Station Groundwater Monitoring** - Limited monitoring as part of this task has occurred in the program. Results of monitoring are presented in this report. OWRB staff has made recommendations in this report related to the scope and magnitude of groundwater monitoring activities that the state should pursue in the future. Any proposed groundwater monitoring efforts will be coordinated with the Oklahoma Department of Environmental Quality (ODEQ).

Intensive Investigations - If beneficial use impairment is identified or suspected, then all appropriate state agencies will be alerted and an investigation will be initiated to confirm if beneficial use impairment is occurring. If routine monitoring cannot definitively identify impairments, then an intensive study will be undertaken, and if impairment is present, the source of the impairment will be identified if possible. One potential use for the intensive studies envisioned was identified during the data analysis phase of this reporting process. For example, monies could be spent to identify if high turbidity readings in rivers and streams are due to natural processes or due to human activities in the watershed of concern. Some potential causes of beneficial use impairment are improper beneficial use or criteria (Oklahoma Water Resources Board jurisdiction), point source problems (Oklahoma Department of Environmental Quality or Oklahoma Department of Agriculture, Food & Forestry), non-point source problems (Oklahoma Conservation Commission, Oklahoma Department of Agriculture, Oklahoma Corporation Commission, or Oklahoma Department of Environmental Quality), oil and gas contamination (Oklahoma Corporation Commission), agricultural activities (Oklahoma Department of Agriculture, Food & Forestry), or mining activities (Oklahoma Department of Mines). All monitoring activities will be cooperative in nature with the agency with statutory authority assuming the lead role for intensive monitoring. If water bodies are not identified for intensive study as part of this task, then monies will be reallocated for routine monitoring of beneficial use attainment. Other entities (e.g., tribal or governmental units outside of Oklahoma) will be involved as appropriate. All intensive-monitoring activities will be consistent with the WQS and the USAP. If no protocols exist, then best professional judgment or State/Environmental Protection Agency guidance will be used as appropriate.

LAKES MONITORING PROGRAM

Lake trophic status is important from a water quality perspective because it is an indicator of potential nutrient impacts to a lake. In general, the higher the trophic state index (TSI) of a lake, the more nutrient loading into the system is occurring and the more productive the lake. One outcome of historical trophic assessment activity on Oklahoma's lakes was the prioritization of lakes most in need of remediation. Outcomes have included in-lake restoration activities or implementation of best management practices in the lake watershed. Results from the BUMP sampling effort should be viewed as a means to make relative comparisons between lakes and to determine beneficial use impairments based on USAP, detailed in Oklahoma Administrative Code (OAC) 785:46-15-5. Lakes with relatively poor water quality are identified, but that does not necessarily mean that these lakes have beneficial use impairments. Some lakes, due to the nature of their watershed and basin morphometry, may never attain the water quality of some of the state's more pristine waters. For example, an expectation that Broken Bow Lake and Great Salt Plains Reservoir can attain the same level of water quality would be unrealistic, because these two reservoirs exhibit great differences in basin morphometry and substrate material and are located in totally different parts of the state. Soil types such as clays have a very small particle size such that the clay particulates are constantly re-suspended in the lake water column and never settle out, which is evident in some lakes across the state. In addition, the shallow nature of many of our lakes contributes to lake bottom sediments being re-suspended in the water column due to wind action. Because so many factors affect the water quality of a reservoir, comparing lakes from various parts of the state should only be viewed as a relative comparison.

For each lake assessed, a general analysis of water quality was made and a water quality condition map generated. The maps presented are a representation of the water quality throughout the year based on the average of the data collected. Turbidity, measured in nephelometric turbidity units (NTU), and chlorophyll-a values were averaged to obtain an annual value for each site in the lake, and then the maps were generated accordingly. Graphics for seasonal TSI values at each site were also created, as well as seasonal turbidity and true color graphics for each site. A brief narrative summary is included for each lake that presents water quality issues related to the reservoir and assessment of beneficial use support for that lake. Dissolved oxygen/temperature vertical profiles recorded at site 1 (the dam) for each quarter are also included on a graphics page following the lake summary. Hydrolab® profile information is discussed in the narrative section for each lake. The brief synopsis of information presented for each lake should be beneficial in providing a relative comparison of water quality for lakes across the state.

For 2005-2006, the BUMP identified lakes that had beneficial use impairments or threats. However, a data set to truly determine which lakes are not supporting their beneficial uses due to excess nutrients does not currently exist, nor have nutrient criteria for lakes been promulgated into the WQS. The OWRB has previously identified 14 lakes that are listed in the WQS as Nutrient Limited Watersheds (NLW). More intensive work on these lakes is required before a definitive assessment of nutrient impairment or non-support can be made. The OWRB recommends a Nutrient Impairment Study (NIS) be performed on identified NLW lakes. An NLW is defined in the WQS as "a watershed of a waterbody with a designated beneficial use which is adversely affected by excess nutrients as determined by Carlson's TSI (chlorophyll-a) of 62 or

greater." If a lake is identified as having a TSI ≥62 based on chlorophyll-a, and the minimum data requirements are met (n=10 on lakes with <250 surface acres; n=20 on lakes with >250 surface acres), it is recommended for listing as an NLW through the WQS setting process. Currently, the parameters that are analyzed to determine whether or not there is beneficial use impairment or threat include turbidity, true color, dissolved oxygen, metals, chloride, sulfates, biological collections, total dissolved solids, and pH values. A brief discussion on lake monitoring procedures and methods is provided below with data results following.

MATERIALS & METHODS FOR LAKE SAMPLING

Data was collected quarterly on 36 lakes across the state from the fall of 2005 through the summer of 2006. Vertical water quality profiles were recorded at one meter intervals from the lake surface to the lake bottom for the following parameters; temperature, pH, dissolved oxygen, salinity, dissolved oxygen % saturation, oxidation-reduction potential (redox), specific conductivity, and total dissolved solids (TDS). A vertical profile was recorded for at least three sites per reservoir: in the central pool area near the dam (lacustrine zone), in the upper portion of the lake and in the major arms of the water body (riverine zone), and in the area between the lacustrine zone and the riverine zone (transitional zone). Turbidity values for each surface site were measured using a HACH portable turbidimeter. For lakes greater than 250 acres in size with only three routine chemical monitoring stations, additional sample sites have been established to ensure minimum data requirements are met. Secchi disk depths (in centimeters) were determined at all routine water chemistry sample sites. Water quality samples were collected at each site at the surface and one meter from the lake bottom at site 1, the dam, and preserved for analysis of nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, kjeldahl nitrogen, ortho-phosphorus, total phosphorus, true color, chloride, sulfate, and total alkalinity. OWRB staff calculated total nitrogen based on laboratory-derived values. A Van Dorn sampler was used to collect samples near the lake bottom and grab samples were collected at the lake surface. At the dam site, a churn-splitter was used to split the surface sample for Quality Assurance (QA) purposes. Surface samples were also collected at all sites and analyzed for chlorophyll-a and pheophytin concentrations. Additional chlorophyll-a samples were collected for QA purposes. Filtration and grinding (extraction of the chlorophyll-a collected in a filter with acetone) of the samples was performed immediately upon return to the OWRB lab. All chlorophyll-a samples were filtered, as stated in Standard Methods (APHA 1995), within 24 hours and stored for no more than 30 days in the freezer.

SAMPLE LAKE LOCATIONS

Lakes sampled by the BUMP Lakes staff in 2004-2005 are shown in Figure 3. Lake locations are identified on the map and are shaded in different colors based on their calculated TSI values.

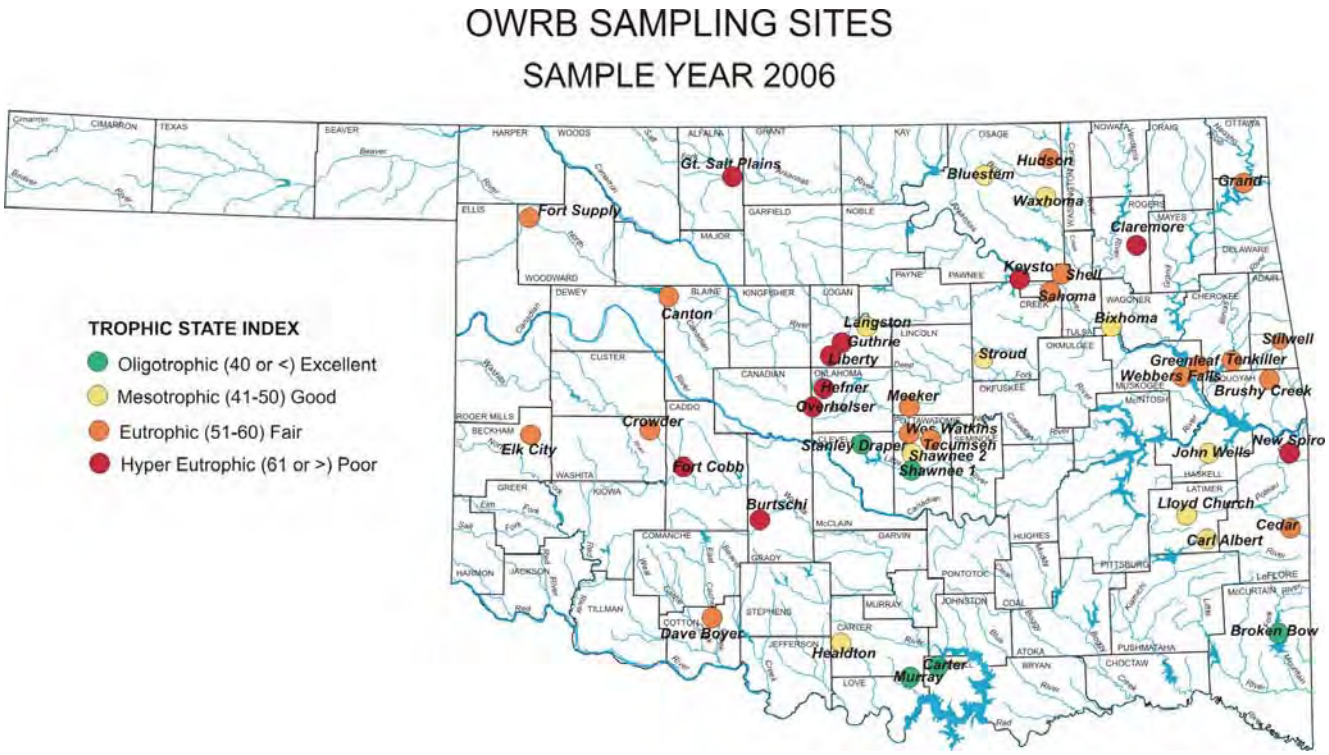


Figure 3. Lakes Sampled by the Beneficial Use Monitoring Program.

LAKE DATA ANALYSIS PROTOCOLS

There are numerous methods available for determining the trophic status of lakes. The majority of the trophic state models rely on a mathematical calculation to generate a single numerical value that is then categorized in an assessment hierarchy. Numerous chemical, and in some cases biological data are utilized in the various trophic indices, which characterize the "trophic status" of a water body. Some of the commonly used water quality parameters utilized in trophic state indices include chlorophyll-a, secchi disc depth, total phosphorus, total nitrogen, aquatic macrophytes, organic nitrogen, turbidity, lake user surveys, and hypolimnetic oxygen depletion rates, etc. Most indices use one or more variables in the determination of trophic status with varying degrees of applicability to reservoir systems. The OWRB has traditionally used Carlson's Trophic State Index (TSI) (Carlson, 1977) for reporting purposes, utilizing chlorophyll-a concentrations in calculating the lake trophic status. Carlson's TSI equation using chlorophyll-a (in µg/L) as the trophic status indicator is as follows:

$$\mathbf{TSI = 9.81 \times \ln(chlorophyll\text{-}a) + 30.6}.$$

In 1998, 1999, and 2000, the TSI was calculated using chlorophyll-a concentrations from the growing season (spring and summer only). Beginning in sample year 2001, an annualized trophic assessment was made as this was determined to be a more accurate reflection of trophic conditions for each reservoir. In order to make beneficial use determinations, minimum data requirements must be met as listed in OAC 785:46-15-3. A minimum of 20 samples is required on lakes greater than 250 surface acres, and a minimum of 10 samples on lakes 250

surface acres and less. In 2001-2002, sites were added for chlorophyll-a and turbidity collections on lakes greater than 250 surface acres, in order to meet the minimum data requirements annually. Although data can be aggregated and historical values used, there was a concern in using data that was collected in the summer only as this would bias the data. An analysis of the limnological data collected on lakes is performed to determine the trophic state of each lake monitored. Chlorophyll-a concentrations for each lake sample site are determined and all values are averaged for each lake for all four sampling quarters. This annual chlorophyll-a value is then used in Carlson's TSI equation to determine trophic status of the lake. Through use of this technique the presence of localized trophic conditions are minimized (i.e. the effects of a single elevated chlorophyll-a value is minimized in the calculation of the TSI). The derived TSI represents an accurate assessment of the water quality of the reservoir as a whole and individual isolated areas that may be impacted due to eutrophication will be minimized in the reported TSI. A list of lake trophic state categories and corresponding TSI numerical values are displayed in Table 2. There are other descriptive terms and subset categories for trophic status, like dystrophic; however, Carlson's TSI has four major categories and these will be used to describe lake trophic status. Further discussion is included in each of the lake summaries as necessary. As stated earlier, prior to 2001, the TSI was based on growing season (spring and summer) chlorophyll-a concentrations. However, beginning in 2001, all TSI evaluations were based on an annualized chlorophyll-a value for each lake and comparisons to previous TSI calculations will be specified as annual, growing season, or summer only evaluations. Prior to the onset of BUMP collections, lakes were sampled only in the summer and therefore the TSI was typically much higher than the annual assessments that are being done currently.

Table 2. Lake Trophic State Categories.

Carlson TSI No.	Trophic State	Definition
≤ 40	Oligotrophic	Low primary productivity and/or low nutrient levels
41 - 50	Mesotrophic	Moderate primary productivity with moderate nutrient levels
51 – 60	Eutrophic	High primary productivity and nutrient rich
≥ 61	Hypereutrophic	Excessive primary productivity and excessive nutrients

The beneficial use support determinations for the reservoirs sampled were determined following guidelines outline in the Use Support Assessment Protocols (USAP) promulgated into Oklahoma Administrative Code (OAC) 785-46: Subchapter 15. In general the USAP states that environmental data must be collected to take seasonal conditions into consideration. A minimum of 20 samples is required on lakes more than 250 surface acres to assess beneficial use support for water quality parameters such as dissolved oxygen, pH and temperature. In addition, data more than ten years old should not be used for use support purposes unless more recent data is not available. A minimum of 10 samples is required on lakes or lake-arms of 250 surface acres of less. Samples may be aggregated to meet the minimum data requirements. For some parameters such as metals, organic compounds, or toxics, fewer samples are required. Toxicants (metals and organics) require a minimum of 5 samples to determine use support, but less than 5 samples can be used to determine if a use is partially supported or not supported. Furthermore, if at least 2 sample concentrations of a toxicant exceed the criteria prescribed in the WQS by two or more orders of magnitude, then the use is determined to be "not supporting".

The USAP also addresses the issue of how the data should be used spatially for lake monitoring. In general, when determining what size area the data is representative of best

professional judgment is used. Such things as major tributaries and major lake arms are considered when deciding the extent of the area that the data was applied to. Arms or portions of lake may be treated separately from the main body of a lake, however in most instances Water Resources Board staff chose to deal with the lake as a single unit. Unless it was demonstrated to the contrary, a single site was not considered representative of an entire lake or an arm of the lake that was greater than two hundred and fifty surface acres in size.

Default Protocols. USAP outlines the procedures for determining whether a set of data points for a particular variable support, partially support, or do not support a particular beneficial use. These protocols are constructed around two distinct types of numerical variables — short-term averages and long-term averages. In each case, samples collected for the range of water quality parameters are analyzed and aggregated in different ways.

Short-term average numerical variables measure variables with exposure periods of less than seven days (e.g., turbidity or a sample standard for chlorides). In other words, the set of samples that is being analyzed considers each sample as a separate entity. For example, turbidity samples collected monthly from January through December are considered unique samples, and consequently, are not aggregated into a single sample for analysis but are considered a fraction of the whole. Use support determination for short-term numerical variables requires a three-step process:

1. Each sample exceeding the prescribed criterion or screening level for a particular variable is identified,
2. The number of samples exceeding the prescribed criterion or screening level is divided by the total number of samples collected to obtain a percent exceedance, and
3. The percent exceedance is compared to a range of prescribed percent exceedances to determine use support. The prescribed percent exceedances are:
    - i) supporting — less than or equal to 10%,
    - ii) partially supporting — greater than 10% but less than 25%,
    - iii) not supporting — greater than or equal to 25%.

Long-term average numerical variables measure variables with exposure periods of greater than or equal to seven days (e.g., yearly mean standard for chlorides). In other words, the set of samples that is being analyzed is considered a unique entity. For example, chloride samples collected monthly from January through December are aggregated through the calculation of a geometric mean. Use support determination for long-term numerical variables requires a three-step process:

1. Samples for a particular variable are aggregated into a geometric mean,
2. The geometric mean is compared to the prescribed criterion or screening level, and
3. Use support is determined to be supporting if the mean is less than the prescribed criterion or screening level or not supporting if the mean is greater than the prescribed criterion or screening level.

Because the long-term average compares only one value (the geometric mean) to the prescribed criterion or screening level, it cannot be considered partially supporting. In most instances, at least 10 samples are required to calculate a geometric mean.

Assessment of Fish & Wildlife Propagation Beneficial Use Support. The FWP beneficial use utilizes five different water quality variables to assess use support: dissolved oxygen (D.O.) concentration, toxicants, hydrogen ion activity (pH), and turbidity. For purposes of this report,

only D.O., metals concentrations in the water column, pH, and turbidity will be used in the assessment. The USAP for dissolved oxygen beneficial use support for lakes reads as follows:

(A) If greater than 70% of the water column at any given sample site in a lake or an arm of a lake is less than 2 mg/L, the Fish and Wildlife Propagation beneficial use shall be deemed to be not supported.

(B) If 50% or more, but not greater than 70%, of the water column at any given sample site in a lake or arm of a lake is less than 2 mg/L, the Fish and Wildlife Propagation beneficial use shall be deemed to be partially supported.

(C) The screening level for surface D.O. in a lake or arm of a lake shall be 4 mg/L from June 16 through October 15 each year and 5.0 mg/L for the remainder of the year.

Use support for dissolved oxygen concentrations was determined following the above criteria. Estimations of lake volume were made based on the depth at each site sampled and USAP criteria were applied accordingly. Water column information at each site is likely representative of lake volume conditions and is currently considered adequate for reporting purposes. A proposal to modify the USAP for assessment of dissolved oxygen during the last WQS revision process was made to more accurately reflect the decision criteria being followed. As of July 1, 2002, the word "volume" was changed to "column" to more accurately reflect the decision criteria utilized. It is possible that in the future a bathymetric map will be constructed for each of the BUMP lakes and a better assessment of dissolved oxygen conditions for the lake volume can be made. For assessing Fish & Wildlife propagation use support related to turbidity concentrations, the criterion outlined in the WQS was used as the screening level. If an average lake-wide turbidity concentration of >25 nephelometric turbidity units was detected, then the lake was listed as not supporting its Fish & Wildlife propagation beneficial use for turbidity. Rain and storm events were considered when making this determination as conditions dictated. The protocol for short-term average numerical parameters is used to assess the level of support.

For assessing the beneficial use support from pH concentrations, the following criteria were used:

1) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be fully supported with respect to pH occurring other than by natural causes if no more than 10% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(g)(3).

2) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be partially supported with respect to pH occurring other than by natural causes if greater than 10% but less than 25% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(g)(3).

3) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be not supported with respect to pH occurring other than by natural causes if at least 25% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(g)(3).

Each lake was profiled using a Hydrolab, and pH concentrations were recorded at all sites for all four quarters. Based on all the data collected per sample year, the percentage of pH values above or below the acceptable range of 6.5 to 9 units was assessed for each site and this percentage determined whether or not the lake was supporting the Fish & Wildlife Propagation beneficial use. All lakes that exceeded the pH criteria have been only listed as not supporting at this point in time as further examination is necessary to determine "natural causes".

Numerical criteria is prescribed for toxicants in WQS 785:45-5-12(g)(6)(G) in a table entitled "Numerical Criteria for Toxic Substances". To determine use support, the protocol for short-term average numerical parameters is used. Sample values must be compared to both acute and chronic criterion. Both criterions need not be exceeded for the variable to be partially supported or not supported.

Assessment of Agriculture Beneficial Use Support. The AG beneficial use utilizes three variables to assess use support: total dissolved solids, chlorides, and sulfates. Numerical criteria for both yearly mean standards and sample standards are located in Appendix F of OAC 785:45. The yearly mean standard for each variable is compared to the geometric mean of the samples using a long-term average numerical protocol. The sample standard for each variable is also compared to each sample using a short-term average numerical protocol. Use support assessment for each variable requires a three-step process:

1) The sample standard and yearly mean standard for the six digit management segment which encompasses the monitoring must be located in Appendix F of OAC 785:45;
2) The geometric mean of the samples is compared to the yearly mean standard (if the geometric mean exceeds the yearly mean standard, the use is not supported and no further analysis is necessary);
3) If the geometric mean meets the yearly mean standard, the sample standard is compared to each sample and percent exceedance is calculated (depending on the percent exceedance, the variable is supporting, partially supporting, or not supporting). Regardless of the criteria in Appendix F of OAC 785:45, if all TDS samples are less than 750 mg/L and all chloride and sulfate samples are less than 250 mg/L, the AG beneficial use is supported. Only one variable needs to violate the assessment protocol for the beneficial use to be partially supported or not supported.

Assessment of Aesthetics Beneficial Use Support. The Aesthetics beneficial use is assessed using a couple of water quality parameters--true color and nutrients. The sample standard for each variable is compared to the each sample using a short-term average numerical protocol. Criteria are located in OAC 785:45-5-19 and read as follows.

1) **Color.** Surface waters of the state shall be virtually free from all coloring materials that produce an aesthetically unpleasant appearance. Color producing substances, from other than natural sources, shall be limited to concentrations equivalent to 70 Platinum-cobalt true color units.

2) **Nutrients.** Nutrients from point source discharges or other sources shall not cause excessive growth of periphyton, phytoplankton, or aquatic macrophyte communities, which impairs any existing or designated beneficial use.

For assessing the Aesthetics beneficial use support status for color, data collected was compared to the numerical standard of 70 units for true color. Assessment of use support for this water quality parameter was simple and straightforward.

For assessing the Aesthetics beneficial use support status for nutrients, Carlson's TSI was applied. As stated in Table 2 a TSI value ≥ 61 is considered to be characteristic of a hypereutrophic lake (excessive primary productivity). Guidelines for determining if a lake is a Nutrient Limited Watershed (NLW) are outlined in the WQS that states a Carlson's TSI value of

> 62 is to be the criterion to be used to classify a lake as an NLW. Classification as an NLW in Appendix A of the WQS means that a lake is considered to be threatened due to nutrients. A TSI value of 62 was chosen as the "break-point" because it is a conservative number. As noted in Table 5, several lakes had a TSI value greater than 62 and have not yet been listed as an NLW, and likewise, there are lakes listed as NLW that have a TSI less than 62. This will be addressed during the next standards revision process. If it can be demonstrated that nutrient loading to a lake may be adversely impacting a beneficial use designated for that lake, then the OWRB may determine that the lake and its watershed is an NLW and the lake and watershed will be identified as NLW in Appendix A of OAC 785:45. Once a lake is identified as an NLW, it is assumed to be threatened until an NLW Impairment Study has been conducted to definitively assess if the water body is partially supporting or not supporting. If an NLW Impairment Study demonstrates that beneficial uses are not threatened, then the Board will remove the NLW identification in the WQS.

Assessment of Primary Body Contact Recreation (PBCR) Support. The PBCR beneficial use utilizes two different bacteriological classes and one bacteriological species to assess use support: fecal coliform (FC), *Escherichia coli* (*E. coli*), and enterococci (Ent.). The assessment is performed by using the long-term average numerical protocol to compare to a prescribed geometric mean and by using a modified version of the short-term average numerical protocol to compare each sample to a prescribed screening level. The prescribed geometric means (GM) and screening levels (SL) are: FC—GM of 400 colony forming units/mL (cfu/mL) and SL of 400 cfu/mL; *E. coli*—GM of 126 cfu/mL and SL of 235 cfu/mL in scenic rivers and 406 cfu/mL in all other waters; and Ent.—GM of 33 cfu/mL and SL of 61 cfu/mL in scenic rivers and 406 cfu/mL in all other waters. For *E. coli* and Ent., both the SL (only one sample exceedance is necessary) and the GM must be exceeded for the use to not be supported. If all of the samples meet the SL or the GM is met, the use is supported. In the case of FC, the use may only be supported if the GM is met and no greater than 25% of the sample concentrations exceed the SL. If either the GM is exceeded or greater than 25% of the sample concentrations exceed the SL, the use is not supported for FC. In no instance is the PBCR beneficial use partially supported. Furthermore, PBCR support is only determined from samples collected during the recreational season from May 1 through September 30 of each year. Only one variable needs to violate the assessment protocol for the beneficial use to be not supported.

LAKE MONITORING RESULTS & DISCUSSION

A lake-wide annual average of the chlorophyll-a values was calculated for each lake and used in the final calculation of the TSI. A summary table is included (Table 3) to present the number of lakes and appropriate surface acre size for each of the four trophic categories in 2005-2006 as well as the percentages of the total. As shown in Table 3, ten lakes were hypereutrophic, fourteen were eutrophic, nine were mesotrophic, and three were oligotrophic. Of the total 166,431 surface acres sampled, 41,745 were classified hypereutrophic, 97,879 were classified as eutrophic, 3,979 were classified as mesotrophic and 22,828 acres were classified as oligotrophic. TSI results, county, surface area, and volume for lakes sampled in 2005-2006 are listed in Table 4.

Although TSI based on the chlorophyll-a concentration is used for the BUMP, a comparison of TSI values calculated with total phosphorus and secchi disk depth was generated and is displayed as Table 5. Data displayed is for the growing season using the various water quality parameters that can be used in calculating Carlson's TSI. The chlorophyll and phosphorus TSI

calculations were derived through results of regression analysis relating secchi disk depth to the other two variables.

Table 3. Summary of Lake Trophic Status Results

Trophic Status	Number of Lakes	% of Total Lakes	Surface Area (Acres)	% of Total Surface Acres
Hyper-Eutrophic	10	28%	41,475	25%
Eutrophic	14	39%	97,879	59%
Mesotrophic	9	53%	3,979	2%
Oligotrophic	3	8%	22,828	14%
Totals =	36	100%	166,161	100%

Table 4. List of Lakes Sampled in Sample Year 2005-2006.

Lake Name	County	Surface Area	Volume	TSI	Year Sampled	Threats or Impairments	Carlson's TSI
Bixhoma	Wagoner	110	3,130	46	2006	D.O. (PS)	Mesotrophic
Bluestem	Osage	762	17,000	44	2006	D.O. (PS) Turbidity (PS)	Mesotrophic
Broken Bow	McCurtain	14,200	918,070	35	2006	pH NS D.O. (PS)	Oligotrophic
Brushy Creek	Sequoyah	358	3,258	51	2004	D.O. (PS) pH (PS)	Eutrophic
Burtschi, Louis	Grady	180	2,140	63	2006	pH (PS)	Hypereutrophic
Canton	Blaine	7,910	111,310	57	2006	Turbidity (PS)	Eutrophic
Carl Albert	Latimer	183	2,739	41	2004	D.O. (PS) pH (NS)	Mesotrophic
Carter	Marshall	108	990	44	2004		Mesotrophic
Cedar (Mena)	LeFlore	78	1,000	53	2006	D.O. (NS) pH (NS)	Eutrophic
Claremore	Rogers	470	7,900	67	2006	NLW	Hypereutrophic
Crowder	Washita	158	2,094	57	2006	NLW	Eutrophic
Elk City	Beckham	240	2,583	59	2006	NLW	Eutrophic
Fort Cobb	Caddo	4,100	80,010	65	2006	NLW Turbidity (PS)	Hypereutrophic
Fort Supply=	Woodward	1,820	13,900	57	2006	Turbidity (NS) & NLW	Eutrophic
Grand Lake	Mayes	46,500	1,672,000	59	2006	D.O. (PS)	Eutrophic
Great Salt Plains	Alfalfa	8,690	31,240	71	2006	Turbidity (NS) NLW	Hypereutrophic

LAKE NAME	COUNTY	SURFACE AREA	VOLUME	TSI	YEAR SAMPLED	THREATS OR IMPAIRMENTS	CARLSON'S TSI
						SULFATES& CHLORIDES	
GREENLEAF	MUSKOGEE	920	14,720	52	2006	D.O. (NS)	EUTROPHIC
GUTHRIE	LOGAN	274	3,875	61	2006	NLW TURBIDITY (PS)	HYPEREUTROPHIC
HEALDTON	CARTER	370	3,766	49	2006		MESOTROPHIC
HEFNER	OKLAHOMA	2,500	75,000	63	2006	D.O. (PS)	HYPEREUTROPHIC
HUDSON	OSAGE	250	4,000	57	2006	D.O. (PS)	EUTROPHIC
JOHN WELLS	HASKELL	194	1,352	46	2006		MESOTROPHIC
KEYSTONE	TULSA	23,610	557,600	61	2006	TURBIDITY (NS)	HYPEREUTROPHIC
LANGSTON	LOGAN	304	5,792		2004		
LIBERTY	LOGAN	167	2,740	67	2006	TURBIDITY (PS)	HYPEREUTROPHIC
LLOYD CHURCH	LATIMER	160	3,060	45	2006	D.O. (PS) PH (NS)	MESOTROPHIC
MEEKER	LINCOLN	250	1,818	50	2006	TURBIDITY (NS)	MESOTROPHIC
MURRAY	LOVE	5,728	153,250	36	2006	D.O. (PS)	OLIGOTROPHIC
OVERHOLSER	OKLAHOMA	1,500	15,000	67	2006	TURBIDITY (NS) COLOR (PS) NLW	HYPEREUTROPHIC
SAHOMA	CREEK	312	4,850	51	2006	D.O. (PS)	EUTROPHIC
SHAWNEE TWIN NO. 1	POTTAWATOMIE	1,336	22,600	41	2006	D.O. (PS)	MESOTROPHIC
SHAWNEE TWIN NO. 2	POTTAWATOMIE	1,100	11,400	44	2004	D.O. (PS)	MESOTROPHIC
SHELL CREEK	OSAGE	573	9,500	53	2006	D.O. (PS)	EUTROPHIC
SPIRO, NEW	LEFLORE	254	2,160	68	2006	PH (PS) NLW	HYPEREUTROPHIC
STANLEY DRAPER	CLEVELAND	2,900	100,000	40	2006	D.O. (PS)	OLIGOTROPHIC
STILWELL	ADAIR	188	3,110	54	2006	D.O. (NS)	EUTROPHIC
STROUD	CREEK	600	8,800	41	2006	D.O. (PS) SULFATES & CHLORIDES (NS)	MESOTROPHIC
TECUMSEH	POTTAWATOMIE	127	1,118	48	2004	COLOR (NS) TURBIDITY (NS)	MESOTROPHIC
TENKILLER	SEQUOYAH	12,900	654,100	55	2006	D.O. (PS) NLW	EUTROPHIC
WALTERS	COTTON	148	861		2004		
WAXHOMA	OSAGE	197	2,100	45	2006	D.O. (PS)	MESOTROPHIC
WEBBERS FALLS	MUSKOGEE	11,600	170,100	56	2006	TURBIDITY (PS)	EUTROPHIC
WES WATKINS	POTTAWATOMIE	1,132		53	2006		EUTROPHIC

The TSI calculation using total phosphorus (in mg/m^3) as the variable is:

TSI = 14.42 x ln(total phosphorus) + 4.15.

The TSI calculation using secchi disk depth (in meters) as the variable is:

TSI = 60 – (14.41 x ln(secchi depth)).

Calculations using secchi disk depth could be erroneous, because this is not a good parameter to use in highly turbid reservoirs where turbidity is inorganic in nature or colored lakes, both fairly common occurrences in Oklahoma. Phosphorus may not be an accurate variable to use in calculating the TSI in lakes that are not phosphorus-limited or lakes that are highly turbid due to clay particulates. Carlson (1977) stated chlorophyll-a seems to be the most acceptable parameter to use in calculating TSI, especially during the growing season and for estimating algal biomass. In accordance with historical calculations at OWRB, and Carlson's suggestion to use chlorophyll-a concentration in the growing season, rather than secchi disk depth or total phosphorus, it is the utilized variable for TSI calculations for BUMP. Values displayed in Table 5 were calculated using lake-wide annual averages for all three parameters.

Using chlorophyll-a, ten lakes were hypereutrophic, fourteen lakes were eutrophic, nine lakes were mesotrophic, and three were oligotrophic. Using total phosphorus and secchi disk depth in the TSI calculation produced a much different result, although classification using these two variables is somewhat comparable to each other. Seventeen lakes were hypereutrophic, ten lakes were eutrophic, six lakes were mesotrophic and three was oligotrophic using the total phosphorus variable for TSI. For the secchi disk depth trophic evaluation, twenty-four lakes were identified as hypereutrophic, eleven lakes were eutrophic, zero lakes were mesotrophic and one was oligotrophic. The TSI values calculated using secchi depth were the highest of the three variables. For example, Bluestem Lake was classified as mesotrophic using chlorophyll-a concentration, eutrophic using total phosphorus as the trophic state indicator, and hypereutrophic using secchi disk depth as the trophic state indicator. Most of the TSI values were lowest using the chlorophyll-a concentration; therefore, it seems reasonable to say that this parameter is the most conservative variable to use.

Table 5. Comparison of Methods Used to Calculate Carlson's Trophic State Index for 2005-2006.

LAKE NAME	CHL-A	TROPHIC STATE	TOTAL P	TROPHIC STATE	SECCHI	TROPHIC STATE
LAKE BIXHOMA	45	Mesotrophic	45	Mesotrophic	55	Eutrophic
BLUESTEM LAKE	44	Mesotrophic	53	Eutrophic	63	Hypereutrophic
BROKEN BOW LAKE	35	Oligotrophic	39	Oligotrophic	45	Oligotrophic
BRUSHY CREEK RESERVOIR						
LAKE BURTSCHI	63	Hypereutrophic	62	Hypereutrophic	65	Hypereutrophic
CANTON LAKE	57	Eutrophic	64	Hypereutrophic	67	Hypereutrophic
CARL ALBERT LAKE						
CARTER LAKE						
CEDAR LAKE	53	Eutrophic	66	Hypereutrophic	53	Eutrophic
CLAREMORE LAKE	67	Hypereutrophic	71	Hypereutrophic	73	Hypereutrophic
CROWDER LAKE	57	Eutrophic	55	Eutrophic	66	Hypereutrophic
DAVE BOYER LAKE						
LAKE ELK CITY	59	Eutrophic	62	Hypereutrophic	68	Hypereutrophic
FT. COBB RESERVOIR	65	Hypereutrophic	70	Hypereutrophic	67	Hypereutrophic
FT. SUPPLY LAKE	57	Eutrophic	67	Hypereutrophic	75	Hypereutrophic

LAKE NAME	CHL-A	TROPHIC STATE	TOTAL P	TROPHIC STATE	SECCHI	TROPHIC STATE
GRAND LAKE	59	Eutrophic	68	Hypereutrophic	61	Hypereutrophic
GREAT SALT PLAINS LAKE	71	Hypereutrophic	85	Hypereutrophic	91	Hypereutrophic
GREENLEAF LAKE	52	Eutrophic	57	Eutrophic	58	Eutrophic
GUTHRIE LAKE	61	Hypereutrophic	65	Hypereutrophic	70	Hypereutrophic
HEALDTON CITY LAKE	49	Mesotrophic	64	Hypereutrophic	75	Hypereutrophic
LAKE HEFNER	63	Hypereutrophic	68	Hypereutrophic	61	Hypereutrophic
HUDSON LAKE	57	Eutrophic	55	Eutrophic	60	Eutrophic
JOHN WELLS LAKE	46	Mesotrophic	44	Mesotrophic	54	Eutrophic
KEYSTONE LAKE	61	Hypereutrophic	74	Hypereutrophic	67	Hypereutrophic
LANGSTON LAKE						
LIBERTY LAKE	67	Hypereutrophic	66	Hypereutrophic	73	Hypereutrophic
LLOYD CHURCH LAKE	45	Mesotrophic	54	Eutrophic	66	Hypereutrophic
MEEKER LAKE	50	Eutrophic	60	Eutrophic	74	Hypereutrophic
LAKE MURRAY	36	Oligotrophic	45	Mesotrophic	51	Eutrophic
NEW SPIRO LAKE	68	Hypereutrophic	72	Hypereutrophic	71	Hypereutrophic
LAKE OVERHOLSER	67	Hypereutrophic	81	Hypereutrophic	76	Hypereutrophic
LAKE SAHOMA	51	Eutrophic	53	Eutrophic	64	Hypereutrophic
SHAWNEE TWIN LAKE # 1	41	Mesotrophic	40	Oligotrophic	63	Hypereutrophic
SHAWNEE TWIN LAKE # 2						
SHELL CREEK LAKE	53	Eutrophic	49	Mesotrophic	63	Hypereutrophic
LAKE STANLEY DRAPER	40	Oligotrophic	40	Oligotrophic	56	Eutrophic
STILWELL CITY LAKE	54	Eutrophic	51	Eutrophic	53	Eutrophic
STROUD LAKE	41	Mesotrophic	41	Mesotrophic	57	Eutrophic
TECUMSEH LAKE						
TENKILLER FERRY LAKE	55	Eutrophic	53	Eutrophic	54	Eutrophic
LAKE WAXHOMA	45	Mesotrophic	49	Mesotrophic	54	Eutrophic
WEBBERS FALLS RES.	56	Eutrophic	78	Hypereutrophic	69	Hypereutrophic
WES WATKINS LAKE	53	Eutrophic	51	Eutrophic	61	Hypereutrophic

Results for each of the 130 BUMP lakes from the most recent sampling are listed in Table 6. As stated previously, the OWRB is currently monitoring 40 to 45 lakes with repeat sampling on each reservoir scheduled to occur every two to three years. Prior to 1998, data was only collected once for each lake during the summer months. In 1998, the OWRB began collecting data on lakes on a quarterly basis resulting in a great improvement to the data set available to make management decisions on our lake resources. Lakes that are identified as hypereutrophic should be sampled more often than quarterly, especially during the warmer months. Lakes identified as "Nutrient-Limited Watersheds" (NLW) should also be sampled more intensively to confirm if a water quality threat or impairment is present. Minimum data requirements as listed in USAP were closely followed to make beneficial use determinations. All impairments are listed in Table 6. Toxicity concerns, if present, are listed as provided by the ODEQ as part of their Rotating Lakes Toxics Program and/or through sampling conducted by the OWRB.

Table 6. Lakes Sampled by the BUMP with Their Associated Use Attainment Status.

LAKE NAME	COUNTY	W.Q. SEGMENT #	LAST YEAR SAMPLED	FWP	PPWS	PBCR	AG	AES
AMERICAN HORSE	BLAINE		2003-2004	D.O.				
ARBUCKLE	MURRAY	310800	2004-2005	D.O.				
ARCADIA	OKLAHOMA	520710	2004-2005					
ARDMORE CITY	CARTER	310800	2004-2005					
ATOKA	ATOKA	410400	2003-2004	TURBIDITY D.O.				TRUE COLOR
BELLCOW	LINCOLN	520700	2003-2004	D.O.				
BIRCH	OSAGE	121300	2004-2005					
BIXHOMA	WAGONER		2005-2006	D.O.				
BLUESTEM	OSAGE	121300	2005-2006	D.O. TURBIDITY				
BOOMER	PAYNE	620900	2004-2005	TURBIDITY				
BROKEN BOW	MCCURTAIN	410210	2005-2006	PH D.O.				
BRUSHY CREEK	SEQUOYAH	220200	2003-2004	PH		ENT.		
BURTSCHI◘	GRADY		2005-2006	PH				NLW
CANTON	BLAINE	720500	2005-2006	TURBIDITY				
CARL ALBERT	LATIMER	410310	2003-2004					
CARL BLACKWELL	PAYNE	620900	2004-2005	TURBIDITY				
CARTER	MARSHALL	310800	2003-2004					
CEDAR (MENA)	LEFLORE	410210 410300	2005-2006	D.O. PH				
CHANDLER	LINCOLN	520700	2004-2005					
CHICKASHA◘	CADDO	310830	2004-2005	TURBIDITY				NLW
CLAREMORE	ROGERS	121500	2005-2006					NLW
CLEAR CREEK	STEPHENS	310810	2004-2005					
CLEVELAND CITY	PAWNEE		2003-2004	D.O.				
CLINTON◘	WASHITA	310830	2003-2004	TURBIDITY		ENT.		TRUE COLOR
COALGATE CITY	COAL	410400	2003-2004	D.O. TURBIDITY				TRUE COLOR
COMANCHE	STEPHENS	311300	2004-2005					
COPAN	WASHINGTON	121400	2004-2005	TURBIDITY D.O.				TRUE COLOR
CROWDER	WASHITA	310830	2005-2006					NLW
CUSHING MUNICIPAL	PAYNE	620900	2003-2004	TURBIDITY				TRUE COLOR
DAVE BOYER (WALTERS)	COTTON	311300	2003-2004	TURBIDITY				TRUE COLOR
DRIPPING SPRINGS	OKMULGEE	520700	2004-2005	TURBIDITY D.O.				TRUE COLOR

LAKE NAME	COUNTY	W.Q. SEGMENT #	LAST YEAR SAMPLED	FWP	PPWS	PBCR	AG	AES
DUNCAN	STEPHENS	310810	2004-2005					
EL RENO◘	CANADIAN		2004-2005	TURBIDITY				TRUE COLOR NLW
ELK CITY	BECKHAM	311500	2005-2006					NLW
ELLSWORTH	COMANCHE	311300	2003-2004	TURBIDITY D.O.				
ELMER THOMAS	COMANCHE	311300	2004-2005					
ETLING, CARL◘	CIMARRON	720900	2003-2004	TURBIDITY pH				NLW
EUCHA●	DELAWARE	121600	2004-2005	D.O.				NLW
EUFAULA	HASKELL	220600	2004-2005	D.O. TURBIDITY				TRUE COLOR
FAIRFAX CITY	OSAGE	621200	2003-2004	D.O.				
FORT COBB	CADDO	310830	2005-2006	TURBIDITY				NLW
FORT GIBSON	CHEROKEE	121600	2003-2004					NLW
FORT SUPPLY†	WOODWARD	720500	2005-2006	TURBIDITY				NLW
FOSS	CUSTER	310800 310810 310820 310830 310840	2004-2005					
FREDERICK	TILLMAN	311310	2004-2005	TURBIDITY				TRUE COLOR
FUQUA	STEPHENS	310810	2004-2005					
GRAND LAKE	MAYES	121600	2005-2006	D.O.				
GREAT SALT PLAINS	ALFALFA	621010	2005-2006	TURBIDITY			SULFATES & CHLORIDES	NLW
GREENLEAF	MUSKOGEE	120400	2005-2006	D.O.				
GUTHRIE◘	LOGAN	620910	2005-2006					NLW
HEALDTON CITY	CARTER	311100	2005-2006					
HEFNER	OKLAHOMA	520520 520530	2005-2006	D.O.				
HENRYETTA♦	OKMULGEE	520700	2004-2005	TURBIDITY				TRUE COLOR
HEYBURN	CREEK	120420	2004-2005	D.O. TURBIDITY		ENT.		TRUE COLOR
HOLDENVILLE	HUGHES	520800	2001-2002	D.O.		ENT.		
HOMINY MUNICIPAL	OSAGE	121300	2003-2004	D.O.				
HUDSON	OSAGE		2005-2006	D.O.				
HUDSON	MAYES	121600	2004-2005					
HUGO	CHOCTAW	410300	2004-2005	TURBIDITY				TRUE COLOR
HULAH	OSAGE	121400	2004-2005	TURBIDITY				NLW
HUMPHREYS	STEPHENS	310810	2004-2005					
JEAN NEUSTADT	CARTER	310800	2004-2005					

LAKE NAME	COUNTY	W.Q. SEGMENT #	LAST YEAR SAMPLED	FWP	PPWS	PBCR	AG	AES
JOHN WELLS	HASKELL	220200	2005-2006					
KAW	OSAGE	621210	2004-2005	TURBIDITY D.O.				
KEYSTONE	TULSA	621200 620900	2005-2006	TURBIDITY			SULFATES & CHLORIDES	
KONAWA	SEMINOLE		2004-2005					
LANGSTON	LOGAN	620900	2003-2004					
LAWTONKA	COMANCHE	311300	2003-2004					
LIBERTY	LOGAN	620910	2005-2006	TURBIDITY				
LLOYD CHURCH	LATIMER	220100	2005-2006	D.O. pH				TRUE COLOR
LONE CHIMNEY	PAWNEE	621200	2003-2004					
LUGERT-ALTUS	GREER	311500 311510	2004-2005	TURBIDITY				
MAYSVILLE/WILEY POST	MCCLAIN		2004-2005	TURBIDITY				TRUE COLOR
MCALESTER	PITTSBURG	220600	2004-2005					TRUE COLOR
MCGEE CREEK	ATOKA	410400	2003-2004	D.O. pH				
MCMURTRY	NOBLE	620900	2004-2005	TURBIDITY				
MEEKER	LINCOLN	520700	2005-2006	TURBIDITY				
MURRAY	LOVE	311100	2005-2006	D.O.				
NANIH WAIYA	PUSHMATAHA		2004-2005					
NEW SPIRO ◘	LEFLORE	220100	2005-2006	pH				NLW
OKEMAH	OKFUSKEE	520700	2004-2005	D.O.				TRUE COLOR
OKMULGEE	OKMULGEE	520700	2004-2005	D.O.				TRUE COLOR
OOLOGAH	ROGERS	121510	2004-2005	TURBIDITY D.O.				
OVERHOLSER ◘	OKLAHOMA	520520 520530	2005-2006	TURBIDITY				NLW TRUE COLOR
OZZIE COBB	PUSHMATAHA	410300	2004-2005	pH				NLW
PAULS VALLEY CITY	GARVIN	310810	2004-2005	TURBIDITY				TRUE COLOR
PAWHUSKA	OSAGE	121600	2004-2005					
PAWNEE	PAWNEE	621200	2003-2004					
PERRY	NOBLE	621200	2004-2005	TURBIDITY				TRUE COLOR
PINE CREEK	MCCURTAIN	410210	2003-2004	D.O. TURBIDITY pH				
PONCA	KAY	621200	2004-2005	D.O.				
PRAGUE CITY	LINCOLN	520510	2004-2005					
PURCELL	MCCLAIN	520610	2004-2005	TURBIDITY				
RAYMOND GARY	CHOCTAW	410300	2004-2005	D.O. TURBIDITY				TRUE COLOR

LAKE NAME	COUNTY	W.Q. SEGMENT #	LAST YEAR SAMPLED	FWP	PPWS	PBCR	AG	AES
R.C. LONGMIRE	GARVIN	310810	2004-2005	D.O.				
ROBERT S. KERR	SEQUOYAH	220200	2004-2005	TURBIDITY				
ROCK CREEK	CARTER	310800	2004-2005	D.O.				
ROCKY (HOBART) ◘	WASHITA	311500	2003-2004	TURBIDITY		ENT.		NLW
SAHOMA	CREEK	120420	2005-2006	D.O.				
SARDIS	PUSHMATAHA	410310	2004-2005	D.O. TURBIDITY				TRUE COLOR
SHAWNEE TWIN # 1	POTTAWATOMIE	520510	2005-2006	D.O.				
SHAWNEE TWIN # 2	POTTAWATOMIE	520510	2003-2004					
SHELL	OSAGE	120420	2005-2006	D.O.				
SKIATOOK	OSAGE	121300	2004-2005	D.O.				
SOONER	PAWNEE		2004-2005					
SPAVINAW ●	MAYES	121600	2004-2005	D.O.				NLW
SPORTSMAN	SEMINOLE	520500	2004-2005	TURBIDITY				TRUE COLOR
STANLEY DRAPER	CLEVELAND		2005-2006	D.O.				
STILWELL CITY	ADAIR	220200	2005-2006	D.O.				
STROUD	CREEK	520700	2005-2006	D.O.			SULFATES & CHLORIDES	
TALAWANDA # 1	PITTSBURG	220600	2004-2005	D.O. pH				
TALAWANDA # 2	PITTSBURG	220600	2004-2005	pH				
TAYLOR (MARLOW)	GRADY	310840	2004-2005					NLW
TECUMSEH	POTTAWATOMIE	520510	2003-2004					
TENKILLER FERRY◘	SEQUOYAH	121700	2005-2006	D.O.				NLW
TEXOMA	BRYAN	311100 310800	2004-2005	D.O. TURBIDITY				TRUE COLOR
THUNDERBIRD◘	CLEVELAND	520810	2003-2004	TURBIDITY				NLW
TOM STEED◘	KIOWA	311500	2004-2005	TURBIDITY				NLW
VANDERWORK	WASHITA	310830	2003-2004					NLW
VINCENT, LOYD	ELLIS	720500	2004-2005	D.O.				
W.R. HOLWAY	MAYES		2004-2005					
WAURIKA	JEFFERSON	311210	2004-2005	TURBIDITY				
WAXHOMA	OSAGE		2005-2006	D.O.				
WAYNE WALLACE	LATIMER	220100	2004-2005					
WEBBERS FALLS	MUSKOGEE	121400	2005-2006					
WES WATKINS	POTTAWATOMIE	520510	2005-2006					
WETUMKA	HUGHES		2003-2004	D.O.				

LAKE NAME	COUNTY	W.Q. SEGMENT #	LAST YEAR SAMPLED	FWP	PPWS	PBCR	AG	AES
WEWOKA	SEMINOLE	520500	2003-2004					
WISTER♣	LEFLORE	220100	2004-2005	D.O. TURBIDITY				NLW TRUE COLOR
YAHOLA●	TULSA	121300	1998-1999					

† Lake Listed Based Upon 1995 U.S. Army Corps. Of Engineers Intensive Study

♣ Lake Listed Based Upon OWRB Phase I Clean Lakes Study

♦ Lake does not fit classic definition of oligotrophy. Inorganic particulates are limiting biological productivity

● Lake was not assessed through the BUMP, but through another OWRB project

◘ These Lakes will be recommended for NLW listing as part of the next WQS revision process

IMPAIRMENT CODES		
NS = NOT SUPPORTING	PS = PARTIALLY SUPPORTING	

ACRONYMS	
NLW = NUTRIENT LIMITED WATER	D.O. = DISSOLVED OXYGEN
ENT. = ENTEROCOCCI BACTERIA	

ASSIGNED WQS BENEFICIAL USES	
FWP = FISH & WILDLIFE PROPAGATION	AES = AESTHETICS
PPWS = PUBLIC & PRIVATE WATER SUPPLY	AG = AGRICULTURE
PBCR = PRIMARY BODY CONTACT RECREATION	

The pH was examined and compared to the WQS for pH, 6.5 to 9 units, listed in 785:45-5. Three of the 36 lakes sampled in 2005-2006 were listed as partially supporting the FWP beneficial use based on pH values and two lakes were listed as not supporting (Figure 4). Turbidity, in Nephelometric turbidity units (NTU), was measured via a HACH turbidimeter for all sites on each lake sampled to identify lakes that exceeded the WQS of 25 NTU. Seasonal turbidity values at each site are displayed for each lake as well as the lake-wide annual turbidity value. Of the 36 lakes sampled in 2005-2006, six lakes were not supporting their Fish & Wildlife Propagation (FWP) beneficial use, six were partially supporting the and twenty-four were fully supporting their FWP beneficial use based on turbidity values (see Figure 6). True color units were also averaged for the year to compare to the WQS of 70 units. Seasonal true color values per site are displayed graphically for each lake (see Figure 5.). In 2005-2006, two lakes were not supporting the Aesthetics beneficial use based on high true color values. Vertical profiles recorded with a Hydrolab® were examined to determine if anoxic conditions were present and whether or not the lake was meeting the FWP beneficial use. The USAP lists dissolved oxygen violations as values below 2.0 mg/L for 70% of the entire water column and partially supporting if between 50% and 70% of the lake. Of the 36 lakes sampled in 2005-2006, only two were not supporting the FWP beneficial use based on anoxic conditions, primarily in the summer season (See Figure 9.). Chloride and sulfate water quality parameters were also added to the lake sampling program in year 2003-2004. These additions allow for an assessment of the agriculture beneficial use of our reservoirs and much like metals sampling is a sampling effort that we plan on continuing into the future. Analysis of the chloride and sulfate data

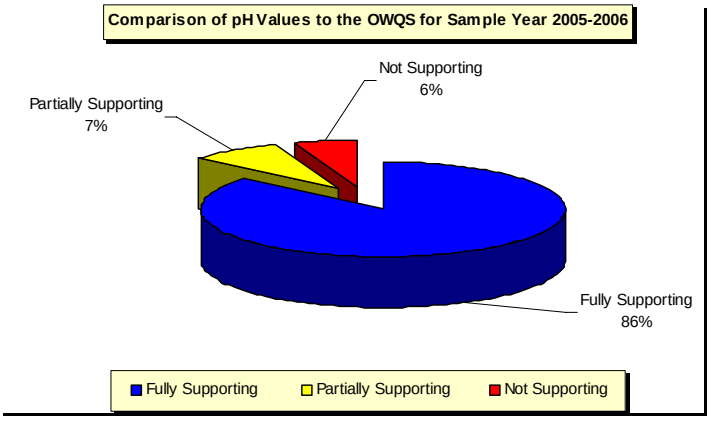


Figure 4. Percent of lakes assessed that exceeds or meets the WQS for pH.

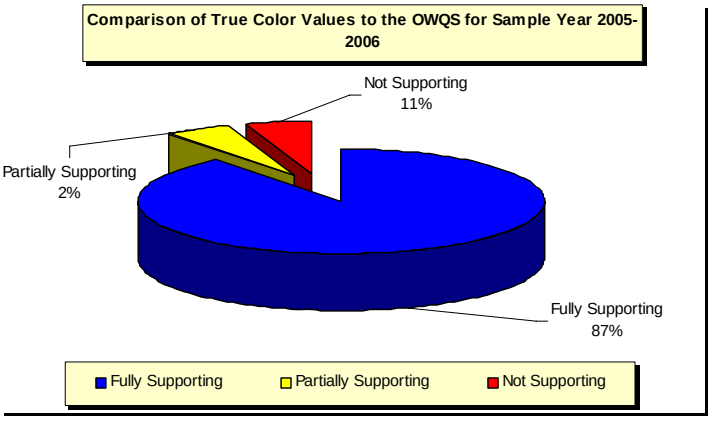


Figure 5. Percent of lakes assessed that exceeds or meets the WQS for true color.

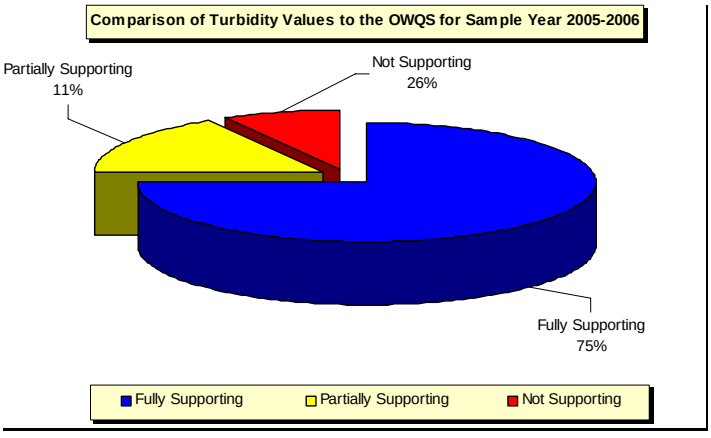


Figure 6. Percent of lakes assessed that exceeds or meets the WQS for turbidity.

revealed that only two lakes sampled were not supporting the agriculture beneficial use (See Figure 8). The lakes not supporting were Great Salt Plains Reservoir and Keystone Lake, Cimarron River arm. This was not an unexpected result and these waterbody are the "saltiest" in the state. Analysis of the bacteria data indicated that all of the lakes sampled were supporting their Primary Body Contact Recreation beneficial use (See Figure 8).

It is the intent of the OWRB monitoring program to pursue adding additional monitoring parameters to the lake sampling initiative to allow all beneficial uses to be assessed. It is also the OWRB intent to accomplish this without having to reduce the number of lakes sampled annually.

A brief synopsis of the results from OWRB field sampling for each of the 36 lakes sampled in 2005-2006 as well as the 64 lakes sampled in 2004-2005 is discussed in alphabetical order on the following pages.

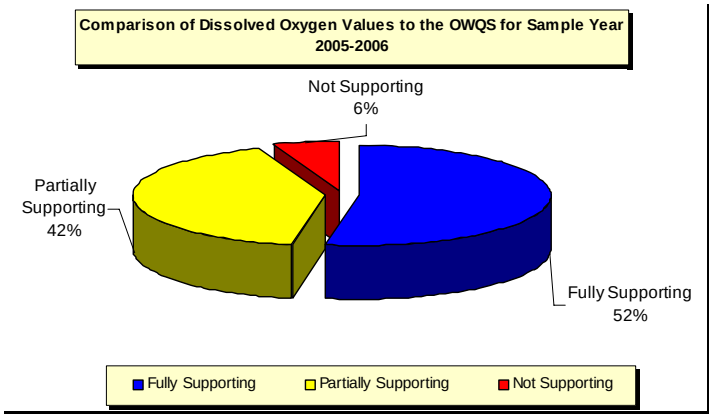


Figure 7. Percent of lakes assessed and their support status of the WQS for dissolved oxygen

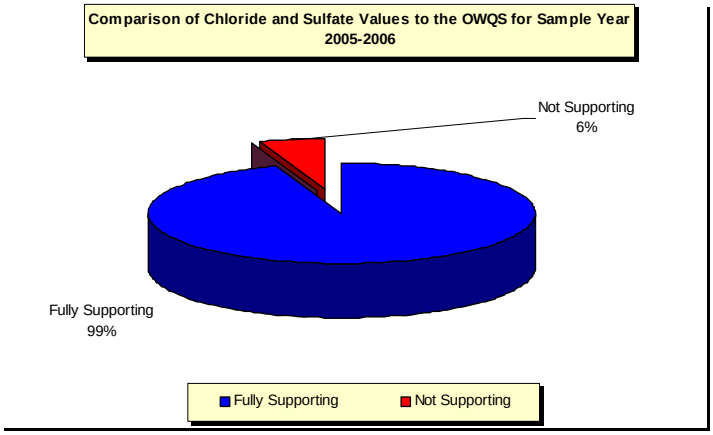


Figure 9. Percent of lakes assessed and their support status of the WQS for chlorides & sulfates.

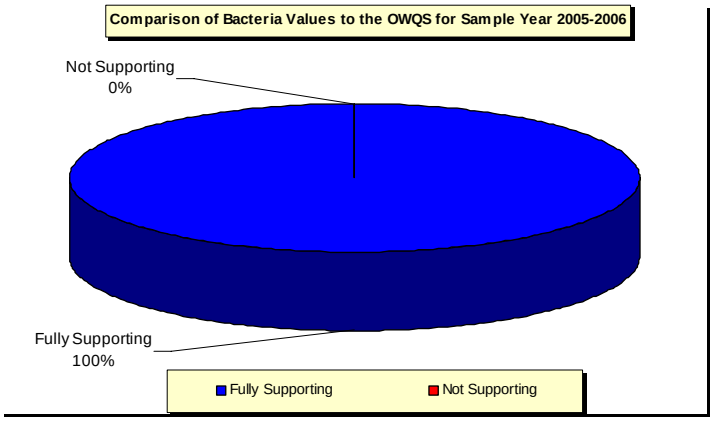
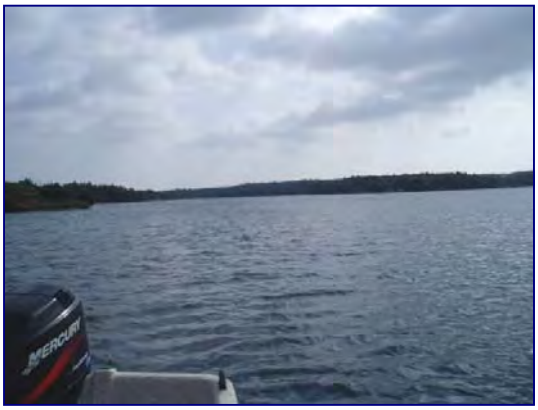


Figure 8. Percent of lakes assessed and their support status of the WQS for bacteria.

American Horse Lake



American Horse Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at three (3) sites to represent the riverine, transition and lacustrine zones of the lake. Samples were collected from the lake surface at all sites and at 0.5 meters from the bottom at site 1, the dam. The lake-wide annual average turbidity was 2 NTU (Plate 1), true color was 12 units and secchi disk depth was 288 centimeters in sample year 2004-2005. Based on these three parameters, American Horse Lake had excellent water clarity. The trophic state index, using Carlson's TSI (chlorophyll-a) was calculated using values collected at all three sites for four quarters (n=11). The result was a TSI of 49 (Plate 1), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions. This is slightly lower than the value calculated in 2003 (TSI=55). The TSI values were upper mesotrophic to eutrophic throughout the year with the exception of the spring quarter when values fell into the oligotrophic category. Seasonal turbidity are displayed in Figure 10a. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With a 100% of the turbidity values well below the Oklahoma Water Quality Standard (WQS) of 25 NTU the lake is meeting the Fish and Wildlife Propagation (FWP) the beneficial use. Seasonal true color values are displayed in (Figure 10b). Applying the same default protocol, the Aesthetics beneficial use is fully supported with all collected values below the WQS of 70 units.

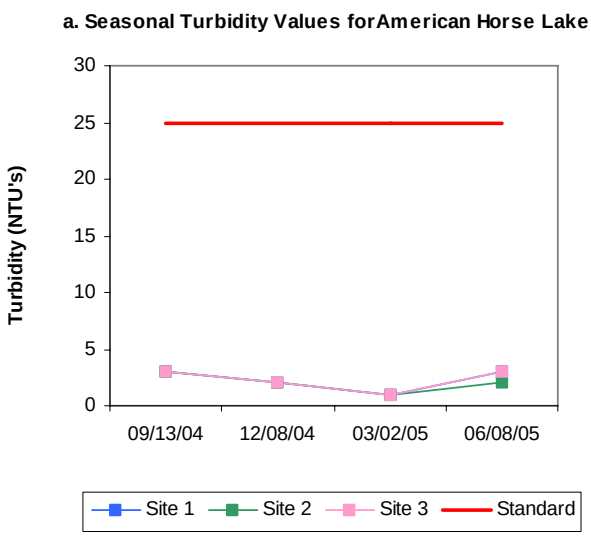
In sample year 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity; oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 0.15 parts per thousand (ppt) to 0.18 ppt for this sample year. Specific conductivity ranged from 310 µS/cm to 372.7 µS/cm, which falls within the range of values commonly reported for Oklahoma lakes. These values indicate a moderate level of current conducting ions (salts) were present in the system. The pH values at American Horse Lake ranged from 6.97 to 8.28, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Based on pH values collected American Horse Lake is currently supporting its FWP beneficial use. Oxidation-reduction potentials ranged from 3 mV in the fall quarter near the sediment-water interface to 495 mV in the spring. Reducing conditions were present at sites 2 and 3 in the fall sampling interval, when a large portion of the water column was anoxic. During the winter and spring sampling intervals, thermal stratification was not present (Figure 10d-10e). Thermal stratification was evident in both fall and summer quarters and anoxic conditions were present. In the fall stratification occurred at between 7 and 8 meters in depth at which point dissolved oxygen dropped below 2.0 mg/L at all three sites. During the summer quarter the lake exhibited strong thermal stratification between 4 and 5 meters at which point the dissolved oxygen dropped below 2 mg/L for the remainder of

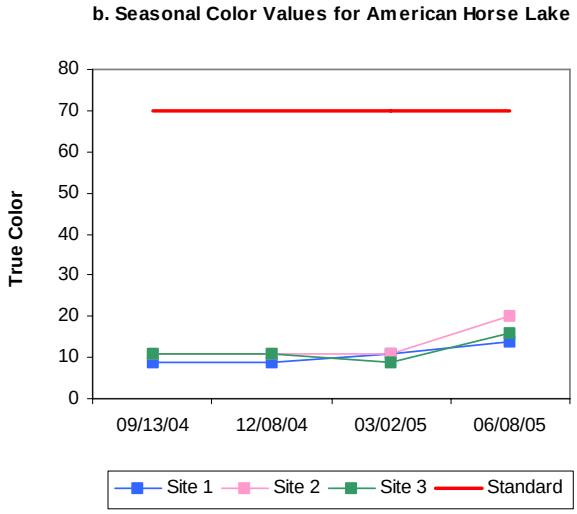
the water column (Figure 10f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. In the fall quarter anoxic conditions comprised approximately 58% of the water column at site 2. Similar conditions were present during the summer quarter with 54 to 67% of the water column less than 2.0 mg/L. Based on this information the FWP beneficial use is considered partially supported at American Horse Lake. These conditions could pose a serious concern, threatening fish and wildlife propagation and the lake should be closely monitored in the future. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported bases on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

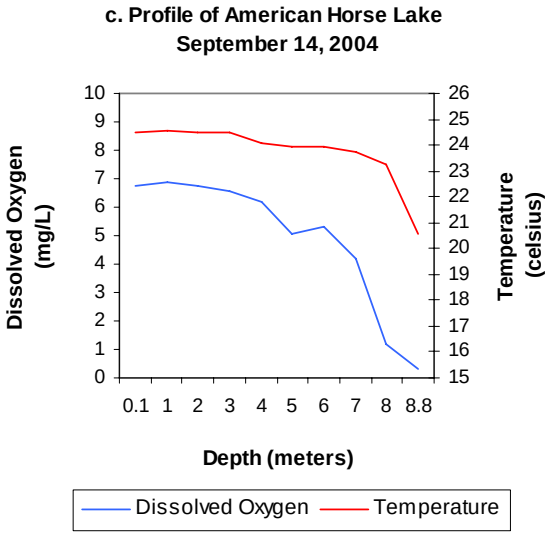
Bacteriological samples were not collected during the study period; therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

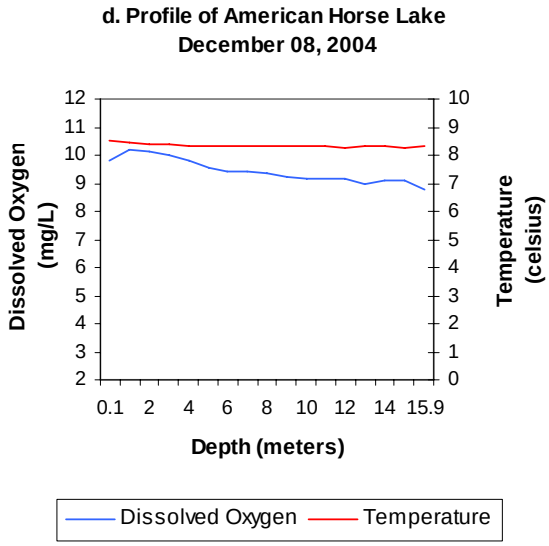
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.63 mg/L. The TN at the surface ranged from 0.46 mg/L in the summer to 0.77 mg/L in the spring quarter. The lake-wide total phosphorus (TP) average was 0.032 mg/L. The total phosphorus at the surfaced ranged from 0.018 mg/L to 0.050 mg/L with lower values occurring in the spring quarter. The nitrogen to phosphorus ration (TN:TP) was 21:1 for sample year 2003. This value is much higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

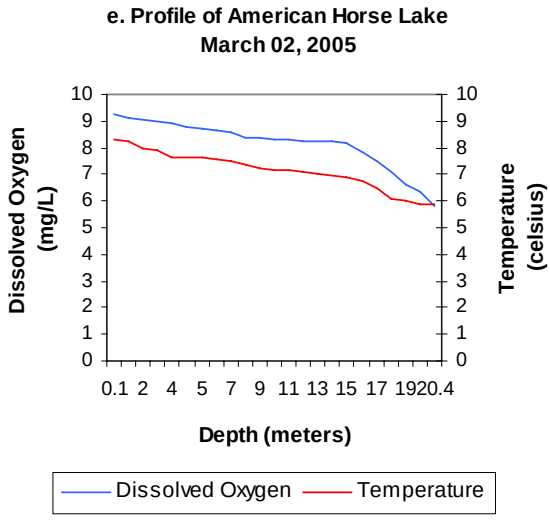
In summary, American Horse Lake was mesotrophic, indicative of moderate primary productivity and nutrient conditions slightly lower than the results from the 2002-2003 data collection efforts. Water clarity was excellent based on true color, turbidity and secchi disk depth. The lake is supporting the FWP beneficial use based on pH, and turbidity. Anoxic conditions present in both fall and summer months constitute a listing of partial support for the FWP beneficial use based on dissolved oxygen concentrations at American Horse Lake. With an annual average for true color of 3 units and a TSI of 49 the Aesthetics beneficial use is supported. This reservoir is located in Blaine County and is managed by the Oklahoma Department of Wildlife Conservation for the recreational purposes.











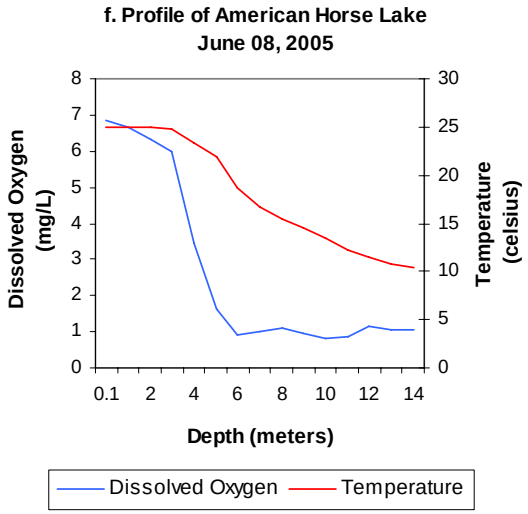


Figure 10a-10f. Graphical representation of data results for American Horse Lake.

American Horse Lake
Location

American Horse Lake
and
Watershed

POOR EXCELLENT

Turbidity
2005

POOR EXCELLENT

Trophic State
2005

Lake Data

Owner	State of Oklahoma
County	Blaine
Constructed in	1966
Surface Area	100 acres
Volume	2,200 acre/feet
Shoreline Length	7 miles
Mean Depth	22.00 feet
Watershed Area	3,124 acres

Plate 1 - Lake Water Quality for

American Horse Lake

LAKES MONITORING PROGRAM

Arbuckle Reservoir

Arbuckle Reservoir was sampled for four quarters from November 2004 through August 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition and lacustrine zones of the lake. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 5 NTU, (Plate 2), true color was 17 units and average secchi disk depth was 166 centimeters. Based on these parameters water clarity at Arbuckle Reservoir was excellent in sample year 2005. The trophic state index using Carlson's TSI (chlorophyll-a) was calculated using values collected at all sites for four quarters (n=20). The result was a TSI of 46 (Plate 2), indicating the lake was mesotrophic in sample year 2005. This value is similar to the one calculated in 2003 (TSI=48), indicating no significant change in productivity has occurred. The TSI values were fairly consistent and ranged from mesotrophic in the fall, spring and summer quarters to oligotrophic at sites 1 and 5 during the winter. Seasonal turbidity values are displayed in Figure 11a. All turbidity values were well below the Oklahoma Water Quality Standard (WQS) turbidity standard of 25 NTU with values ranging between 3 and 6 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the values below the numerical criteria the lake is considered to be fully supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 11b. All color values were well below the WQS of 70 units; therefore the aesthetics beneficial use is considered fully supported.

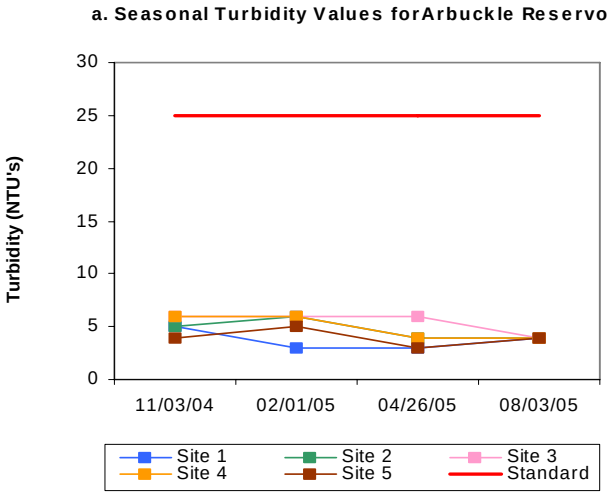
In sample year 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential and salinity were recorded at all sample sites. Salinity ranged from 0.18 ppt to 0.22 ppt. This value is within the average range recorded for Oklahoma lakes. Specific conductivity ranged from 357 µS/cm to 467.8 µS/cm, indicating moderate levels of current conducting ions were present in the lake system. Oxidation-reduction potentials (ORP) ranged from 288 mV at the lake bottom in the winter to 480 mV in the summer. Reducing conditions were not present in the reservoir in the 2004-2005-sample year. The pH values at Arbuckle Reservoir ranged from 7.15 in the summer quarter to 8.30 in the spring representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Based on pH values collected Arbuckle Reservoir is currently supporting its FWP beneficial use. Thermal stratification was not present during the fall, winter or spring quarters and the water column was evenly mixed. Dissolved oxygen (D.O) levels remained above 6.0 mg/L during the fall and above 9 mg/L in the winter sampling quarters respectively (Figure 11c-11e). Thermal stratification was evident and anoxic conditions were present in the

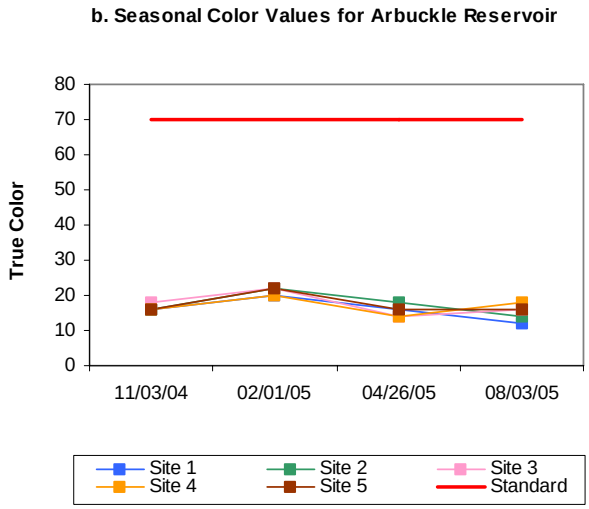
summer quarter. In the summer stratification occurred between 6 and 7 meters with dissolved oxygen levels less than 2.0 mg/L from 8 meters below the surface to the lake bottom of 21.8 meters accounting for 65% of the water column at site 1, to be experiencing anoxic conditions (see Figure 11f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With anoxic conditions present in 65% of the water column in the summer Arbuckle Reservoir is considered to be partially supporting the FWP beneficial use. These conditions could however pose a serious concern, threatening the FWP beneficial use and the lake should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

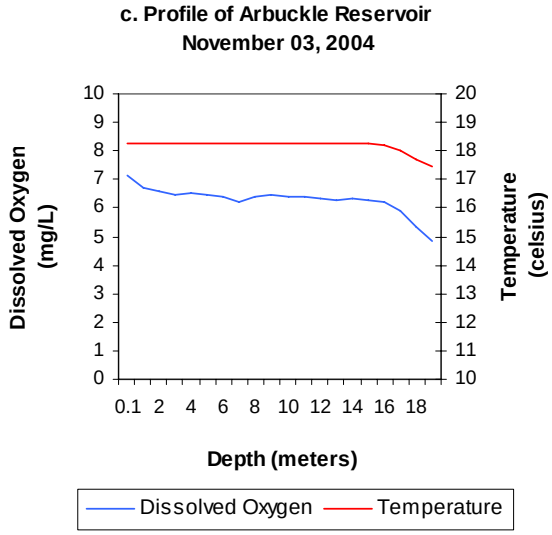
Arbuckle Reservoir was not sampled for bacteria during the study period and an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

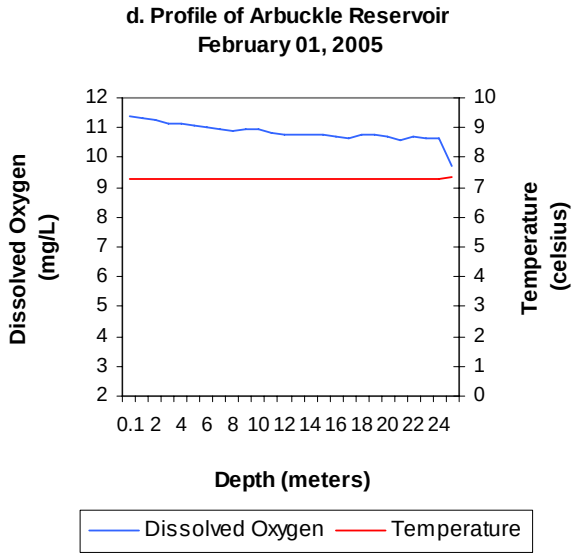
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.43 mg/L. Surface TN ranged from 0.17mg/L to 1.13 mg/L, with the highest values occurring in the summer and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.024 mg/L. Total phosphorus at the surface ranged from 0.013 mg/L to 0.038 mg/L. Similar to nitrogen, surface TP was lowest in the spring quarter however the highest values were recorded during the winter months. The nitrogen to phosphorus ratio (TN:TP) was 18:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

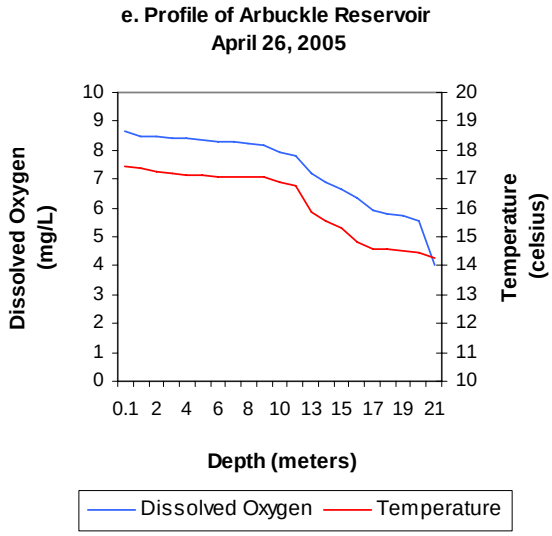
In summary, Arbuckle Reservoir was classified as mesotrophic indicative of moderate productivity and nutrient levels in 2004-2005 (Plate 2). This classification is the same as that in 2003, indicating no significant increase or decrease in productivity has occurred over time. Water clarity was excellent based on true color, turbidity, and high secchi disk depth readings. The lake is fully supporting the FWP beneficial use based on pH and partially supporting based on anoxic conditions present during the summer. The Aesthetics beneficial use is also supported based on its trophic status and extremely low true color readings. Arbuckle Reservoir, located in Murray County, was constructed by the Bureau of Reclamation and is utilized as a municipal water supply, flood control, and fish and wildlife recreation lake.











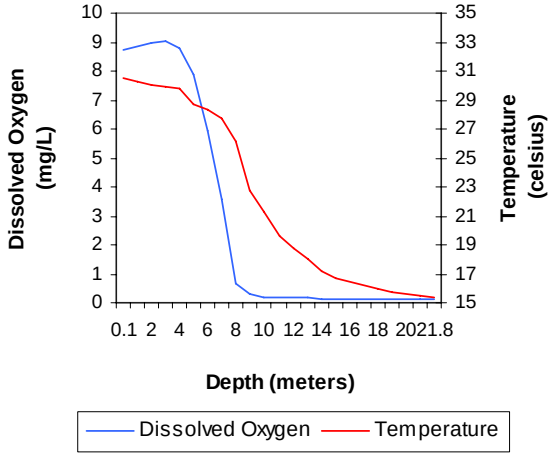
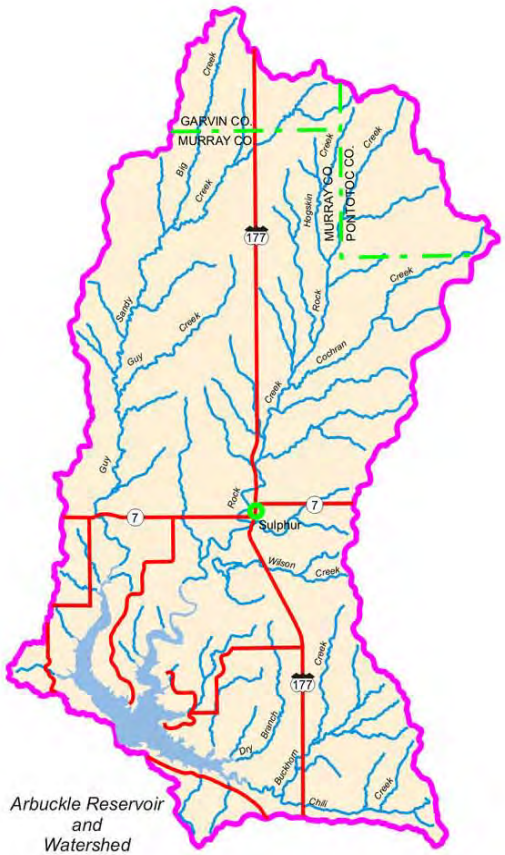
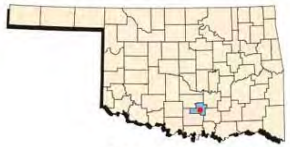


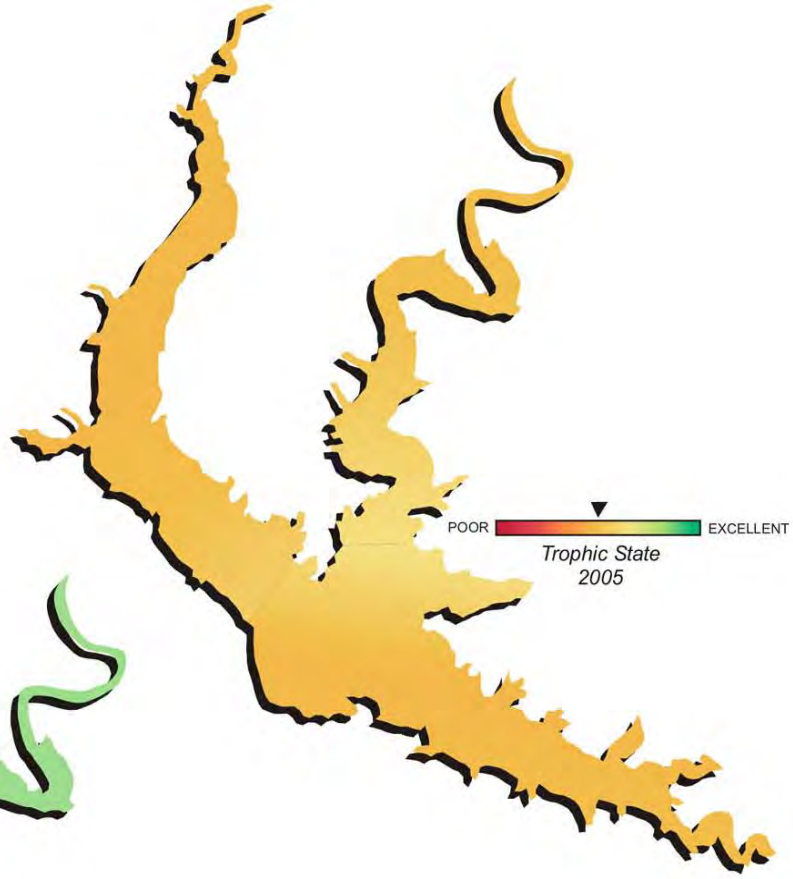
Figure 11a-11f. Graphical representation of data results for Arbuckle Reservoir.



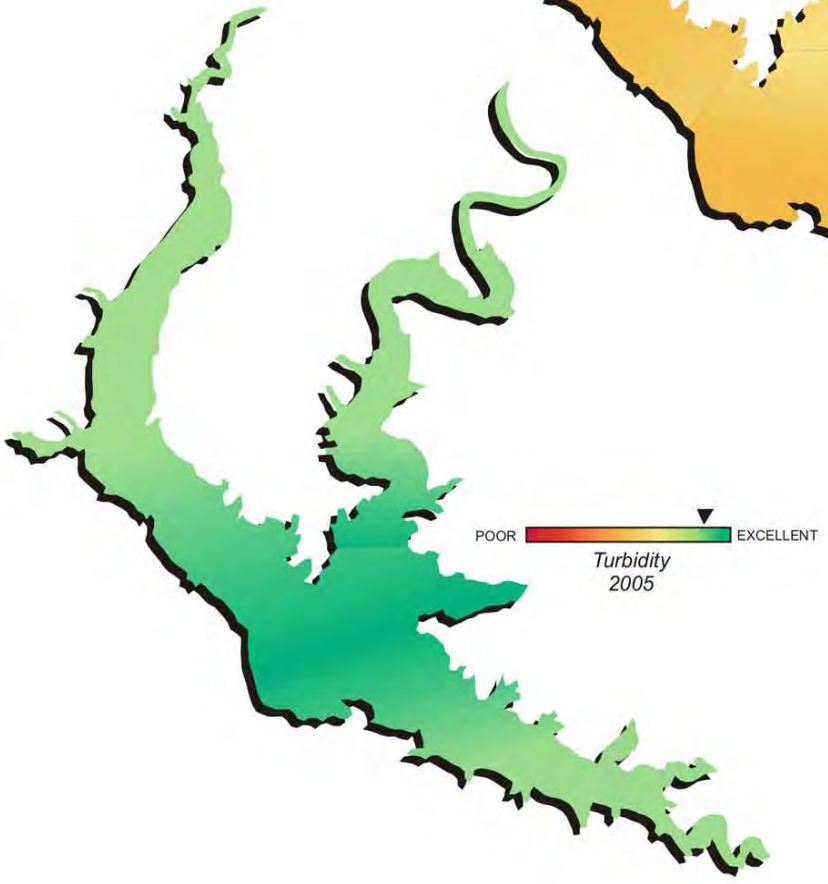
Arbuckle Reservoir and Watershed



Arbuckle Reservoir Location



Trophic State 2005



Turbidity 2005

Lake Data	
Constructed by	Bureau of Reclamation
County	Murray
Constructed in	1967
Surface Area	2,350 acres
Volume	72,400 acre/feet
Shoreline Length	36 miles
Mean Depth	30.8 feet
Watershed Area	126 square miles

Plate 2 - Lake Water Quality for

Arbuckle Reservoir

LAKES MONITORING PROGRAM

Arcadia Lake

Arcadia Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition and lacustrine zones and major arms of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 31 NTU (Plate 3), true color was 34 units, and average secchi disk depth was 67 centimeters in sample year 2004-2005. Water clarity was average at Arcadia Lake based on these three parameters. Results for turbidity, true color, and secchi disk depth are similar to those recorded in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 62 (Plate 3), indicating the lake was hypereutrophic, with high to excessive levels of productivity and nutrient conditions for sample year 2005. This value is slightly higher than the value calculated in 2003 (TSI=59). The TSI for all sites ranged from hypereutrophic in the fall and winter to upper eutrophy in both the spring and summer. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Turbidity values were fairly consistent throughout the year with large peak recorded at site 5 during the spring sampling event (see Figure 12a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. Although 15% of the values exceed the numerical criteria of 25 NTU, field observations and photo documentation recoded by staff along with available flow and rainfall data suggest that this is the result of a seasonal storm event. The FWP beneficial use will therefore be considered supported in regards to turbidity for this sample period. Seasonal true color values are displayed in Figure 12b. With only 1(5%) of the recorded values exceeding the numerical criteria of 70 units, the Aesthetics beneficial use is considered fully supported at Arcadia Lake.

In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.10 parts per thousand (ppt) to 0.27 ppt. This is within the average range of values recorded in Oklahoma reservoirs. Specific conductivity ranged from 213.9 µS/cm to 523.6 µS/cm, indicative of moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.64 in the summer to 8.53 in the winter representing a neutral to slightly alkaline lake system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Based on pH values collected Arcadia Lake is currently supporting its FWP beneficial use. Oxidation-reduction potentials (ORP) ranged from 140mV to 535 mV, both

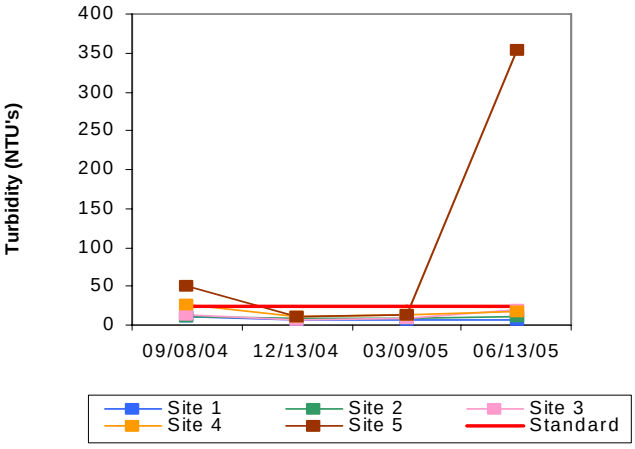
recorded in the fall, indicating reducing conditions were not present at this reservoir during the 2004-2005-sample period. Arcadia Lake was not thermally stratified the in first three sampling quarters (Figure 12c-12e). The lake was stratified and anoxic conditions were present in the hypolimnion during the summer. Stratification occurred several 1-meter intervals, the first at the 7 to 8 meter depth and again between 9 and 10 meters at which point dissolved oxygen (D.O.) levels dropped below 2 mg/L for the remainder of the water column (Figure 12f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. levels are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is considered partially supported. With approximately 29% of the water column experiencing anoxic conditions in the summer months Arcadia Lake is listed as supporting the Fish and Wildlife Propagation beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the study period therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

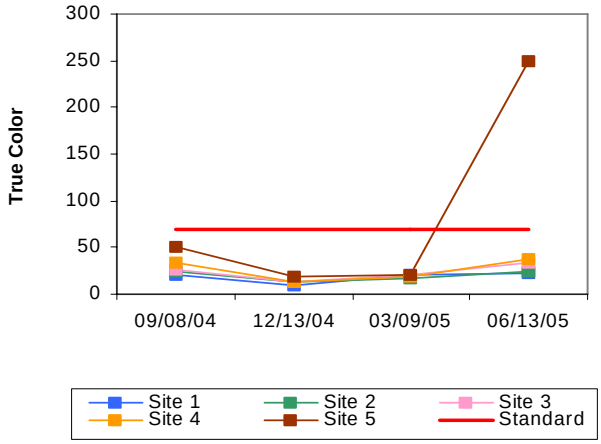
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.73 mg/L. Surface TN ranged from 0.40 mg/L to 1.10 mg/L with the highest values recorded in the spring quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.070 mg/L. Surface TP ranged from 0.040 mg/L to 0.276 mg/L was highest in the fall months, and like total nitrogen the low values occurred during the winter sampling quarter. The nitrogen to phosphorus ratio (TN:TP) was 11:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Arcadia Lake was classified as hypereutrophic indicative of high to excessive primary productivity and nutrient levels. The lake will be recommended for listing as an NLW in the next WQS revision process and it Aesthetics beneficial use considered nutrient threatened. Water clarity was average with values for turbidity, true color and secchi disk depth being similar to those recorded in sample year 2003. The lake is currently supporting the FWP beneficial use based on pH, turbidity as well as dissolved oxygen levels. The Aesthetics beneficial use is considered supported with only 5% of the recorded true color values exceeding the numerical criteria of 70 units. The Oklahoma Department of Environmental Quality (ODEQ) sampled the fish community in 2002 and none of the fish tissue samples exceeded the screening level or low consumption advisory for metals toxicity. Arcadia Lake is located in Oklahoma County and was constructed by the United States Army Corps of Engineers (USACE) to serve as the water supply for the City of Edmond as well as flood control and recreation purposes. The OWRB completed a Phase I Diagnostic and Feasibility Study of Arcadia Lake in March 2000 and can be referenced for further information by visiting our website at http://www.owrb.state.ok.us/.

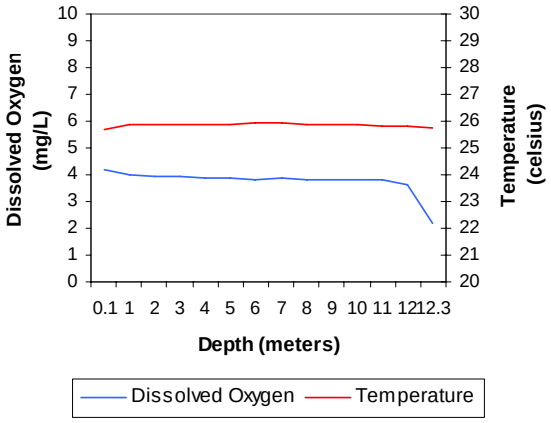
a. Seasonal Turbidity Values forArcadia Lake



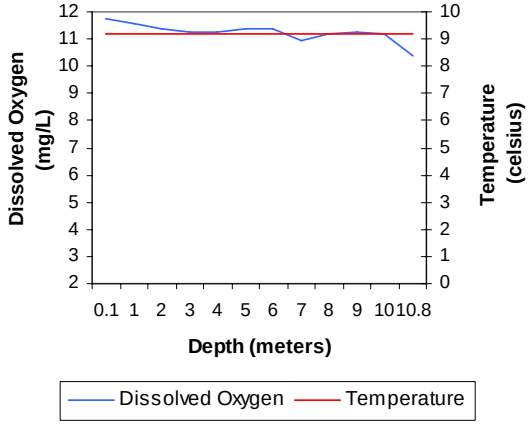
b. Seasonal Color Values for Arcadia Lake



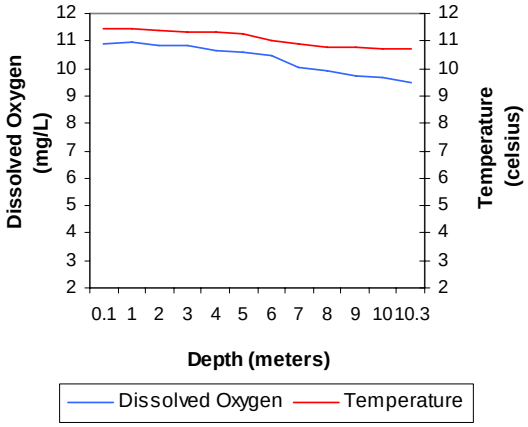
c. Profile of Arcadia Lake
September 08, 2004



d. Profile of Arcadia Lake
December 13, 2004



e. Profile of Arcadia Lake
March 09, 2005



f. Profile of Arcadia Lake
June 13, 2005

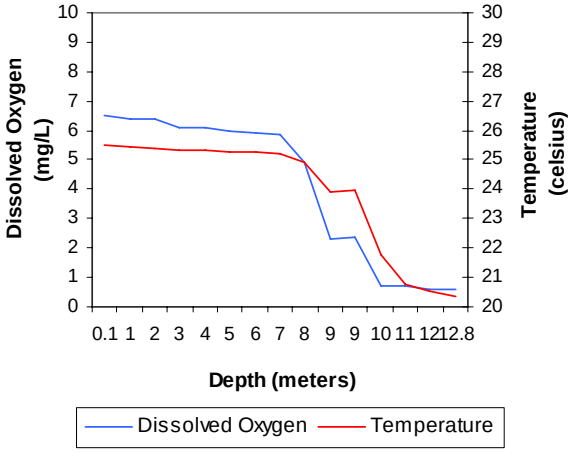
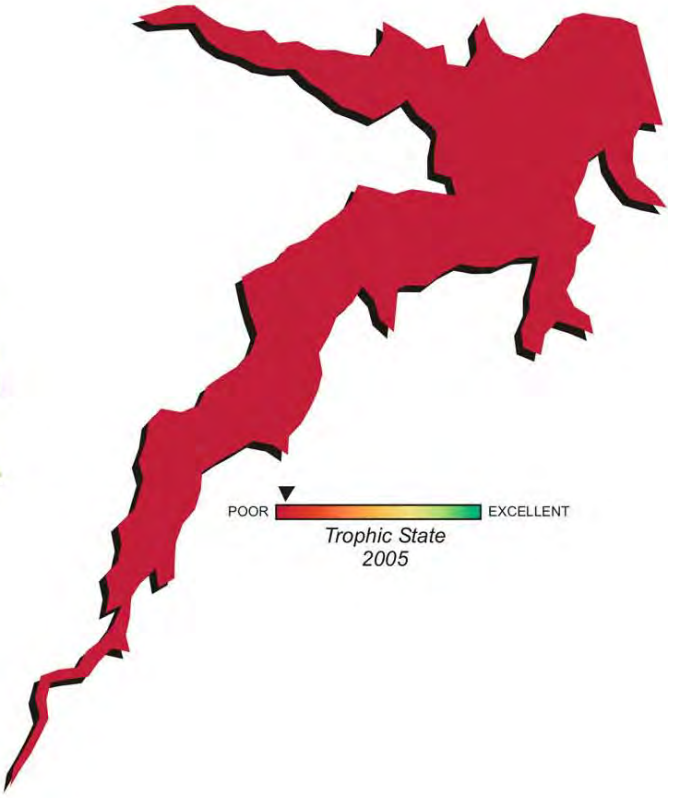
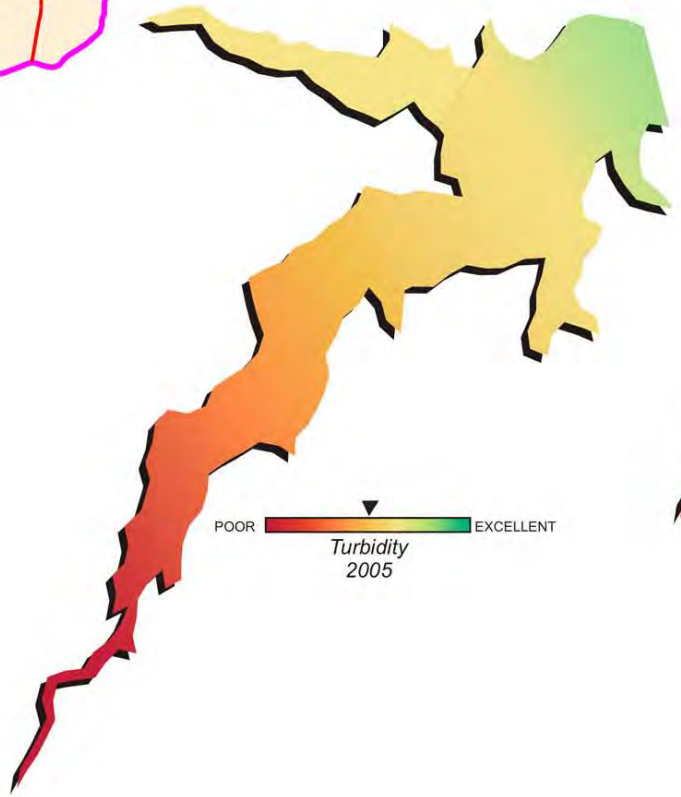


Figure 12a-12f. Graphical representation of data results for Arcadia Lake.





Lake Data	
Constructed by	Corps of Engineers
County	Oklahoma
Constructed in	1980
Surface Area	1,820 acres
Volume	27,520 acre/feet
Shoreline Length	26 miles
Mean Depth	15.14 feet
Watershed Area	105 square miles

Plate 3 - Lake Water Quality for

Arcadia Lake

LAKES MONITORING PROGRAM

Ardmore City Lake

Ardmore City Lake was sampled for four quarters, from October 2004 through September of 2005. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 8 NTU (Plate 4), true color was 17 units, and average secchi disk depth was 98 centimeters in sample year 2005. Water clarity was excellent at Ardmore City Lake based on the high secchi disk depth and low turbidity values and is similar to results from the 2003 evaluation. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 49 (Plate 4), indicating the lake was mesotrophic in sample year 2005. The TSI values for all sites were fairly consistent throughout the sample year with all values being upper mesotrophic in nature. In 2003, the calculated TSI value was also mesotrophic (TSI=45) indicating no significant change in productivity has occurred. All turbidity values were well below the turbidity standard of 25 NTU (Figure 13a). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With a 100% of the turbidity values well below the Oklahoma Water Quality Standard (WQS) of 25 NTU the lake is meeting the Fish and Wildlife Propagation (FWP) the beneficial use. Similar to turbidity all color values were well below the aesthetics WQS for color 70 units (see Figure 13b). Applying the same default protocol the Aesthetics beneficial use is considered supported at Ardmore City Lake.

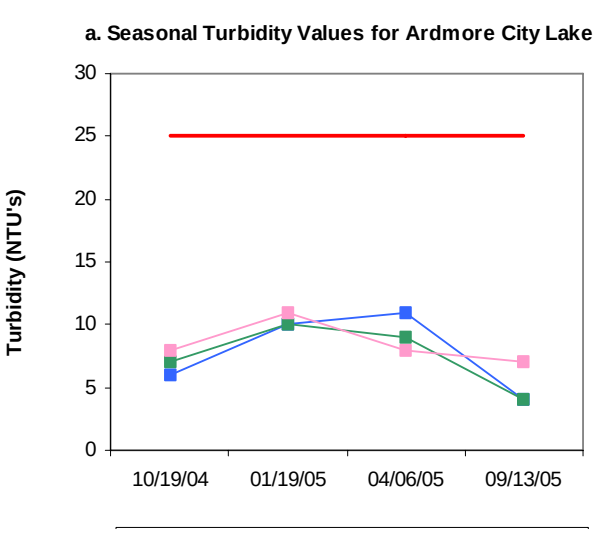
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.14 parts per thousand (ppt) to 0.22 ppt, which is within the average range of values observed in Oklahoma reservoirs. Specific conductivity ranged from 283.4 µS/cm to 446.2 µS/cm, indicative of moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.73 to 8.2 representing a neutral to slightly alkaline lake system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Based on pH values collected Ardmore City Lake is currently supporting its FWP beneficial use. Oxidation-reduction potentials (ORP) ranged from 84mV in the hypolimnion in the spring to 474 mV in the summer. In general, reducing conditions were not present at this reservoir during the 2004-2005-sample year. The lake was well mixed and thermal stratification was not present during the first three sampling events (Figure 13c-13e) Thermal stratification was evident and anoxic condition present during the summer sampling quarter. The lake was stratified between 4 and 5 meters below the surface, with dissolved oxygen levels less than 2.0 mg/L for approximately 40% of the water column at both sites 1 and 2 (Figure 13e). If D.O. values are less than 2.0

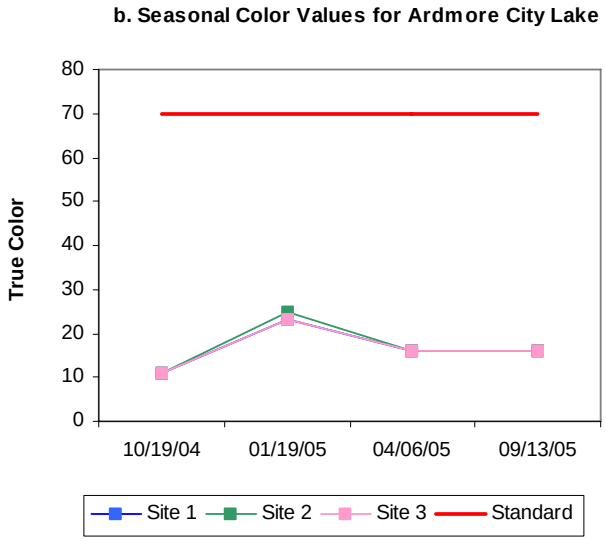
mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. levels are less than 2.0 mg/L for 50 to 70% of the water column the FWP beneficial use is considered partially supported. At this time Ardmore City Lake is considered supporting the FWP beneficial use based on dissolved oxygen concentrations. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

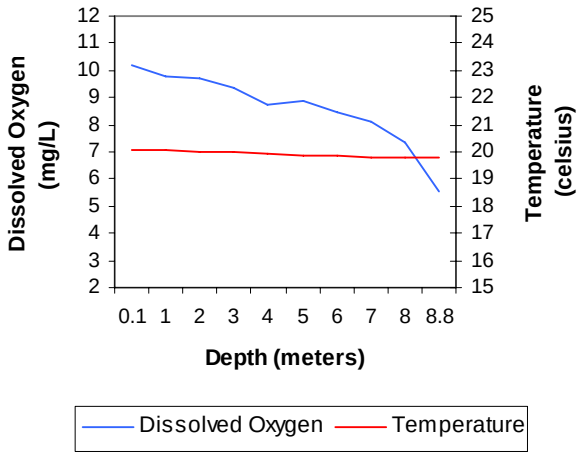
Bacteriological samples were not collected during the study period therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

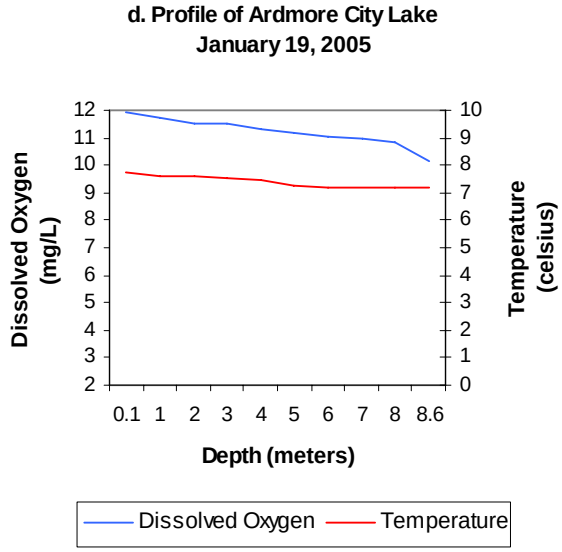
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.46 mg/L at the surface. Surface TN ranged from 0.33 mg/L to 078 mg/L with the highest values recorded in the summer quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.022 mg/L at the surface. Surface TP ranged from 0.016 mg/L to 0.028 mg/L was highest in the winter months and the lowest during the summer sampling quarter. The nitrogen to phosphorus ratio (TN:TP) was 22:1 for sample year 2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

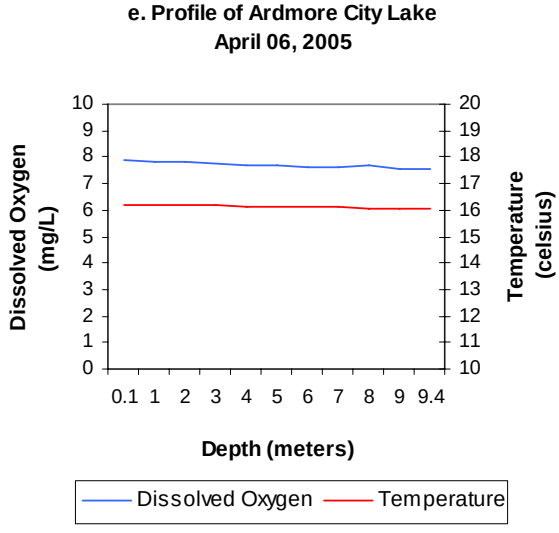
In summary, Ardmore City Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels in sample year 2005 (Plate 4). These results are similar to those seen in 2003 indicating no significant increase or decrease in productivity has occurred since the previous evaluation. Water clarity was excellent based on turbidity, true color, and secchi disk depth readings. The lake is currently supporting the Fish and Wildlife Propagation (FWP) beneficial use based on pH, turbidity and dissolved oxygen concentrations. Ardmore City Lake constructed in 1910 is located in Carter County for the purpose of recreation.











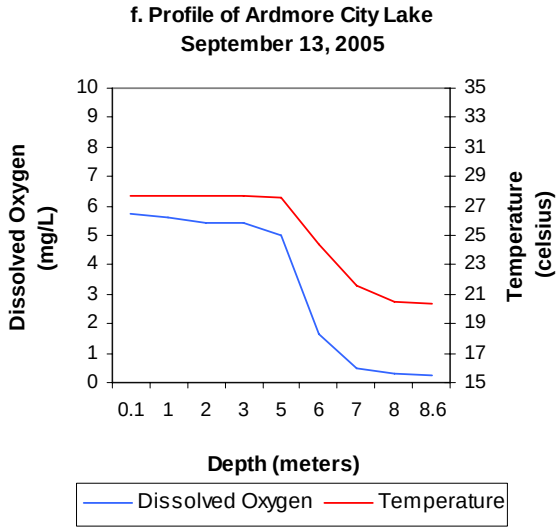
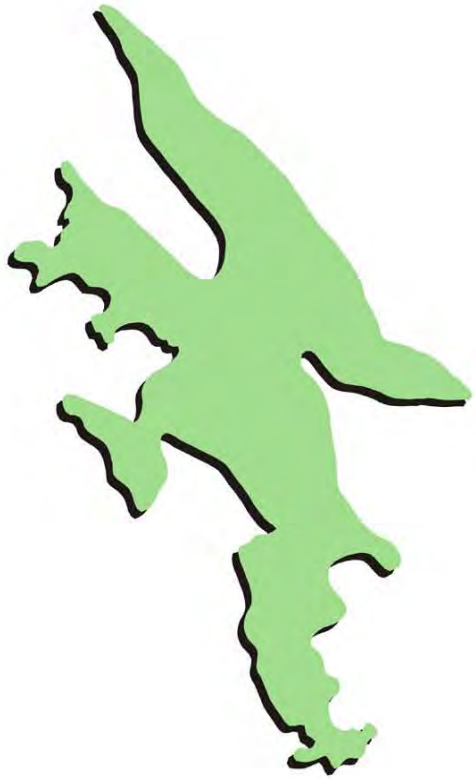


Figure 13a-13e. Graphical representation of data results for Ardmore City Lake.

Ardmore City Lake
Location

Ardmore City Lake
and
Watershed



POOR EXCELLENT

Turbidity
2005

POOR EXCELLENT

Trophic State
2005

Lake Data

Owner	City of Ardmore
County	Carter
Constructed in	1910
Surface Area	142 acres
Volume	600 acre/feet
Shoreline Length	5 miles
Mean Depth	4.23 feet
Watershed Area	2,046 acres

N
W E
S

Plate 4 - Lake Water Quality for
Ardmore City Lake

LAKES MONITORING PROGRAM

Atoka Lake

Atoka Lake was sampled for four quarters, from October 2003 through July of 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and an additional sample was collected at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 94 NTU (Plate 5), true color was 156 units, and average secchi disk depth was 21 centimeters in sample year 2003-2004. Water clarity was poor at Atoka Lake based on the low secchi disk depth and high turbidity values. Atoka Lake has always had high levels of clay particulates suspended in the water column, which results in low water clarity. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 50 (Plate 5), indicating the lake was mesotrophic bordering eutrophic in sample year 2003-2004. The TSI values for all sites throughout the sample year were fairly consistent with all values in the mesotrophic and eutrophic categories. The only exception to this was site 3 during the month of April, which was oligotrophic. Seasonal turbidity values per site for this sample year are displayed in Figure 15a. All turbidity values were well above the turbidity standard of 25 NTU with the lowest recorded value of 47 NTU and the maximum value of 302 NTU. With 100% of the values exceeding the numerical criteria the lake is considered not supporting its Fish & Wildlife Propagation (FWP) beneficial use. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. However, in the case of Atoka Lake, evidence suggests that the high turbidity readings are natural based on the local soil conditions. Seasonal true color values are also displayed in Figure 15b. The average lake-wide color was calculated at 156 units, which greatly exceeded the Aesthetics WQS for color (70 units). The minimum value recorded was 44 units and the maximum value recorded was 282 units. Applying the same default protocol, Atoka Lake is not meeting the aesthetics beneficial use based on true color.

In 2003-2004, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites. The salinity values for Atoka Lake ranged from 0.02 parts per thousand (ppt) to 0.10 ppt for this sample year. Specific conductivity ranged from 57 to 211.1 µS/cm, which falls within the range of values commonly reported for Oklahoma reservoirs. These values indicate relatively low levels of ions were present in the system. The pH values at Atoka Lake ranged from 6.21 units at the lake bottom in the summer to 8.02 at the lake surface in the fall quarter, representing a neutral to slightly acidic system. Oxidation-reduction potentials ranged from 346mV in the hypolimnion in the summer to 582mV in the winter. Reducing conditions were not present at this reservoir in the 2003-2004-sample year. During the fall, winter and spring quarters stratification was not present, the lake was well mixed, and dissolved oxygen values were generally above 7 mg/L (see Figure 15c-15fe. Thermal stratification was evident in the summer quarter and anoxic conditions were present. In the summer the lake was stratified between 11 and 12 meters at

which point dissolved oxygen dropped to <2mg/L for the rest of the water column at site 1 (see Figure 15f). Sites 4 and 5 also exhibited stratification with approximately 57% and 33% respectively below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 33 to 57% of the water column less than 2.0 mg/L the lake is considered to be partially supporting its FWP beneficial use. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

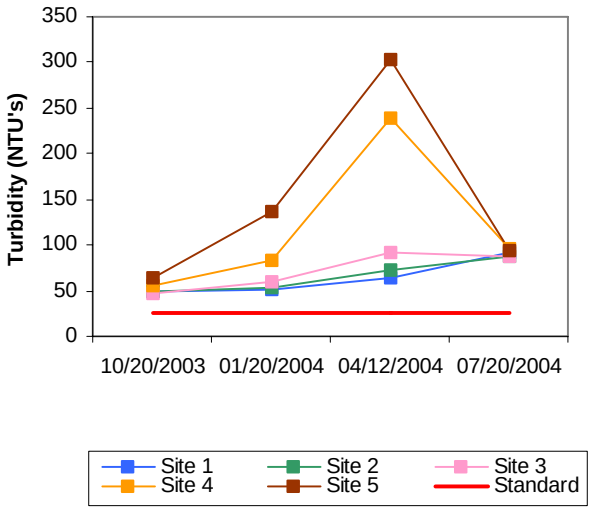
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.65 mg/L. The TN at the surface ranged from 0.30 mg/L in the spring to 1.21mg/L in the winter months. Surface TN was highest in the winter and summer quarters and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.083 mg/L. The TP at the surface ranged from 0.043 mg/L to 0.198mg/L. The surface TP was highest in the spring quarter and lowest in the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003-2004. This value is close to the 7:1 ratio generally used to determine the limiting nutrient, characterizing the lake as potentially phosphorus-limited to co-limited (Wetzel, 1983).

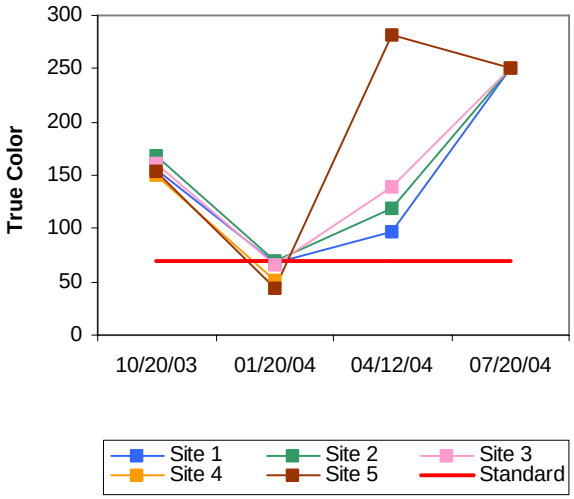
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is considered to be fully supporting its Fish Consumption beneficial use.

In summary, Atoka Lake was classified as mesotrophic with moderate productivity and nutrient levels in 2003-2004, indicating no significant increase or decrease in lake productivity or nutrient levels has occurred since the 2001-2002 evaluation. Water clarity was poor based on secchi disk depth, high turbidity and true color values and is likely to always be poor based on the soil composition of the area. The lake is not supporting its FWP beneficial use based on turbidity, partially supporting based on D.O. and supporting based on pH values. The lake is supporting its Aesthetics beneficial use based on its trophic status, but is not supporting the use due to extremely high true color concentrations. Atoka Lake is a recreational reservoir managed by the City of Oklahoma City. The lake also serves as a water supply for the city with water from Atoka Lake transported via pipeline to Lake Stanley Draper. It is then treated and transported to Oklahoma City water customers. In 1997 the Oklahoma Legislature directed the OWRB to conduct a study on the impact of Confined Animal Feeding Operations (CAFO) in watersheds that supply potable water to municipalities with a population over 250,000. As part of this study a bathymetric survey was completed on Oklahoma City's water supply reservoirs. A bathymetric map (Figure 16) was generated to determine current storage capacity and identify areas of extreme sedimentation. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Paul Koenig at (405) 530-8800.

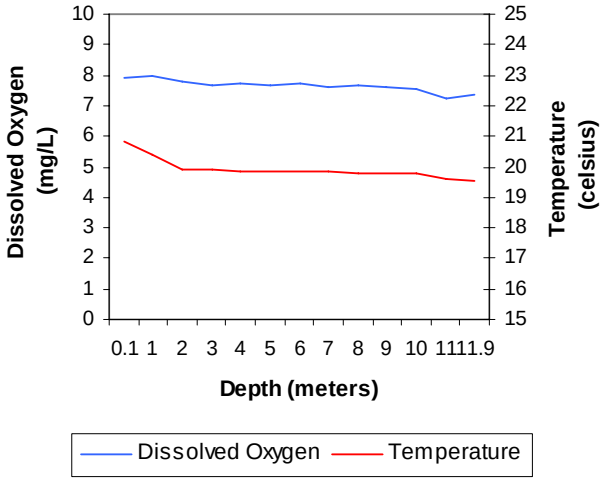
a. Seasonal Turbidity Values for Atoka Lake



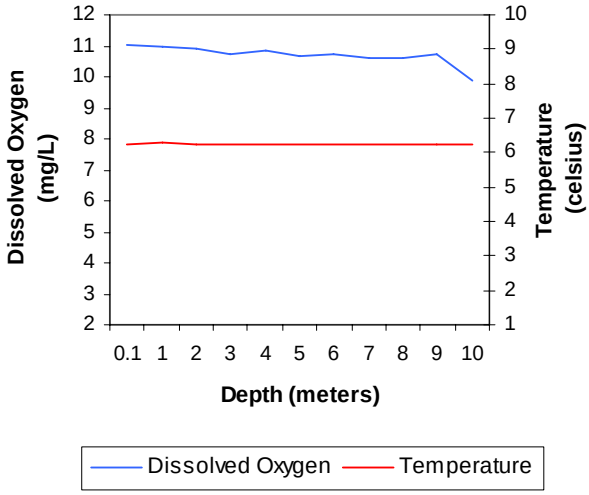
b. Seasonal Color Values for Atoka Lake



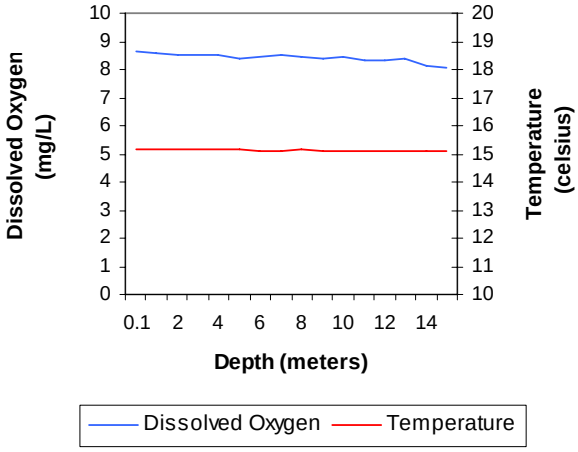
c. Profile ofAtoka Lake
October 20, 2003



d. Profile of Atoka Lake
January 20, 2004



e. Profile of Atoka Lake
April 12, 2004



f. Profile of Atoka Lake
July 20, 2004

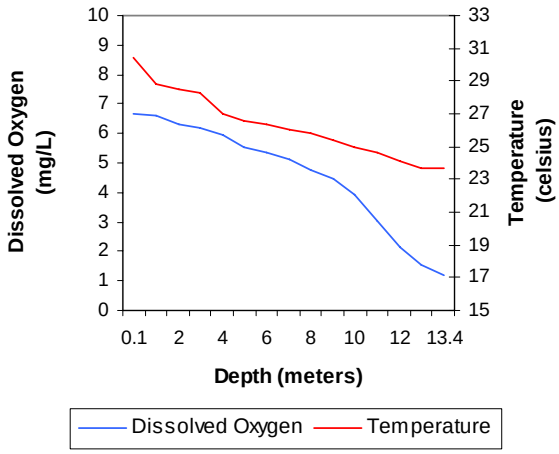


Figure 15a-15f. Graphical representation of data results for Atoka Lake.

Atoka Lake and Watershed

Atoka Lake Location

POOR — EXCELLENT

Turbidity 2004

POOR — EXCELLENT

Trophic State 2004

Lake Data	
Owner	City of Oklahoma City
County	Atoka
Constructed in	1964
Surface Area	5,537 acres
Volume	105,195 acre/feet
Shoreline Length	70.02 miles
Mean Depth	18.32 feet
Watershed Area	172 square miles

Plate 5 - Lake Water Quality for

Atoka Lake

LAKES MONITORING PROGRAM

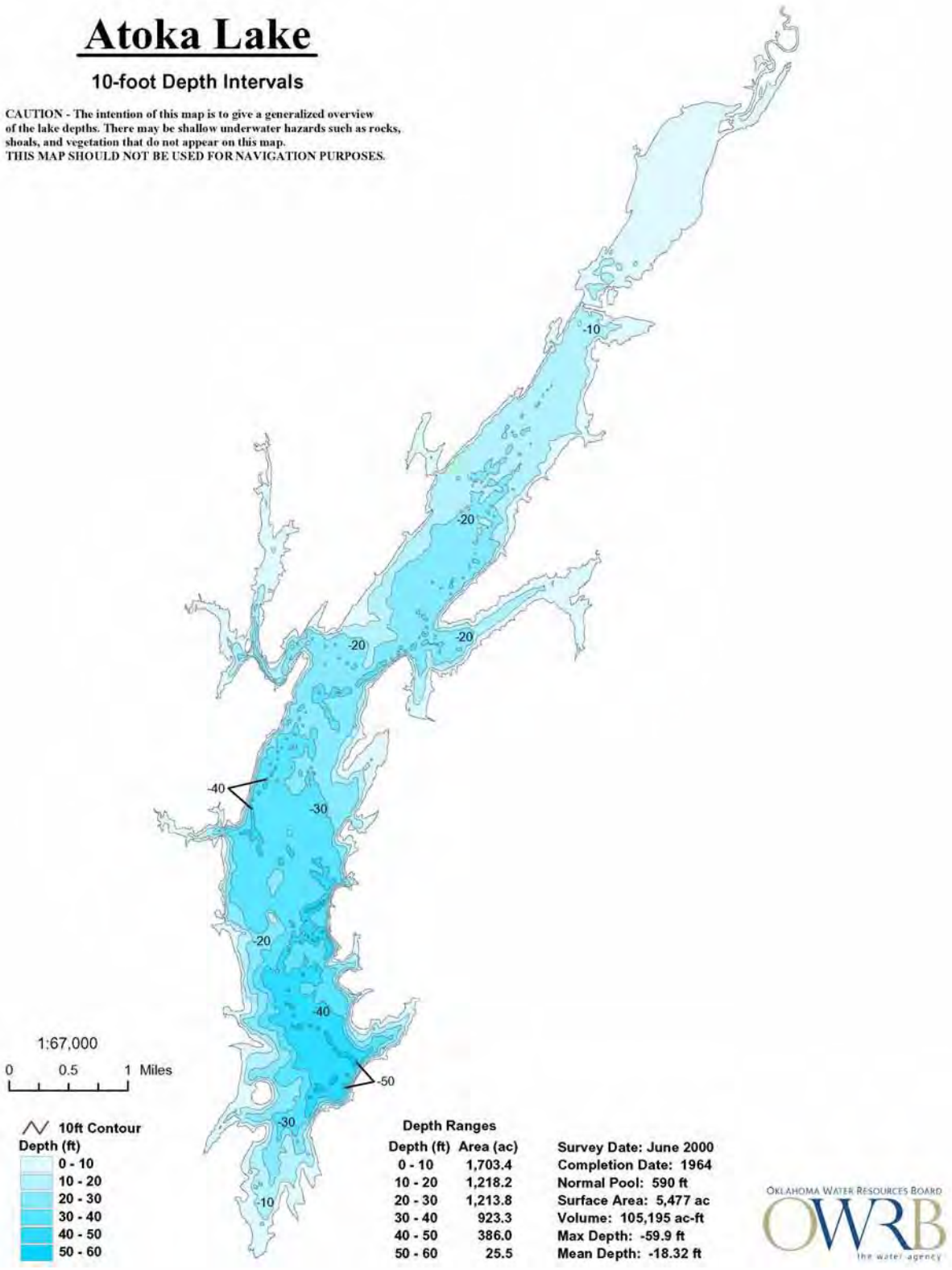


Figure 16. Bathymetric Map of Atoka Lake.

Bellcow Lake

Bellcow Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and an additional sample was collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 18 NTU (Plate 6), true color was 19 units, and average secchi disk depth was 66 centimeters. Water clarity was average based on the secchi disk depth, and turbidity values, similar to the previous sampling in 2001. True color values were excellent throughout the reservoir. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites (n=20). The TSI was 49 (Plate 6), indicating the lake was mesotrophic, indicative of moderate primary productivity and nutrient conditions in sample year 2003-2004. The TSI values for all sites throughout the sample year varied from lower mesotrophy to upper eutrophy. According to seasonal observations, Bellcow Lake is typically mesotrophic in the fall and winter to upper mesotrophic spring and is at the high end of eutrophy during the warmer summer months. Turbidity values for the sample year are displayed in Figure 17a. Turbidity values collected throughout all four sampling intervals were below the Oklahoma Water Quality Standards (WQS) of 25 NTU, with the exception of the site 3 located in the upper end of the lake, which exceeded the WQS in the spring. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use for turbidity with 5% of the collected values exceeding 25 NTU. Seasonal true color values are displayed in Figure 17b. All true color values were well below the Aesthetics WQS of 70 units; therefore the beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity readings ranged from 0.15 parts per thousand (ppt) to 0.20 ppt throughout sample year 2003-2004. Specific conductivity values were moderate in nature, ranging from 310 µS/cm at the lake surface in the winter to 396.8 µS/cm at the lake bottom in the summer. These values are comparable to levels seen in most Oklahoma reservoirs, indicating there are moderate amounts of salts or ions in Bellcow Lake. Values for pH ranged from 7.51 to 8.65 units, indicating the lake was neutral to slightly alkaline in nature. Of the pH values collected, none exceeded the numerical pH criteria for FWP specified in OAC 785:45-5-12. According to Use Support Assessment Protocols (USAP) in OAC 785:46-15-5, if more than 25% of pH values fall outside the 6.5 to 9.0 numerical criteria range the FWP beneficial use is not being met. All recorded values were within the acceptable range, therefore the lake is considered fully supporting the FWP use for pH. Oxidation-reduction potentials (redox) ranged from 403 mV to 483 mV, indicating the absence of reducing conditions in the lake system. Thermal stratification was not evident in the fall, winter or spring quarters and the lake was well oxygenated with dissolved oxygen (D.O) remaining above 5.7 mg/L (Figure 17c-17e). In the summer, a thermocline was present between 3 and 4 meters, with

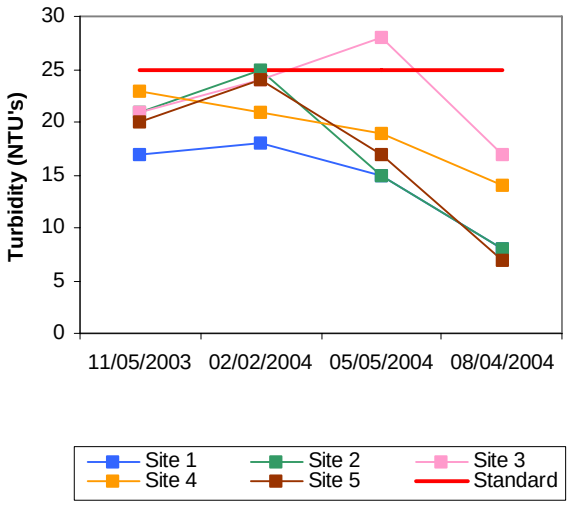
dissolved oxygen (D.O.) values dropping below 2.0mg/L from 5-meters below the surface to the lake bottom of 10.4 meters at site 1, the dam (Figure 17f). During the summer sampling interval all sites exhibited stratification and the presence of anoxic conditions. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 50% of the water column experiencing anoxic conditions at site 1, the dam, the lake is considered partially supporting its FWP beneficial use. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were at or below the detection limit, therefore the PBCR beneficial use is considered fully supported.

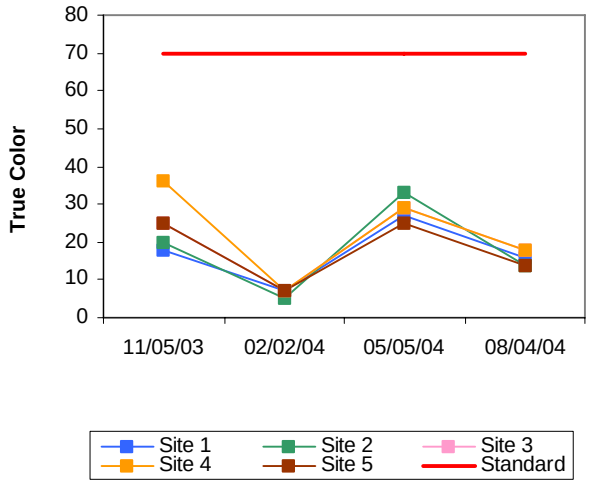
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.75 mg/L and 1.05 at the lake bottom. The surface TN ranged from 0.47 mg/L to 1.05 mg/L. TN was highest in the winter quarter and lowest in the fall quarter. The lake-wide total phosphorus (TP) average was 0.027 mg/L at the surface and 0.079 at the lake bottom. The TP ranged from 0.024 mg/L to 0.033 mg/L. TP was highest in the spring and lowest in the winter. The nitrogen to phosphorus ratio (TN:TP) was 27:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Bellcow Lake was mesotrophic, indicative of moderate to high primary productivity and nutrient levels. Results were slightly lower than previous historical data. Water clarity was average in comparison to other Oklahoma reservoirs based on turbidity, true color values and secchi disk depth. The lake was fully supporting its Aesthetics beneficial use based on true color and trophic state. The lake was fully supporting its FWP beneficial use based on turbidity and pH concentrations, but will be listed as partially supporting based on D.O. concentrations. Bellcow Lake, constructed by the Natural Resource Conservation Service (NRCS), was constructed to serve for flood control, water supply, recreation and fish and wildlife purposes.

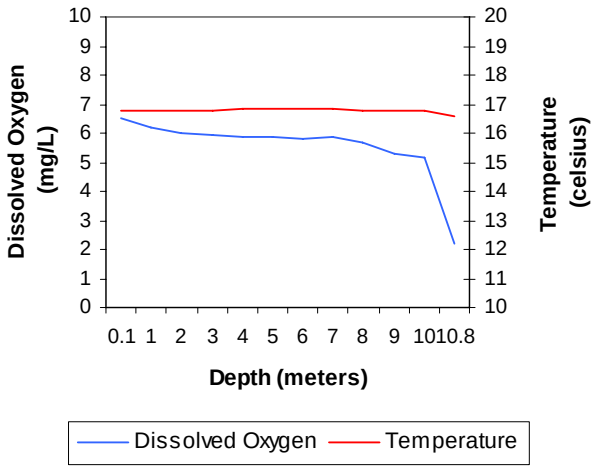
a.Seasonal Turbidity Values for Bellcow Lake



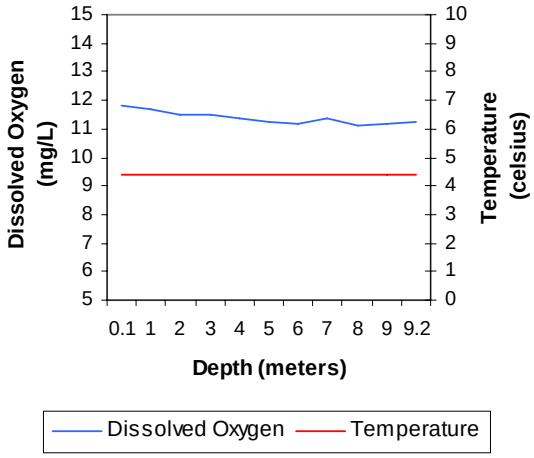
b. Seasonal Color Values for Bellcow Lake



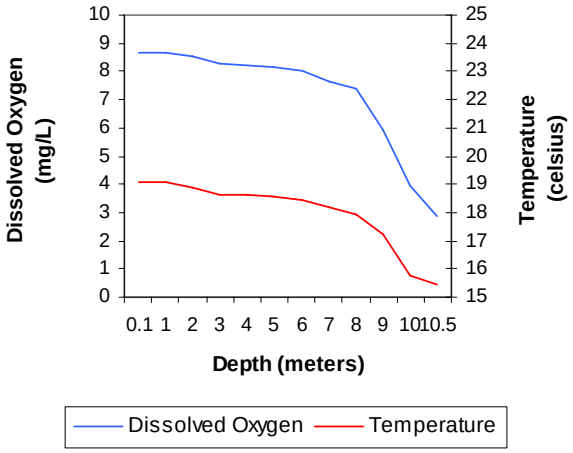
c. Profile of Bellcow Lake
November 05, 2003



d. Profile of Bellcow Lake
February 02, 2004



e. Profile of Bellcow Lake
May 05, 2004



f. Profile of Bellcow Lake
August 04, 2004

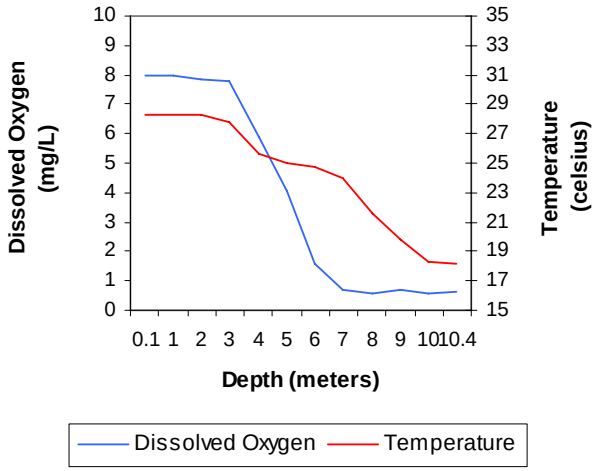
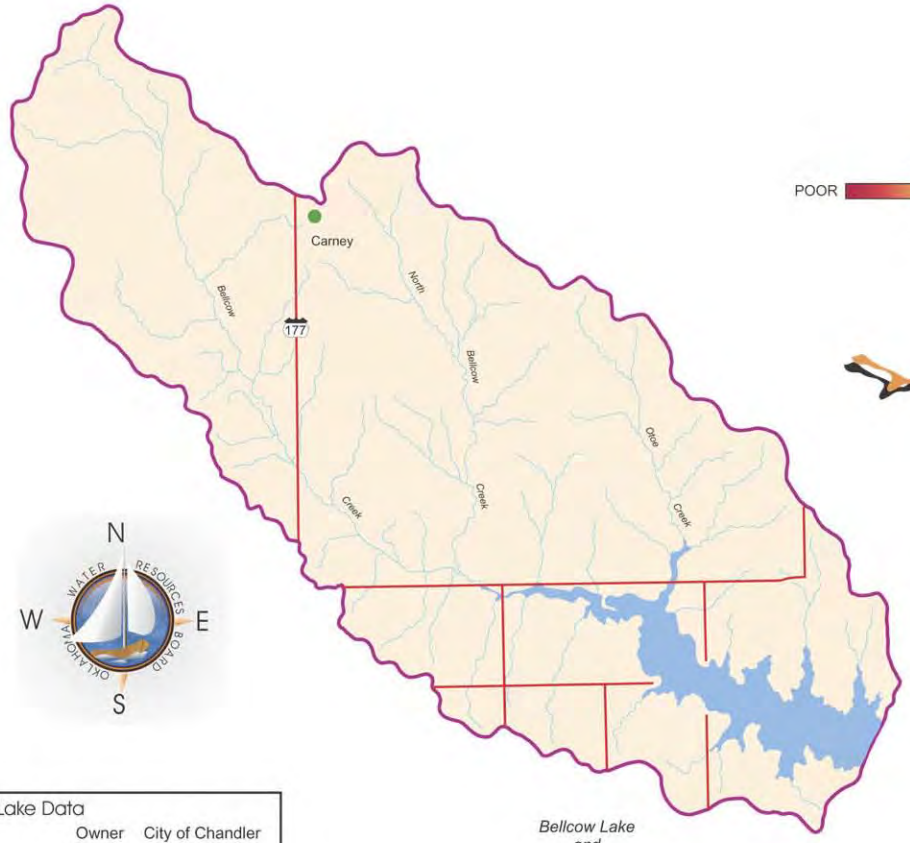


Figure 17a-17f. Graphical representation of data results for Bellcow Lake.



Bellcow Lake
and
Watershed

Lake Data

Owner	City of Chandler
County	Lincoln
Constructed in	1990
Surface Area	1,113 acres
Volume	16,500 acre/feet
Shoreline Length	19 miles
Mean Depth	14.82 feet
Watershed Area	33 square miles

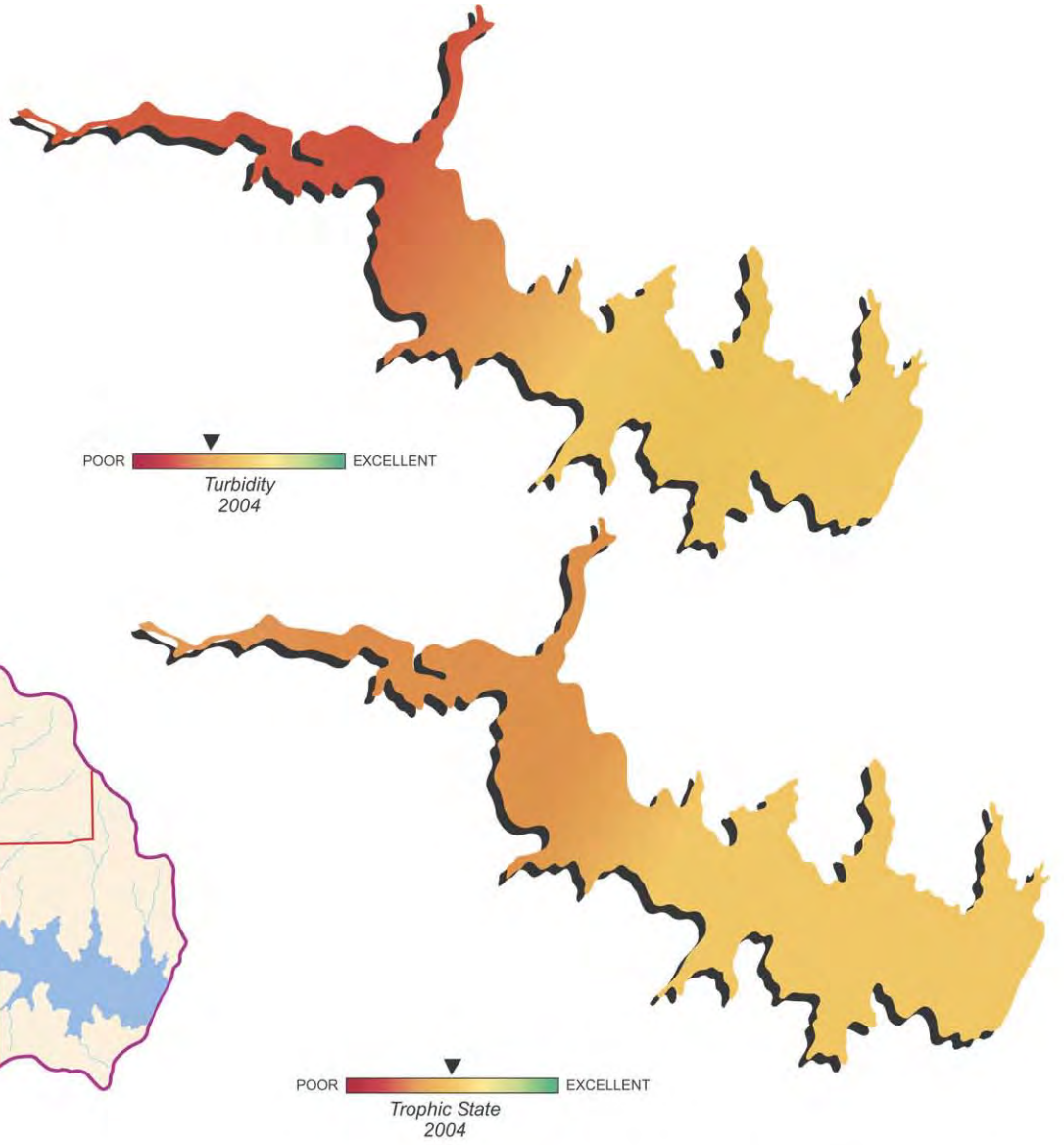


Plate 6 - Lake Water Quality for
Bellcow Lake

LAKES MONITORING PROGRAM

Birch Lake

Birch Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 19 NTU, true color was 65 units and average secchi disk depth was 81 centimeters in sample year 2004-2005. Based on these three parameters water clarity was average at Birch Lake. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 50 (Plate 7), indicating the lake was mesotrophic in sample year 2004-2005. This value is similar to that in 2003 (TSI = 47) indicating no significant increase or decrease in productivity has occurred. The TSI values for all sites throughout the sample year were fairly consistent and ranged from upper mesotrophic to eutrophic and dipped down into the oligotrophic category during the summer. Seasonal turbidity values per site are displayed in Figure 18a. Of the twenty values collected, nine (45%) exceeded the numerical criteria of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 45% of the samples collected, were above the turbidity standard of 25 NTU, available rainfall data suggest that the peak observed during the spring quarter is likely the result of seasonal rain events. The Fish and Wildlife Propagation (FWP) beneficial use is therefore considered supported as it relates to turbidity. Seasonal true color values are also displayed in Figure 18b. Similar to turbidity a peak in true color was observed in the spring; however even if the spring data is excluded 25% of the remaining values are greater than the numerical criteria of 70 units. Applying the same default protocol, the Aesthetics beneficial use is partially supported at Birch Lake.

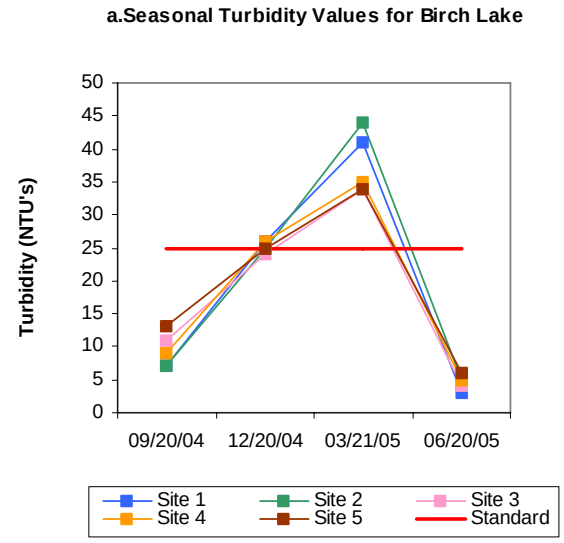
Vertical profiles for dissolved oxygen; pH, temperature, specific conductivity; oxidation-reduction potential and salinity were recorded at all five sample sites during the sample year. Salinity values ranged from 0.04 parts per thousand (ppt) in the fall to 0.11 ppt in the summer. Specific conductivity ranged from 111.5 µS/cm to 229.2 µS/cm, which falls within the range of values commonly observed in Oklahoma reservoirs. These values indicate low levels of current conducting compounds (salts) in the lake system. The pH values were generally neutral and ranged from 6.87 units to 8.29 units, indicative of a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Based on pH values collected Birch Lake is currently supporting its FWP beneficial use. Oxidation-reduction potentials ranged from 63 mV in the fall to 536 mV also in the fall. In general, reducing conditions were not present with all recorded values above 100 mV with the exception of the value recorded near the lake bottom at the dam. Dissolved oxygen (D.O.) levels remained above 7.0 mg/L during both the winter and

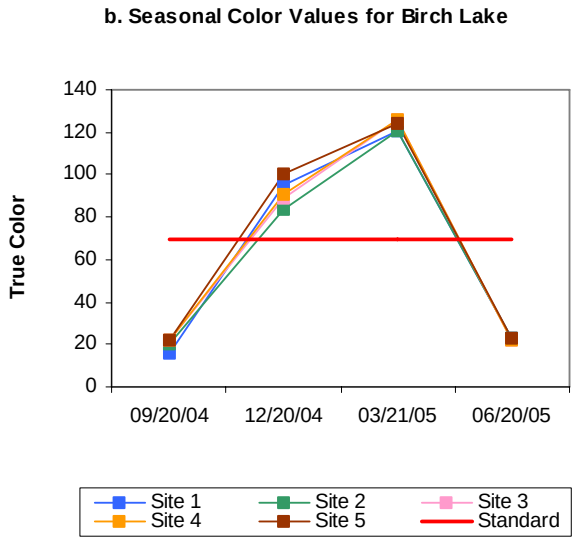
spring sampling quarters (see Figure 18d-18e) when the water column was evenly mixed. Thermal stratification was evident and anoxic conditions were present in both the fall and summer quarters. In the fall stratification occurred at several 1-meter intervals but dissolved oxygen concentrations fell below 2.0 mg/L between 7 and 8 meters in depth, accounting for 44% of the water column at sites 1and 4 to be anoxic. During the summer sampling interval stratification occurred between 4 and 5 meters at sites 1, 2, and 3. At these sites anoxic conditions were present for 45 to 60% of the water column (see Figure 18f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column the FWP beneficial use is deemed partially supported. Birch Lake is considered to be partially supporting the FWP beneficial use based on D.O for this sample year. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

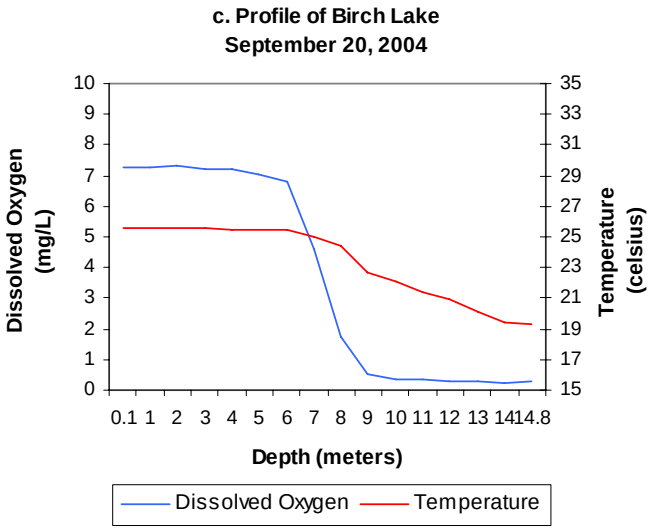
Bacteriological samples were not collected during the study period and an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

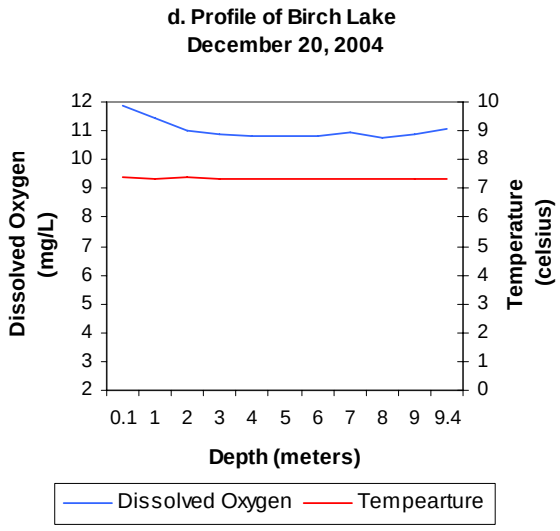
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.40 mg/L at the surface. Surface TN ranged from 0.21 mg/L to 062 mg/L with the highest values recorded in the winter quarter and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.027 mg/L at the surface. Surface TP ranged from 0.015 mg/L to 0.046 mg/L and was highest in the spring months. The lowest values occurred during the winter sampling quarter. The nitrogen to phosphorus ratio (TN:TP) was 15:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

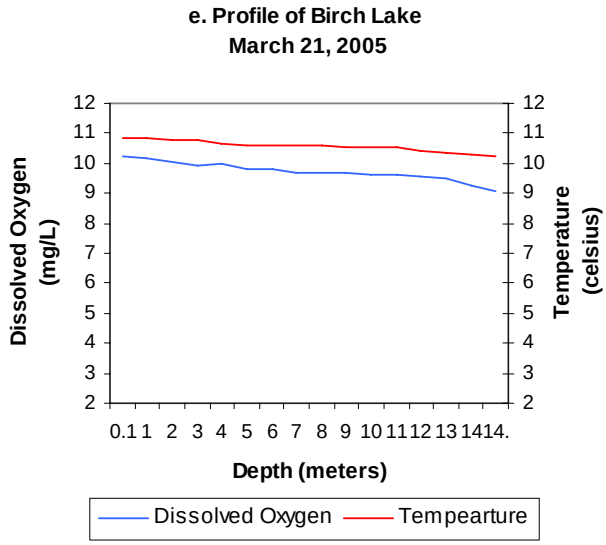
In summary, Birch Lake was classified as mesotrophic with moderate productivity and nutrient levels. This classification is the same as that during previous evaluation in 2003, indicating no significant change in productivity has occurred over time. Water clarity was average based on true color, turbidity, and secchi disk depth. The lake is partially supporting the Fish and Wildlife propagation (FWP) beneficial use based dissolved oxygen and supporting based on pH and turbidity values. Birch Lake is supporting the Aesthetics beneficial use based on its trophic status, but only partially supporting the use based on true color. Birch Lake is located in Osage County and was constructed by the United States Army Corps of Engineers (USACE) to serve as a water supply, flood control and recreation reservoir.











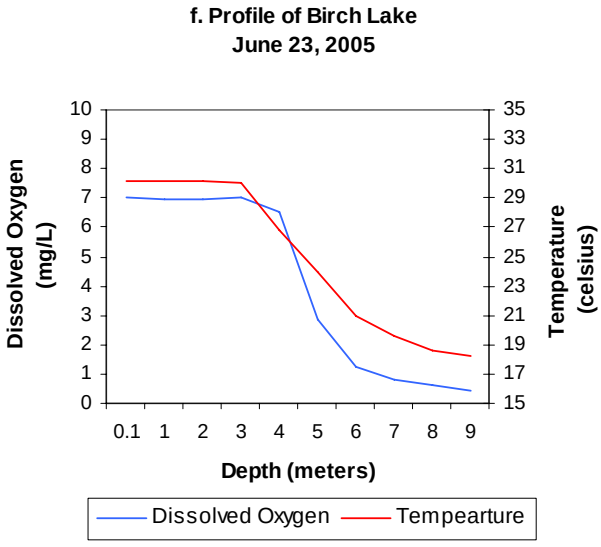
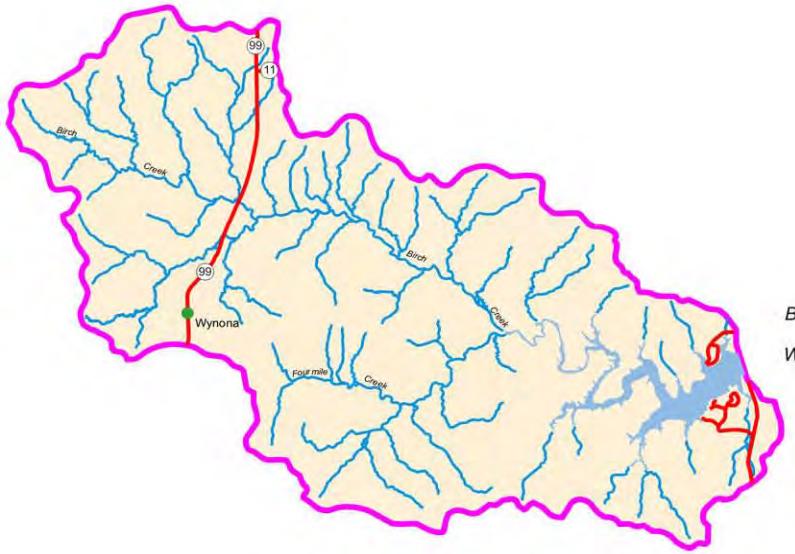
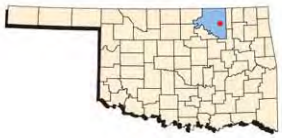


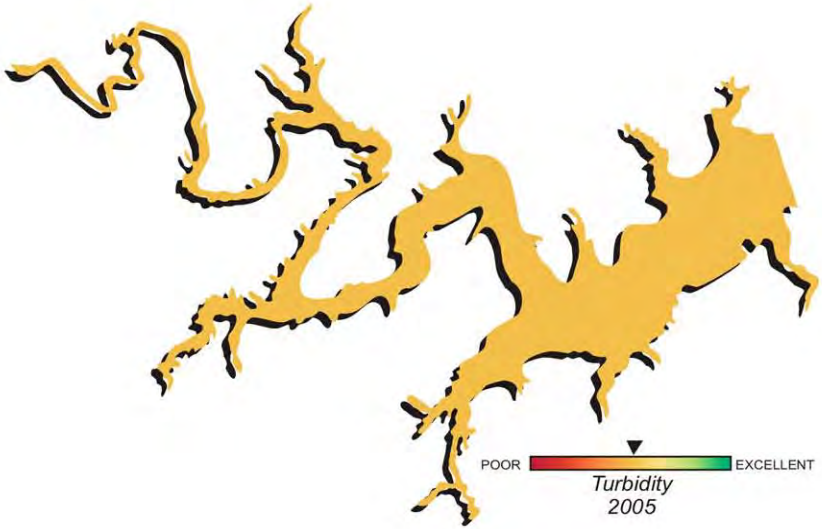
Figure 18a-f. Graphical representation of data results for Birch Lake.



Birch Lake and Watershed

Birch Lake Location





Lake Data	
Constructed by	Corps of Engineers
County	Osage
Constructed in	1977
Surface Area	1,137 acres
Volume	19,200 acre/feet
Shoreline Length	27 miles
Mean Depth	16.88 feet
Watershed Area	66 square miles

Plate 7 - Lake Water Quality for
Birch Lake

LAKES MONITORING PROGRAM

Lake Bixhoma

Lake Bixhoma, located in Wagoner County, is owned by the City of Bixby and was constructed in 1965 to serve as a water supply and recreational outlet for the public use. Lake Bixhoma was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the lake. Samples were collected from the lake surface at all sites. The lake-wide average turbidity value was 5 NTU (Plate 8), true color was 23 units, and average secchi disk depth was 146 centimeters in sample year 2006. Water clarity was excellent based on these three parameters and is consistent with the evaluation in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 45 (Plate 8), indicating the lake was mesotrophic, indicative of moderate primary productivity and nutrient conditions. This is very similar to the value calculated in 2004 (TSI=48), indicating no significant increase or decrease in productivity has occurred over time. The TSI values varied seasonally throughout the year, ranging from oligotrophic in the spring and summer to mesotrophic in the winter quarter, and eutrophic conditions observed in the fall All turbidity values per site for the sample year were all well below the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 19a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Seasonal true color values are displayed in Figure 19b. All true color values were below the Aesthetics WQS of 70 units and were consistent throughout all four-sample quarters. Applying the same default protocol, the lake was fully supporting its Aesthetics beneficial use for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.05 ppt, well within the range of values if not lower than most values observed in Oklahoma lakes. Specific conductivity values ranged from 47.4μS/cm to 127.5 μS/cm, also indicative of negligible salt content and ion levels in the lake system. Values for pH were generally neutral, ranging from 6.44 to 8.63 in the summer. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The low pH values recorded primarily in the summer at Lake Bixhoma may be due to natural conditions and with only 2.3% of the values recorded falling outside the acceptable range the lake is supporting the FWP beneficial use. Oxidation-reduction potentials (ORP) were positive at all sample sites and ranged from 111mV at the lake bottom in the fall to 482mV in the winter. In general, reducing conditions were not present in the reservoir during the study period. Thermal stratification was

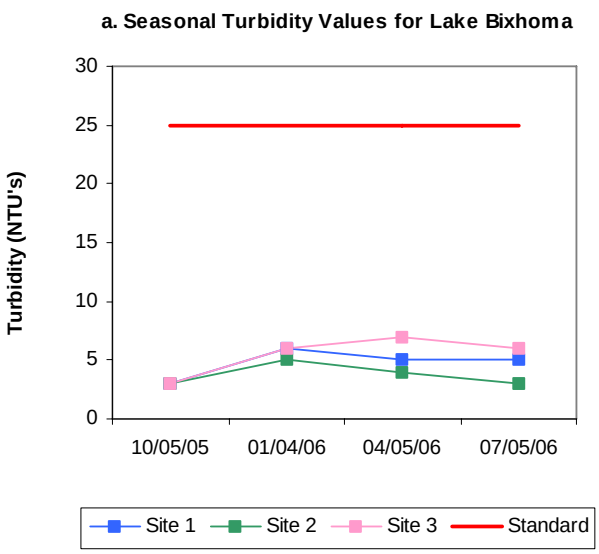
not evident in either the winter or spring intervals (Figure 19d-19e). In the fall, Lake Bixhoma was thermally stratified between 5 and 6 meters in depth with 42 to 56% of the water column having a dissolved oxygen (D.O.) concentration below 2.0 mg/L at both sites 1 and 2 (see Figure 19c). In the summer quarter, stratification occurred at multiple 1-meter intervals, the first being between 3 and 4 meters below the lake surface. The next point of stratification occurred between 4 and 5 meters with dissolved oxygen concentrations less than 2.0 mg/L from 6 meters in depth to the lake bottom of 17.1 meters (Figure 19f). When D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With anoxic conditions present in 56% of the water column in the fall and 67% in the summer, the FWP beneficial use is considered partially supported at Lake Bixhoma. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

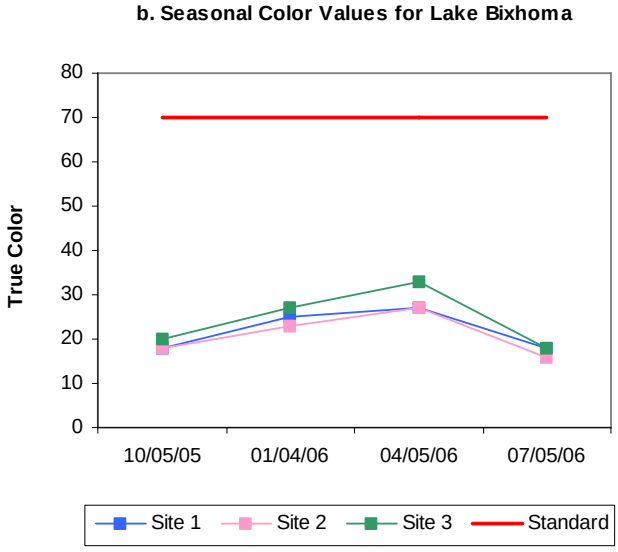
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

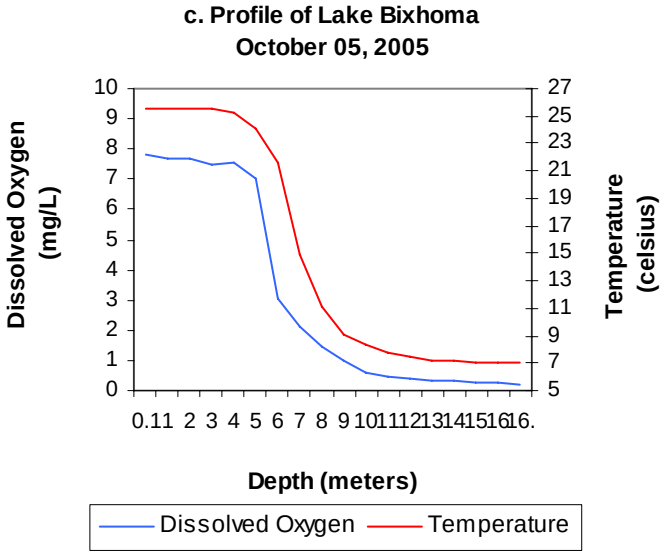
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.36 mg/L. The TN at the surface ranged from 0.25 mg/L to 0.45 mg/L. The highest surface TN was recorded in the winter quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.017 mg/L. The TP ranged from 0.010 mg/L to 0.026 mg/L. Similar to total nitrogen surface TP was lowest in the fall, however and the highest observation was recorded in the spring. The nitrogen to phosphorus ratio (TN:TP) was approximately 22:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

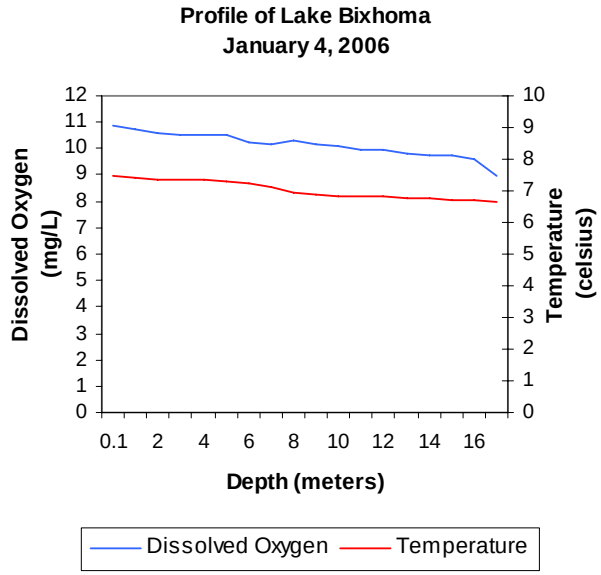
Lake Bixhoma was also sample for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

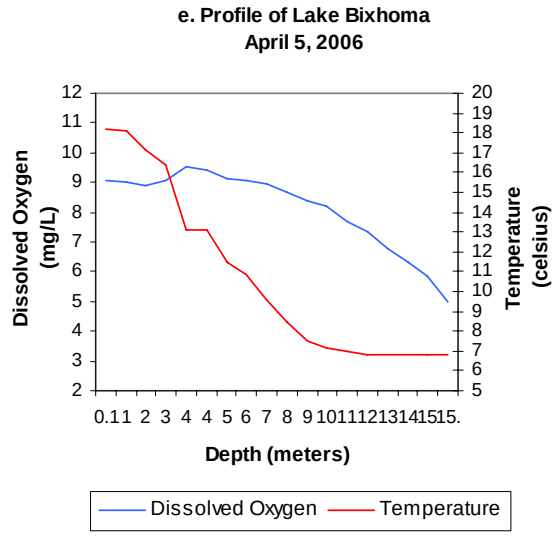
In summary, Lake Bixhoma was classified as mesotrophic, indicative of moderate primary productivity and moderate nutrient conditions (Plate 8). Water clarity was excellent based on true color; turbidity and secchi disk depth and is consistent with observations in the previous evaluation. The FWP beneficial use was fully supported as it relates to turbidity and pH; however was only partially supporting the FWP based on D.O. values in the fall and summer months. The lake is fully supporting its Aesthetics beneficial use based on true color data and trophic status. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.











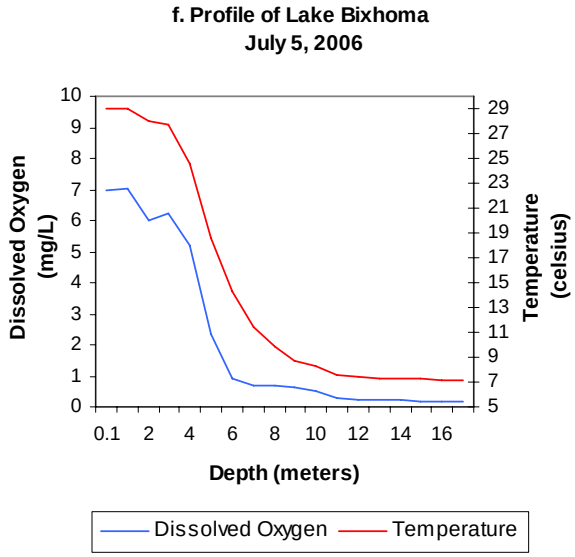
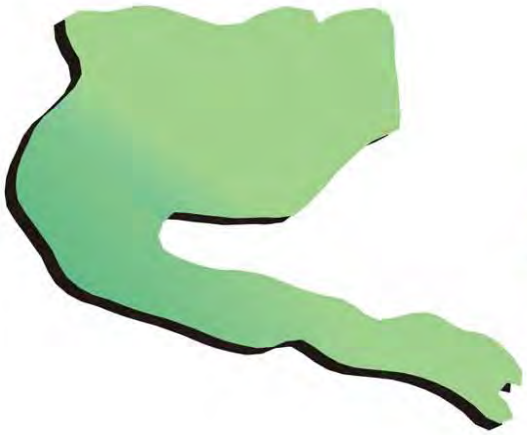
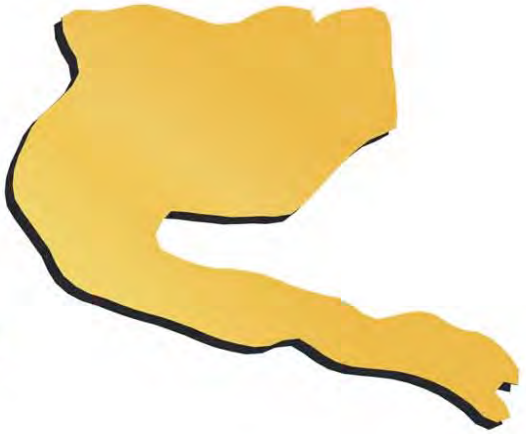


Figure 19a-19f. Graphical representation of data results for Lake Bixhoma.





Lake Data	
Owner	City of Bixby
County	Wagoner
Constructed in	1965
Surface Area	110 acres
Volume	3,130 acre/feet
Shoreline Length	3 miles
Mean Depth	28.45 feet
Watershed Area	3,007 acres

Turbidity 2006

Trophic State 2006

Plate 8 - Lake Water Quality for
Bixhoma Lake

Bluestem Lake

Bluestem Lake, located in Osage County, is approximately 4 miles northwest of the city of Pawhuska. The lake serves as the municipal water supply reservoir for the City of Pawhuska and is also utilized for both flood control and recreational purposes. Bluestem Lake was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites. The lake-wide average turbidity was 14 NTU (Plate 9), true color was 20 units, and average secchi disk depth was 84 centimeters. Water clarity was good based on secchi disk depth, true color and turbidity. Results for these parameters were better than previous lake sampling efforts conducted in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=19). The TSI was 44 (Plate 9), indicating the lake was mesotrophic with moderate primary productivity and nutrient conditions. Due to a post-processing error, no sample for site 3 was submitted for analysis from winter data collection efforts. The current TSI value is consistent with previous monitoring results from 2003-2004 where the calculated TSI was also mesotrophic (TSI=43). The TSI values throughout the sample year were primarily mesotrophic with the exception of site 2 in the winter quarter, which was the only oligotrophic value recorded. During the spring sampling interval, the chlorophyll-a value was much lower and pheophytin value was higher for site 5 than the values reported for the other sample sites. Turbidity values were fairly consistent throughout the year with values ranging from 6 to 27 NTU (see Figure 20a). Only two (10.5%) of the nineteen values exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 10.5% of the turbidity values greater than 25 NTU, Bluestem Lake is considered partially supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 20b. All true color values throughout the sample year were below the Aesthetics WQS of 70 units. Applying the same default protocol, the lake was fully supporting its Aesthetics beneficial use for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites during the study period. Salinity values were consistent throughout the water column for each quarter, ranging from 0.14 parts per thousand (ppt) to 0.18 ppt. Readings for specific conductivity were relatively consistent throughout the water column for each quarter, ranging from 290.7 μS/cm (fall) to 366.6 μS/cm (winter). Both salinity and conductivity values were consistent with values seen in other Oklahoma reservoirs, indicating low to moderate levels of current conducting compounds or salts were present in the lake system. The pH was generally neutral to slightly alkaline with values ranging from 7.18 units to 8.41 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the

waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All pH values recorded were within the range therefore meeting the FWP beneficial use. The oxidation-reduction potential (redox) ranged from 113 mV to 437 mV, indicating an absence of reducing conditions during the study period. Bluestem Lake was well mixed in the winter and spring quarters with thermal stratification absent and dissolved oxygen (D.O.) concentrations above 7.5 mg/L in all instances (see Figure 20d-20e). Thermal stratification and anoxic conditions were present in both fall and summer sampling events. In the fall, the lake was stratified between 9-10 meters with D.O. concentrations falling below 2.0 mg/L to the lake bottom of 14.0 meters (Figure 20c). In the summer, stratification occurred between 6 and 7 meters below the surface at sites 1, 2 and 5. Anoxic conditions were present in approximately 53% of the water column at site 1, the dam (see Figure 20f). When D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Bluestem Lake with anoxic conditions present in 53% of the water column during the summer sampling interval. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

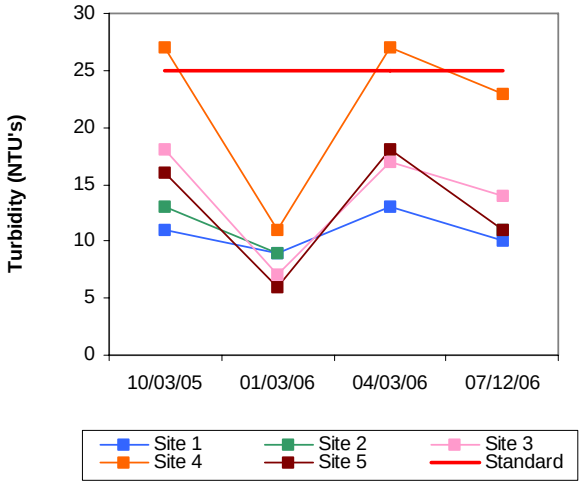
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average for the current sample year was 0.36 mg/L. The TN at the surface ranged from 0.15 mg/L to 0.54 mg/L. Surface TN was highest in the winter and lowest in the fall quarter. The lake-wide total phosphorus (TP) average was 0.030 mg/L. The total phosphorus values ranged from 0.016 mg/L to 0.132 mg/L. The highest TP was recorded in the spring and lowest values were seen in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 12:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Bluestem Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

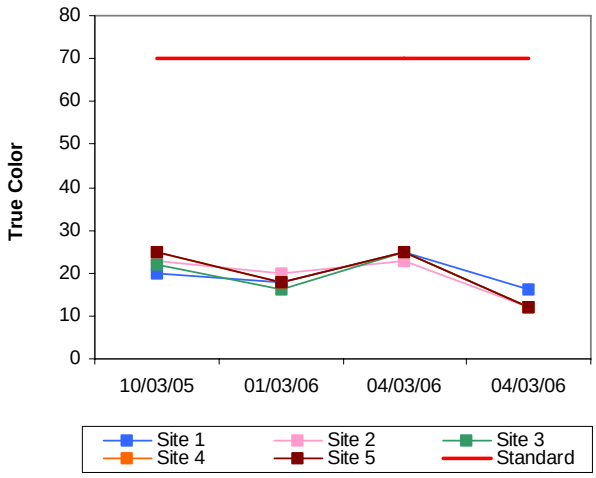
In summary, Bluestem Lake was classified as mesotrophic, indicative of low to moderate primary productivity and nutrient levels (Plate 9). The current TSI value (TSI=44) is consistent with previous monitoring results from 2003-2004 (TSI=43), indicating no significant increase or decrease in productivity has occurred since the previous evaluation. Water clarity was good based on true color, turbidity, and secchi disk depth, slightly better than results reported during the previous study period. With 10.5% of the reported turbidity values exceeding the WQS of 25 NTU, the FWP beneficial use was partially supported as it relates to turbidity The FWP beneficial use was fully supported as it relates to pH; however was only partially supporting the FWP based on anoxic conditions present during the summer months. Bluestem Lake is fully

supporting its Aesthetics beneficial use based on trophic status and true color as 100% of the color values recorded were below the WQS of 70 units. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

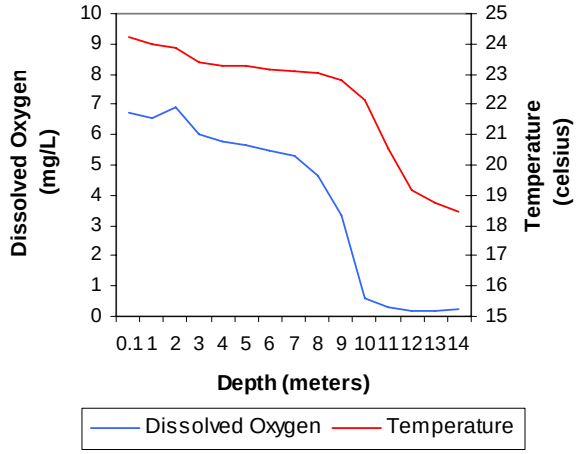
a. Seasonal Turbidity Values for Bluestem Lake



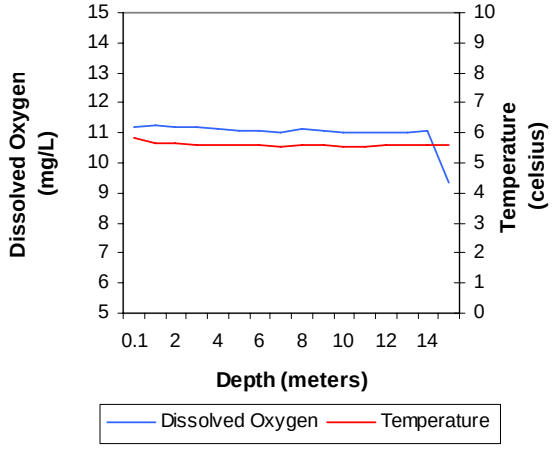
b. Seasonal Color Values for Bluestem Lake



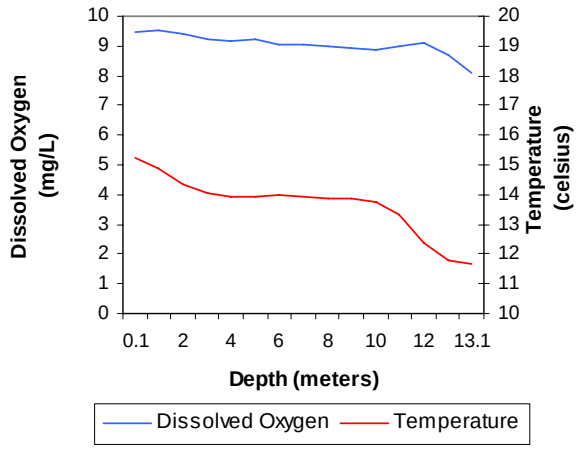
c. Profile of Bluestem Lake
October 03, 2005



d. Profile of Bluestem Lake
January 3, 2006



e. Profile of Bluestem Lake
April 3, 2006



f. Profile of Bluestem Lake
July 11, 2006

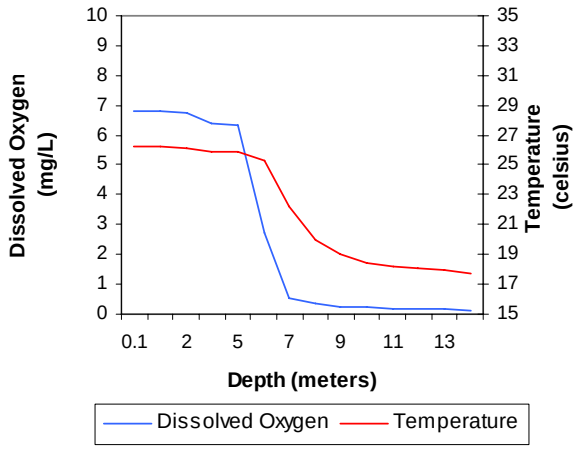
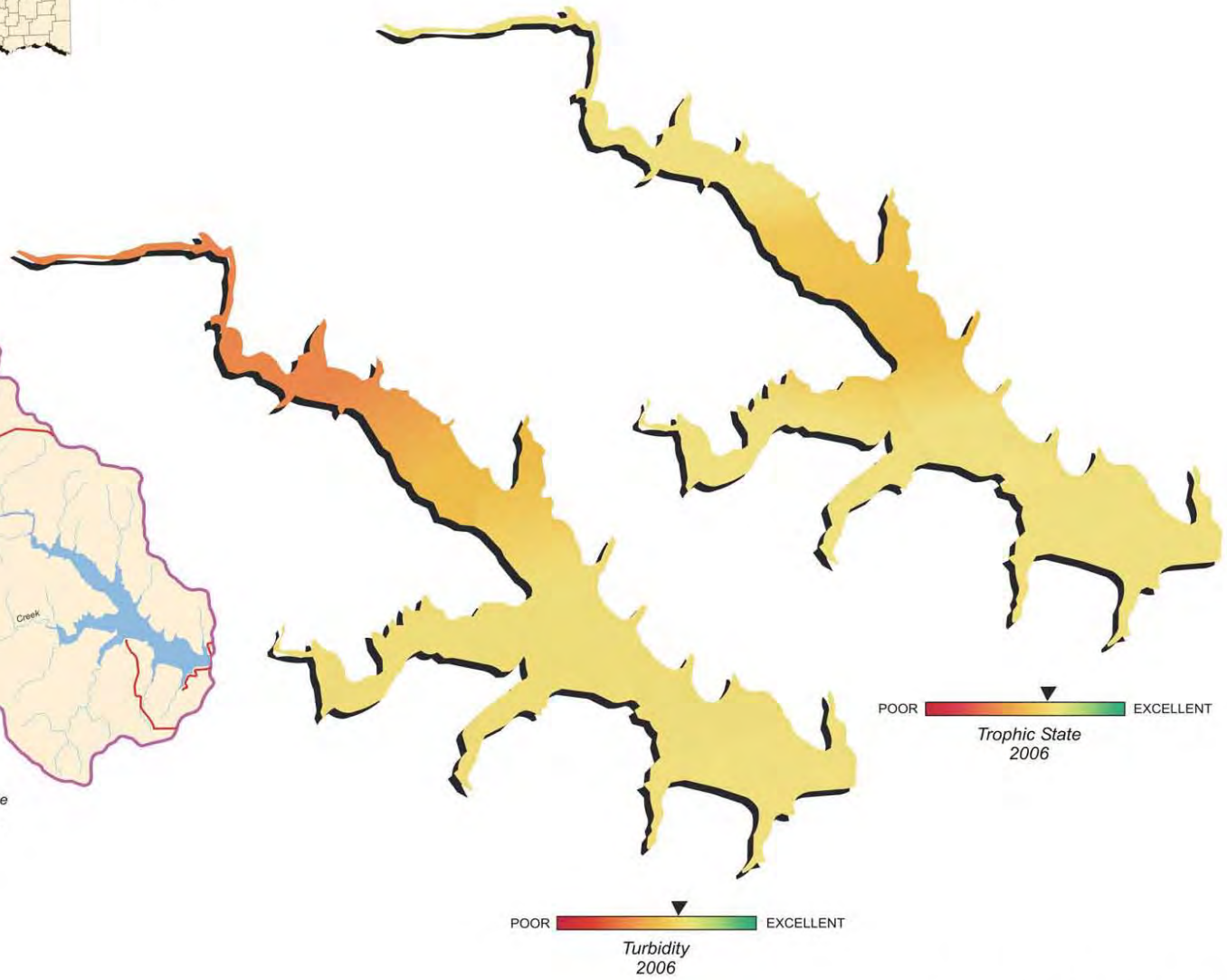


Figure 20a-20f. Graphical representation of data results for Bluestem Lake.

Bluestem Lake Location

Bluestem Lake and Watershed



Lake Data	
Owner	City of Pawhuska
County	Osage
Constructed in	1958
Surface Area	762 acres
Volume	17,000 acre/feet
Shoreline Length	19 miles
Mean Depth	22.31 feet
Watershed Area	47 square miles

Plate 9 - Lake Water Quality for
Bluestem Lake

LAKES MONITORING PROGRAM

Boomer Lake

Boomer Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide turbidity value was 22 NTU (Plate 10), true color was 30 units, and average secchi disk depth was 60 centimeters in 2004-2005. Water clarity was average to slightly poor based on these parameters and is similar to that of 2002. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI calculated was 53 (Plate 10), indicating the lake was eutrophic, indicative of high primary productivity and nutrient rich conditions. The TSI values were generally eutrophic throughout the sample year with mesotrophic values only occurring during the spring sampling interval. Of the turbidity values collected, 7 (35%) were above the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 21a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Boomer Lake is not supporting its Fish & Wildlife Propagation (FWP) beneficial use due to high turbidity concentrations. Seasonal true color values are also displayed in Figure 21b. All true color values were well below the Aesthetics WQS of 70 units therefore the Aesthetics beneficial use is being supported based on true color.

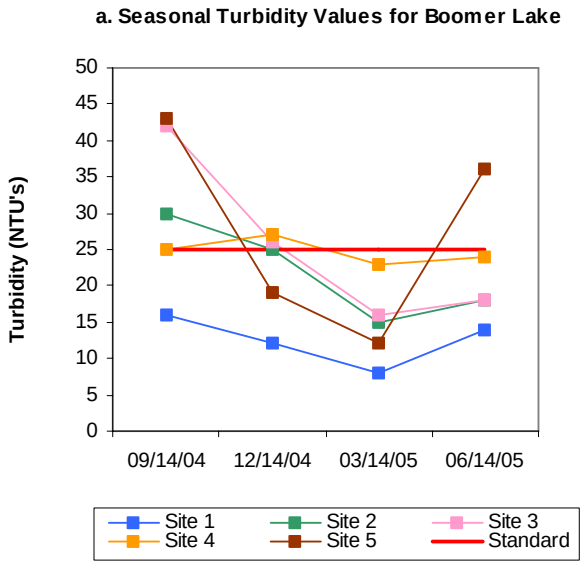
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.09 parts per thousand (ppt) to 0.18 ppt, which was within the range of observed values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Readings for specific conductivity ranged from 191.5 µS/cm to 356.9 µS/cm in the summer. Specific conductivity values were also within the expected range for Oklahoma reservoirs, indicating relatively low levels of electrical current conducting compounds like salts. Oxidation-reduction potentials (redox) ranged from 275 mV to 444 mV, indicating that reducing conditions were not present in the water column during any time of the study period. The pH values in Boomer Lake were neutral, ranging from 7.17 in the summer to 8.27 units in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Boomer Lake is currently supporting its FWP beneficial use based on pH. The lake was well mixed during the winter and spring quarters with dissolved oxygen (D.O.) values above 7.25 mg/L throughout the water column (see Figure 21d-21e). In both the fall and summer, the lake was stratified between 3 and 4 meters, however D.O. only dropped below 2.0 mg/L near the lake bottom of 5.8 meters. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not

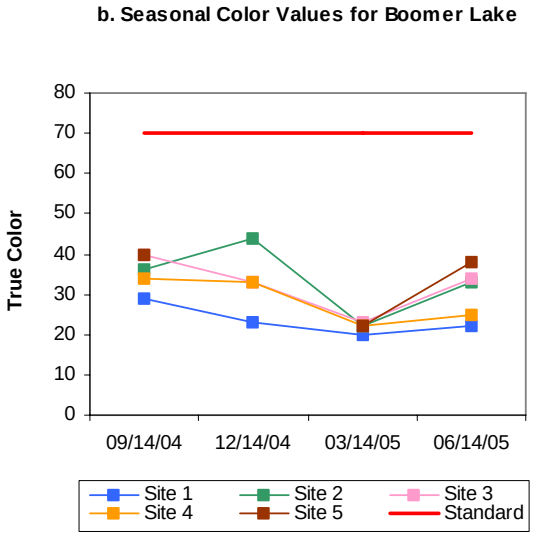
supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With only 14% of the water column was below 2.0-mg/L site 1 in both the fall and summer sampling intervals, the FWP beneficial use was fully supported at Boomer Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

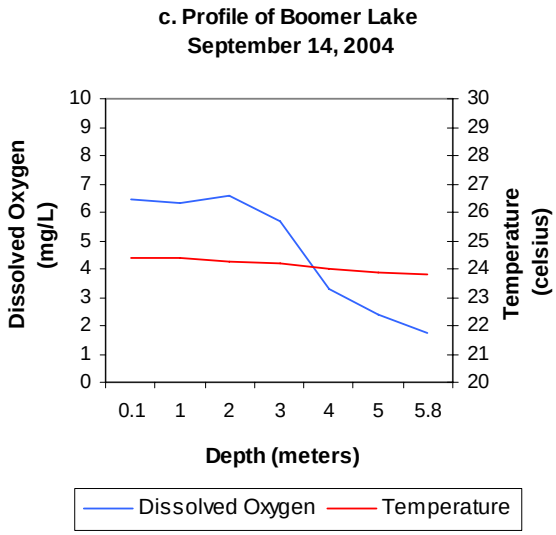
Bacteriological samples were not collected during the study period and an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

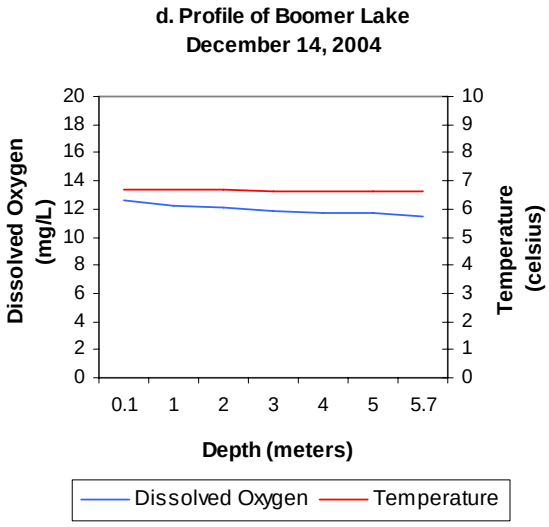
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average for sample year 2004-2005 was 0.58 mg/L at the surface. The epilimnetic TN ranged from 0.38 mg/L to 1.10 mg/L. Surface TN was highest in the spring and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.039 mg/L for the surface. The TP ranged from 0.026 mg/L to 0.054 mg/L at the surface. Surface TP was highest in the fall and lowest in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 11:1 for sample year 2004-2005. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

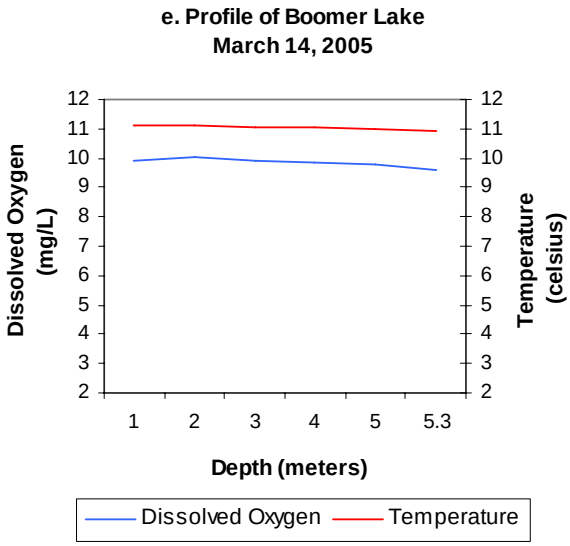
In summary, Boomer Lake was classified as eutrophic, indicative of high productivity and nutrient levels (Plate 10). Water clarity was average to slightly poor based on turbidity, true color and secchi disk depth. The Fish and Wildlife Propagation (FWP) beneficial use is supported based on pH and dissolved oxygen concentrations. However with 35% of the collected turbidity values exceeding 25 NTU the FWP beneficial is not supported as it relates to turbidity. The Aesthetics beneficial use is fully supporting with 100% of the true color values below 70 units. The Aesthetics use is also fully supported based upon lake trophic status. Boomer Lake is owned by the City of Stillwater and was constructed for hydroelectric power and recreational uses. The lake dam has been reconstructed and a significant portion of the shoreline has been stabilized to prevent erosion from occurring.











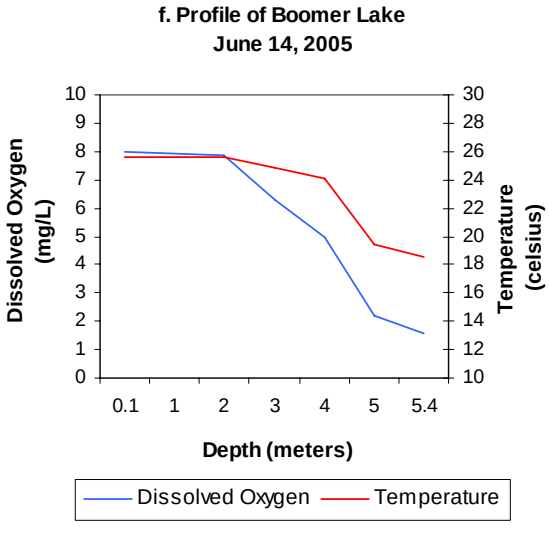
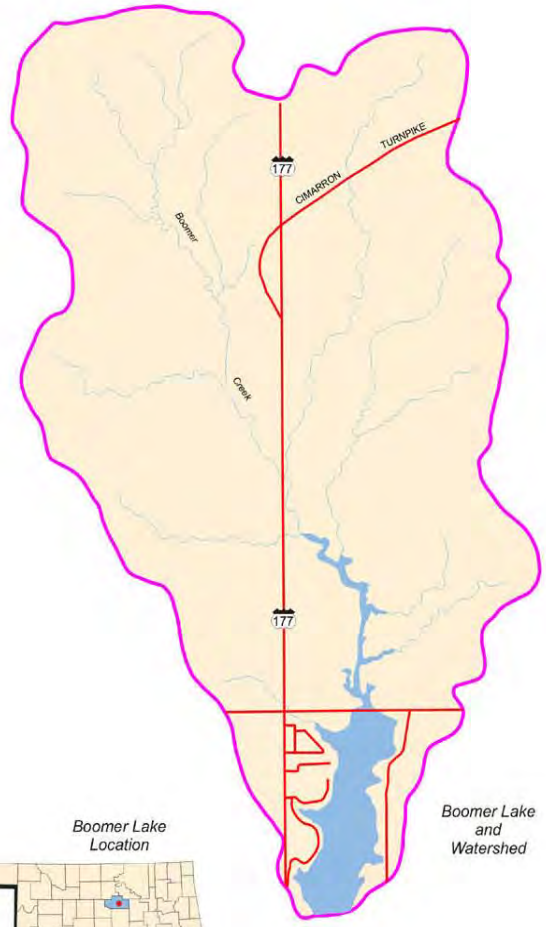


Figure 21a-21f. Graphical representation of data results for Boomer Lake.



Lake Data	
Owner	City of Stillwater
County	Payne
Constructed in	1932
Surface Area	260 acres
Volume	3,200 acre/feet
Shoreline Length	6 miles
Mean Depth	12.31 feet
Watershed Area	9 square miles

POOR — EXCELLENT

Turbidity
2005

POOR — EXCELLENT

Trophic State
2005

Plate 10 - Lake Water Quality for
Boomer Lake

LAKES MONITORING PROGRAM

Broken Bow Lake

Broken Bow Lake, located in McCurtain County, is situated on the Mountain Fork River approximately 9 miles north of the town of Broken Bow. The lake was constructed by the USACE for flood control, hydroelectric power, water supply, recreation, and fish and wildlife purposes. This is truly one of the nicest lakes in our state and has a trout fishery below the dam. Broken Bow Lake was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at eight (8) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as the major arms and tributaries. Samples were collected from the lake surface at all sites. The lake-wide average turbidity value was 4 nephelometric turbidity units (NTU) (Plate 11), true color was 14 units, and average secchi disk depth was 293 centimeters in sample year 2006. Water clarity was excellent based on the high secchi disk depth, low turbidity and low true color values. Results for these parameters are similar to that observed in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=32). The TSI was 35, indicating the lake was oligotrophic, indicative of low primary productivity and nutrient levels (Plate 11), consistent with 2004 sampling results (TSI=40). The TSI values for all sites throughout the sample year were consistently oligotrophic, with the exception of site 1, which was mesotrophic during the winter quarter. Seasonal turbidity values were all well below the Oklahoma Water Quality Standard (WQS) of 25 NTU, ranging from a low of 1 NTU to a high of 15 NTU (Figure 22a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Broken Bow Lake is considered fully supporting the Fish and Wildlife Propagation (FWP) beneficial use with 100% of the turbidity values below the criteria of 25 NTU. Seasonal true color values are displayed in Figure 22b. All true color values were well below the aesthetics WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered supported as it relates to true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values were very low ranging from 0.0 parts per thousand (ppt) to 0.05 ppt. Similarly, specific conductivity values were also very low, ranging from 25.3 to 66.4 µS/cm. The values recorded for both salinity and specific conductivity are much lower than that typically seen in Oklahoma lakes and reservoirs and are indicative of extremely low concentrations of electrical current conducting ions (salts or other chlorides) in Broken Bow Lake. Waters such as these typically have little buffering capacity and are pH sensitive. Values for pH were slightly acidic to neutral, ranging from 5.73 in the hypolimnion in the spring to 7.56 near the surface in the summer. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 69% of the recorded values

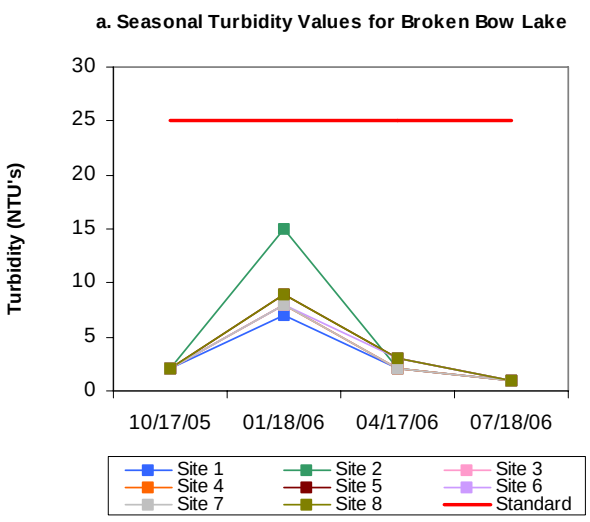
less than 6.5, Broken Bow Lake is not supporting the FWP beneficial use based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (redox) ranged from 193 mV to 532 mV, indicating an absence of reducing conditions during the sample year. In the fall quarter the lake was thermally stratified between 10 and 11 meters at sites 1-5 and between 9 and 10 meters at sites 6-8 in the upper end of the reservoir. Dissolved oxygen concentrations fell below 2.0 mg/L at different points among the sites and accounted for up to 66% (site 6) of the water column to be experiencing anoxic conditions. The lake was not thermally stratified in the winter and the water column was well mixed with dissolved oxygen values generally at or above 6.0 mg/L (see Figure 22d). In the spring quarter, the lake was weakly stratified, however like the winter dissolved oxygen remained above 6.0 mg/L. During the summer quarter, there was a metalimnetic oxygen deficit that occurred throughout the lake to varying degrees between 9 and 11 meters below the surface (Figure 22f). Dissolved oxygen values dip down below 2.0 mg/L within this layer and then raise again. It is not known at this time what causes this to occur and the lake should be studied further as this same phenomena was observed during 2004 data collection efforts. In the upper most reaches of the lake (sites 7 and 8), the water column was stratified at several 1-meter intervals with D.O. falling to below 2.0 mg/L for 48 and 62% of the water column, respectively. When D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Broken Bow Lake with up to 66% of the water column at site 6 (fall) and 62% at site 8 (summer) exhibiting anoxic conditions. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

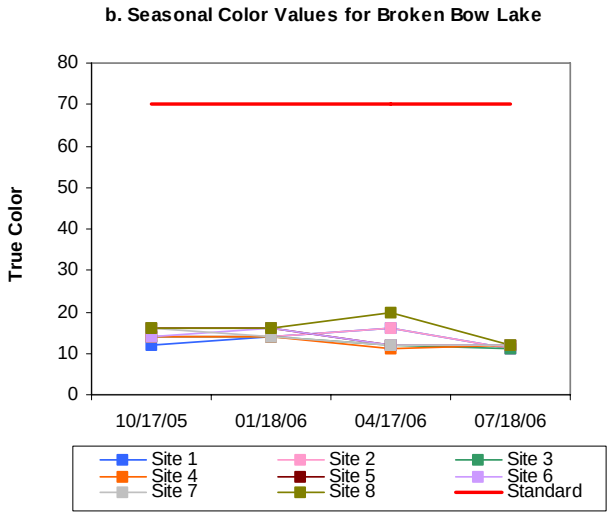
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

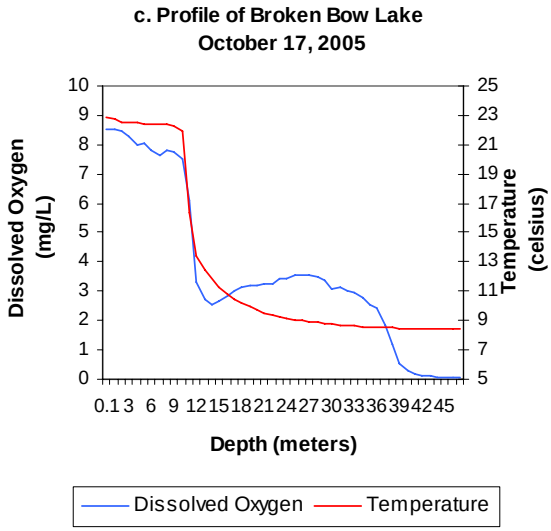
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.21mg/L at the surface. The TN ranged from 0.07 mg/L to 0.39 mg/L. Both the highest and lowest TN values were reported during the winter sampling interval. The lake-wide total phosphorus (TP) average was 0.011 mg/L at the surface. The TP values ranged from 0.008 mg/L to 0.015 mg/L at the surface. Similar to total nitrogen, surface TP was lowest in the winter; however the highest values were reported during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 19:1 for 2005-2006. This value is much greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

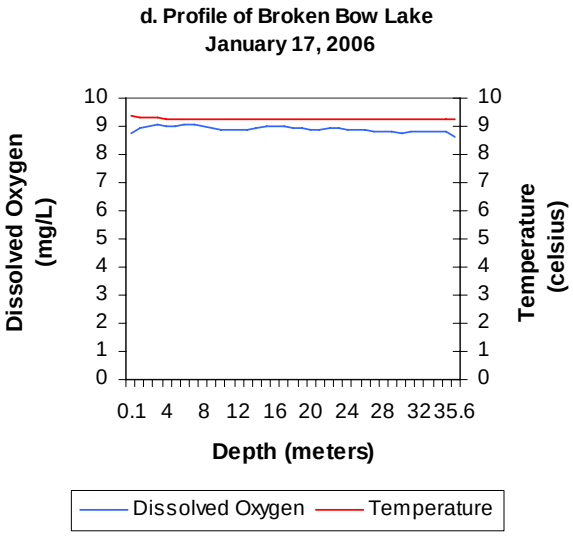
Broken Bow Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

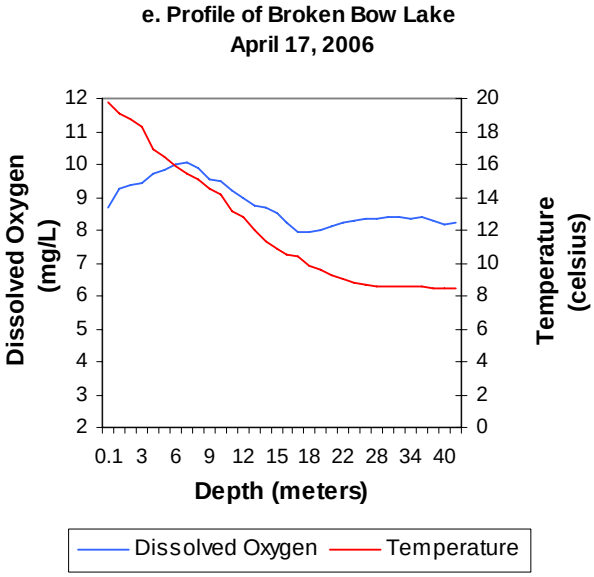
In summary, Broken Bow Lake was classified as oligotrophic, indicative of low primary productivity and nutrient levels (Plate 11), consistent with 2004 sampling results (TSI=40). Water clarity continues to be excellent at this reservoir based on low turbidity, low true color values and the high secchi disk depths. The lake is fully supporting its Aesthetics beneficial use based with 100% of the true color values below the numeric criteria of 70 units and trophic state. The lake is fully supporting its FWP beneficial use based on nephelometric turbidity and partially supporting the use based on anoxic conditions present in the upper end of the reservoir during the fall and summer quarters. In both 2004 and 2006 data collection efforts a metalimnetic oxygen deficit has been observed to varying degrees throughout the main body of the lake. Respiration (largely bacterial) may be driving the metalimnetic oxygen deficit. Dead and dying algal cells are the most likely source of detritus in the lacustrine zone. Anoxic metalimnetic waters is an indication of eutrophication therefore this lake should be studied further since based on chlorophyll-a alone the lake has an oligotrophic classification. With 69% of the recorded pH values less than 6.5, Broken Bow Lake is not supporting the FWP beneficial use. Low pH values are commonly seen in Southeast Oklahoma and are likely due to natural causes. For this reason the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.











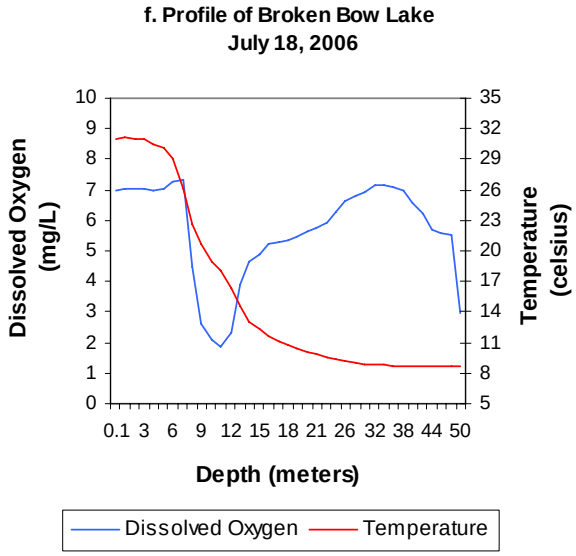


Figure 22a-22f. Graphical representation of data results for Broken Bow Lake.

Broken Bow Lake
and
Watershed

Lake Data	
Constructed by	Corps of Engineers
County	McCurtain
Constructed in	1968
Surface Area	14,200 acres
Volume	918,070 acre/feet
Shoreline Length	180 miles
Mean Depth	64.7 feet
Watershed Area	754 square miles

Turbidity
2006

Trophic State
2006

Plate 11 - Lake Water Quality for
Broken Bow Lake

Brushy Creek Reservoir

Brushy Creek Reservoir, located in Sequoyah County, is approximately 5 miles north of Sallisaw. The lake was scheduled for sampling during the 2005-2006 sample year however due to the drought conditions lake levels were too low for OWRB staff to launch a boat. The lake will be placed on the next sample rotation once water levels rise enough for staff to access the lake safely.

Brushy Creek Reservoir was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, lacustrine zones of the lake. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 7 NTU (Plate 12), true color was 22 units, and average secchi disk depth was 112 centimeters in sample year 2004. Based on these three parameters water clarity was excellent. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 51, indicating the lake was eutrophic, bordering mesotrophic, with moderate to high primary productivity and nutrient conditions. The TSI values throughout the sample year were primarily mesotrophic with the eutrophic values occurring in the fall and summer quarters. Seasonal turbidity values are displayed in. Turbidity values ranged from 4-10 NTU, well below the Oklahoma Water Quality Standard (WQS) of 25 NTU. All true color values were well below the aesthetics WQS of 70 units although there was evident seasonal variability.

Please refer to the "Beneficial Use Monitoring Report 2004 Draft Final Report" for the full discussion of monitoring results for this lake. The report may be access via the OWRB's web page at http://www. owrb.state.ok.us or you may contact the Water Resources for a copy of the 2004 BUMP Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the address below:

Oklahoma Water Resources Board
3800 N. Classen Blvd.
Oklahoma city, Oklahoma 73118
Attn: Nikki Cole

Plate 12 - Lake Water Quality for
Brushy Creek Lake

Lake Data	
Owner	Leased to State of Oklahoma
County	Sequoyah
Constructed in	1964
Surface Area	358 acres
Volume	3,258 acre/feet
Shoreline Length	4 miles
Mean Depth	9.10 feet
Watershed Area	21 square miles

Lake Burtschi

Lake Burtschi, located in Grady County is approximately 10 miles southwest of Chickasha. The State of Oklahoma via the Oklahoma Department of Wildlife Conservation (ODWC) constructed Lake Burtschi in 1954 for the express purpose of promoting recreational activities, primarily fishing. The lake is managed by the ODWC specifically for the purpose of promoting angling activities. Lake Burtschi was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites. The lake-wide turbidity value was 11 NTU (Plate 13), true color was 18 units, and average secchi disk depth was 72 centimeters. Water clarity was good based on secchi disk depth, turbidity, and true color values. Results for these parameters were similar to historical data collection efforts in 2004. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=11). Due to a post-processing error no sample for site 3 was submitted for analysis from spring data collection efforts. The TSI calculated was 63 (Plate 13), indicating the lake was hypereutrophic in sample year 2005-2006. The TSI values throughout the sample year were fairly consistent with eutrophic conditions present in the winter, spring and summer quarters and hypereutrophic in the fall. The only exception to this occurred at site 1, which was mesotrophic in the winter quarter. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Turbidity values per site were all below the WQS of 25 nephelometric turbidity units (NTU) for all seasons with values ranging from 7 to 24 NTU (see Figure 23a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Based upon turbidity concentrations Lake Burtschi was meeting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 23b. All true color values were below the Aesthetics Oklahoma Water Quality Standard (WQS) of 70 units. Applying the same default protocol Lake Burtschi is considered meeting its Aesthetics beneficial as it relates to true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.53 part per thousand (ppt) in the fall to 0.67 ppt recorded in the summer. Moderate salinity values in the water column indicate chlorides or salts were present in large concentrations in the lake system. Specific conductivity was also greater than most values recorded in Oklahoma reservoirs, indicating moderate to high levels of electrical current conducting compounds like salts present in the water column. Values ranged from 1011 µS/cm in the spring to 1273 µS/cm in the summer of 2006. Lake pH values were neutral to slightly alkaline, ranging from 7.19 to 10.74 units. According to USAP (OAC 785:46-15-5), pH values

are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 16% of the recorded values greater than 9.0, Lake Burtschi is partially supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 42 to 428 mV recorded at site 1 in the summer. Reducing conditions were not present at the time of sampling. Low redox values in the hypolimnion are not uncommon when a lake is thermally stratified and anoxic conditions are present. The lake was not thermally stratified in the fall or winter; however stratification was evident during the spring and summer sampling intervals. (See Figure 23c-23f). In the spring quarter the lake was weakly stratified with dissolved oxygen (D.O.) only dipping down to 2.04 mg/L at the lake bottom of 7.4 meters (Figure 23c). The lake was strongly thermally stratified in the summer between 3 and 4 meters with D.O. concentrations less than 1.0 mg/L from 5 meters in depth to the lake bottom of 6.9 meters (see Figure 23f). Although D.O. concentrations fell below 2.0 mg/L, (only 38% of the water column), at site 1, this is not sufficient to result in listing the lake as not supporting its FWP beneficial use. When D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Lake Burtschi. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

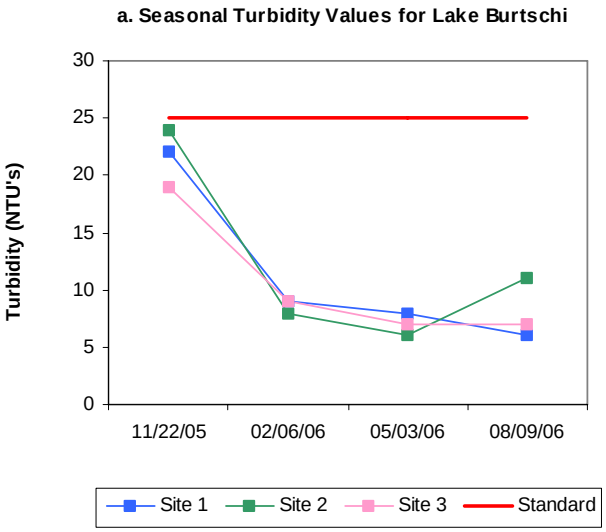
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

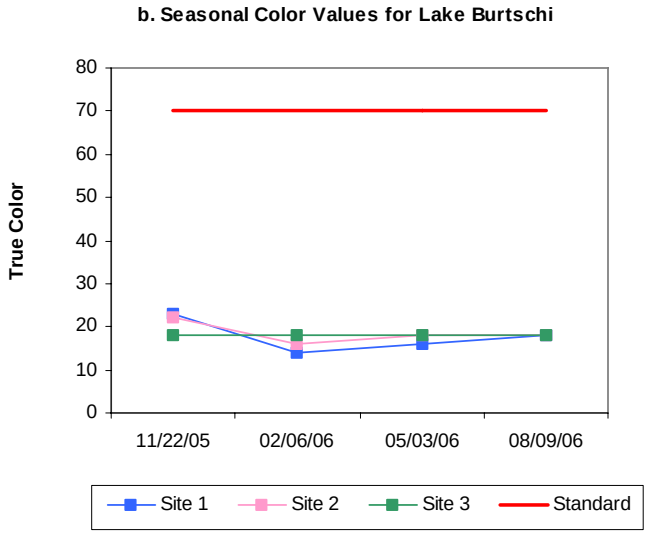
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.36 mg/L, which is a relatively high value when compared to other lakes across the state. The TN at the surface ranged from 0.92 mg/L to 1.82 mg/L. Surface TN was highest in the fall, winter, and summer quarters and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.056 mg/L for sample year 2006. The TP ranged from 0.027 mg/L to 0.109 mg/L at the surface. Surface TP was highest in the fall and lowest in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 24:1 for 2005-2006. This value is much greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

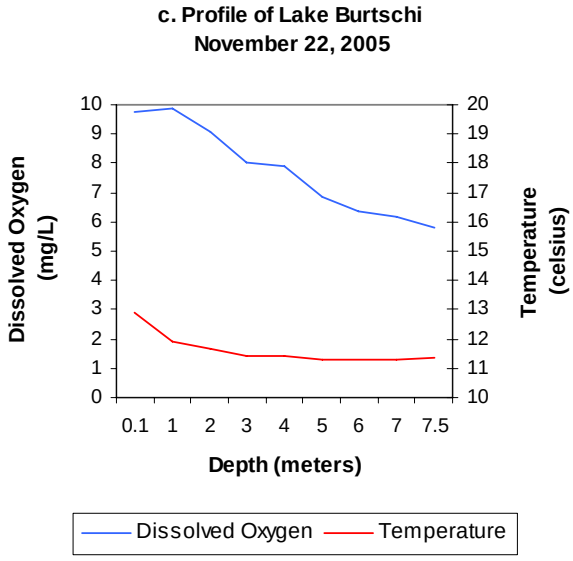
Lake Burtschi was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

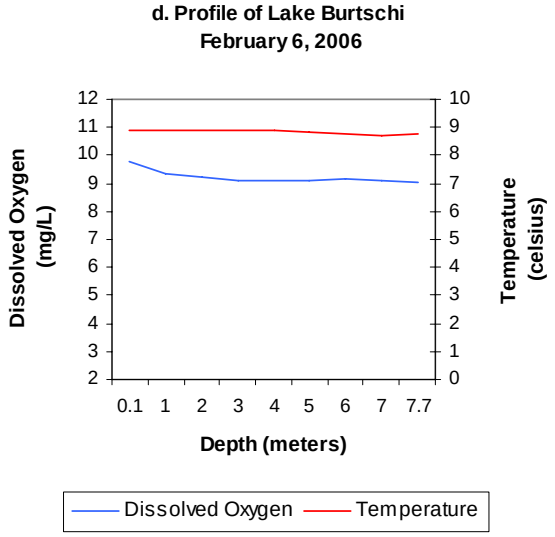
In summary, Lake Burtschi was classified as hypereutrophic in nature, indicative of excessive primary productivity and nutrient conditions (Plate 13). The lake is fully supporting its Aesthetics beneficial use for true color with 100% of the reported values below the standard of 70 units. Based on the calculated TSI, the lake will be recommended for listing as a Nutrient Limited Watershed (NLW) in the next WQS revision process and its Aesthetic beneficial use considered threatened until a study can be conducted to confirm non-support status. Lake Burtschi is fully supporting its FWP beneficial use based on D.O. and nephelometric turbidity. With 16% of the

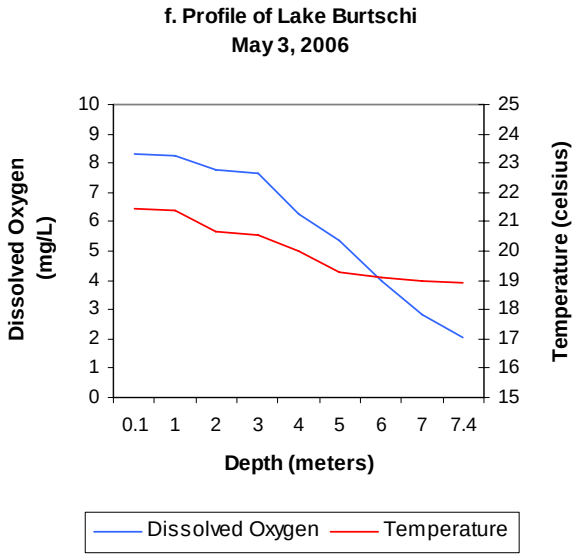
recorded pH values above 9.0 units, the FWP beneficial use is considered partially supported as it related to pH. Bacteriological samples were also collected during the recreation season to assess the Primary Body Contact Recreation (PBCR) beneficial use. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.











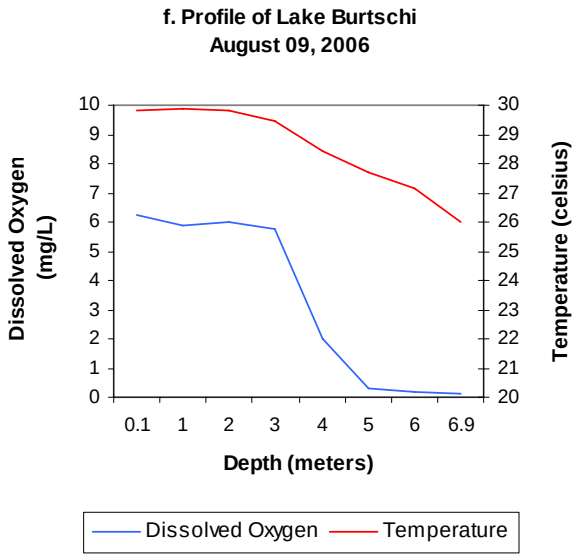
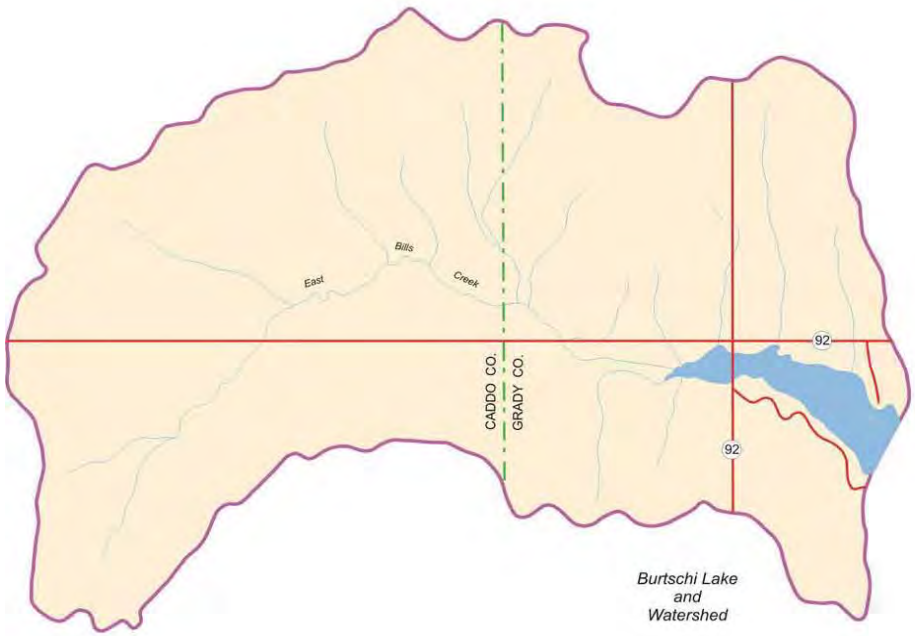


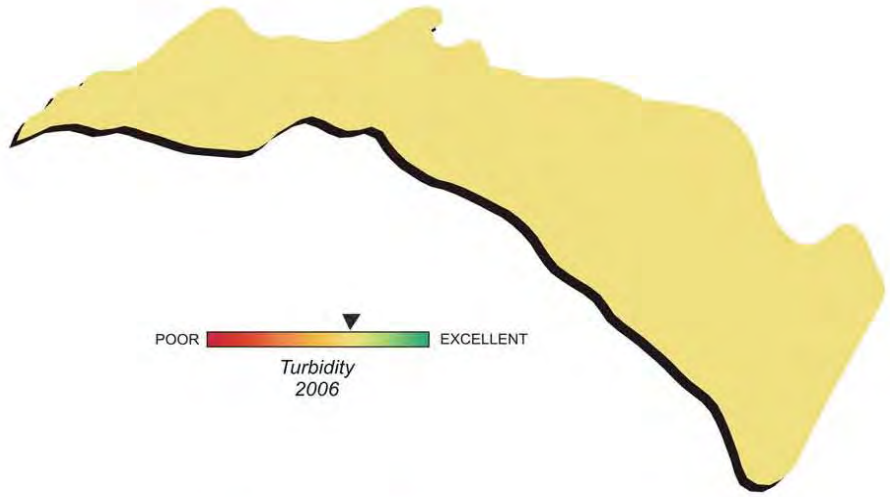
Figure 23a-23f. Graphical representation of data results for Lake Burtschi.



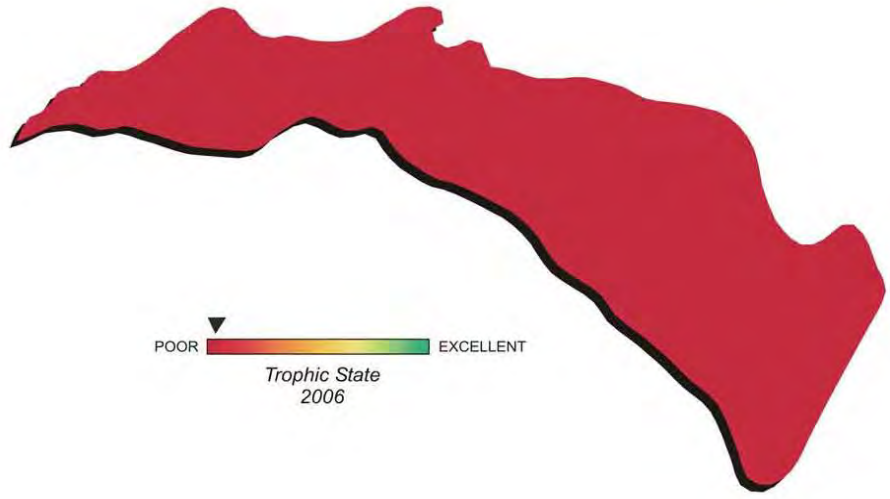
Burtschi Lake and Watershed

Burtschi Lake Location

Lake Data	
Owner	State of Oklahoma
County	Grady
Constructed in	1954
Surface Area	180 acres
Volume	2,140 acre/feet
Shoreline Length	3 miles
Mean Depth	11.89 feet
Watershed Area	4,692 acres



Turbidity 2006



Trophic State 2006

Plate 13 - Lake Water Quality for
Burtschi Lake

Canton Lake

Canton Lake, located in Blaine County, is approximately 2 miles north of the town of Canton. The United States Army Corps of Engineers constructed Canton Lake in 1948 to serve as a flood control, water supply and irrigation reservoir. The lake also serves as a municipal water supply reservoir for the City of Oklahoma City, which pays to have water released from the lake for water supply purposes when necessary. Additionally the lake is famous among anglers for it's walleye rodeo fishing event that is held annually. Canton Lake was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Water chemistry samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 16 NTU (Plate 14), true color was 18 units, and secchi disk depth was 63 centimeters. Water clarity was average based on secchi disk depth, turbidity, and true color values and results for these parameters were similar to that in 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was calculated at 57 (Plate 14), indicative of high primary productivity and nutrient rich conditions. This is similar to previous data collection efforts, indicating no significant change in productivity has occurred. The TSI values throughout the sample year were fairly consistent with hypereutrophic conditions in the fall and eutrophic conditions observed the remaining three sampling intervals. The only exception to this occurred at sites 1 and 2, which were mesotrophic in the summer. Turbidity values ranged from a low of 7 NTU to a maximum of 40 NTU, with the highest values recorded at site 4 in the upper end of the reservoir. Of the twenty values recorded 3 (15%) exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 24a). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Canton Lake is considered partially supporting the Fish & Wildlife Propagation (FWP) beneficial use based on turbidity values recorded for the reservoir. Seasonal true color values are displayed in Figure 24b. All true color values were below the Aesthetics WQS of 70 units for sample year 2005-2006. Applying the same default protocol to determine the average for true color, the Aesthetics beneficial use is supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.63 parts per thousand (ppt) in the winter to 0.93 ppt in the summer. Salinity concentrations were consistently higher than the range of expected values for Oklahoma lakes, reflecting the moderate to high presence of chlorides or other salts in the lake. Specific conductivity values were also higher than the expected range for Oklahoma reservoirs, indicating a high level of electrical current conducting compounds (i.e. salts). Values ranged from 1201 µS/cm in the winter to 1743 µS/cm in the summer. Lake pH values were neutral to

moderately alkaline, ranging from 7.51 to 8.49 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Canton Lake is supporting its FWP beneficial use as it relates to pH with 100% of the collected values falling within the acceptable range. Oxidation-reduction potentials ranged from 368 mV in the summer to 487 mV in the fall, indicating reducing conditions were not present throughout the year. The lake was not stratified during the fall, winter or spring quarters (Figure 24c-24e). During the summer sampling interval thermal stratification was evident and anoxic condition present in 25% of the water column at sites 1 and 2. Stratification occurred between 4 and 5 meters below the surface with dissolved oxygen (D.O.) dropping below 2.0 mg/L from 6 meters to the lake bottom of 6.5 meters (Figure 24f). In previous evaluations there has been an absence of stratification for the entire sample year, which may be attributed to its fairly shallow nature. According to the Use Support Assessment Protocols (USAP), if D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is fully supported at Canton Lake based on D.O. with anoxic conditions present in only 25% of the water column The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

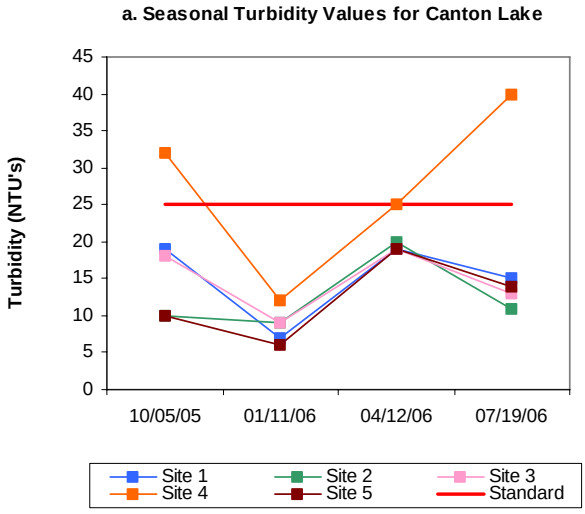
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

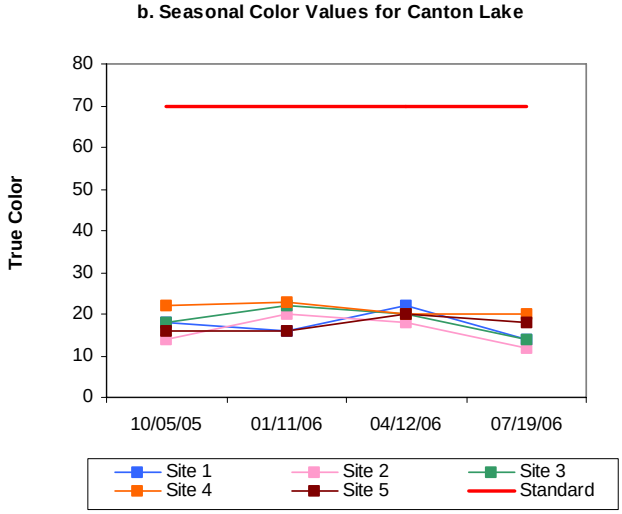
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) was 0.78 mg/L at the lake surface in sample year 2006. The epilimnetic (surface) TN ranged from 0.63 mg/L to 1.03 mg/L. TN was highest at site 5 in the fall. The lake-wide total phosphorus (TP) average was 0.062 mg/L at the lake surface. The TP ranged from 0.033 mg/L to 0.167 mg/L at the surface. Similar to TN, the highest TP was reported both in the fall with the lowest values reported during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 13:1 for sample year 2005-2005. This value is greater than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

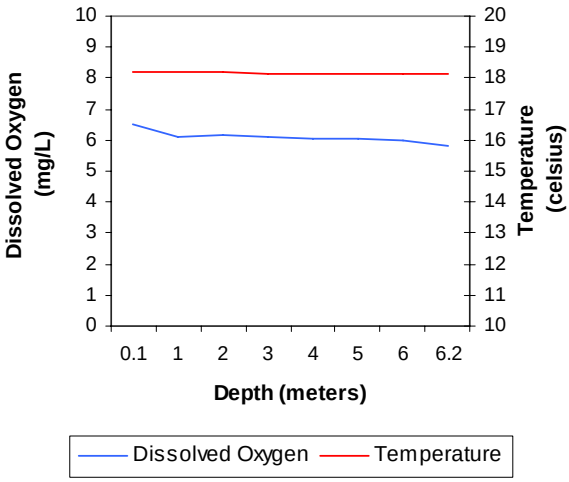
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1999 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use. Canton Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

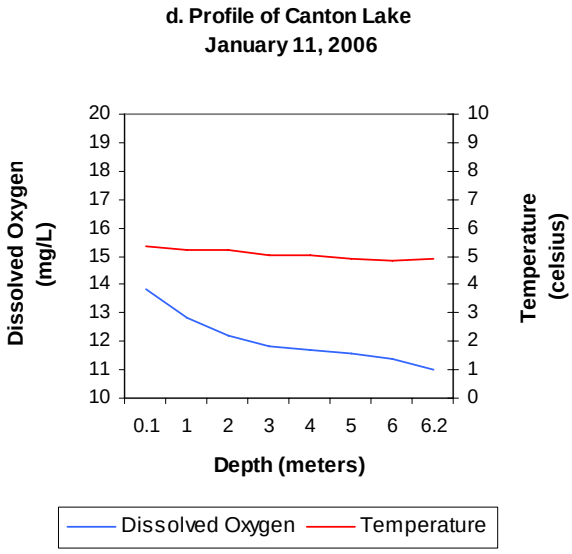
In summary, Canton Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 14). The trophic status of the reservoir was primarily eutrophic with hypereutrophic conditions in the fall of 2005. Water clarity was average based on secchi disk depth, turbidity, and true color values and results for these parameters were similar to that in

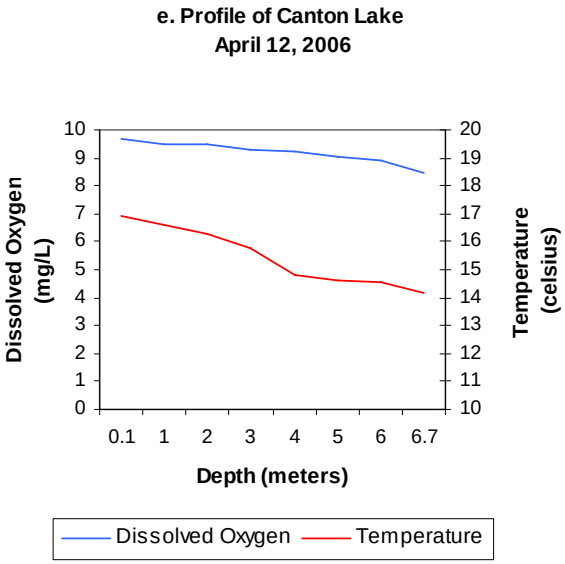
2004. The lake is supporting its FWP beneficial use based on pH and D.O. concentrations however only partially supporting the beneficial use with 15% of the turbidity values exceeding the WQS of 25 NTU. The lake was fully supporting its Aesthetics beneficial use for both trophic state and true color. Of the twenty color values collected, 100% were below the standard of 70 units. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.











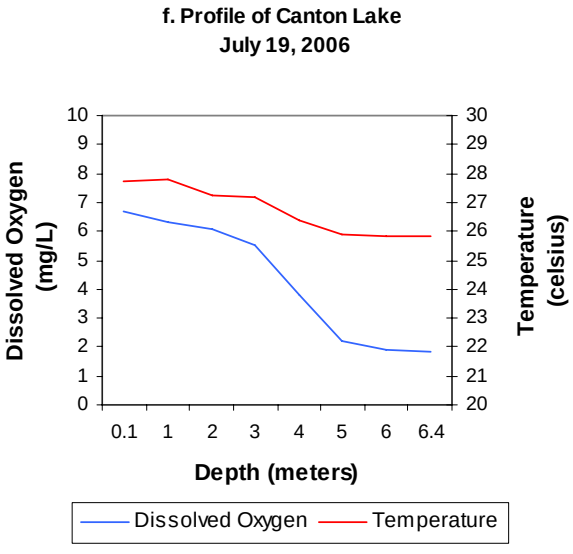
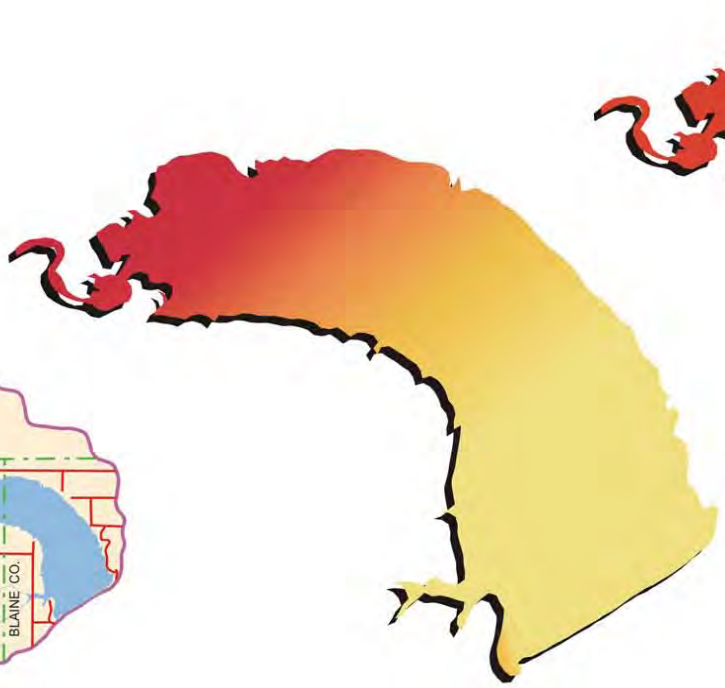


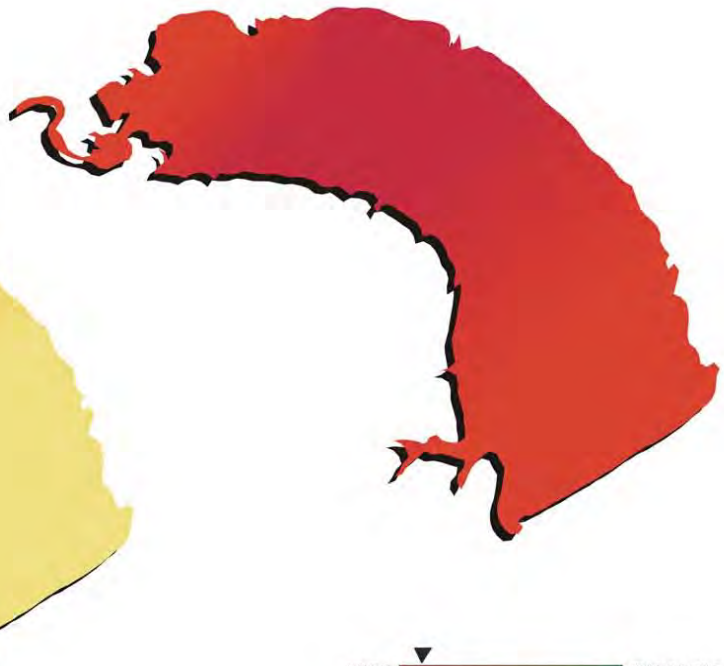
Figure 24a-24f. Graphical representation of data results for Canton Lake.

Canton Lake
and
Watershed



POOR — EXCELLENT

Turbidity
2006



POOR — EXCELLENT

Trophic State
2006

Lake Data	
Constructed by	Corps of Engineers
County	Blaine
Constructed in	1948
Surface Area	7,910 acres
Volume	111,310 acre/feet
Shoreline Length	45 miles
Mean Depth	14.99 feet
Watershed Area	12,483 square miles

Plate 14 - Lake Water Quality for
Canton Lake

Carl Albert Lake

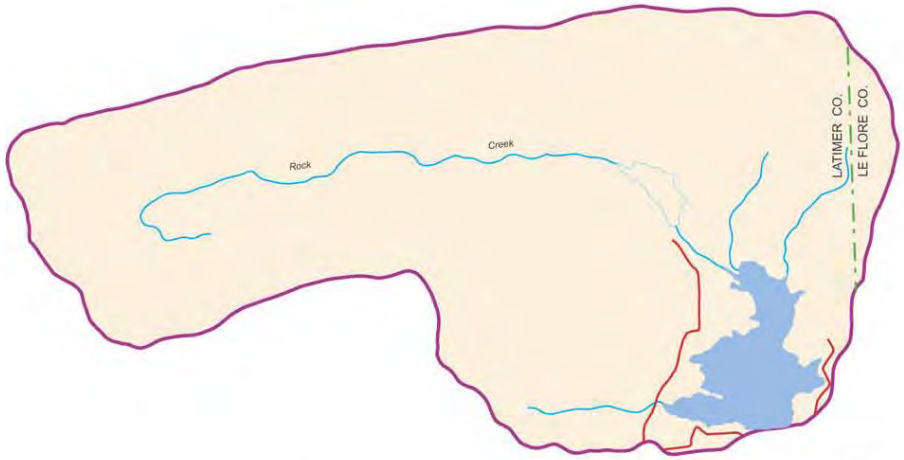
Carl Albert Lake, located in Latimer County, is approximately 1 mile north of Talihina. Carl Albert Lake was constructed in 1964 for the purpose of water supply, flood control and recreation. The lake was scheduled for sampling during the 2005-2006 sample year however due to the drought conditions lake levels were too low for OWRB staff to launch a boat. The lake will be placed on the next sample rotation once water levels rise enough for staff to access the lake safely.

Water quality samples were collected at three sites to represent the riverine, transitional, and lacustrine zones. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 7 NTU (Plate 15), true color was 31 units, and average secchi disk depth was 127 centimeters. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. Results for these parameters were slightly better than the results found in 2001. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 41 (Plate 15), indicating the lake was mesotrophic, bordering oligotrophic, indicative of low to moderate primary productivity and nutrient conditions in sample year 2004. The TSI in 2001 was also 41, indicating no significant increase or decrease has occurred since previous data collection efforts. The TSI values at all sites were oligotrophic in the fall and winter with mesotrophic values in the spring and summer. Turbidity values were fairly consistent among sites with values ranging from 4 to 10 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Carl Albert Lake is currently supporting its Fish & Wildlife Propagation (FWP) beneficial use with 100% of values recorded for the reservoir well below the prescribed numeric criteria. Seasonal true color values are displayed in. All true color values were below the aesthetics WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered supported.

Please refer to the "Beneficial Use Monitoring Report 2004 Draft Final Report" for the full discussion of monitoring results for this lake. The report may be access via the OWRB's web page at http://www. owrb.state.ok.us or you may contact the Water Resources for a copy of the 2004 BUMP Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the address below:

Oklahoma Water Resources Board
3800 N. Classen Blvd.
Oklahoma city, Oklahoma 73118
Attn: Nikki Cole

Carl Albert Lake
Location



Carl Albert Lake
and
Watershed

Lake Data	
Owner	City of Talihina
County	Latimer
Constructed in	1964
Surface Area	183 acres
Volume	2,739 acre/feet
Shoreline Length	4 miles
Mean Depth	14.97 feet
Watershed Area	3850 acres

Turbidity
2004

Trophic State
2004

Plate 15 - Lake Water Quality for
Carl Albert Lake

LAKES MONITORING PROGRAM

Lake Carl Blackwell

Lake Carl Blackwell was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as major arms. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 22 NTU (Plate 16), true color was 24 units, and secchi disk depth was 56 centimeters in 2004-2005. Based on these three parameters, Lake Carl Blackwell had good to fair water clarity, similar to that of the previous evaluation. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The calculated TSI was 56 (Plate 16), indicating the lake was eutrophic with high primary productivity and nutrient conditions. This value is nearly identical to that calculated for 2001-2002 (TSI=55), indicating no significant change in productivity has occurred. The TSI values varied throughout the sample year from upper eutrophic and hypereutrophic in the fall and winter to meso-eutrophic in both spring and summer. Seasonal turbidity values are displayed in Figure 25a. Of the turbidity values collected, only 20% exceeded the turbidity standard of 25 NTU for lakes. According to the Use support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Carl Blackwell is considered supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 25b. All true color values were below the aesthetics WQS of 70 units. Applying the same default protocol to determine the average for true color the Aesthetics beneficial use is supported.

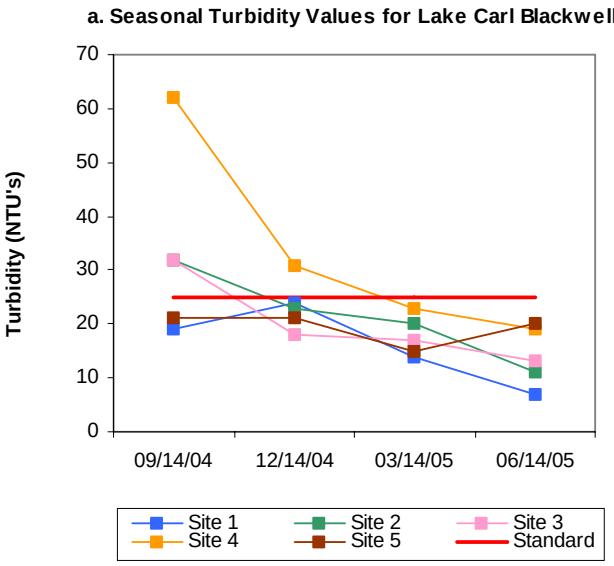
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sites during the study period. Salinity ranged from 0.18 to 0.22 parts per thousand (ppt), which was consistent with values, recorded most Oklahoma reservoirs. Specific conductivity ranged from 355.2 µS/cm to 449.7 µS/cm, indicative of low to moderate levels of current conducting ionic compounds (or other analogous materials) in the lake. The pH values at Lake Carl Blackwell were neutral to slightly alkaline ranging from 7.21 to 8.44 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Carl Blackwell is currently supporting its FWP beneficial use based on pH values. Oxidation-reduction potentials (redox) ranged from 211 mV in the spring to 431 mV in the winter, indicating an absence of reducing conditions within the lake system. During the fall quarter the lake was fairly well mixed with weak stratification occurring only in the lower portions of the water column. Dissolved Oxygen (D.O.) only fell below 2.0 mg/L between 12 and 13 meters, the lake bottom (Figure 25c). The lake was not thermally stratified in the winter or spring and dissolved oxygen (D.O.) concentrations remained well above 7.0 mg/L throughout the water (see Figure 25d-25e). In the summer, the lake was thermally stratified at several 1-meter intervals. However; similar to the fall, quarter; D.O. only fell below 2.0 mg/L near the lake bottom between 9 and 10 meters (see Figure 25f). Anoxic conditions were not present at any of the other sites probably because they are shallower in depth. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70% of the

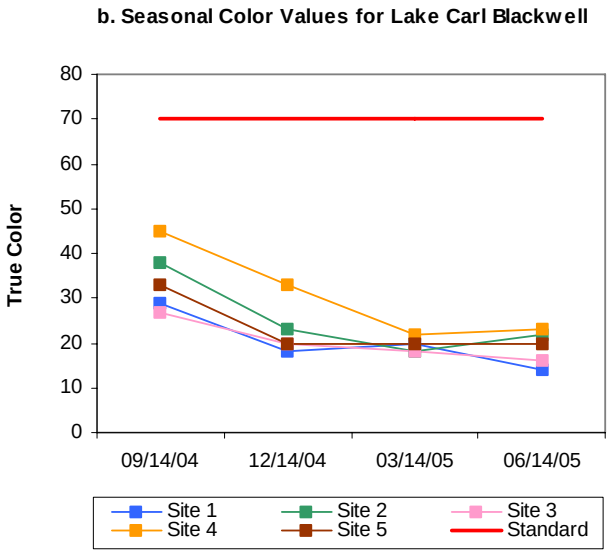
water column, the FWP beneficial use is deemed partially supported. According to USAP, the lake is fully supporting its FWP beneficial use with 10% of the water column in the summer less than the prescribed 2.0-mg/L water quality standard. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

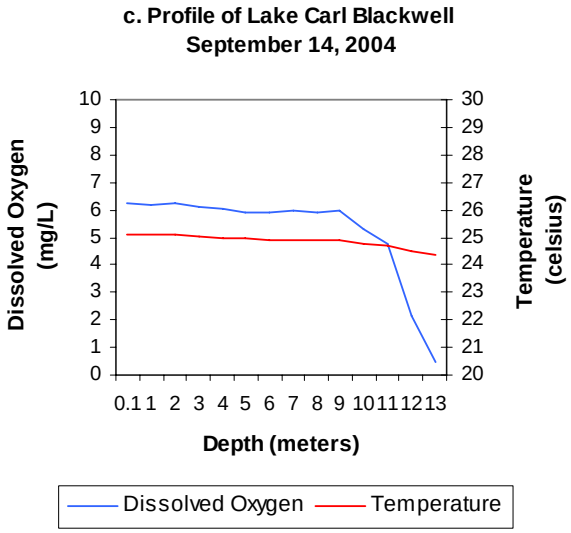
Bacteriological samples were not collected during the study period therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

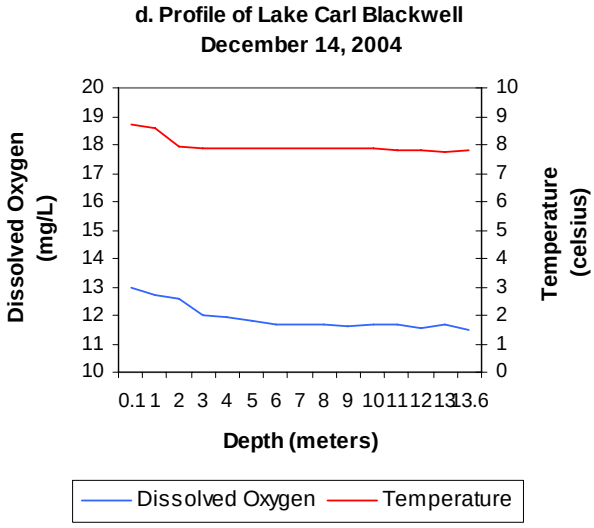
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average for sample year 2004-2005 was 0.55 mg/L at the lake surface. The epilimnetic (surface) TN ranged from 0.34 mg/L to 0.85 mg/L. TN was highest at site 1 in the fall and lowest in the spring also at site 1, the dam. The lake-wide total phosphorus (TP) average was 0.036 mg/L for the lake surface. The TP ranged from 0.024 mg/L to 0.062 mg/L at the lake surface. Similar to total nitrogen, TP was highest in the winter and lowest in the spring. The nitrogen to phosphorus ratio (TN:TP) was approximately 15:1 for sample year 2004-2005. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

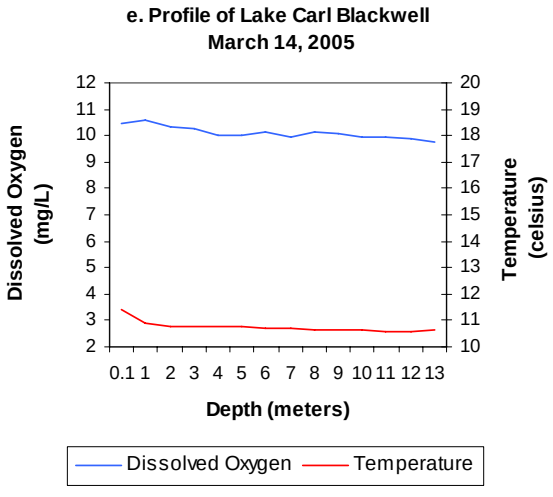
In summary, Lake Carl Blackwell was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 16). The current classification is the same as that observed in 2002 (TSI=55), indicating no significant increase or decrease in productivity has occurred. Water clarity was average to fair based on turbidity, true color, and secchi disk depth. The Aesthetics beneficial use was fully supported based on true color data and trophic status. Additionally, the FWP beneficial use is fully supported based on pH data and D.O. conditions, and partially supporting for turbidity. Bacteria data were not collected during the recreational season and an assessment of the PBCR use cannot be made. The OWRB has recently completed a demonstration of shoreline erosion control at Lake Carl Blackwell funded through Section 319 of the Clean Water Act. These relatively low cost and fish friendly methods have been enacted in cooperation with Oklahoma State University. In addition Oklahoma Water Watch has an active volunteer monitoring group at Lake Carl Blackwell. For more information on these programs contact Derek Smithee at (405) 530-8800. Lake Carl Blackwell is owned and managed by Oklahoma State University and the State of Oklahoma. The lake is managed as a municipal water supply and source of recreational activities.











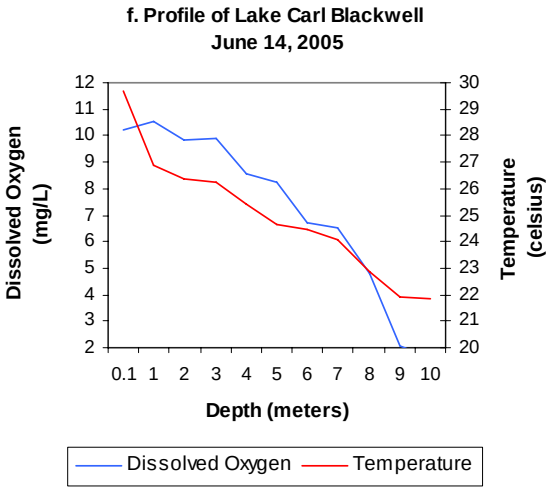
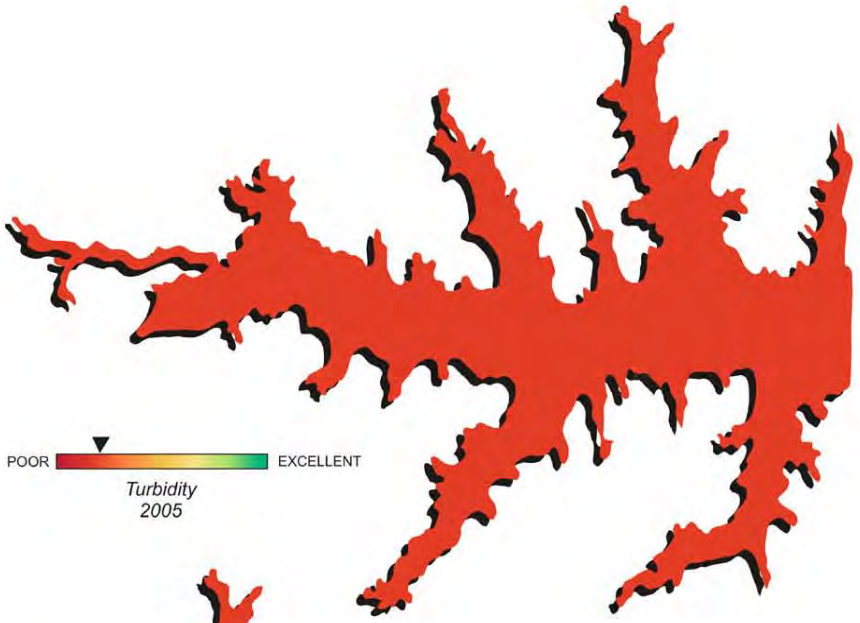


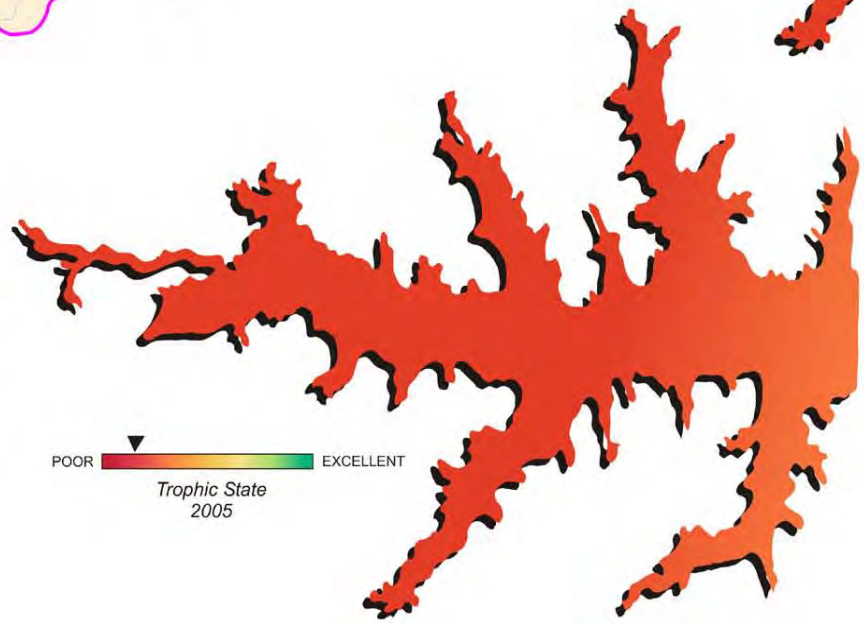
Figure 25a-25f. Graphical representation of data results for Lake Carl Blackwell.

Lake Carl Blackwell and Watershed

Lake Carl Blackwell Location



Turbidity 2005



Trophic State 2005

Lake Data	
Owner	Oklahoma State University
County	Payne
Constructed in	1937
Surface Area	3,370 acres
Volume	61,500 acre/feet
Shoreline Length	58 miles
Mean Depth	18.25 feet
Watershed Area	49,278 square miles

Plate 16 - Lake Water Quality for
Lake Carl Blackwell

LAKES MONITORING PROGRAM

Carter Lake

Carter Lake, located in Marshall County, is approximately 5 mile northwest of Madill. The lake was constructed in 1960 and is managed by the city for both water supply and recreation purposes. The lake was scheduled for sampling during the 2005-2006 sample year however due to the drought conditions lake levels were too low for OWRB staff to launch a boat. The lake will be placed on the next sample rotation once water levels raise enough for staff to access the lake safely.

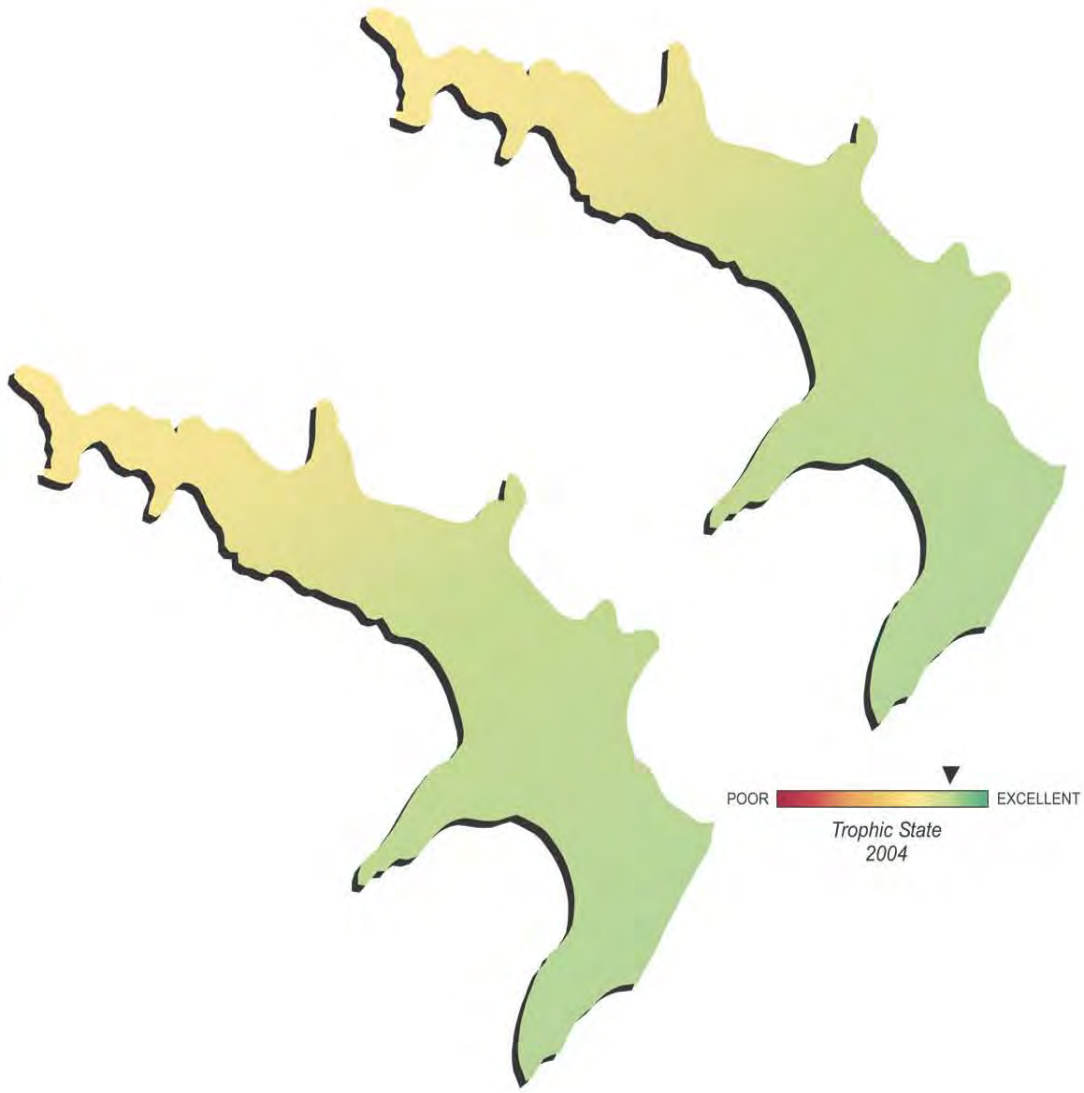
Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and as well as 0.5 meters from the lake bottom at site 1, the dam. The lake-wide turbidity value was 8 NTU (Plate 17), true color was 15 units, and average secchi disk depth was 108 centimeters. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 40, indicating the lake was oligotrophic bordering mesotrophic with low primary productivity and nutrient conditions in sample year 2004. This value is less than that reported in 2001 (TSI=44); however it is likely a more accurate depiction of lake productivity as it is based on four seasons of data versus three in the previous evaluation. The TSI values throughout the sample year were primarily oligotrophic with mesotrophic values at all sites in the spring and site 3 during the summer. Seasonal turbidity values per site for the sample year were below the Oklahoma Water Quality Standard (WQS) of 25 NTU for all seasons. According to the Use support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake is considered supporting its Fish & Wildlife Propagation (FWP) beneficial use with 100% of the collected turbidity data below the criteria. Similar to turbidity, all true color values were below the aesthetics WQS of 70 units. Applying the same default protocol to determine the average for true color the Aesthetics beneficial use is supported.

Please refer to the "Beneficial Use Monitoring Report 2004 Draft Final Report" for the full discussion of monitoring results for this lake. The report may be access via the OWRB's web page at http://www. owrb.state.ok.us or you may contact the Water Resources for a copy of the 2004 BUMP Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the address below:

Oklahoma Water Resources Board
3800 N. Classen Blvd.
Oklahoma city, Oklahoma 73118
Attn: Nikki Cole

Carter Lake
Location

Carter Lake
and
Watershed



Lake Data	
Owner	City of Madill
County	Marshall
Constructed in	1960
Surface Area	108 acres
Volume	990 acre/feet
Shoreline Length	4 miles
Mean Depth	9.17 feet
Watershed Area	1,134 acres

Plate 17 - Lake Water Quality for
Carter Lake

LAKES MONITORING PROGRAM

Cedar Lake

Cedar Lake, located in Le Flore County, is approximately 3 miles N.W of the town of Stapp. The USDA constructed this lake in the Ouchita National Forest in 1937 for recreational purposes. Cedar Lake was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites during the study period. The lake-wide turbidity value was 4 NTU (Plate 18), true color was 19 units, and average secchi disk depth was 162 centimeters. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. Results for these parameters were similar to if not slightly better than the results of the 2004 data collection efforts. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=9). The TSI was 53, indicating the lake was eutrophic with high primary productivity and nutrient conditions. This is consistent with the previous evaluation in 2004, which had a calculated TSI of 55. Due to a post processing error no samples were submitted for analysis from the winter data collection efforts. The TSI values throughout the sample year varied seasonally from mesotrophic in the fall and spring to upper eutrophic during the summer quarter. Turbidity values per site for sample year 2004 were well below the Oklahoma Water Quality Standard (WQS) of 25 NTU for all seasons (See Figure 26a). The lake-wide annual turbidity of 4 NTU seems to accurately represent conditions at Cedar Lake. According to the Use support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake is considered supporting its Fish & Wildlife Propagation (FWP) beneficial use with 100% of the collected turbidity data below the criteria. Seasonal true color values are displayed in Figure 26b. All true color values were below the Aesthetics WQS of 70 units. Applying the same default protocol to determine the average for true color, the Aesthetics beneficial use is supported.

In 2006, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity ranged from 0.0 parts per thousand (ppt) to 0.09 ppt for this sample year. Specific conductivity ranged from 4.9 µS/cm to 195.7 µS/cm, which falls within the range, if not lower than values commonly reported for Oklahoma lakes. These values indicate a minimal presence of ions (chlorides or other salts) present in the system. The pH values at Cedar Lake ranged from 5.43 to 9.16, representing a slightly acidic system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 36% of the recorded values falling below 6.5 pH units and 6% of the values greater than 9 pH units the FWP beneficial use is considered not supporting based on pH

concentrations. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Due to these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 18 mV in the summer to 560 mV in the fall. The near reducing conditions observed in the summer correspond to the anoxic conditions present in a large portion of the water column recorded at site 1, the dam site. Thermal stratification was evident and anoxic conditions present in three of the four sampling intervals (Figure 26c-26f). In the fall quarter, stratification occurred between 4 and 5 meters at sites 1 and 2, at which point dissolved oxygen (D.O) was below 2.0 mg/L to the lake bottom 8.7 meters. The lake was stratified between 2 and 3 meters below the surface in the spring with oxygen concentrations less than 2.0 mg/L in 20-22% of the water column at the same two sites (Figure 26e). During the summer quarter the lake was strongly thermally stratified between 1 and 2 meters below the surface with dissolved oxygen levels below 1 mg/L for up to 70% water column at site 1 (Figure 26f). According to the Use Support Assessment Protocols (USAP), if the D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 70% of the water column falling below 2.0 mg/L at site 1 in the summer, the FWP beneficial use is not supported at Cedar Lake. Low dissolved oxygen concentrations in the water column throughout most of the year could pose a threat to fish and wildlife propagation and the lake should be monitored closely in the future. The lake was also sampled for chlorides, and sulfates to assess the Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

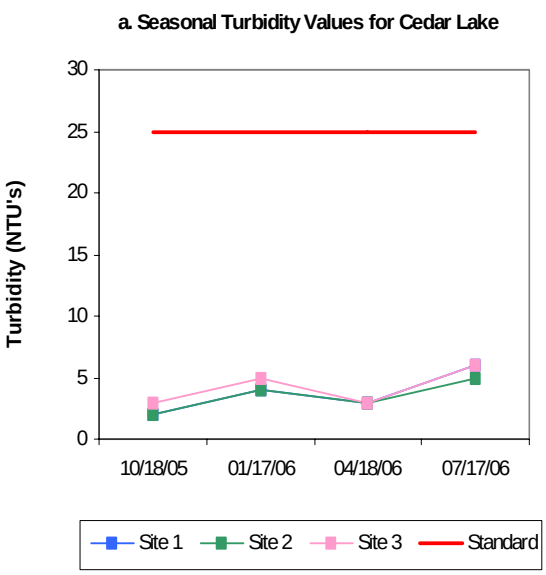
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

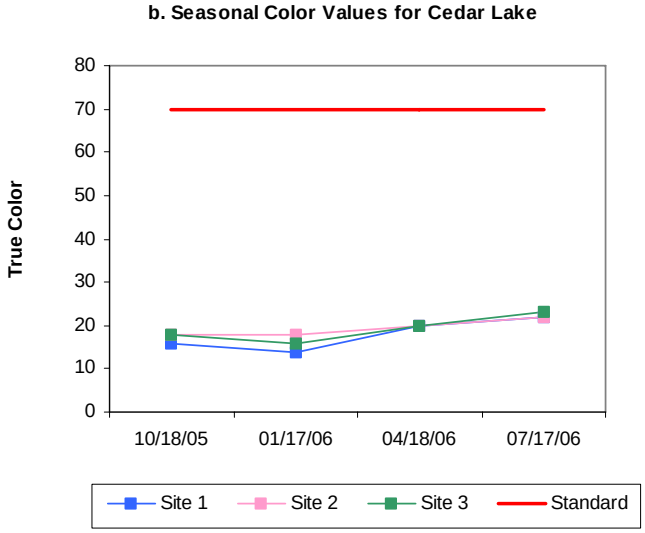
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.48 mg/L at the surface. The TN at the surface ranged from 0.34 mg/L in the spring to 0.84 mg/L in the summer sampling interval. The lake-wide total phosphorus (TP) average was 0.072 mg/L at the surface. The total phosphorus at the surface ranged from 0.019 mg/L to 0.376 mg/L with lower values occurring in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was 7:1 for sample year 2005-2006. This value is the same as 7:1, characterizing the lake possibly co-limited (Wetzel, 1983).

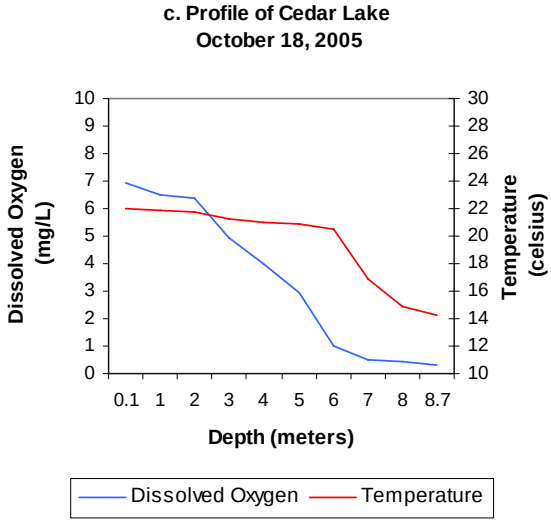
Cedar Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

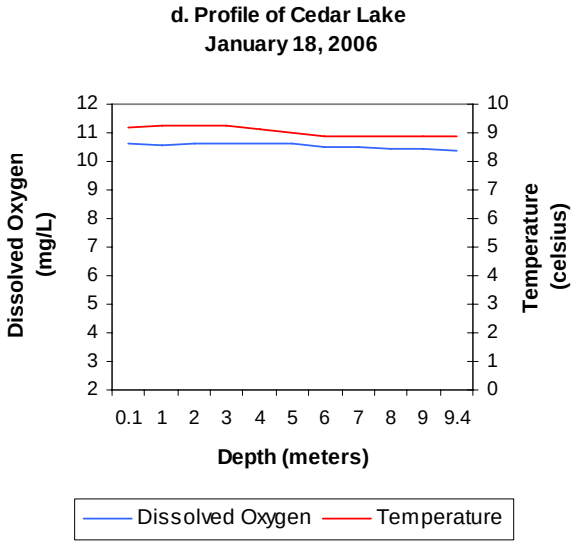
In summary, Cedar Lake is classified as eutrophic, with high levels of primary productivity and nutrient rich conditions (Plate 18). Results were similar to 2004 (TSI=55) indicating no significant increase or decrease in productivity has occurred over time. Water clarity continues to be excellent in comparison to other Oklahoma lakes based on true color, turbidity and high secchi disk depths. The FWP beneficial use is supported as it relates to turbidity with 100% of

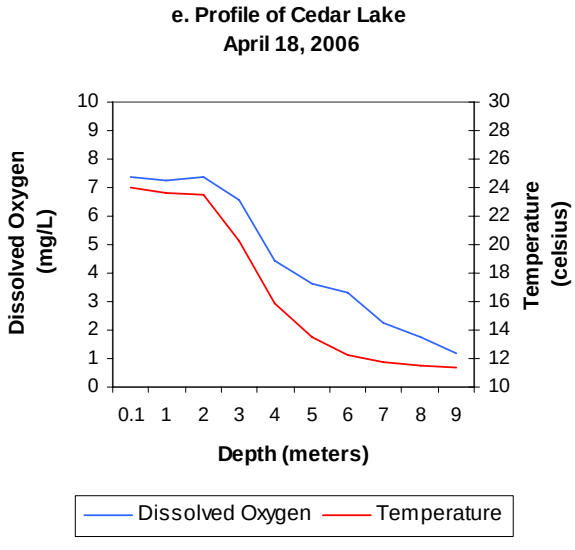
the recorded values below the WQS of 25 NTU and is not supported for dissolved oxygen concentrations. Anoxic conditions were present in three of the four sampling intervals with approximately 70% of the water column less than 2.0 mg/L during the summer; therefore the FWP use is not supported. Low dissolved oxygen (D.O.) throughout most of the year could pose a threat to fish and wildlife propagation. Cedar Lake was also not supporting the FWP beneficial use with 36% of the pH values less than 6.5 units. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial use is considered fully supported based on trophic status and true color.











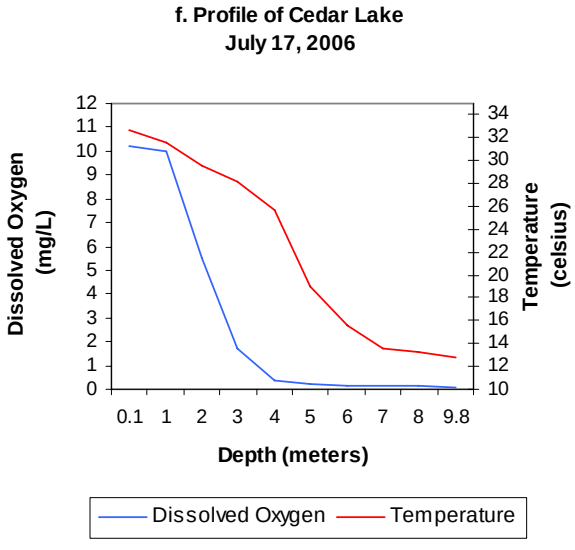
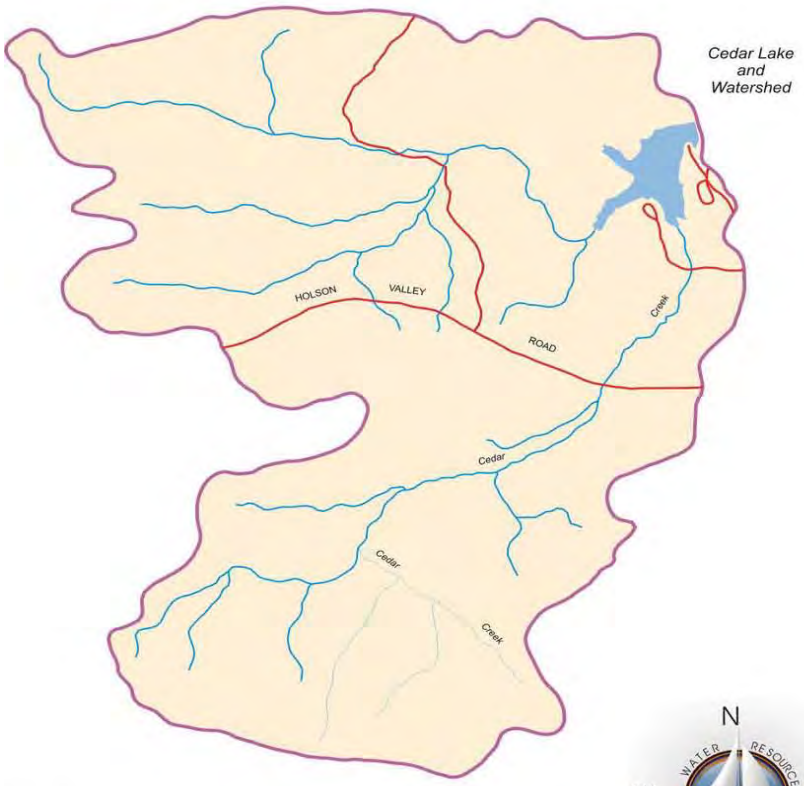


Figure 26a-26f. Graphical representation of data results for Cedar Lake.

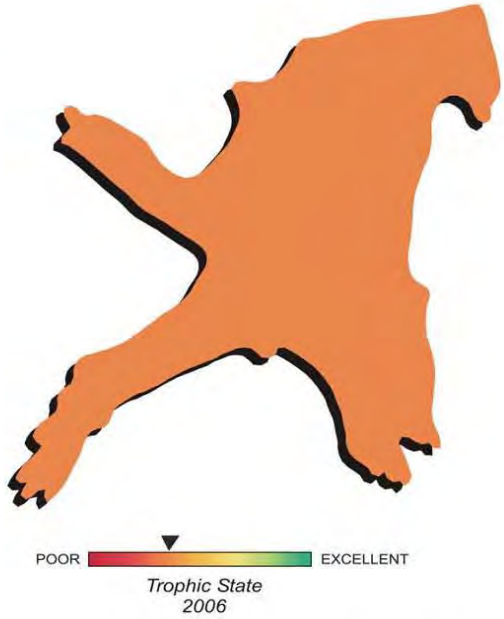
Cedar Lake Location



Cedar Lake and Watershed

Lake Data	
Owner	U.S. Dept. of Agriculture
County	LeFlore
Constructed in	1937
Surface Area	78 acres
Volume	1,000 acre/feet
Shoreline Length	3 miles
Mean Depth	12.82 feet
Watershed Area	9 square miles

Turbidity 2006



Trophic State 2006

Plate 18 - Lake Water Quality for
Cedar Lake

Chandler Lake

Chandler Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 11 NTU (Plate 19), true color was 17 units, and secchi disk depth was 87 centimeters in 2005. Water clarity was good based on secchi disk depth, turbidity, and true color values. Compared to values recorded in 2003, results for these parameters are very similar, although secchi disk depth was a little lower than previously reported. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 50 (Plate 14), indicating the lake was mesotrophic bordering eutrophic with moderate to high primary productivity and nutrient conditions in sample year 2005. The TSI values throughout the sample year varied seasonally from eutrophic in the fall, mesotrophic in the winter and back to eutrophic during the summer. Seasonal turbidity values are displayed in Figure 27a. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Of the twelve values collected, only 1 (8.3%) exceeded the numerical criteria of 25 NTU. The FWP beneficial use is therefore considered fully supported. Seasonal true color values are displayed in Figure 27b. All true color values collected during the study period were below the aesthetics WQS of 70 units. Applying the same default protocol, Chandler Lake is meeting the Aesthetic beneficial use.

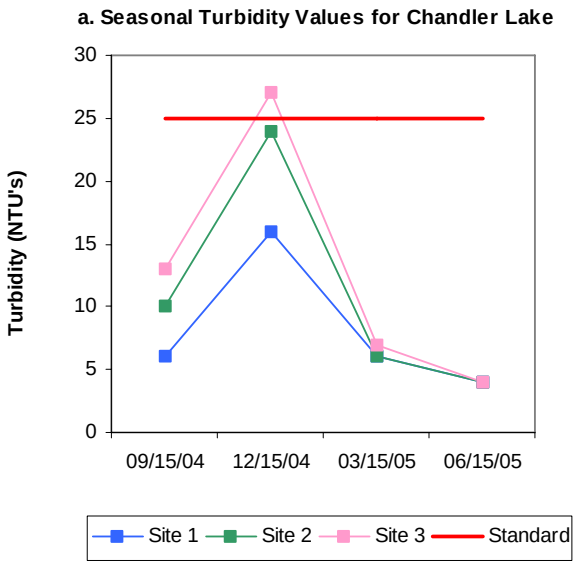
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity ranged from 0.13 parts per thousand (ppt) to 0.29 ppt for this sample year, which falls within the range of values commonly reported for Oklahoma lakes. Specific conductivity ranged from 270.7 µS/cm to 565.1 µS/cm, indicative of moderate levels of ions (chlorides or other salts) present in the system. The pH values at Chandler Lake ranged from 7.14 to 8.56, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Chandler Lake is currently supporting its FWP beneficial use based on pH values. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 49 mV in the fall to 474 mV in the winter. In general, reducing conditions were not present in this reservoir. The low value of 49 was the only value indicative of near reducing conditions and most likely resulted because it was recorded at the lake bottom at the dam site. The lake exhibited strong thermal stratification during the fall quarter with approximately half the water column below 2.0 mg/L (Figure 27c). During the winter and spring quarters (see Figure 27d-30e) the lake was well mixed with dissolved oxygen (D.O.) concentrations above 7.0 mg/L

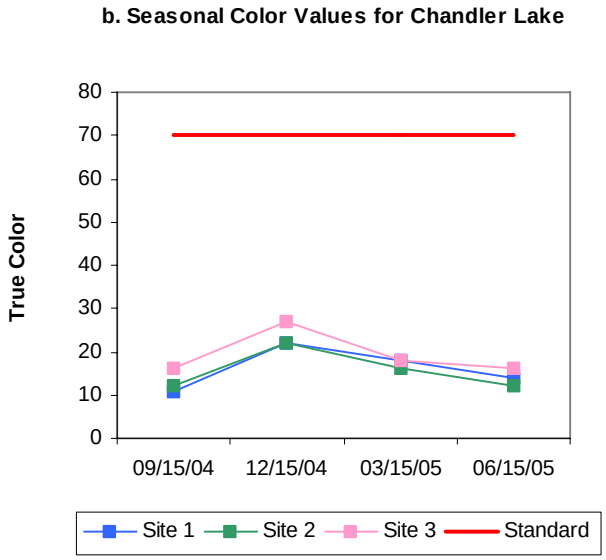
throughout the lake. During the summer quarter the lake exhibited thermal stratification between 3 and 4 meters and again between 5 and 6 meters at which point the dissolved oxygen dropped below 1 mg/L for the remainder of the water column. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With approximately 38% of the water column experiencing anoxic conditions at site 1, the FWP beneficial use is considered supported at Chandler Lake. The lake was also sampled for total dissolved solids, chlorides, and sulfates to assess the Agriculture beneficial use. Sampling 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

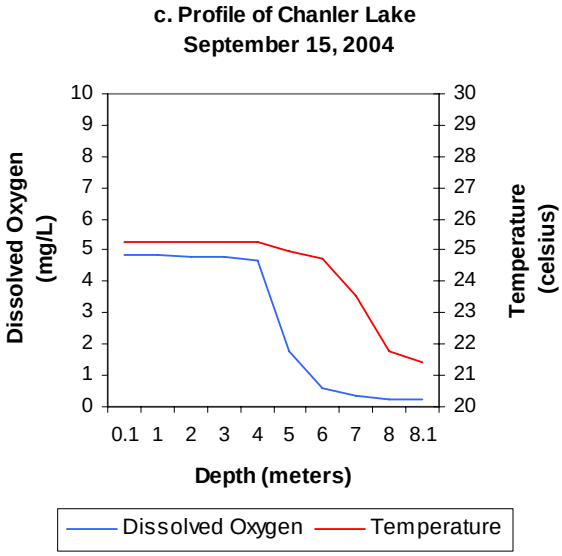
Bacteriological samples were not collected during the study period, therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

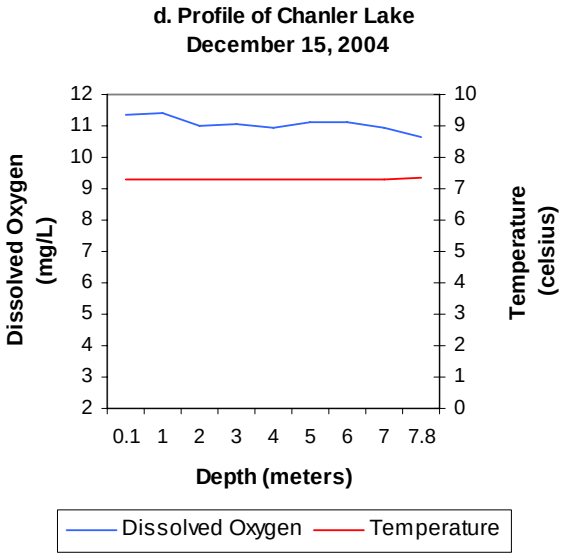
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.68mg/L at the surface. The TN at the surface ranged from 0.49 mg/L in the summer to 0.88 mg/L in the fall. The lake-wide total phosphorus (TP) average was 0.035 mg/L at the surface. The total phosphorus at the surfaced ranged from 0.023 mg/L to 0.053 mg/L with lower values occurring in the summer quarter. The nitrogen to phosphorus ration (TN:TP) was 20:1 for sample year 2004-2005. This value is much higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

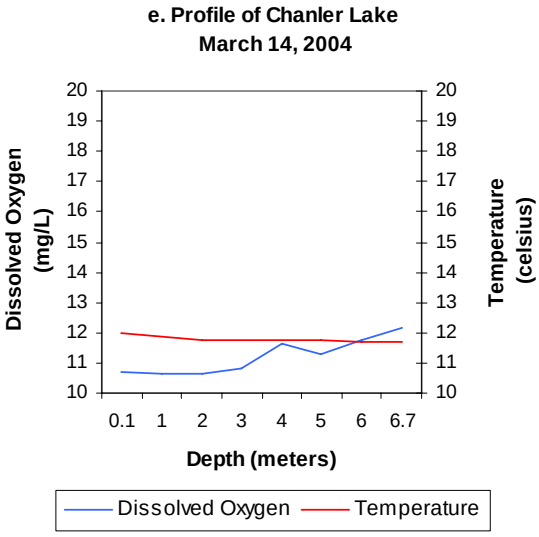
In summary, Chandler Lake was classified as mesotrophic bordering eutrophic, indicative of moderate primary productivity and nutrient conditions (Plate 19). Water clarity was good based on turbidity, true color and secchi disk depth and results were similar to those observed in 2003. The lake is supporting the FWP beneficial use based on pH and turbidity, dissolved oxygen levels. The Aesthetics beneficial use is also being met by both the trophic status and true color concentrations. An assessment of the PBCR cannot be at this time as bacteria samples were not collected during the study period. Chandler Lake is located in Lincoln County and is owned by the city of Chandler. Constructed in 1954 it serves as the city's municipal water supply and is also utilized for recreation.











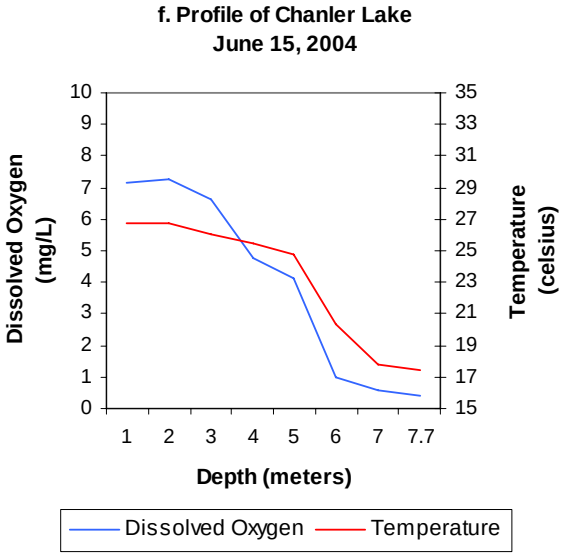


Figure 27a-27f. Graphical representation of data results for Chandler Lake.

POOR — EXCELLENT

Turbidity
2005

POOR — EXCELLENT

Trophic State
2005

Lake Data	
Owner	City of Chandler
County	Lincoln
Constructed in	1954
Surface Area	129 acres
Volume	2,778 acre/feet
Shoreline Length	4 miles
Mean Depth	21.53
Watershed Area	3,403 acres

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WATER RESOURCES BOARD
OKLAHOMA

Plate 19 - Lake Water Quality for
Chandler Lake

LAKES MONITORING PROGRAM

Lake Chickasha

Lake Chickasha was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the lacustrine, transition and riverine zones of the reservoir. Samples were collected at the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 14 NTU (Plate 15), true color was 14 units, and annual average secchi disk depth was 54 centimeters. Based on these three parameters water clarity was good at Lake Chickasha in sample year 2005. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The result was a TSI of 66 (Plate 15), indicating the lake was hypereutrophic with excessive primary productivity and nutrient levels in sample year 2004-2005. This value is higher than that calculated in 2003 (TSI=59). The TSI values for all sites varied seasonally ranging from hypereutrophic in the fall and spring to eutrophic in the in both winter and summer quarters. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Seasonal turbidity values are displayed in Figure 28a. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With two (20%) of the turbidity exceeding of 25 NTU the lake is partially supporting the FWP beneficial use. Seasonal true color values were all well below the WQS of 70 units and are displayed in Figure 28b. Applying the same default protocol, Lake Chickasha is meeting the Aesthetic beneficial use as it relates to true color.

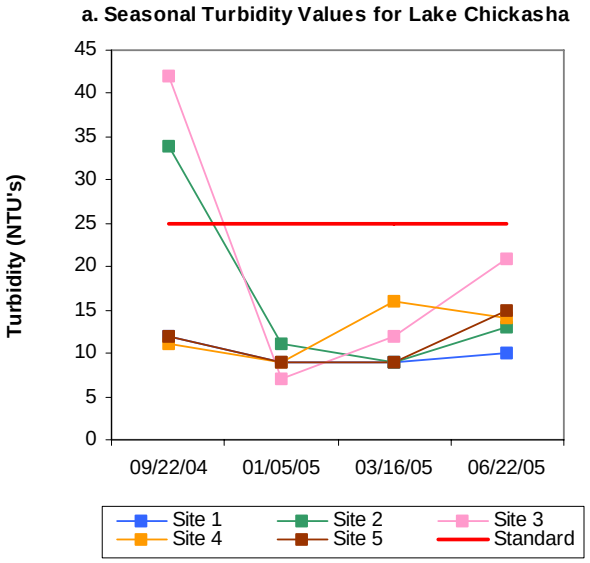
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 1.43 parts per thousand (ppt) to 1.51 ppt for this sample year. Specific conductivity ranged from 2654 µS/cm to 2800 µS/cm, which is higher than most Oklahoma reservoirs. These values indicate the presence of high levels of electrical current conducting compounds (salts) in the lake, consistent with higher salinity concentrations. The pH values at Lake Chickasha ranged from 7.16 to 8.46, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Chickasha is currently supporting its FWP beneficial use based on pH values. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 118 mV in the fall to 446 mV in the summer, indicative of an absence of reducing conditions in this reservoir. The lake was not stratified during the first three the sampling quarters (see Figure 28c-28e) and dissolved oxygen (D.O.) levels were generally above 6.0 mg/L. The absence of stratification during much of the year may be attributed to the shallow nature of this reservoir where wind and wave action keep the lake well mixed. Thermal

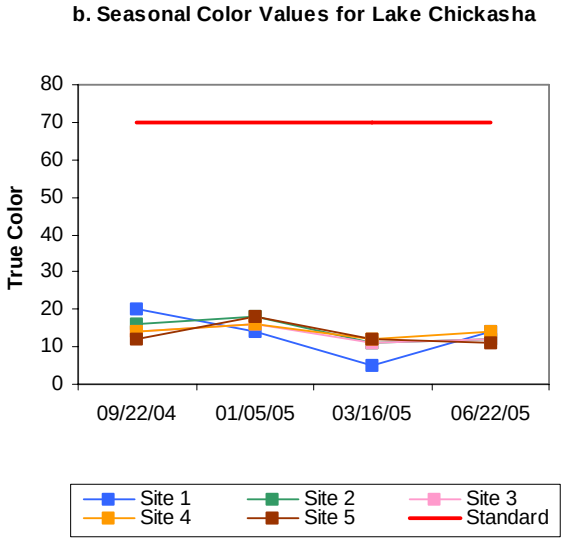
stratification and anoxic conditions were both present during the summer sampling interval. The lake was stratified at several 1-meter intervals with D.O. falling below 2.0 mg/L between 5 and 6 meters in depth. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 33% of the water column below 2.0 mg/L at site 1 during the summer quarter, the FWP beneficial use is fully supported at Lake Chickasha. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2004-2005 found the Agriculture beneficial use to be fully supported bases on numerical criteria located in OAC 785:45 – Appendix F.

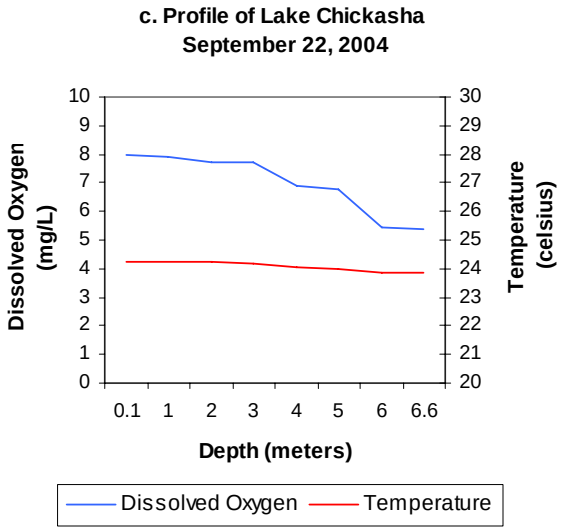
Bacteriological samples were not collected during the study period therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made.

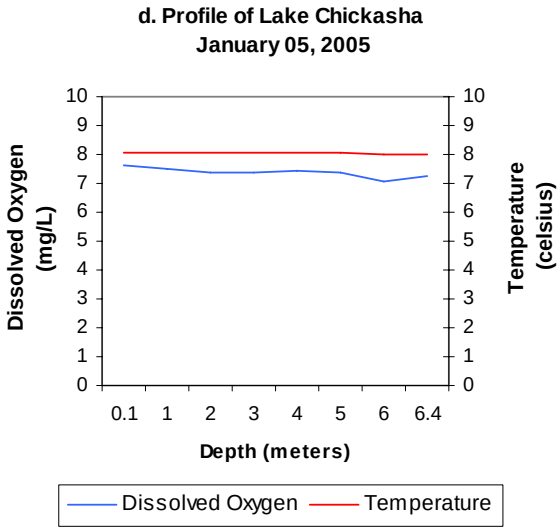
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 2.03 mg/L at the surface. The TN at the surface ranged from 1.39 mg/L in the summer to 2.77 mg/L in the winter. The lake-wide total phosphorus (TP) average was 0.050 mg/L at the surface. The total phosphorus at the surface ranged from 0.031 mg/L to 0.082 mg/L with lower values occurring in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was 41:1 for sample year 2003. This value is much higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

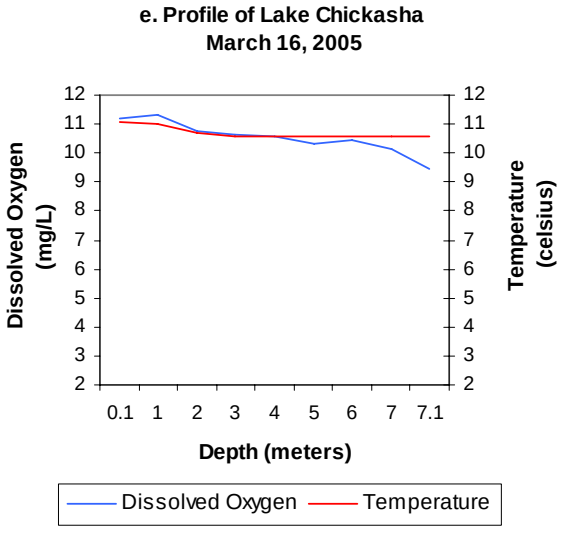
In summary, Lake Chickasha was classified as hypereutrophic, indicative of excessive primary productivity and nutrient rich conditions. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on pH and dissolved oxygen levels. With 20% of the collected values exceeding 25 NTU, the FWP beneficial use is considered partially supported as it relates to turbidity. The Aesthetics beneficial use is being met with 100% of the true color values below the WQS of 70 units. The PBCR beneficial use could not be assessed, as bacteria samples were not collected during the study period. Lake Chickasha is located in Caddo County serves as a municipal water supply as well as a recreational reservoir.











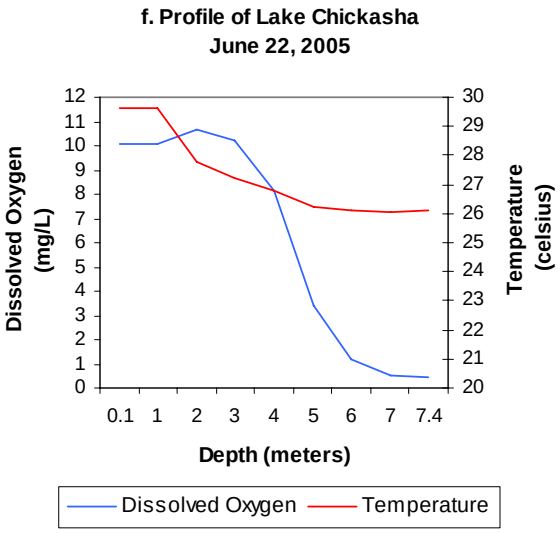
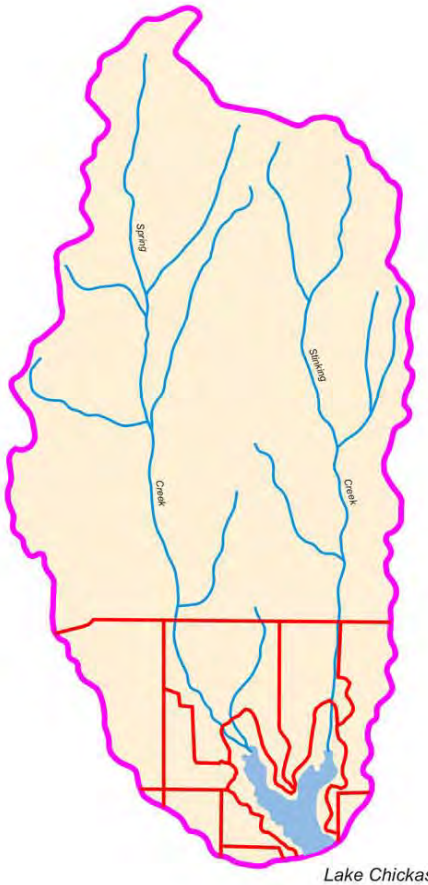


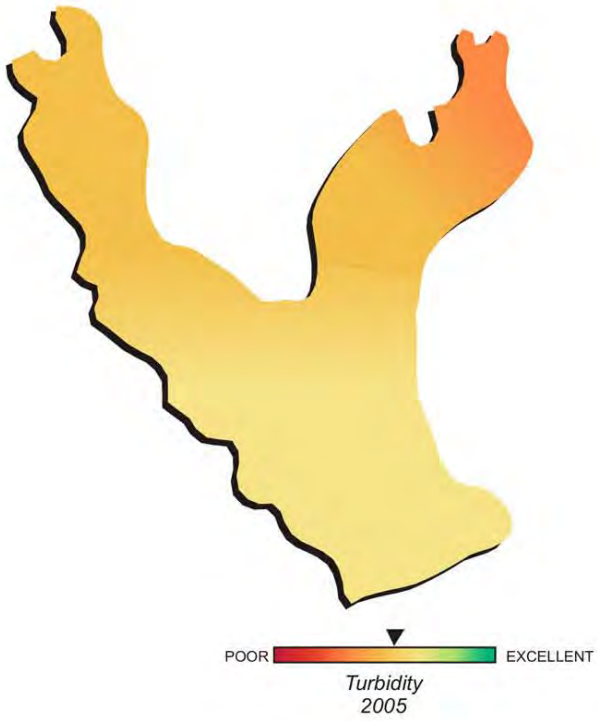
Figure 28a-28f. Graphical representation of data results for Lake Chickasha.



Lake Chickasha and Watershed

Lake Chickasha Location

Trophic State 2005



Turbidity 2005

Lake Data	
Owner	City of Chickasha
County	Caddo
Constructed in	1958
Surface Area	820 acres
Volume	41,080 acre/feet
Shoreline Length	10 miles
Mean Depth	50.10 feet
Watershed Area	74 square miles

Plate 20 - Lake Water Quality for
Lake Chickasha

LAKES MONITORING PROGRAM

Claremore Lake

Claremore Lake, located in Rogers County, is the municipal water supply reservoir for the City of Claremore and is owned and operated by the city. The lake was constructed in 1930 and also provides recreational opportunities for the public. Claremore Lake was sampled for three quarters from November 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. All water samples were collected from the lake surface during the study period. The lake-wide annual turbidity value was 19 NTU (Plate 21), true color was 24 units, and secchi disk depth was 41 centimeters in 2005-2006. Based on these three parameters, Claremore Lake had average to good water clarity in comparison to other Oklahoma reservoirs. These findings are similar to those observed in 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=15). Due to low lake levels the lake was closed and OWRB staff were unable to collect data during the winter sampling interval. The calculated TSI was 67 (Plate 21), indicating the lake was hypereutrophic during the study period. The TSI values throughout the sample year were consistently in the hypereutrophic range. These results are consistent with historical data collection efforts on the lake, which also found the lake to be hypereutrophic in nature. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (WQS) and is considered nutrient threatened. Seasonal turbidity values are displayed in Figure 29a. According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 2 (13%) of the 15 turbidity values recorded exceeded the water quality standard of 25 NTU, an assessment of the Fish & Wildlife Propagation (FWP) beneficial use based on turbidity cannot be made at this time as minimum data requirements were not met for this sample year. Seasonal true color values are displayed in Figure 29b. Although none of values exceeded the standard of 70 units, the minimum data requirements were not met and a definitive assessment of beneficial uses cannot be made.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. The salinity concentrations at Claremore Lake ranged from 0.11 parts per thousand (ppt) to 0.12 ppt. This is well within the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Specific conductivity values were also well within the expected range for Oklahoma reservoirs, indicating minimal presence of electrical current conducting compounds like salts. Specific conductivity values ranged from 242.0 µS/cm in the spring quarter to 257.4 µS/cm recorded in the fall quarter. The pH values at Claremore Lake were neutral to slightly alkaline ranging from 7.03 to 8.10 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially

supporting its FWP beneficial use. With 100% of collected values within the acceptable range Claremore Lake is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (redox) ranged from 252 mV to 454 mV with both the high and low recorded in the spring quarter, which indicated an absence of reducing conditions. The lake was not thermally stratified in the fall and dissolved oxygen levels remained well above 5 mg/L (Figure 29c). In the spring quarter the lake was weakly stratified with anoxic conditions present only in the bottom of the water column (See Figure 29d). Due to low lake levels in the winter and a Hydrolab malfunction in the summer quarter, profile data is unavailable for assessment. When D.O. values are less than 2 .0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, Claremore Lake is fully supporting its FWP beneficial use based on the available information with 29% of the water column less than 2.0 mg/L. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.23 mg/L at the lake surface during the study period. The TN at the surface ranged from 0.91 mg/L to 2.00 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average was 0.103 mg/L at the lake surface. The TP ranged from 0.072 mg/L to 0.193 mg/L at the lake surface. Similar to TN, the highest surface TP values were reported in the summer quarter however the lowest were in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 12:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Claremore Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Claremore Lake was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels (Plate 21). This finding is consistent with historical data collection efforts in 2004 (TSI=61). Currently, the lake is listed in the WQS as a NLW indicating that the Aesthetics beneficial use is considered threatened by nutrients until studies can be conducted to confirm non-support status. The Aesthetics beneficial use is considered undetermined for the current sample year as it relates to true color due to insufficient data. Based on available data Claremore Lake is fully supporting the FWP beneficial use based on pH and dissolved oxygen levels. Although 2 (13%) of the 15 turbidity values recorded exceeded the water quality standard of 25 NTU, an assessment of the Fish & Wildlife Propagation (FWP) beneficial use based on turbidity cannot be made at this time as minimum data requirements have not met for this sample year. The PBCR beneficial use is considered fully supported for sample year 2005-2006 as all sample results were below both the screening level and geometric mean.

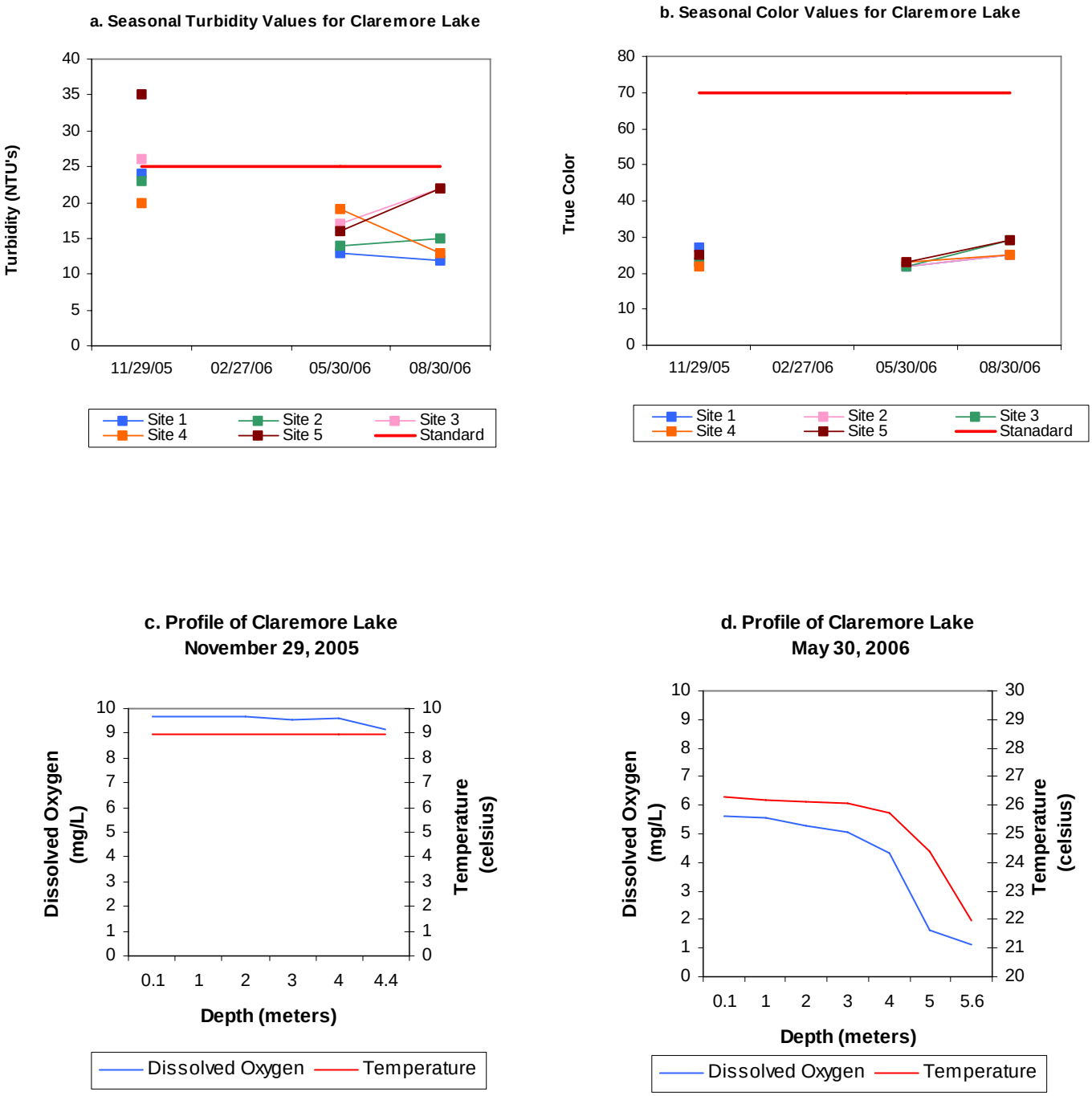
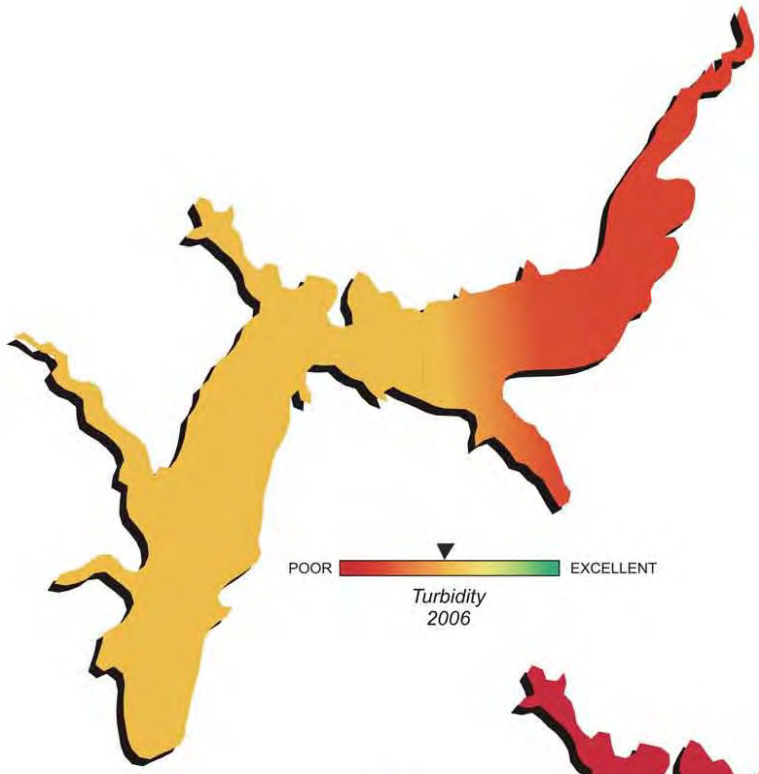


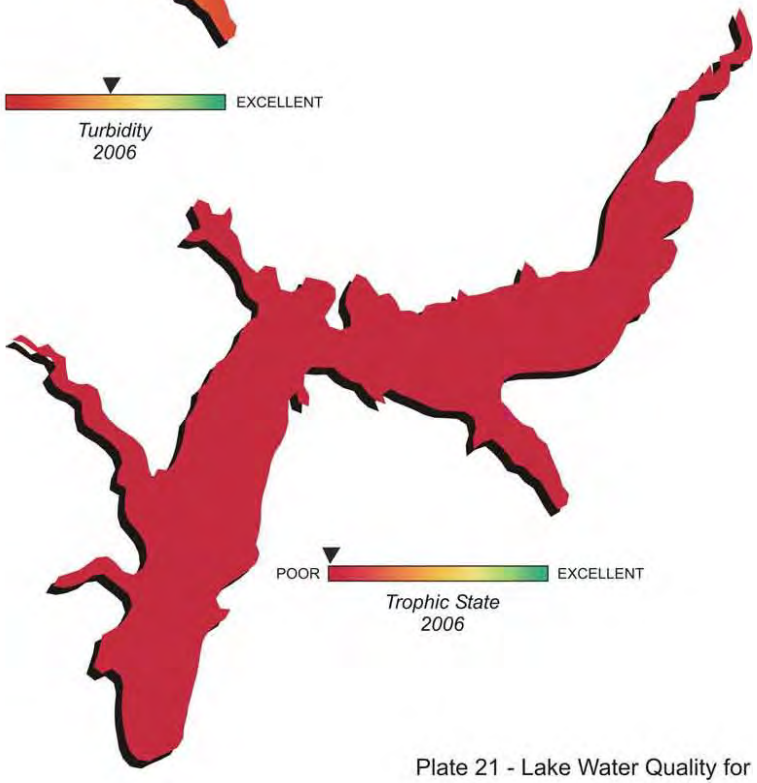
Figure 29a-29d. Graphical Representation of data results for Claremore Lake.

Claremore Lake and Watershed

Claremore Lake Location



Turbidity 2006



Trophic State 2006

Lake Data

Owner	City of Claremore
County	Rogers
Constructed in	1930
Surface Area	470 acres
Volume	7,900 acre/feet
Shoreline Length	9 miles
Mean Depth	16.81 feet
Watershed Area	57 square miles

Plate 21 - Lake Water Quality for
Claremore Lake

Clear Creek Lake

Clear Creek Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 7 NTU (Plate 22), true color was 10 units, and secchi disk depth was 95 centimeters in 2005. Based on these three parameters, Clear Creek Lake had good water clarity. These values are very similar if not slightly better to those observed in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 48 (Plate 22), indicating the lake was mesotrophic with moderate primary productivity and nutrient conditions in sample year 2005. The TSI values varied throughout the sample year ranging from eutrophic in the fall to oligotrophic in both the spring and summer and mesotrophic during the summer quarter. The TSI in 2003 was also 48 indicating no significant change in productivity has occurred since the previous evaluation. Turbidity values for the sample year are displayed in Figure 30a. Turbidity values collected throughout all four sampling intervals were well below the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥ 25% of the samples exceed the WQS of 25 NTU. If 10 to 25% of the turbidity values exceed the numerical criteria, the lake should be listed as partially supporting beneficial uses. With only 100% of the values below 25 NTU, the Fish and Wildlife Propagation (FWP) beneficial use is supported based on turbidity. Seasonal true color values were all well below the WQS of 70 units and are displayed in Figure 30b. Applying the same default protocol, the Aesthetic beneficial use is considered fully supported.

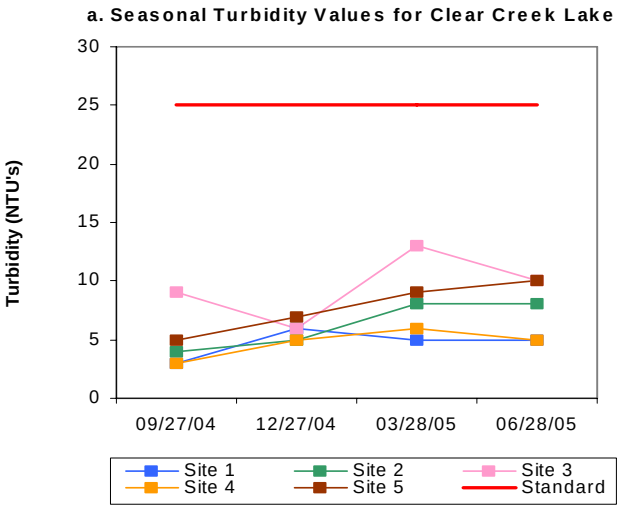
In 2004-2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 0.30 parts per thousand (ppt) to 0.39 ppt for this sample year. Specific conductivity ranged from 635.8 µS/cm to 762.2 µS/cm, which is higher than most Oklahoma reservoirs. These values indicate the presence of moderate levels of current conducting compounds (chlorides and salts) in the lake, consistent with recorded salinity concentrations. The pH values at Clear Creek Lake ranged from 7.12 to 8.38, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of collected values within the acceptable range Clear Creek Lake is meeting its FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 67 mV in the hypolimnion during the summer to 444 mV in the spring. In general, reducing conditions were not present in this reservoir. Although the temperature was fairly constant during the fall quarter, dissolved oxygen (D.O) concentrations fell from 6.17 to 2.16 mg/L between 6 and 7 meters below the surface (Figure 30c). D.O. remained below 2.0mg/L from 8 meters to the lake bottom

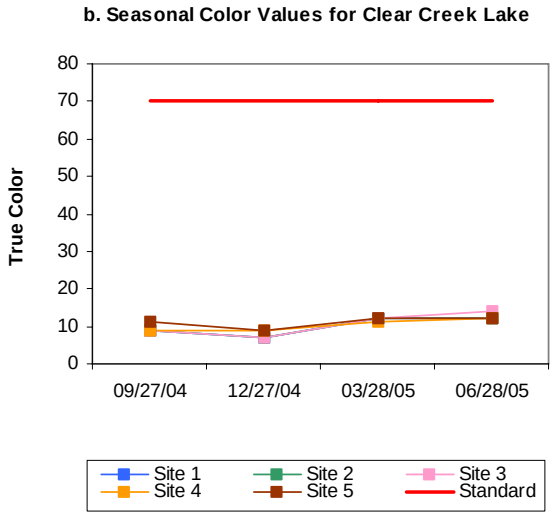
at 8.7 meters. The lake was well mixed and D.O. concentrations were generally above 7.0g/L in both winter and spring sampling intervals (see Figure 30d-30e). Thermal stratification and anoxic conditions were evident in the summer sampling interval. Stratification occurred at several 1-meter intervals throughout the water column with dissolved oxygen levels dropping below 2.0 mg/L from 6 meters to the lake bottom of 8.4 meters. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 40% of the water column below 2.0 mg/L during the summer, the FWP beneficial use is considered supported at Clear Creek Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

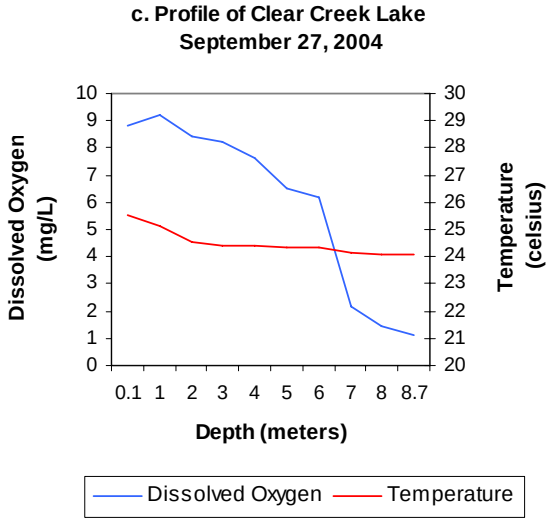
Bacteriological samples were not collected during the current sample year and an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

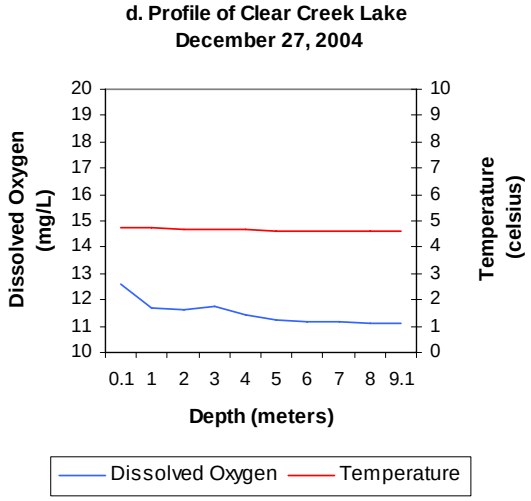
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.49 mg/L at the surface. The TN at the surface ranged from 0.24 mg/L in the spring to 0.64 mg/L in the fall and winter quarters. The lake-wide total phosphorus (TP) average was 0.018 mg/L at the surface. The total phosphorus at the surface ranged from 0.007 mg/L to 0.024 mg/L. Similar to total nitrogen the lowest TP values were recorded in the spring quarter. The nitrogen to phosphorus ration (TN:TP) was 27:1 for sample year 2004-2005. This value is much higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

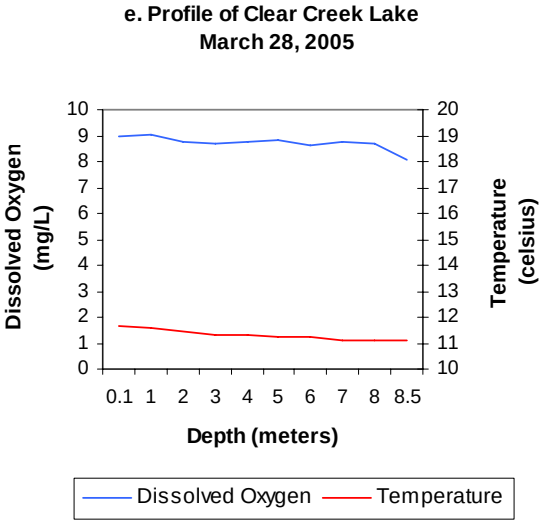
In summary, Clear Creek Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions (Plate 22). This classification is consistent with the 2003 evaluation indicating no significant increase or decrease in productivity has occurred. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is fully supporting the FWP beneficial use based on pH and turbidity. Although anoxic conditions were present in 40% of the water column, the FWP beneficial use is still considered supported as it relates to dissolved oxygen concentration. The Aesthetics beneficial use is being supported based on trophic status and low true color values. Bacteriological data was not collected during 2004-2005; therefore an assessment of the PBCR beneficial use cannot be made at this time. Clear Creek Lake, located in Stephens County, serves as a municipal water supply as well as a recreational reservoir for the city of Duncan.











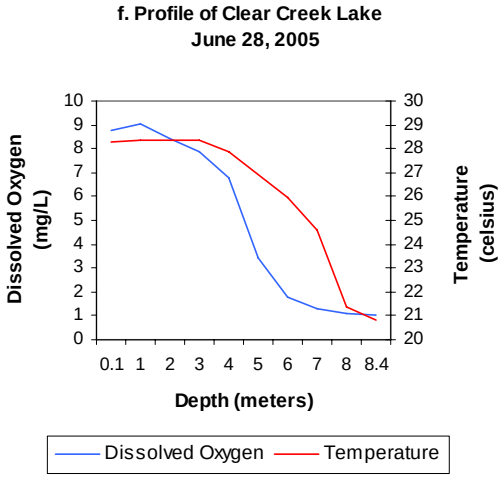
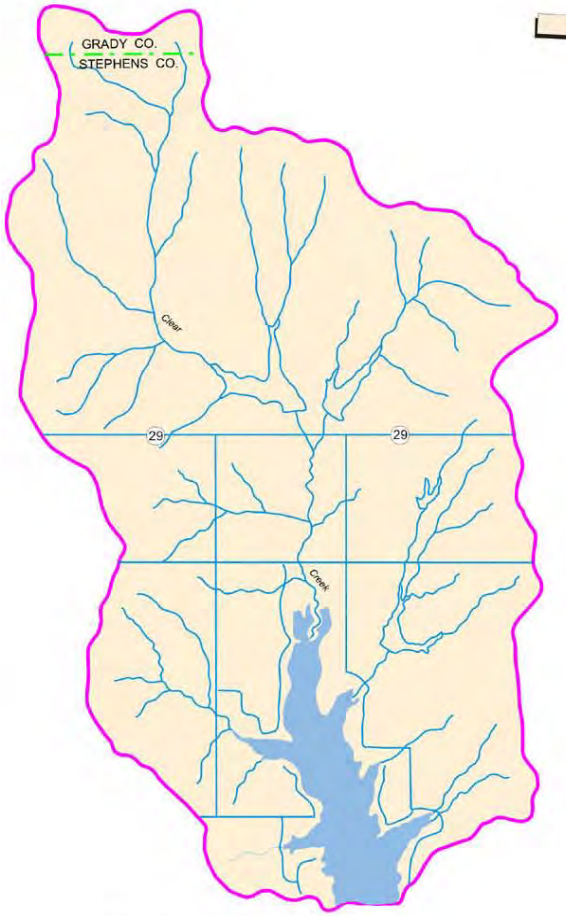


Figure 30a-33f. Graphical representation of data results for Clear Creek Lake.



Clear Creek Lake and Watershed

Clear Creek Lake Location

Turbidity 2005

Trophic State 2005

Lake Data	
Owner	City of Duncan
County	Stephens
Constructed in	1948
Surface Area	722 acres
Volume	7,710 acre/feet
Shoreline Length	11 miles
Mean Depth	10.68 feet
Watershed Area	20 square miles

Plate 22 - Lake Water Quality for
Clear Creek Lake

Cleveland City Lake

Cleveland City Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 39 NTU (Plate 23), true color was 75 units, and secchi disk depth was 49 centimeters. Based on these three parameters, Cleveland City Lake had moderate to fair water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average calculated TSI was 50 (Plate 23), indicating the lake was mesotrophic bordering eutrophic, with moderate to high levels of primary productivity and nutrients conditions. The TSI values throughout the sample year varied seasonally from eutrophic in the fall and summer to mesotrophic during the winter. In the spring values were lower mesotrophic at site 1 and upper oligotrophic at sites 2 and 3. Of the turbidity values collected, 50% were above the turbidity standard of 25 NTU, however available flow and rainfall data suggest the elevated readings are likely the result of storm events and the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity (see Figure 31a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Seasonal true color values are displayed in Figure 31b. Of the 12 samples collected at Cleveland City Lake in 2003-2004, 25% of the true color values exceeded the 70 units criteria listed in WQS. Similar to turbidity, a peak in true color occurred in the spring quarter and is likely the result of seasonal storm events and the Aesthetics beneficial use is considered supported at Cleveland City Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.04 parts per thousand (ppt) to 0.12 ppt. This is well within the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Specific conductivity values were also well within the expected range for Oklahoma reservoirs, coinciding with the low salinity concentrations. Specific Conductivity values ranged from 94.5 µS/cm in the spring to 260.3 µS/cm in the summer. Oxidation-reduction potentials (redox) ranged from 315 mV in the spring quarter to 520 mV in the winter season, indicating reducing conditions were not present in the lake during the study period. The pH values indicated that the lake was neutral to slightly alkaline with values ranging from 6.83 to 8.01 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range for 25% of the values and the lake should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting its FWP beneficial use. Cleveland Lake is fully supporting its FWP as it relates to pH. During the fall quarter the lake exhibited weak stratification with anoxic conditions present for 25 % of the water column (Figure 31c). The lake

was not thermally stratified and the water column appeared to be well mixed during the winter and spring months (see Figure 31d-31e). In the summer, the lake was strongly thermally stratified between 2 and 3 meters from the lake surface. At which point the D.O. concentrations fell below 2.0 mg/L all the way to the lake bottom at 8.9 meters (see Figure 31f). Site 2 was also stratified between 2 and 3 meters in depth with 50% of the water column below 2.0 mg/L during the summer. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 50 to 60% of the water column of Cleveland Lake being less than 2.0 mg/L the lake is listed as "partially supporting" its FWP beneficial use. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. The PBCR beneficial use is considered supported for sample year 2003-2004.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.91 mg/L at the lake surface. The TN at the surface ranged from 0.49 mg/L to 1.23 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average was 0.053 mg/L at the lake surface. The TP ranged from 0.035 mg/l to 0.092 mg/L. Similar to the TN values, the highest surface TP values were reported in the fall quarter however the lowest were seen in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 17:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Cleveland City Lake was classified as mesotrophic bordering eutrophic, indicative of moderate to high primary productivity and nutrient rich conditions. Water clarity was moderate to fair in this reservoir when compared to other Oklahoma reservoirs. The lake is fully supporting its Aesthetics beneficial use for and trophic state (for nutrients) and true color. Cleveland City Lake is fully supporting its FWP beneficial use based on pH and partially supporting the beneficial use based on low D.O. concentrations in the water column during the summer sampling interval. Of the turbidity values collected, 50% were above the turbidity standard of 25 NTU, however available flow and rainfall data suggest the elevated readings are likely the result of storm events and the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. The PBCR beneficial is considered supported. Cleveland City Lake is owned and operated by the City of Cleveland and serves as the municipal water supply reservoir for the city and is also utilized for recreation purposes.

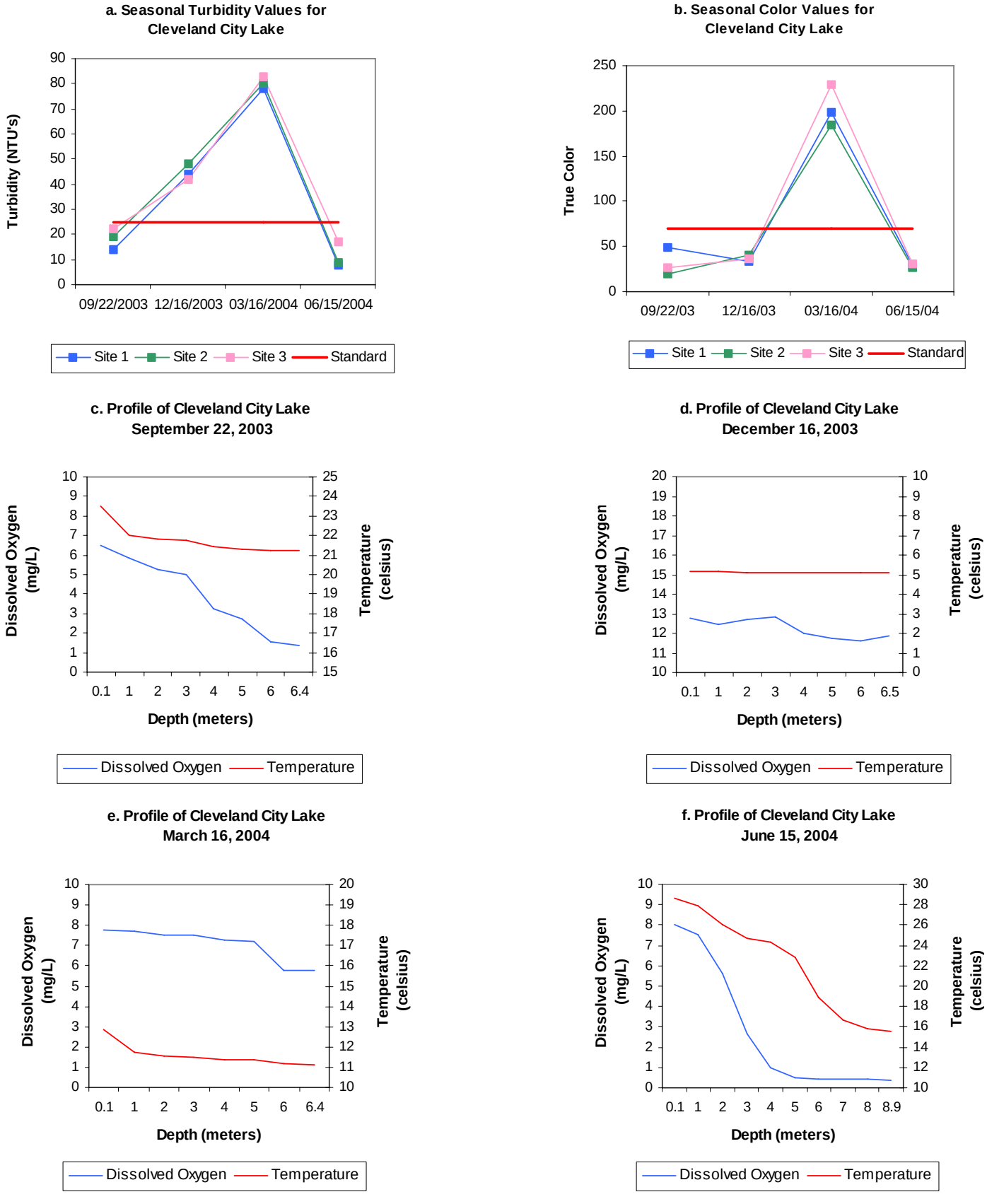
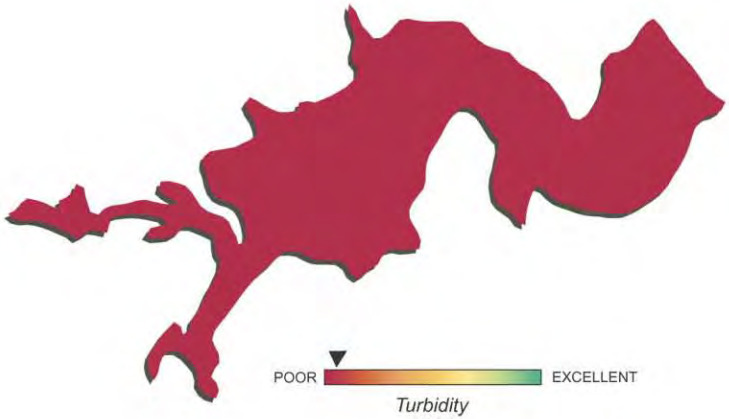
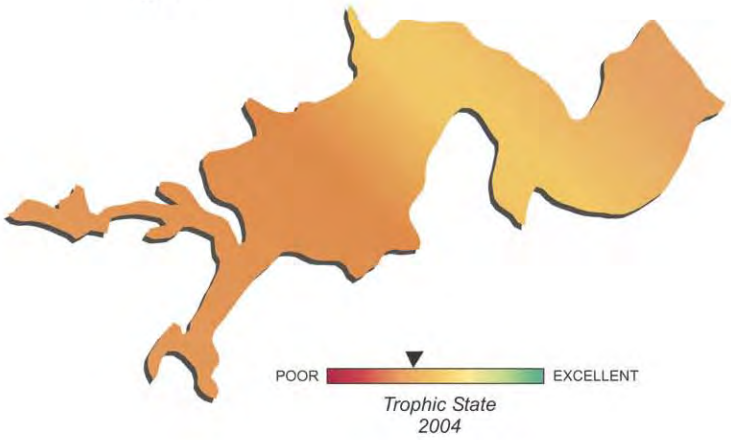


Figure 31a-31f. Graphical representation of data results for Cleveland City Lake.





Lake Data	
Owner	City of Cleveland
County	Pawnee
Constructed in	1936
Surface Area	159 acres
Volume	2,200 acre/feet
Shoreline Length	5 miles
Mean Depth	13.84 feet
Watershed Area	22 square miles

Plate 23 - Lake Water Quality for
Cleveland Lake

LAKES MONITORING PROGRAM

Clinton Lake

Clinton Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the surface at all sites and an additional sample was collected at 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 67 NTU (Plate 24), true color was 36 units, and secchi disk depth was 23 centimeters. Based on these three parameters, Clinton Lake had poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 66 (Plate 24), indicating the lake was hypereutrophic in nature, with high to excessive levels of productivity and nutrients. The TSI values fluctuated very little based on the season and sample site, never varying from upper eutrophy to hypereutrophy at all sites. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Turbidity values per site were generally above the Oklahoma Water Quality Standard (WQS) of 25 NTU for all seasons with 80% of the collected data exceeding the WQS (see Figure 32a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting its FWP beneficial use. The lake-wide annual turbidity of 67 NTU was representative of conditions at Clinton Lake in 2003-2004 and consistent with historical findings. Clinton Lake is currently not meeting its Fish & Wildlife Propagation (FWP) beneficial use due to high turbidity values. The system should be further examined to determine if the high turbidity present is due to natural conditions. Seasonal true color values are displayed in (Figure 32b). Of the 12 values collected, three (15%) exceeded the numeric criteria of 70 units. Applying the same default protocol, the Aesthetics use is partially supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.23 parts per thousand (ppt) to 0.33ppt, which slightly higher than the range of values observed in most Oklahoma lakes. Reflecting moderate levels of chlorides or other salts in the lake. Specific conductivity values were also slightly higher than most Oklahoma reservoirs, with values ranging from 460.4 µS/cm in the summer to 642.9 µS/cm in the fall. Oxidation-reduction potentials ranged from 149 mV to 534 mV, indicating reducing conditions were not present in the lake. The pH was neutral to slightly alkaline with values ranging from 8.0 to 8.74 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Based on pH values collected Clinton Lake is currently supporting its FWP beneficial use. The lake was not

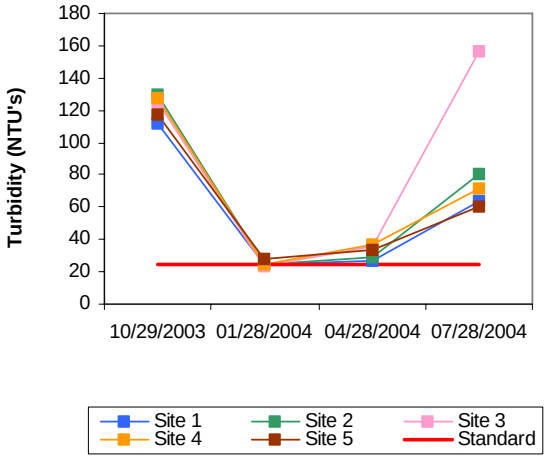
thermally stratified and the water column appeared to be well mixed throughout all four quarters, this can be attributed to the shallow nature of the lake and limited shoreline structure to prevent wind-mixing of the lake (see Figure 32c-32f). Dissolved oxygen (D.O.) values remained above 4.0 mg/L and the D.O. percent saturation was never less than 50% in any of the sample quarters except at the very bottom of the lake. The FWP beneficial use is fully supported based on D.O. concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (42.3 cfu/ml) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

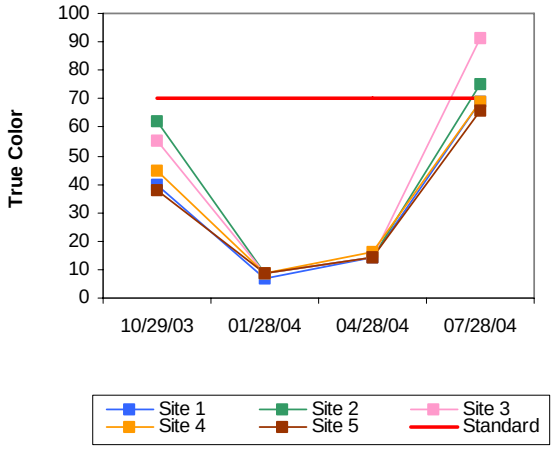
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.94 mg/L at the surface and 1.80mg/L at the lake bottom. The TN at the surface ranged from 1.36 mg/L to 3.06 mg/L, which is higher than generally seen in Oklahoma lakes. The highest surface TN value was reported in the summer quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.152 mg/L at the surface and 0.157 mg/L at the lake bottom. The TP ranged from 0.089 mg/L to 0.244 mg/L at the lake surface. The highest surface TP values were reported in the fall quarter and the lowest were in the spring quarter. Nitrogen values in Clinton Lake were higher than normally seen in most Oklahoma Lakes. The nitrogen to phosphorus ratio (TN:TP) was approximately 13:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Clinton Lake was classified as hypereutrophic, indicative of high to excessive primary productivity and nutrient levels (Plate 24). The lake will be recommended for listing as an NLW in the next WQS revision process and its Aesthetics beneficial use is considered nutrient threatened. Based on reported true color values the Aesthetics use is partially supported at Clinton Lake. D.O. and pH values were fully supporting the FWP beneficial use, however the Lake was not meeting its FWP beneficial use due to high turbidity values. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (42.3 cfu/ml) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported. Clinton Lake is one of the municipal water supply reservoirs for the City of Clinton and is utilized for recreation purposes. The lake was constructed in 1931 and is owned by the City of Clinton.

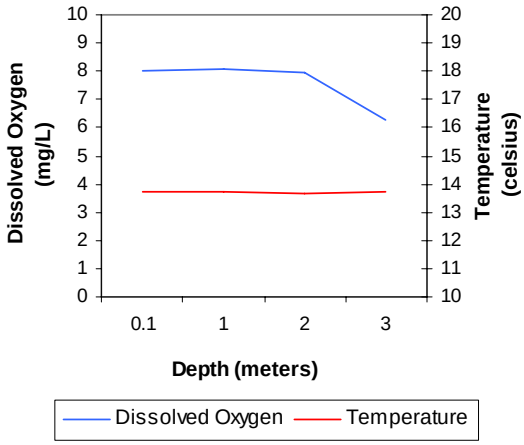
a. Seasonal Turbidity Values for Clinton Lake



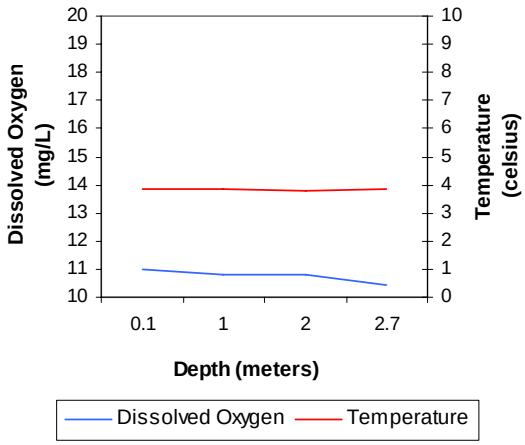
b. Seasonal Color Values for Clinton Lake



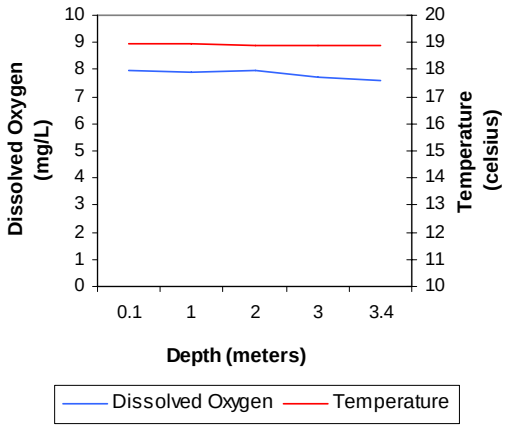
c. Profile of Clinton Lake October 29, 2003



d. Profile of Clinton Lake January 28, 2004



e. Profile of Clinton Lake April 28, 2004



f. Profile of Clinton Lake July 28, 2004

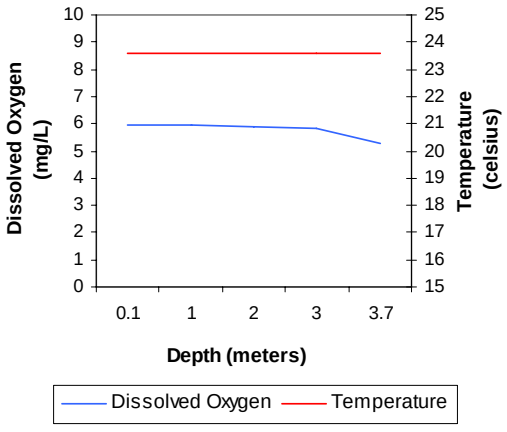


Figure 32a-32f. Graphical representation of data results for Clinton Lake.

Lake Data	
Owner	City Clinton
County	Washita
Constructed	1931
Surface Area	335 acres
Volume	3,980 acre/feet
Shoreline Length	5 miles
Mean Depth	11.88 feet
Watershed Area	27 square miles

Plate 24- Lake Water Quality for
Clinton Lake

LAKES MONITORING PROGRAM

Coalgate City Lake

Coalgate City Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. All samples were collected at the lake surface and 0.5 meters from the lake bottom at sample site 1, near the dam. The lake-wide annual turbidity value was 77 NTU (Plate 25), true color was 202 units, and secchi disk depth was 22 centimeters. Based on these three parameters, Coalgate City Lake had poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 46 (Plate 25), indicating the lake was mesotrophic, with moderate levels of productivity and nutrients. This value is consistent with historical data collection efforts, indicating no significant change in productivity has occurred over time. The TSI values varied seasonally from lower mesotrophic in the fall quarter to oligotrophic values present in the winter quarter and eutrophic conditions present in the summer season. Turbidity values per site for sample year 2003-2004 were all above the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 33a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake-wide annual turbidity of 77 NTU is representative of conditions at Coalgate City Lake and is consistent with historical findings for this lake. Coalgate Lake is currently not meeting its Fish & Wildlife Propagation (FWP) beneficial use based on high turbidity concentrations in the lake. Approximately 95% of the true color values were above the aesthetics WQS of 70 units, (see Figure 33b). Applying the same default protocol for determining the short-term average for true color, the Aesthetics beneficial use is considered not supported.

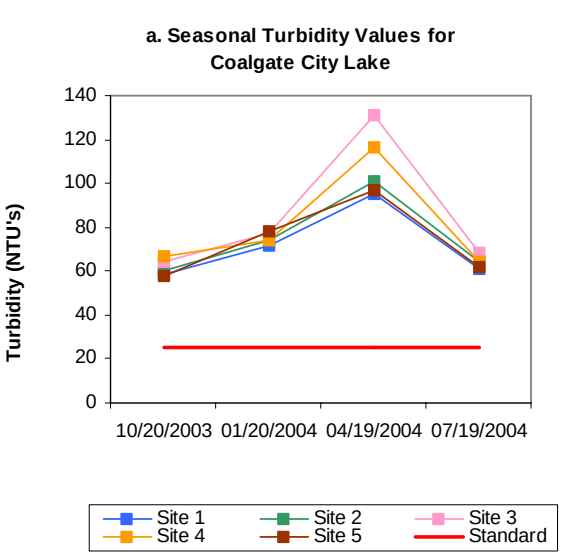
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.03 ppt, well within the expected range for most Oklahoma lakes if not less than what is normally seen. Values reflect the minimal presence of chlorides or other salts in the lake system. Specific conductivity values followed a similar pattern and were much lower than most Oklahoma reservoirs, with values ranging from 52 µS/cm in the winter to 147.3 µS/cm in the summer, which indicates a very low content of electrical current conducting compounds or salts. Oxidation-reduction potentials ranged from 353 mV to 636 mV, indicating reducing conditions were not present in the reservoir at the time data collection occurred. The pH was generally neutral with values ranging from 6.8 to 7.86 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 for and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Coalgate Lake was fully supporting its FWP beneficial use as it relates to pH. The lake was not thermally stratified in the fall, winter or spring and the water column was well mixed (see Figure 33c-33e). Dissolved oxygen (D.O.)

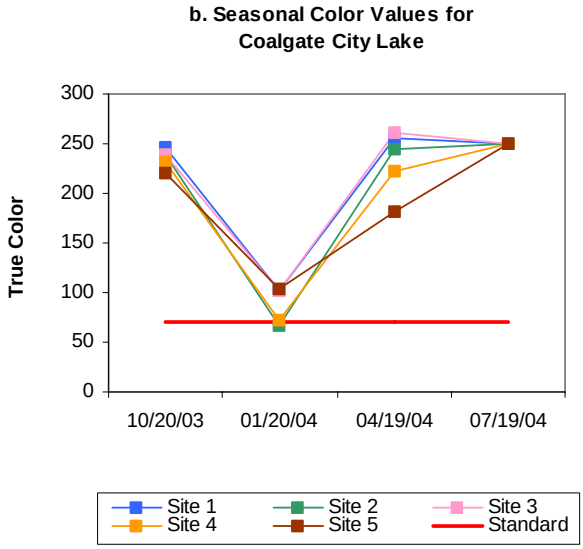
values remained above 6.0 mg/L (except at the very bottom of the lake) and the dissolved oxygen percent saturation was never less than 70% in these three sampling intervals. In the summer quarter, the lake was strongly stratified between 2 and 3 meters and the D.O. concentration dropped to less than 2.0 mg/L from 4 meters in depth to the lake bottom at 7.8 meters (see Figure 33f). Readings at sites 2 and 5 were very similar and anoxic conditions were also present in the bottom two meters of the lake. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 33 to 55% of the water column in the summer less than 2.0mg/L, Coalgate Lake is considered partially supporting its FWP. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

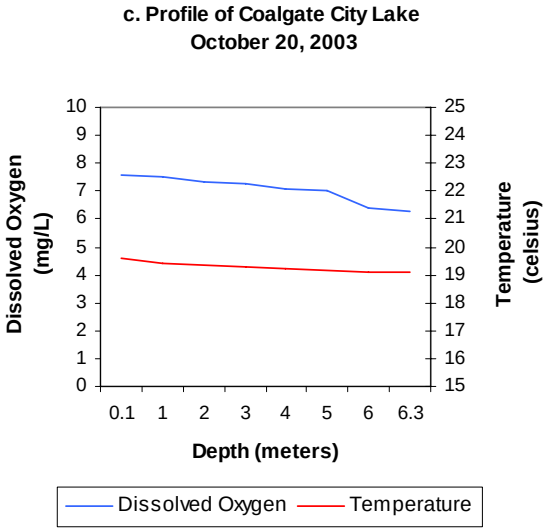
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

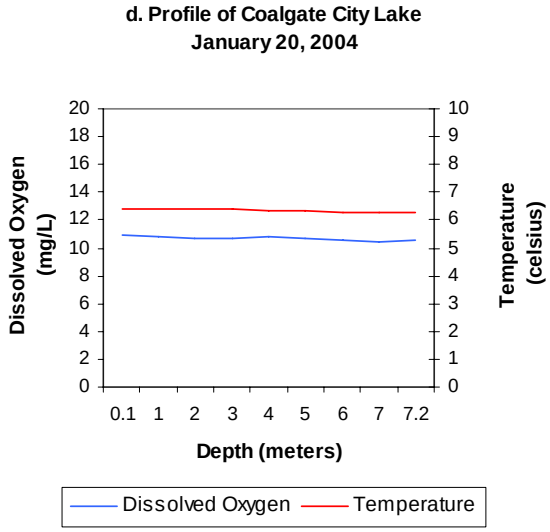
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.81 mg/L at the lake surface. The TN at the surface ranged from 0.61 mg/L to 1.25 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average was 0.079 mg/L at the lake surface. The TP ranged from 0.063 to 0.095 mg/L at the lake surface. Similar to total nitrogen, the highest surface TP values were reported in the spring quarter and the lowest were in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

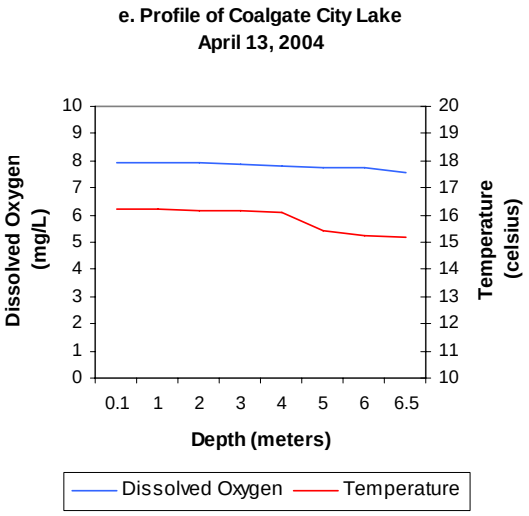
In summary, Coalgate City Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 25). The high levels of inorganic turbidity contribute to the lack of productivity in the lake as it is limiting the amount if light available. The lake is fully supporting its Aesthetics beneficial use for trophic state but not supporting the use with 95% of the collected values exceeding the WQS of 70 units. Values for pH were not a cause for concern in meeting the FWP beneficial use. Coalgate City Lake was found to be partially supporting its FWP beneficial use based on D.O concentrations and not supporting the FWP beneficial use based on elevated turbidity in the lake. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Coalgate City Lake is the municipal water supply reservoir for the City of Coalgate and is owned and operated by the city. The lake is also utilized for recreational and flood control purposes.











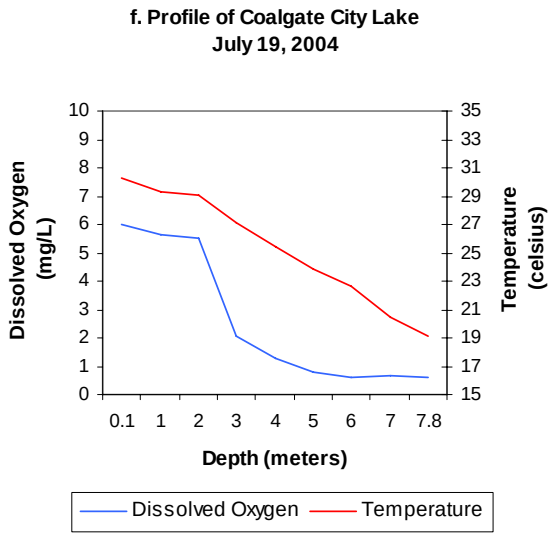
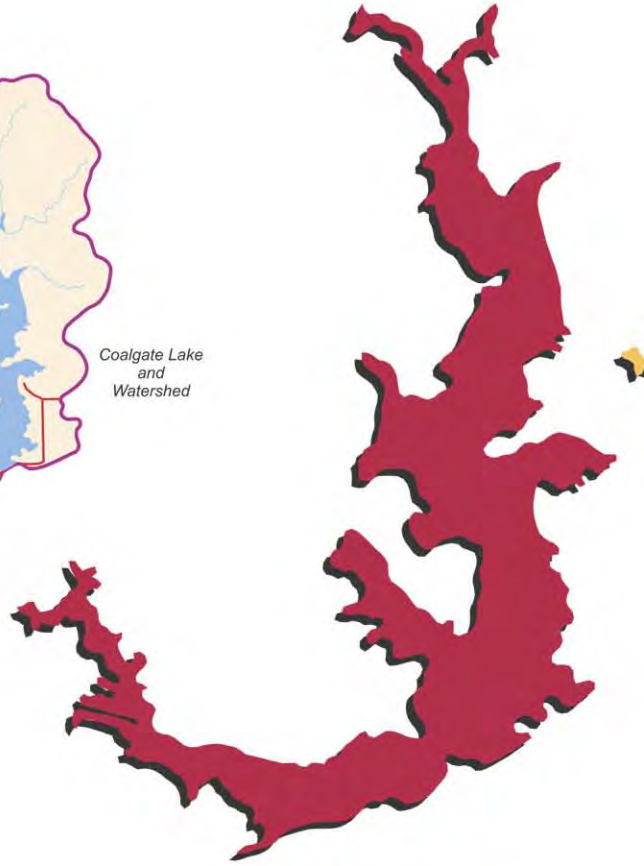


Figure 33a-33f. Graphical representation of data results for Coalgate City Lake.

Coalgate Lake and Watershed

Coalgate Lake Location

Lake Data	
Owner	City of Coalgate
County	Coal
Constructed in	1965
Surface Area	352 acres
Volume	3,437 acre/feet
Shoreline Length	6 miles
Mean Depth	9.76 feet
Watershed Area	14 square miles



Turbidity 2004

Trophic State 2004

Plate 25 - Lake Water Quality for
Coalgate Lake

LAKES MONITORING PROGRAM

Comanche Lake

Comanche Lake was sampled for four quarters from September 2004 through June 2005. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 9 NTU (Plate 26), true color was 22 units, and secchi disk depth was 101 centimeters in 2005. Based on these three parameters, Comanche Lake had good water clarity in comparison to other Oklahoma reservoirs. Results are similar to those seen in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 46 (Plate 26), indicating the lake was mesotrophic in sample year 2005. This value is similar to the one calculated in 2003(TSI=45), indicating little or no change in productivity has occurred. The TSI values throughout the sample year were fairly consistent with values ranging from the mesotrophic category for three of the four sampling intervals to eutrophic at all sites in the winter. The only exception to this was site 1, which was oligotrophic in both fall and spring quarters. Seasonal turbidity values are displayed in Figure 34a. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the turbidity values well below the standard, the Fish and Wildlife Propagation beneficial use is fully supported based on turbidity. Of the 12 samples collected at Comanche Lake in 2003, none of the true color values exceeded the 70 units criteria listed in WQS (Figure 34b). Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on recorded true color values.

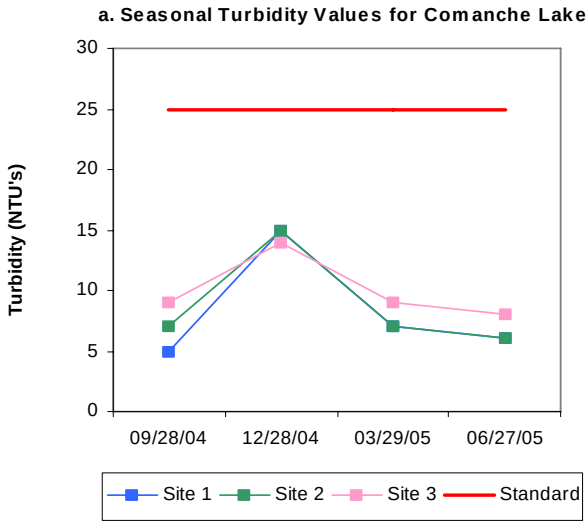
In 2004-2005, vertical al profiles for dissolved oxygen, pH, temperature, specific conductivity; oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 0.10 parts per thousand (ppt) to 0.17 ppt for this sample year. Specific conductivity ranged from 237.9 µS/cm to 333.1 µS/cm, which is within the range recorded for most Oklahoma reservoirs. These values indicate the presence of moderate levels of current conducting compounds (chlorides and salts) in the lake. The pH values at Comanche Lake ranged from 6.97 to 8.4, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of collected values within the acceptable range the lake is meeting its FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 95 mV in the summer to 446 mV in the spring. In general, reducing conditions were not present in this reservoir. During the fall, the lake was stratified between 7 and 8 meters, at which point with dissolved oxygen concentrations fell below 2.0 mg/L for remainder of the water column (Figure 34c). In both winter and spring quarters, the lake was well mixed stratification was not present (see Figure 34d-37e). Thermal

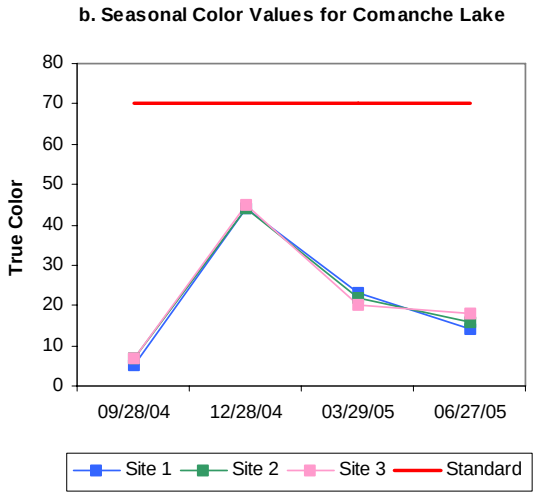
stratification was evident and anoxic conditions were present during the summer. Stratification occurred between 3 and 4 meters in depth at both sites 1 and 2, with anoxic conditions comprising approximately 46% and 38% of the water column respectively (Figure 34f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 46% of the water column less than 2.0mg/L in the summer, Comanche Lake is considered supporting its FWP. The lake was sampled for total dissolved solids, chlorides, and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

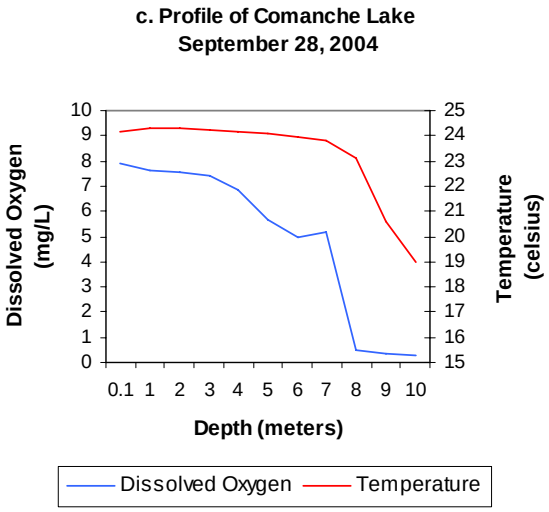
Bacteriological samples were not collected during the current sample year and an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

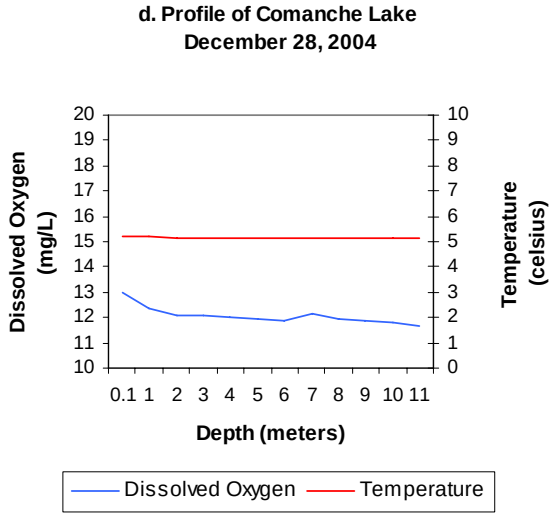
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.48 mg/L at the surface. The TN at the surface ranged from 0.29 mg/L in the winter to 0.83 mg/L in the summer quarter. The lake-wide total phosphorus (TP) average was 0.019 mg/L at the surface. The total phosphorus at the surface ranged from 0.013 mg/L to 0.023 mg/L, with higher values reported during the spring sampling interval. Similar to total nitrogen the lowest TP values were recorded in the spring quarter. The nitrogen to phosphorus ration (TN:TP) was 25:1 for sample year 2004-2005. This value is much higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

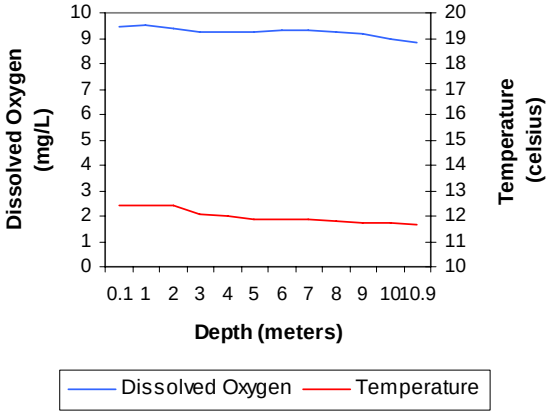
In summary, Comanche was classified as mesotrophic with moderate primary productivity and nutrient conditions in 2004-2005, indicating no significant change has occurred since previous data collection efforts were conducted in 2003. Water clarity was good based on turbidity, true color and secchi disk depth. The lake was found to be supporting the FWP beneficial use based on pH, turbidity, and dissolved oxygen levels recorded during the study period. The Aesthetics beneficial use is also considered fully supported based on true color and trophic status. Bacteriological samples were not collected during the current sample year and an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Comanche Lake is located in Stephens County and serves as a municipal water supply as well as a recreational reservoir for the City of Comanche.











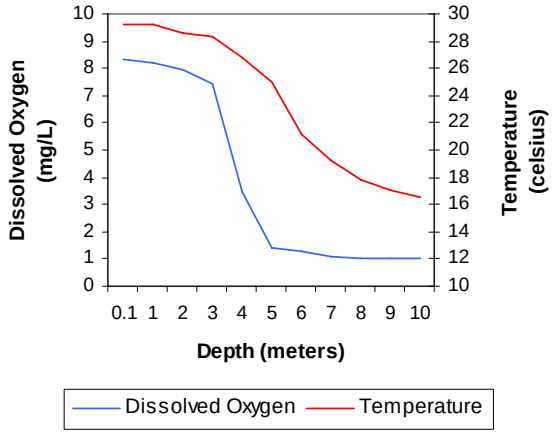
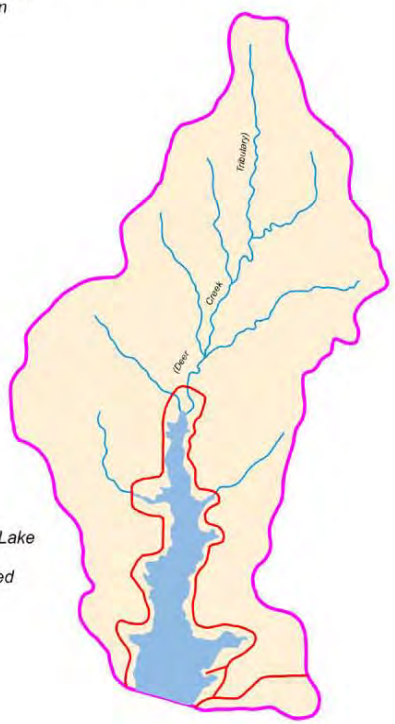


Figure 34a-34f. Graphical representation of data results for Comanche Lake.

Comanche Lake
Location



Comanche Lake
and
Watershed

POOR EXCELLENT

Turbidity
2005

POOR EXCELLENT

Trophic State
2005

Lake Data	
Owner	City of Comanche
County	Stephens
Constructed	1960
Surface Area	184 acres
Volume	2,500 acre/feet
Shoreline Length	5 miles
Mean Depth	13.59
Watershed Area	2,288 acres

Plate 26 - Lake Water Quality for
Comanche Lake

Copan Lake

Copan Lake was sampled for four quarters, from October 2004 through July 2005. Samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites, and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 58 NTU (Plate 27), true color was 75 units, and average secchi disk depth was 25 centimeters in sample year 2004-2005. Water clarity was poor at Copan Lake based on these three parameters. Results for turbidity, true color and secchi disk depth are slightly higher than those recorded in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=15). The TSI was 51 (Plate 27), indicating the lake was eutrophic, with high levels of productivity and nutrient conditions for sample year 2005. Due to a post-processing error no samples were submitted to lab for analysis from the fall data collection efforts. This value although lower than the value calculated in 2003 (TSI=59), is in the same trophic category, indicating no significant change in productivity has occurred. Chlorophyll samples were not collected during the fall quarter, which may account for the lower annual TSI. The TSI values for all sites were fairly consistent and ranged from lower mesotrophic, bordering oligotrophic, in the winter to lower hypereutrophic at sites 4 and 5 in the summer quarter. Seasonal turbidity values by site are displayed in Figure 35a. Of the twenty values collected, only one was less than the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is not supported at Copan Lake, as 95% of the values exceed the turbidity standard of 25 NTU. Seasonal true color values are displayed in Figure 35b. Of the 20 samples collected, 50% exceeded the WQS of 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is partially supported based on the true color values.

In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.08 parts per thousand (ppt) to 0.17 ppt, which is within the range of values seen in Oklahoma reservoirs. Specific conductivity ranged from 176.8 µS/cm to 344.2 µS/cm, indicative of minimal levels of current conducting ions (salts) in the lake system. Values for pH ranged from 6.81 to 8.18, representing a neutral to slightly alkaline lake system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of collected values within the acceptable range, Copan Lake is meeting its FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 312mV in the fall to 457 mV in the hypolimnion during the fall. In general, reducing conditions were not present at this reservoir during the 2004-2005-

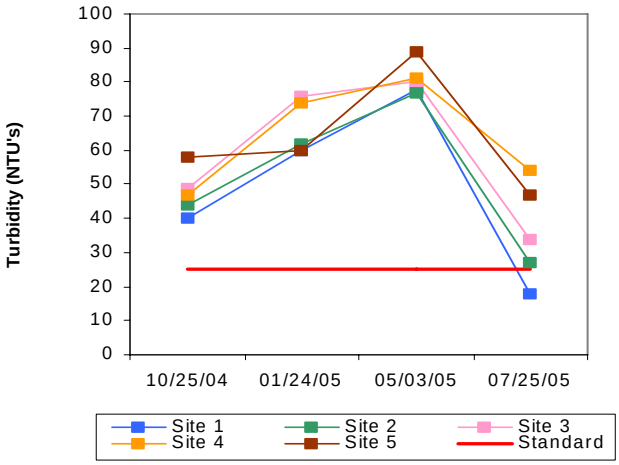
sample year. The lake was well mixed during the fall, winter and spring sampling quarters (see Figure 35c-35e) and dissolved oxygen (D.O.) levels were generally greater than 7.0 mg/L. Thermal stratification was evident and anoxic conditions were present during the summer sampling interval. Dissolved oxygen levels at site 1 dropped below 2.0mg/L between 3 and 4 meters in depth accounting for approximately 50% of the water column to be anoxic. The relatively shallow nature of the lake is likely responsible for keeping rest of the lake well mixed. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 50% of the water column below 2.0 mg/L during the summer the FWP beneficial use is partially supported at Copan Lake. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the current sample year and an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

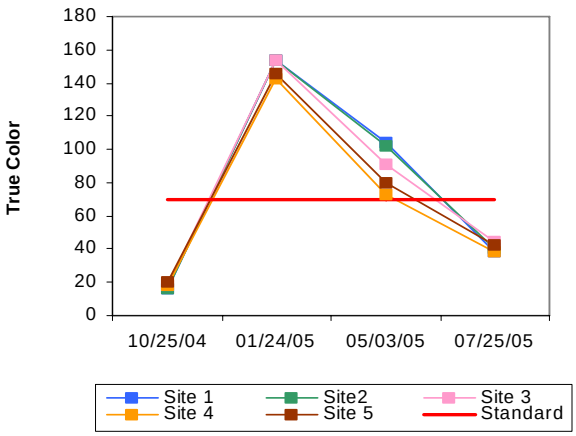
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.79 mg/L at the surface. The TN at the surface ranged from 0.48 mg/L in the fall to 1.44 mg/L in the summer quarter. The lake-wide total phosphorus (TP) average was 0.092 mg/L at the surface. The total phosphorus at the surface ranged from 0.051 mg/L to 0.132 mg/L. Similar to total nitrogen, lower values were reported in the fall; however higher values were reported during the spring sampling interval. Similar to total nitrogen the lowest TP values were recorded in the spring quarter. The nitrogen to phosphorus ration (TN:TP) was approximately 9:1 for sample year 2004-2005. This value is slightly higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Copan Lake was classified as eutrophic with high primary productivity and nutrient levels in 2004-2005 (Plate 27). The current TSI value is less than that calculated in 2003 (TSI=59), however it is in the same trophic category. Chlorophyll samples were not submitted during the fall quarter, which may account for the lower annual TSI. Water clarity was poor based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on pH and partially supporting based on dissolved oxygen concentrations recorded during the study period. With 95% of the turbidity values exceeding 25 NTU, the FWP use is not supported as it relates to turbidity. The Aesthetics beneficial use is supported based on the trophic status, but not supported for true color, as 50% of the collected values exceed the WQS of 70 units. Copan Lake is located in Washington County and was constructed by the United States Army Corps of Engineers (USACE) to serve as a flood control, waters supply, and fish and wildlife reservoir.

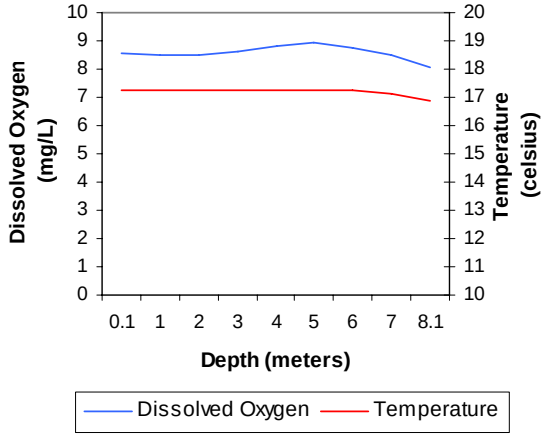
a. Seasonal Turbidity Values for Copan Lake



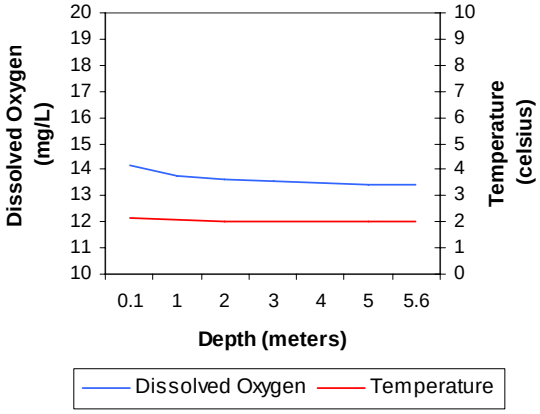
b. Seasonal Color Values for Copan Lake



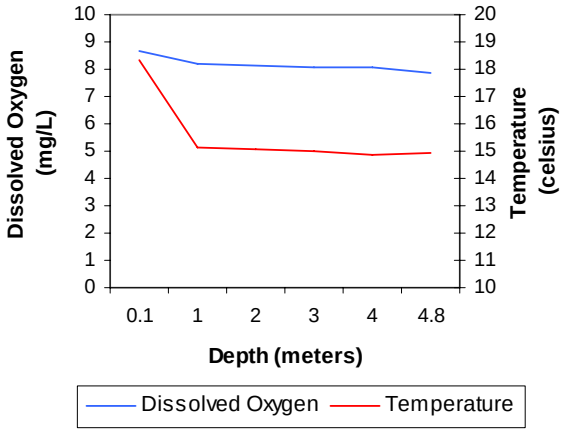
c. Profile of Copan Lake
October 25, 2004



d. Profile of Copan Lake
January 24, 2005



e. Profile of Copan Lake
May 03, 2005



e. Profile of Copan Lake
May 03, 2005

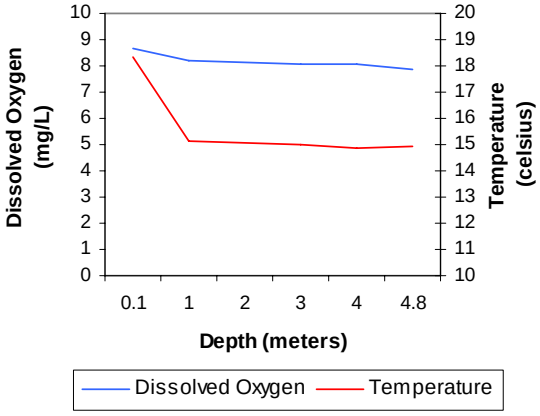
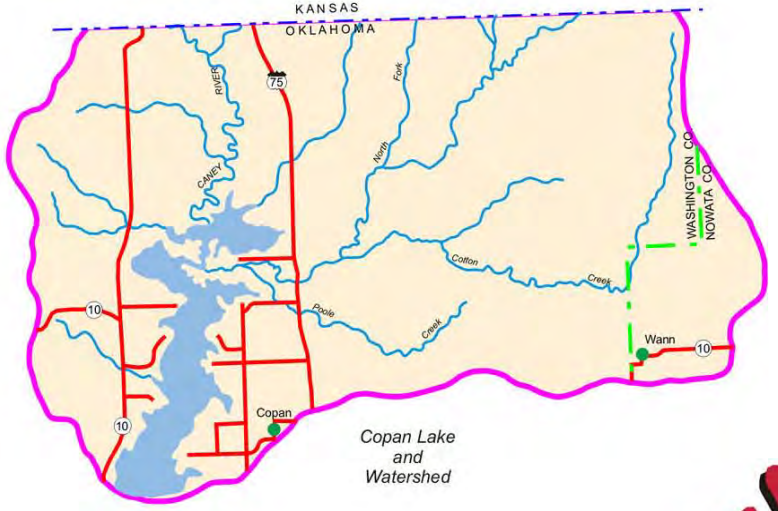


Figure 35a-35f. Graphical representation of data results for Copan Lake.



Copan Lake and Watershed

Copan Lake Location

Lake Data	
Constructed by	Corps of Engineers
County	Washington
Constructed in	1983
Surface Area	4,850 acres
Volume	43,400 acre/feet
Shoreline Length	30 miles
Mean Depth	8.95 feet
Watershed Area	505 square miles

Turbidity 2005

Trophic State 2005

Plate 27 - Lake Water Quality for
Copan Lake

LAKES MONITORING PROGRAM

Crowder Lake

Crowder Lake, located in Washita County, is owned and operated by the State of Oklahoma for the express purpose of providing flood control and recreational opportunities to the citizens of Oklahoma. Crowder Lake was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the surface at all sites during the study period. The lake-wide annual turbidity value was 9 NTU (Plate 28), true color was 17 units, and secchi disk depth was 65 centimeters. Based on these three parameters, Crowder Lake had average water clarity in comparison to other Oklahoma reservoirs. Results for these parameters are consistent with values observed in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 57 (Plate 28), indicating the lake was eutrophic, with high levels of productivity and nutrients levels. The current calculation is exactly the same as that in 2004 (TSI=57) indicating no significant change in productivity has occurred since the previous evaluation. The TSI values were primarily eutrophic throughout the year with hypereutrophic conditions observed at sites 1 and 2 in the fall and again at site 3 during the summer quarter. Crowder Lake is currently listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Turbidity values per site were all below the WQS of 25 NTU with values ranging from a low of 5 NTU to a maximum of 17 NTU (see Figure 36a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the turbidity values below the standard, the Fish and Wildlife Propagation beneficial use is considered fully supported for sample year 2005-2006. Seasonal true color values are displayed in Figure 36b. Similar to turbidity, all true color values were below the Aesthetics WQS of 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the true color values.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.38 parts per thousand (ppt) to 0.57 ppt, which is higher than the expected range for most Oklahoma lakes. Salinity values indicate a moderate to high presence of chlorides or other salts in the lake. Specific conductivity values exhibited a similar pattern and were somewhat higher than most Oklahoma reservoirs with values ranging from 744 µS/cm in the fall to 1088 µS/cm in the spring, which is indicative of a high content of electrical current conducting compounds or salts throughout the lake system. Oxidation-reduction potentials (redox) ranged from 275 mV to 445 mV, indicating reducing conditions were not present during the study period. The pH was neutral to slightly alkaline with values ranging from 6.94 to 8.34 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the

values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Crowder Lake is fully supporting its FWP as it relates pH. The lake was not thermally stratified and the water column was well mixed at all sites throughout the fall and winter quarters (see Figure 36c-36d). Dissolved oxygen (D.O.) values remained above 4.0 mg/L throughout the water column and were generally above 7.0 mg/L and the dissolved oxygen percent saturation was never less than 65% in the first two seasons. During the spring sampling interval thermal stratification was evident and anoxic conditions were present in 38% of the water column at both sites 1 and 2 (Figure 36e). Stratification occurred between 4 and 5 meters below the lake surface with dissolved oxygen (D.O.) less than 1.0 mg/L from 5 meters to the lake bottom of 6.7 meters. Due to equipment failure there is no profile data available for the summer sampling interval. When D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Crowder Lake based on data collected in the first three quarters. Because the summer profile data is missing an assessment for that season cannot be made at this time. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.73 mg/L at the lake surface. The TN at the surface ranged from 0.54 mg/L to 0.93 mg/L. The highest TN was observed in the winter while the lowest surface TN value was reported in the spring quarter. The lake-wide total phosphorus (TP) average was 0.035 mg/L at the lake surface. The TP ranged from 0.026 mg/L to 0.053 mg/L at the lake surface. The highest surface TP values were reported at site 3 in the summer quarter and the lowest were in the winter quarter. The total nitrogen phosphorus ratio (TN:TP) was 21:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Crowder Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Crowder Lake was classified as eutrophic bordering on hypereutrophic, indicative of high to excessive primary productivity and nutrient levels (Plate 28). The current TSI is the same as that in 2004 (TSI=57), indicating no significant change in productivity has taken place since the previous evaluation. Based on secchi disk depth, turbidity and true color, Crowder Lake had average water clarity in comparison to other Oklahoma reservoirs. The FWP beneficial use was fully supported based on pH, turbidity and dissolved oxygen levels collected during the study period. With 100% of the reported true color values below the WQS of 70 units, the lake was fully supporting its Aesthetics beneficial use for true color. Crowder Lake is currently listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited

Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

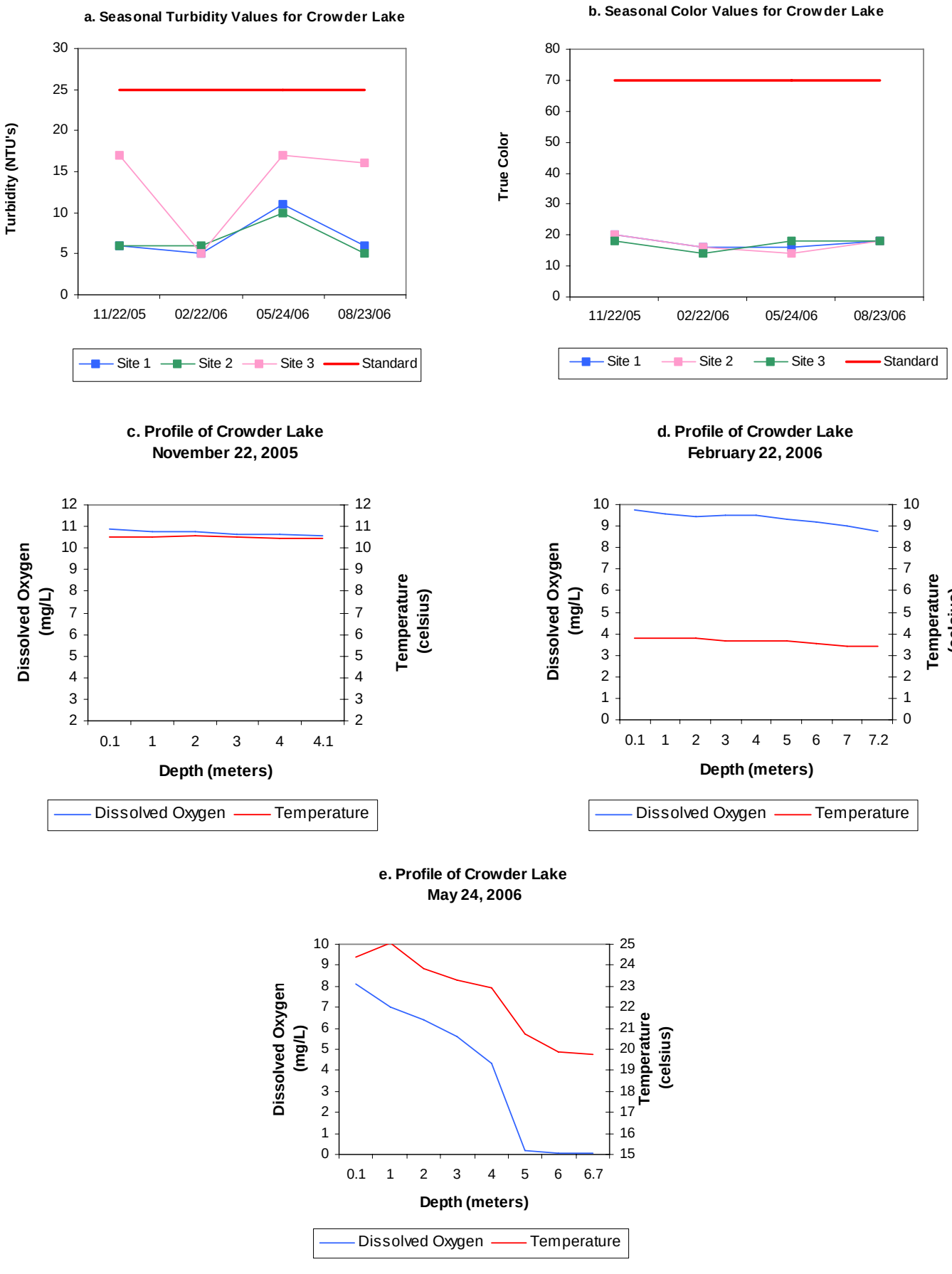
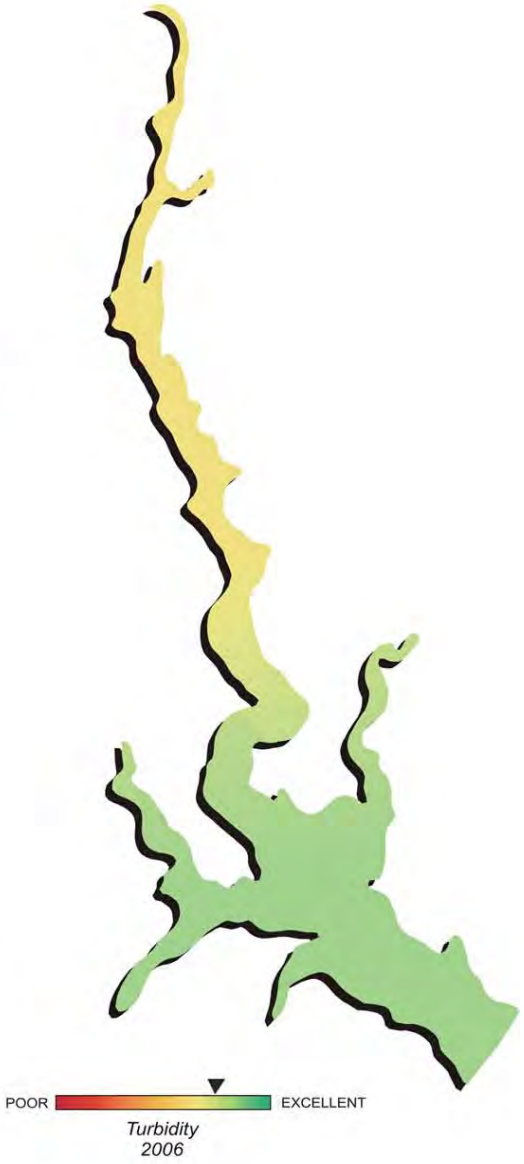


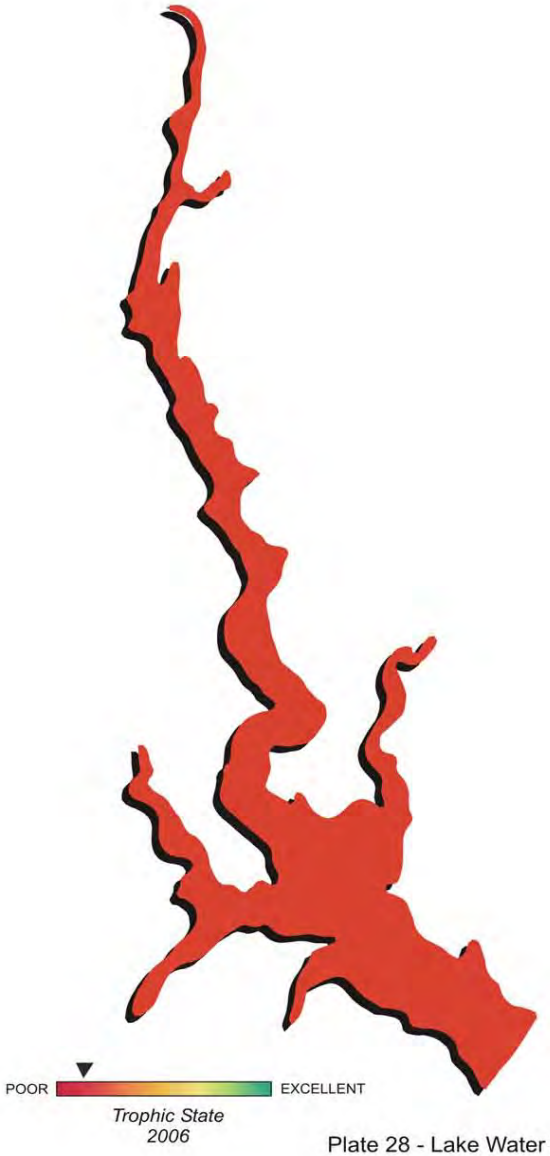
Figure 36a-36e. Graphical representation of data results for Crowder Lake.

Crowder Lake and Watershed

Lake Data	
Operator	State of Oklahoma
County	Washita
Constructed	1959
Surface Area	158 acres
Volume	2,094 acre/feet
Shoreline Length	9 miles
Mean Depth	13.25 feet
Watershed Area	27 square miles



Turbidity 2006



Trophic State 2006

Plate 28 - Lake Water Quality for
Crowder Lake

Cushing Municipal Lake

Cushing Municipal Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected at the surface at all sites as well as 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 49 NTU (Plate 29), true color was 101 units, and secchi disk depth was 34 centimeters. Based on these three parameters, Cushing Municipal Lake had poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 51 (Plate 29), indicating the lake was eutrophic, with high levels of productivity and nutrients. This is similar to the findings in 2002, indicating no significant increase or decrease in productivity had occurred. The TSI values were very consistent across the seasons and were either at the extreme upper end of mesotrophy or the lower end of eutrophy. Turbidity values per site for sample year were all near or above the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 37a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 80% of the samples collected above the standard, Cushing Lake is not meeting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. The lake-wide annual turbidity of 49 NTU is in consistent with historical data collection results seen for the lake. Of the twenty true color values collected 40% were above the aesthetics WQS of 70 units (see Figure 37b). Applying the same default protocol, the Aesthetics beneficial use is considered not supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.09 parts per thousand (ppt) to 0.13 ppt, which was within the expected range for most Oklahoma lakes and reflecting minimal presence of chlorides or other salts in the lake system. Specific conductivity values were also consistent with values that would normally be seen in Oklahoma reservoirs, with values ranging from 197.4 µS/cm in the fall to 274.6 µS/cm in the summer. Values did not indicate a high content of electrical current conducting compounds or salts in the lake. Oxidation-reduction potentials ranged from 392 mV to 583 mV, indicating reducing conditions were not present at any time during the sampling period. The pH was neutral to slightly alkaline with values ranging from 7.06 to 8.53 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The FWP beneficial use was fully supporting based on pH values collected during the study period. The lake was not thermally stratified and the water column appeared to be well mixed throughout the fall, winter and spring sampling quarters at all sites (see Figure 37c-69e). Dissolved oxygen (D.O.) values remained above 6.5 mg/L and the

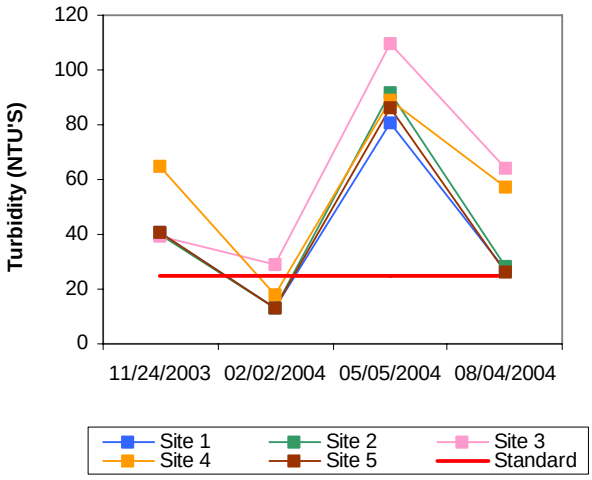
D.O. percent saturation was never less than 60% in the first three sampling intervals (see Figure 37c-37e). In the summer the lake was stratified at site 1 between 3 and 4 meters and the D.O. concentration dropped from 6.91 mg/L to 0.45 mg/L at the lake bottom of 6.1 meters (Figure 37f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the (FWP) beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 38% of D.O. readings collected at site 1 in the summer less than 2.0 mg/L, the lake is partially supporting its FWP beneficial use. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 samples collected all were below the prescribed screening levels. The PBCR beneficial use is therefore considered supported.

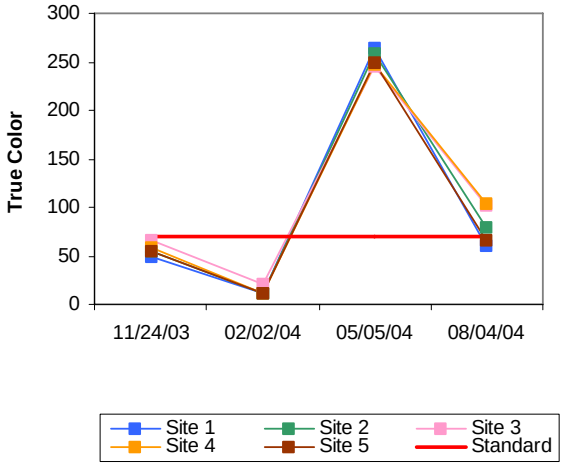
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.86 mg/L at the lake surface. The TN at the surface ranged from 0.60 mg/L to 1.28 mg/L. The highest surface TN value was reported in the spring and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average was 0.086 mg/L at the lake surface. The TP ranged from 0.039 mg/L to 0.184 mg/L at the lake surface. The highest surface TP values were reported in the spring quarter and the lowest were in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Cushing Municipal Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 29). Given the level of nutrients present in the lake system, the high levels of inorganic turbidity are serving as a mitigating factor for lake productivity through light limitation. The lake is fully supporting its Aesthetics beneficial use based on trophic status and not supporting for true color with 40% of the recorded values exceeding 70 units. The FWP beneficial use was fully supported based on pH and dissolved oxygen concentrations. The lake was not meeting its FWP beneficial use due to high turbidity. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 samples collected all were below the prescribed screening levels. The PBCR beneficial use is therefore considered supported. Cushing Municipal Lake constructed in 1950, is the municipal water supply for the City of Cushing and is also utilized for recreational purposes.

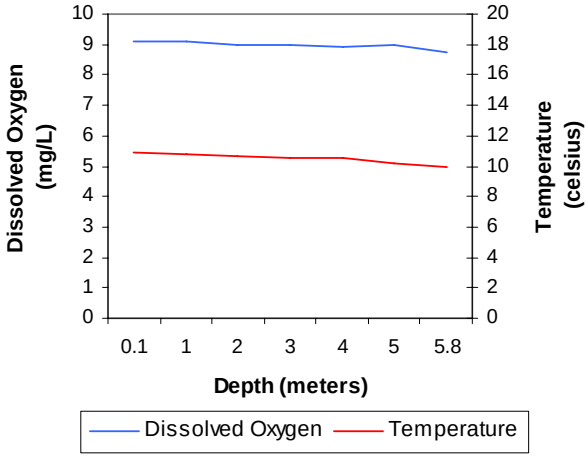
a. Seasonal Turbidity Values for Cushing Municipal Lake



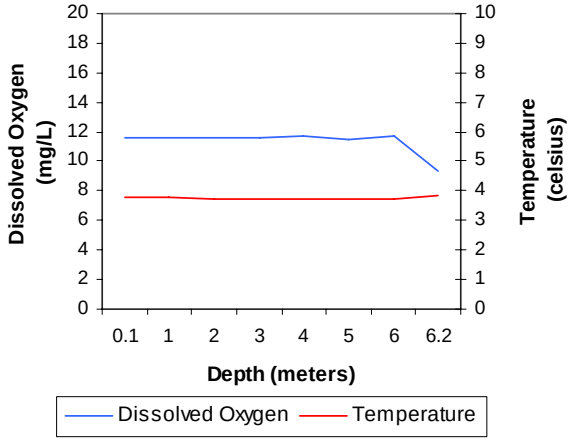
b. Seasonal Color Values for Cushing Municipal Lake



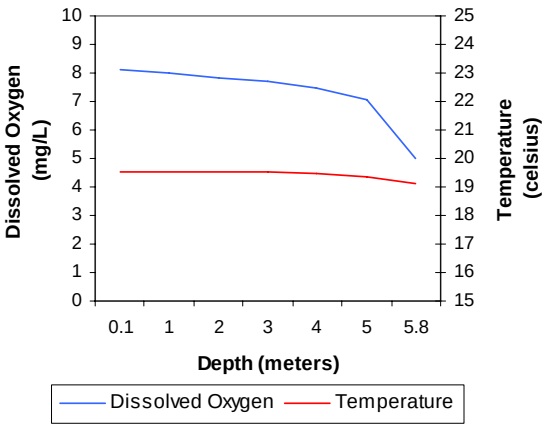
c. Profile of Cushing Municipal Lake November 24, 2003



d. Profile of Cushing Municipal Lake February 02, 2004



e. Profile of Cushing Municipal Lake May 05, 2004



f. Profile of Cushing Municipal Lake May 05, 2004

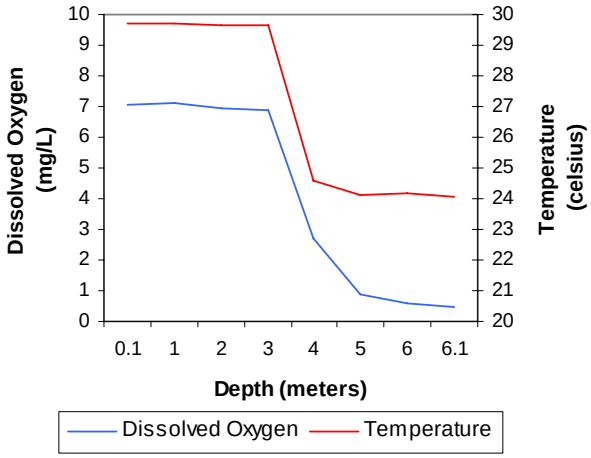


Figure 37a-37f. Graphical representation of data results for Cushing Municipal Lake.

POOR — EXCELLENT

Trophic State
2004

POOR — EXCELLENT

Turbidity
2004

Lake Data	
Owner	City of Cushing
County	Payne
Constructed in	1950
Surface Area	592 acres
Volume	3,304 acre/feet
Shoreline Length	9 miles
Mean Depth	5.58 feet
Watershed Area	32 square miles

Plate 29 - Lake Water Quality for
Cushing Lake

LAKES MONITORING PROGRAM

Dave Boyer (Walters) Lake

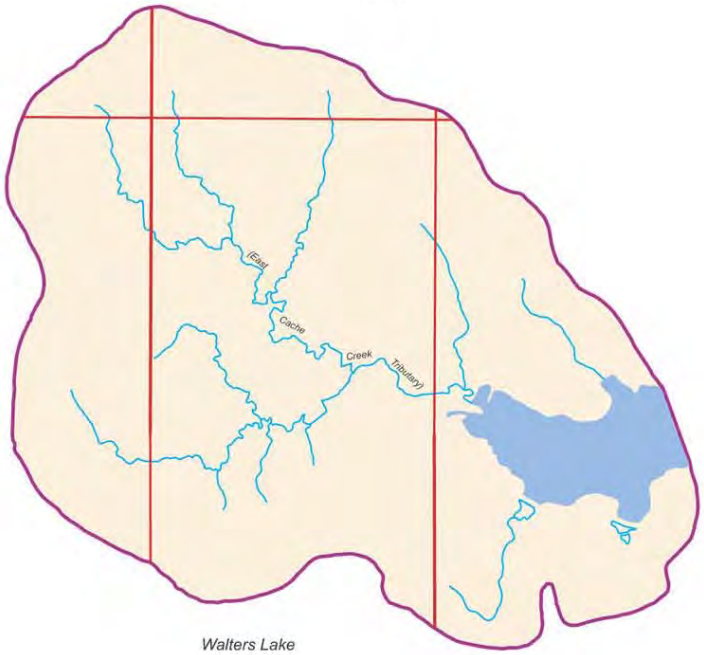
Dave Boyer Lake, located in Cotton County, is owned by the city of Walters and serves as a water supply and recreation reservoir. The lake was scheduled for sampling during the 2005-2006 sample year however due to the drought conditions lake levels were too low for OWRB staff to launch a boat. The lake will be placed on the next sample rotation once water levels rise enough for staff to access the lake safely.

Water quality samples were collected at three sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 89 NTU (Plate 120), true color was 48 units, and secchi disk depth was 16 centimeters in 2003-2004. Based on these three parameters, Dave Boyer Lake had poor water clarity in comparison to other Oklahoma reservoirs. Water clarity was similar in the 2001, and is always poor based on the soil composition and nature of this lake. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 52 (Plate 120), indicating the lake was eutrophic with high levels of productivity and nutrients. This value is similar to the TSI in 2001 (TSI= 51), indicating no change in productivity has occurred since the last evaluation. The TSI values were generally eutrophic with the exception of the winter when two of the three sites were mesotrophic. Turbidity values were well above the turbidity standard of 25 NTU at all sites throughout the year. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the Oklahoma Water Quality Standard (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The FWP beneficial use is considered not supported at Dave Boyer Lake with 100% of the collected values exceeding the numeric criteria of 25 NTU. Of the 12 samples collected at Dave Boyer Lake in 2003-2004, 25% of the true color values exceeded the 70 units criteria listed in WQS. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is considered not supported based on the high true color values.

Please refer to the "Beneficial Use Monitoring Report 2004 Draft Final Report" for the full discussion of monitoring results for this lake. The report may be access via the OWRB's web page at http://www. owrb.state.ok.us or you may contact the Water Resources for a copy of the 2004 BUMP Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the address below:

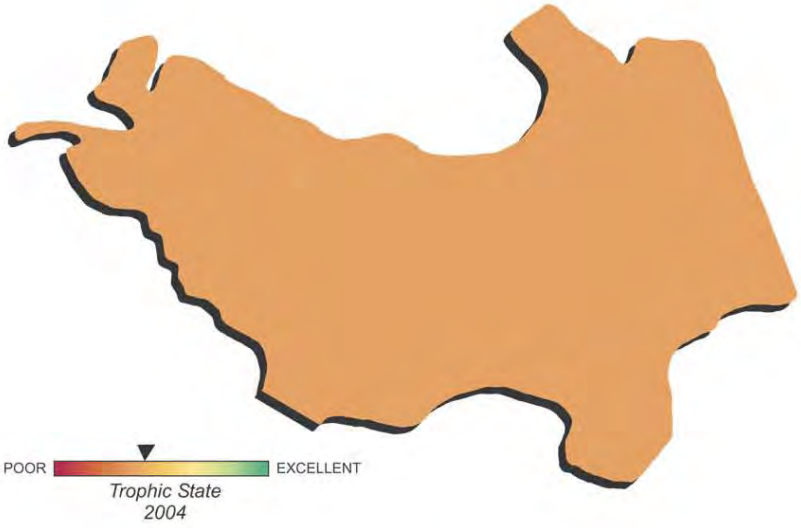
Oklahoma Water Resources Board
3800 N. Classen Blvd.
Oklahoma city, Oklahoma 73118
Attn: Nikki Cole

Walters Lake
Location

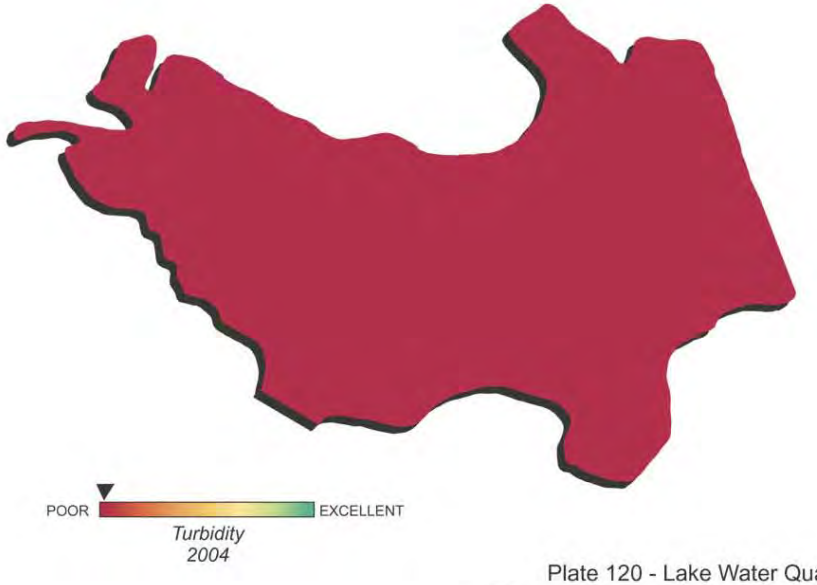


Walters Lake
and
Watershed

Lake Data	
Owner	City of Walters
County	Cotton
Constructed	1936
Surface Area	148 acres
Volume	861 acre/feet
Shoreline Length	3 miles
Mean Depth	5.82 feet
Watershed Area	2,389 acres



Trophic State
2004



Turbidity
2004

Plate 120 - Lake Water Quality for

Dave Boyer (Walters) Lake

LAKES MONITORING PROGRAM

Dripping Springs Lake

Dripping Springs Lake was sampled for four quarters, from November 2004 through August 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones as well as major arms of the reservoir. Samples were collected at the surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 16 NTU (Plate 30), true color was 65 units, and secchi disk depth was 83 centimeters in 2004-2005. Based on these three parameters, Dripping Springs Lake had average water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 42 (Plate 30), indicating the lake was mesotrophic, with moderate levels of productivity and nutrients. This value is similar to the TSI calculated in 2003 (TSI=46), indicating no insignificant increase or decrease in productivity has occurred since the lake was last evaluated. The TSI values were fairly consistent throughout the year with values ranging from upper oligotrophic to low and mid- mesotrophic. Seasonal turbidity values are displayed in (a.) Of the twenty values collected, 30% were greater than the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The lake is not supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity concentrations. Seasonal true color values are displayed in Figure 38 b. Fifty percent of the color values exceeded the WQS standard of 70 units. Similar to turbidity an increase in true color was observed during the winter quarter. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is considered not supported based on the true color values.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.03 parts per thousand (ppt) to 0.07 ppt, which was well within the expected range for most Oklahoma lakes if not lower than the normally recorded values. The low salinity concentrations reflect a minimal presence of chlorides or other salts in the lake. Specific conductivity values were also very low when compared to most Oklahoma reservoirs, with values ranging from 75.7 µS/cm in the fall quarter to 149.9 µS/cm in the summer quarter, which is indicative of a very low content of electrical current conducting compounds or salts in the lake system. Oxidation-reduction potentials ranged from 249 mV to 499 mV, indicating reducing conditions were not present at any point in the water column when sampling occurred. The pH was neutral to alkaline with values ranging from 6.4 to 7.83 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and they waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only 4% of the pH values collected fall outside the prescribed range, Dripping Spring Lake is meeting its FWP beneficial use based on pH. The lake was not thermally stratified and the water column appeared to be well mixed in both fall and winter quarters. During this time dissolved oxygen (D.O.) values generally above 7.0 mg/L except at the very bottom of the lake, which is likely the result of the Hydrolab probe resting on the bottom sediment (see Figure 38c-38d). In the spring quarter there was a gradual decline in both temperature and dissolved oxygen, with D.O. concentration remaining above 2.0 mg/ until the last two meters of the water column. Thermal stratification and anoxic conditions

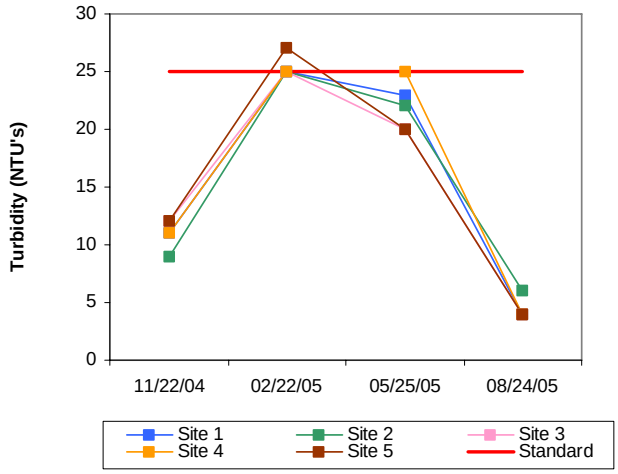
were present in the summer. Stratification occurred between 5 and 6 meters at which point the D.O. concentration fell below 2.0 mg/L for the remainder of the water column (see Figure 38f). The readings in the lake hypolimnion were anoxic both sites 1 and 4 and approximately 57% of the values collected at site 1 were below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Dripping Springs Lake is partially supporting its FWP beneficial use based on D.O. concentrations in the water column. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the current sample year and an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.38 mg/L at the surface. The TN at the surface ranged from 0.22 mg/L in the summer to 0.58 mg/L in the winter quarter. The lake-wide total phosphorus (TP) average was 0.024 mg/L at the surface. The total phosphorus at the surface ranged from 0.013 mg/L to 0.030 mg/L. Similar to total nitrogen, lower values were reported in the summer; however higher values were reported during the spring and summer sampling intervals. The nitrogen to phosphorus ration (TN:TP) was approximately 16:1 for sample year 2004-2005. This value is slightly higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

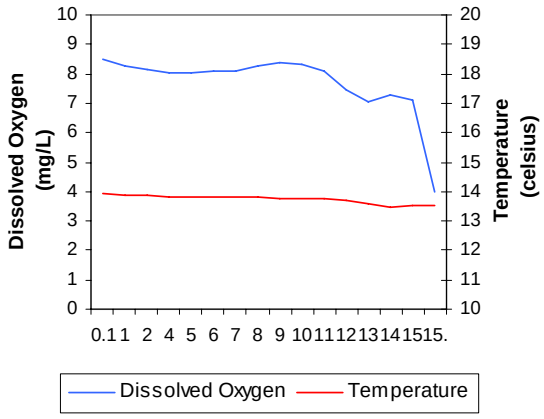
In summary, Dripping Springs Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 30). This is consistent with results of 2003, which also found the lake to be mesotrophic in nature (TSI=46). Water clarity was average in comparison to other Oklahoma reservoirs, based on turbidity, true color, and secchi disk depth. The Fish and Wildlife Propagation (FWP) beneficial use was found to be supporting for pH, but only partially supported based on anoxic conditions present during the summer. With 30% of the turbidity values exceeding 25 NTU the FWP use is not supported as it relates to turbidity. The Aesthetics beneficial use was fully supporting based on trophic state, but not supported for true color as 50% of the samples exceeded the WQS of 70 units. Bacteriological samples were not collected during the current sample year and an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Dripping Springs Lake is owned and operated by the City of Okmulgee and is managed for water supply uses, flood control uses and for recreational purposes.

a. Seasonal Turbidity Values for Dripping Springs Lake

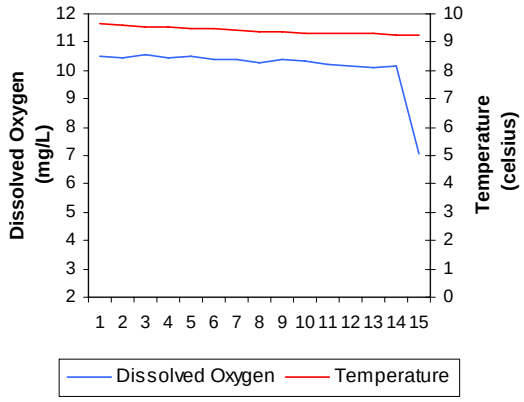


b. Seasonal Color Values for Dripping Springs Lake

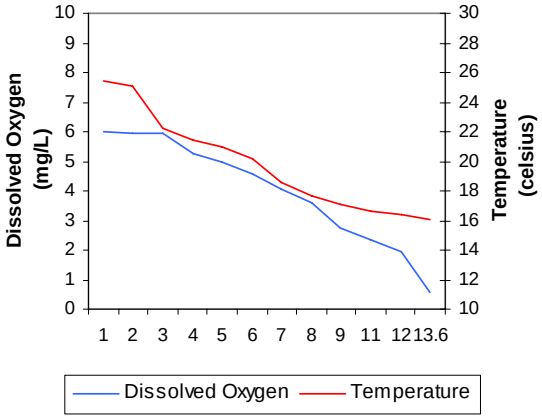
c. Profile of Dripping Springs Lake
November 22, 2004



d. Profile of Dripping Springs Lake
February 22, 2005



e. Profile of Dripping Springs Lake
May 25, 2005



f. Profile of Dripping Springs Lake
August 24, 2005

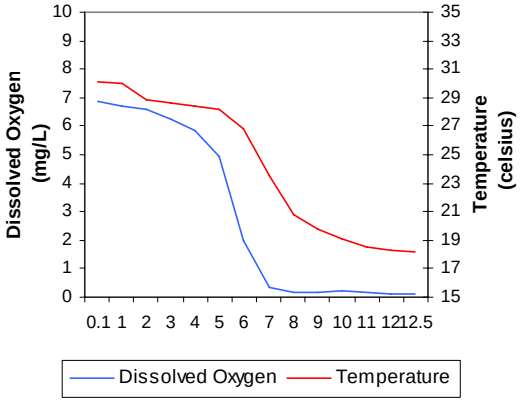
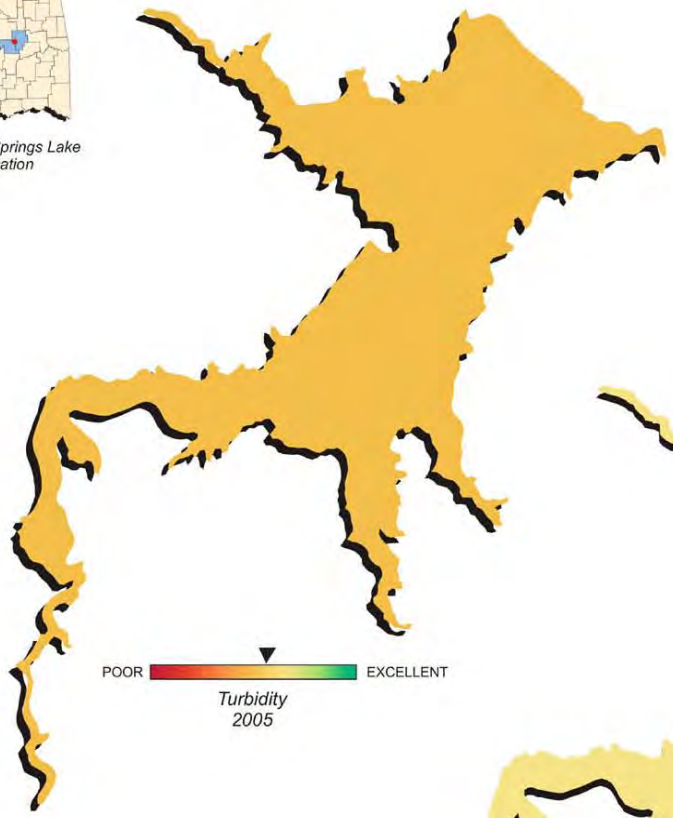


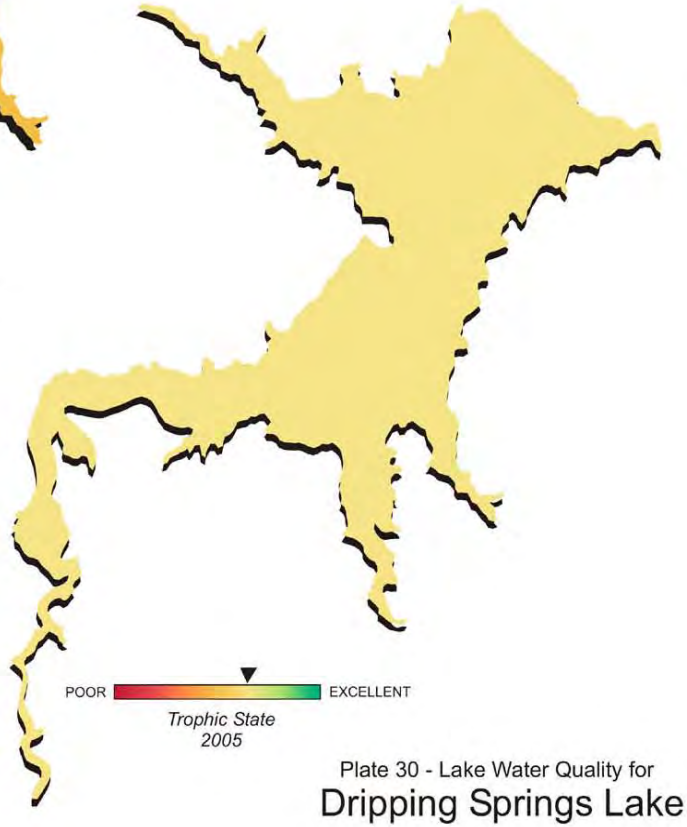
Figure 38a-38f. Graphical representation of data results for Dripping Spring Lake.

Dripping Springs Lake Location

Dripping Springs Lake and Watershed



Turbidity 2005



Trophic State 2005

Lake Data	
Owner	City of Okmulgee
County	Okmulgee
Constructed in	1976
Surface Area	1,150 acres
Volume	16,200 acre/feet
Shoreline Length	18 miles
Mean Depth	14.09 feet
Watershed Area	25 square miles

Plate 30 - Lake Water Quality for
Dripping Springs Lake

LAKES MONITORING PROGRAM

Duncan Lake

Duncan Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The lake-wide annual turbidity value was 11 NTU (Plate 31), true color was 14 units, and secchi disk depth was 81 centimeters in 2005. Based on these three parameters, Duncan Lake had good water clarity comparable to other Oklahoma reservoirs. Water clarity was slightly better than in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 48 (Plate 31), indicating the lake was mesotrophic, with moderate levels of productivity and nutrients. This value is similar to the TSI in 2003 (TSI=47), indicating no significant increase or decrease over time. The TSI values varied by sites and season with values ranging from eutrophic and upper mesotrophic in the fall and winter to oligotrophic and mesotrophic in the spring and summer quarters. Seasonal turbidity values are displayed in Figure 39a. All turbidity values recorded during the study period were below the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the values below the standard, the Fish and Wildlife Propagation (FWP) beneficial use is fully supported based on turbidity. Seasonal true colors are displayed in Figure 39b. Similar to turbidity, all true color values were below the Aesthetics WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered supported.

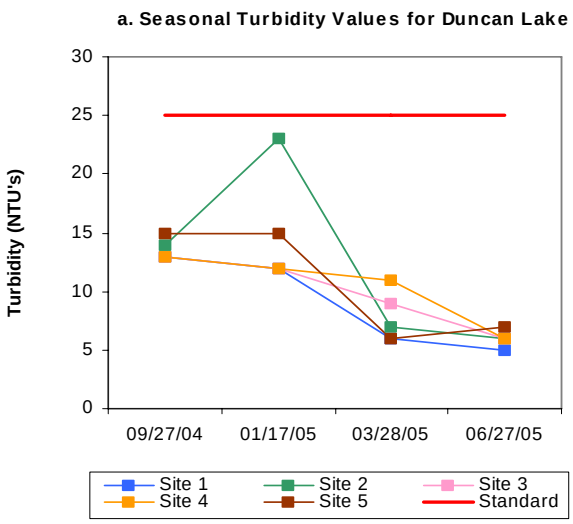
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity; oxidation-reduction potential and salinity were recorded at all five sample sites in 2004-2005. Salinity values ranged from 0.20 parts per thousand (ppt) to 0.25 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductivity ranged from 393.3 µS/cm to 494.4 µS/cm, indicative of moderate levels of current conducting ions (chlorides and salts) present in the lake system. The pH values were neutral to slightly alkaline ranging from 7.18 in the summer to 8.42 in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of collected values within the acceptable range Duncan Lake is meeting its FWP beneficial based on pH. Oxidation-reduction potentials (ORP) ranged from 110mV in the summer to 433 mV in the spring. In general, reducing conditions were not present at this reservoir during the 2004-2005-sample year. Duncan Lake was not thermally stratified during the fall, winter and spring quarters (see Figure 39c-39e). The lake was stratified and anoxic conditions were present in the hypolimnion during the summer. Stratification occurred between 4 and 5 meters (Figure 39f) and dissolved oxygen (D.O.) levels were below 2 mg/L from 6 meters to the lake bottom at 7.5

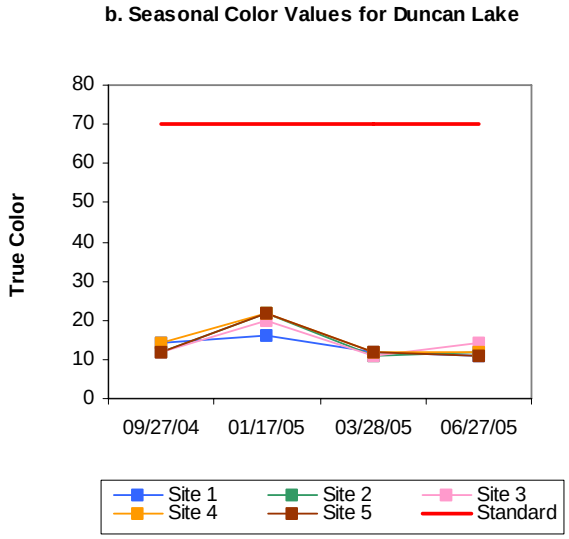
meters. Anoxic conditions were present in 33% of the water column at site 1. Sites 2 and 4 were also stratified with anoxic conditions present in 25% of the water column. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 25-33% of the water column below 2.0 mg/L the FWP beneficial use is supported at Duncan Lake. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

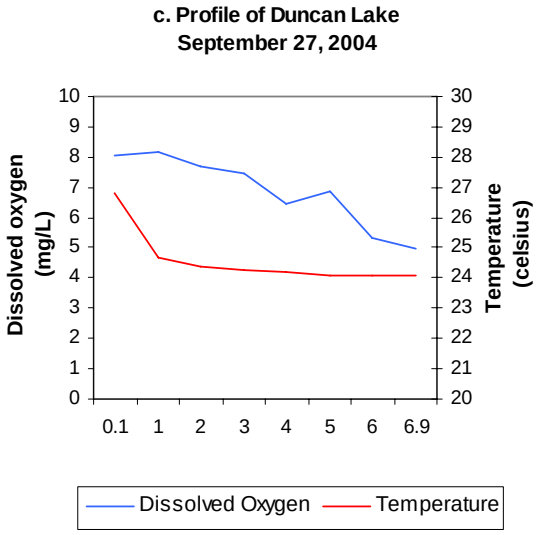
Bacteriological samples were not collected during the sample year, therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

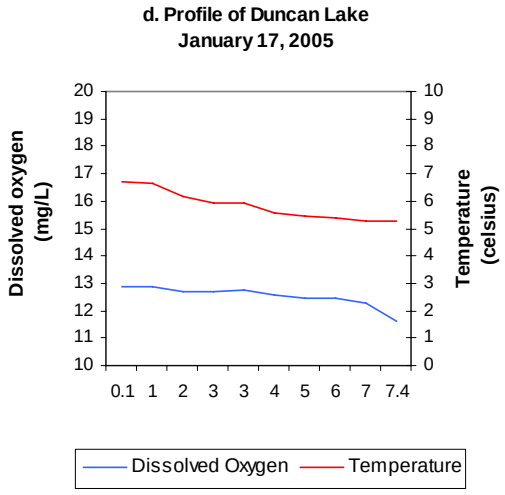
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.49 mg/L at the surface. Surface TN ranged from 0.30 mg/L to 0.73 mg/L with the highest values recorded in the fall quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.024 mg/L at the surface Similar to total nitrogen surface TP was highest in the fall quarter but lowest were observed in the spring with values ranging from 0.019 mg/L to 0.032 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 20:1 for sample year 2004-2005. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

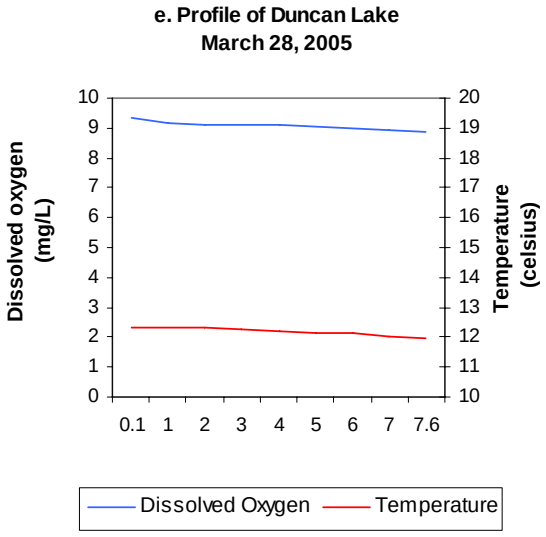
In summary, Duncan Lake was classified as mesotrophic with moderate primary productivity and nutrient levels (plate 31). This value is similar to the TSI in 2003 (TSI=47), indicating no significant increase or decrease since the previous evaluation. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on turbidity, pH values recorded in 2004-2005. The FWP beneficial use is also supported based on dissolved oxygen as anoxic conditions were present in only 25-33% of the water column during the summer quarter. The Aesthetics beneficial use is considered supported based on the trophic status and true color. Bacteriological samples were not collected during the sample year, therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Duncan Lake is located in Stephens County serves as a water supply and recreation reservoir for the city of Duncan.











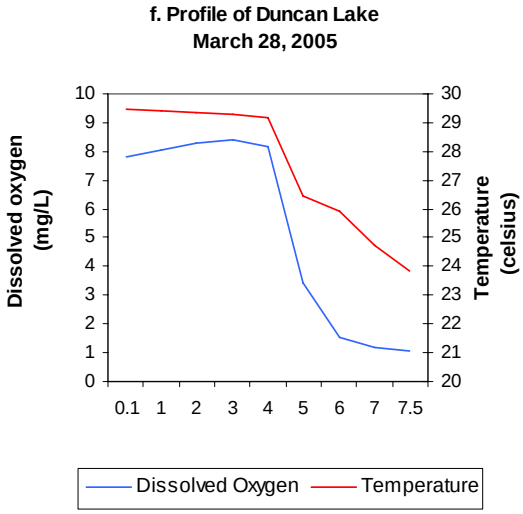
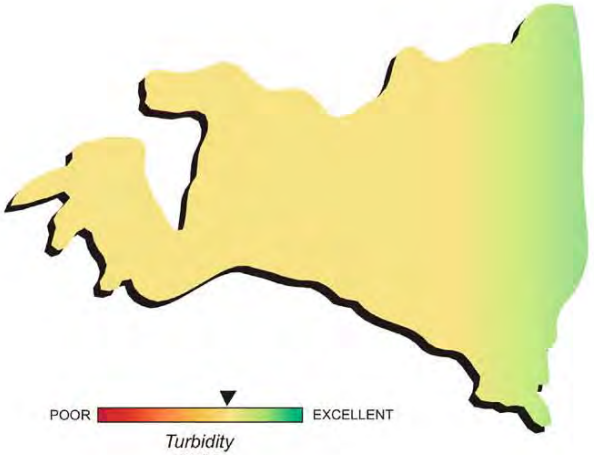
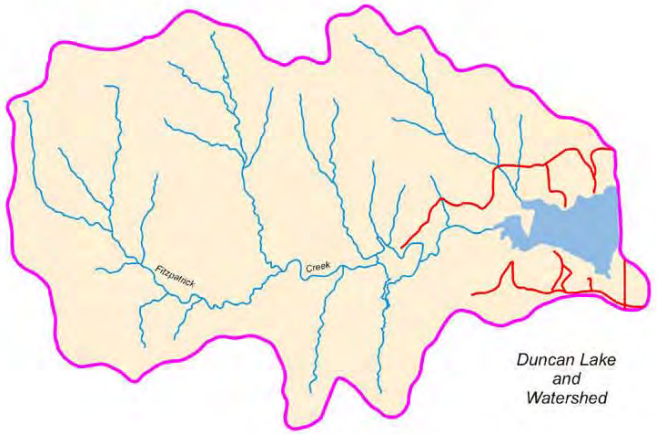


Figure 39a-39f. Graphical representation of data results for Duncan Lake.

Duncan Lake
Location



Turbidity
2005



Duncan Lake
and
Watershed

Trophic State
2005

Lake Data	
Owner	City of Duncan
County	Stephens
Constructed	1960
Surface Area	500 acres
Volume	7,200 acre/feet
Shoreline Length	4 miles
Mean Depth	14.40 feet
Watershed Area	11 square miles

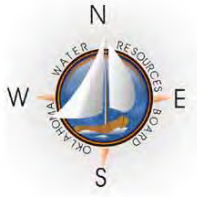


Plate 31 - Lake Water Quality for
Duncan Lake

LAKES MONITORING PROGRAM

Lake El Reno

Lake El Reno was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 46 NTU (Plate 32), true color was 61 units, and secchi disk depth was 32 centimeters in 2005. Based on these three parameters, Lake El Reno had fair to poor water clarity in comparison to other Oklahoma reservoirs. These results are similar if not a little worse than those in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 63 (Plate 32), indicating the lake was hypereutrophic, indicative of excessive levels of productivity and nutrient rich conditions. This value higher than the TSI in 2003 (TSI=59), placing the lake in a higher trophic category. The only exception to this was site 3, which was mesotrophic in the summer quarter. Based on the current trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The TSI values were primarily eutrophic throughout the year, with hypereutrophic values in the fall and summer quarters. Seasonal turbidity values are displayed in (Figure 40a. Turbidity values ranged from a low of 21 NTU to a maximum of 212 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The Fish & Wildlife Propagation (FWP) beneficial use is not supported at Lake El Reno with 67% values recorded exceeding the WQS of 25 NTU. Seasonal true color values are displayed in Figure 40b. Of the twelve values collected, four (33%) exceeded the Aesthetics WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is not supported based on true color.

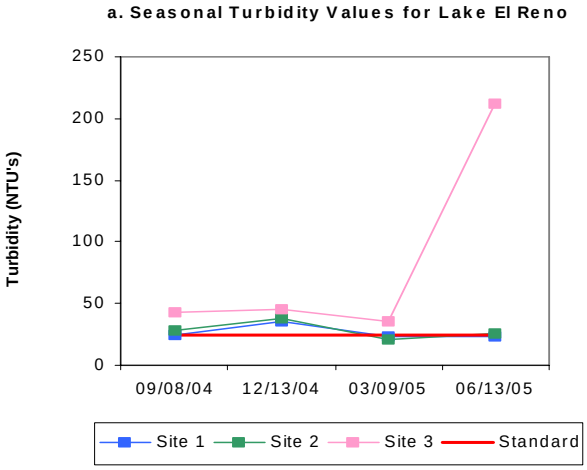
In 2004-2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity ranged from 0.12 parts per thousand (ppt) to 0.86 ppt, which is higher than most Oklahoma reservoirs. Specific conductivity ranged from 261.5 µS/cm in the summer to 1624 µS/cm in the fall. These values indicate the presence of moderate to high levels of current conducting compounds (salts) in the lake, consistent with higher recorded salinity concentrations. The pH values ranged from 6.94 to 8.62, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of collected values within the acceptable range Lake El Reno is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 316 mV in the hypolimnion during

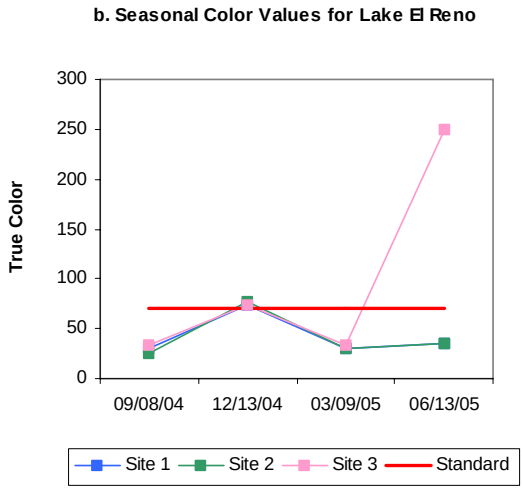
the spring to 448 mV in the fall. In general, reducing conditions were not present in this reservoir during the study period. The lake was not stratified during any of the sampling quarters (see Figure 40c-40f) and dissolved oxygen (D.O.) levels were generally above 6.0 mg/L. The absence of stratification may be attributed to the shallow nature of this reservoir where wind and wave action keep the lake well mixed. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 100% of the water column above 2.0 mg/L the FWP beneficial use is supported at Lake El Reno. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

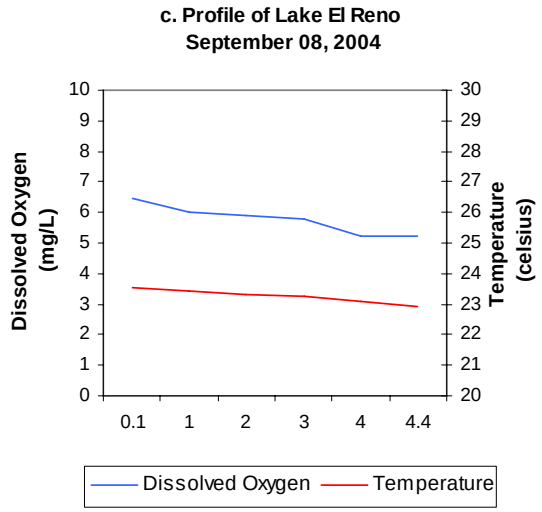
Bacteriological samples were not collected during this sample year, therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

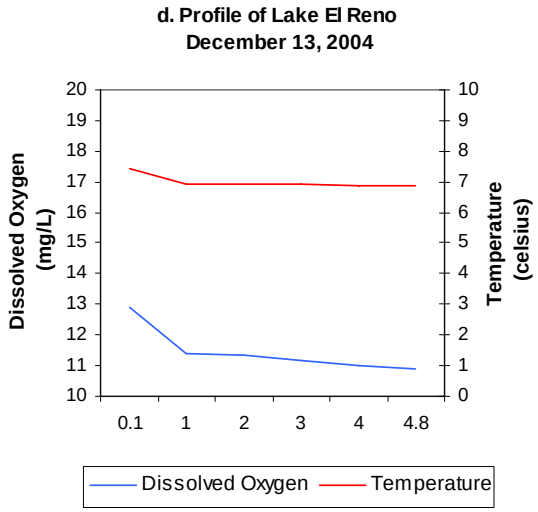
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.40 mg/L at the surface. The TN at the surface ranged from 0.87 mg/L in the summer to 1.91 mg/L in the fall. The lake-wide total phosphorus (TP) average was 0.236 mg/L at the surface. The total phosphorus at the surface ranged from 0.087 mg/L in the spring to 0.515 mg/L in the summer quarter. These values are very similar, if not higher to those seen in 2003. The nitrogen to phosphorus ration (TN:TP) was 6:1 for sample year 2003. This value is very close to 7:I, characterizing the lake as nitrogen limited or possibly co-limited (Wetzel, 1983).

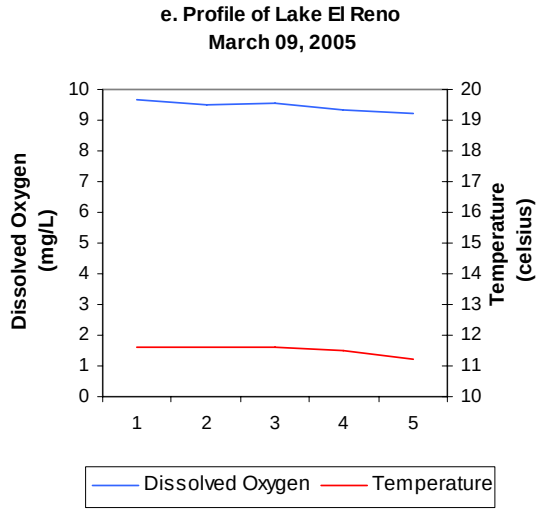
In summary, Lake El Reno was classified as hypereutrophic, indicative of high primary productivity and nutrient conditions (Plate 32). This classification differs from that in 2003, which had a TSI of 59. Based on the current trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Water clarity was fair to poor based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use for pH and dissolved oxygen levels, but not supporting based on turbidity. With 33% of the true color values recorded exceeding the WQS of 70 units the Aesthetics beneficial use is considered not supported. Bacteriological samples were not collected during this sample year, therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake El Reno, located in Canadian County, is owned by the city of El Reno and serves as a flood control and recreation reservoir.











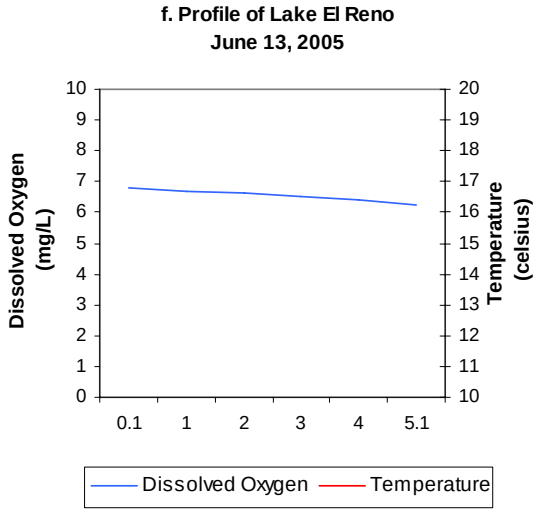
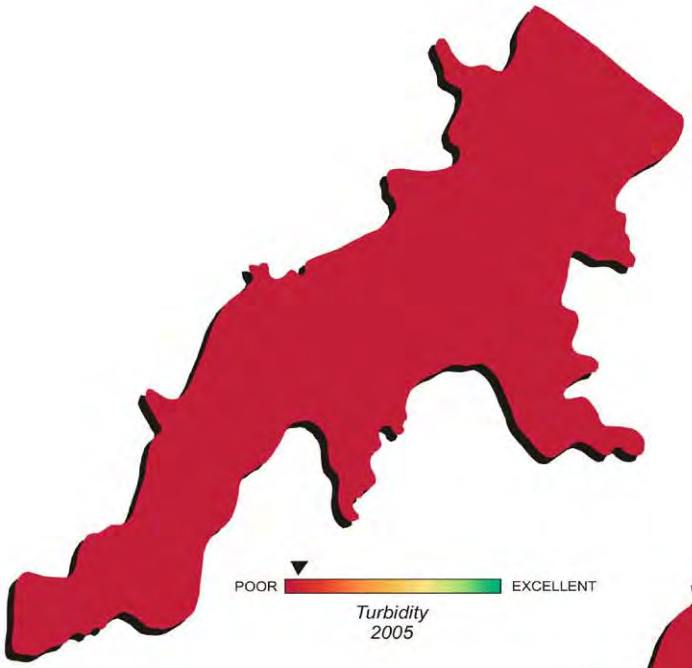


Figure 40a-40f. Graphical representation of data results for Lake El Reno.

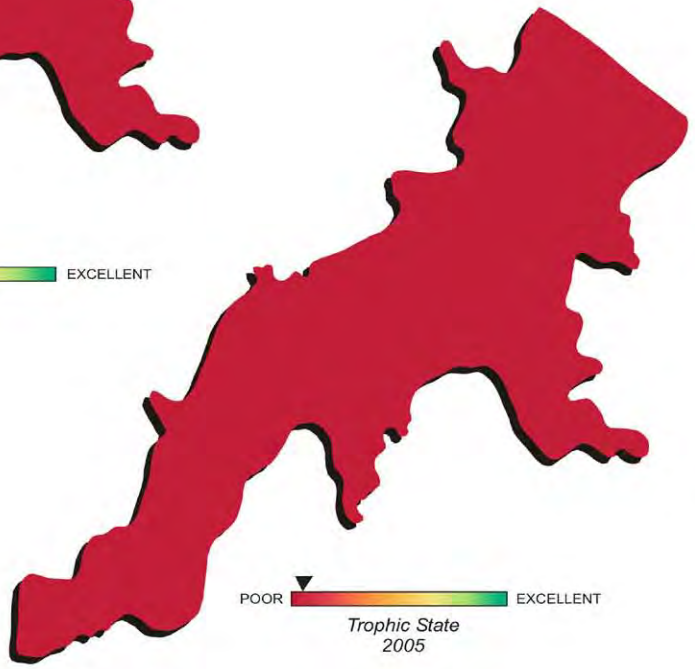
El Reno Lake Location

El Reno Lake and Watershed



POOR — EXCELLENT

Turbidity 2005



POOR — EXCELLENT

Trophic State 2005

Lake Data	
Owner	City of El Reno
County	Canadian
Constructed	1966
Surface Area	170 acres
Volume	709 acre/feet
Shoreline Length	4 miles
Mean Depth	4.17 feet
Watershed Area	4,242 acres

N W E S

Plate 32 - Lake Water Quality for
Lake El Reno

LAKES MONITORING PROGRAM

Lake Elk City

Lake Elk City, located in Beckham County, was constructed in 1970 and is owned and operated by the City of Elk City. The lake is utilized by the city for flood control and recreational purposes. Lake Elk City was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 15 NTU (Plate 33), true color was 26 units, and secchi disk depth was 56 centimeters. Results were similar to those observed during the 2003-2004 evaluation. Based on these three parameters, Lake Elk City had fair to poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 59 (Plate 33), indicating the lake was eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values varied seasonally from eutrophic in the winter and spring, with one mesotrophic value present at site 2 in the spring quarter, and hypereutrophic conditions present in the fall and summer quarters. Lake Elk City is currently listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The lake should be further studied to understand the nutrient dynamics involved. Turbidity values were all below the WQS of 25 NTU (see Figure 41a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Elk City was supporting its Fish & Wildlife Propagation (FWP) beneficial use based on OAC 785:46 during sample year 2005-2006. All true color values were below the Aesthetics WQS of 70 units (See Figure 41b). Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the reported true color values.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were performed at all sample sites and yielded the following results. Salinity readings ranged from 0.30 parts per thousand (ppt) to 0.39 ppt, slightly higher than most values recorded in Oklahoma reservoirs. Readings for specific conductivity were also slightly higher than values normally seen in most Oklahoma reservoirs. Specific Conductivity ranged from 593.3 µS/cm in the fall quarter to 749.9 µS/cm in the spring quarter, indicating moderate to slightly elevated concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 374 mV to 448 mV, indicating reducing conditions were not present during any sampling events. Lake pH values were neutral to slightly alkaline, ranging from 7.70 to 8.49 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its

FWP beneficial use. Lake Elk City was fully supporting its FWP beneficial use based on pH values collected during the study period. The lake was not thermally stratified during the fall and winter quarters (see Figure 41c-41d). The water column was evenly mixed and oxygenated during these two sampling intervals with dissolved oxygen concentrations above 7.0mg/L (see Figure 41c-45d). In the spring the lake was stratified at both sites 1 and 2 with anoxic conditions present from 6 meters below the surface to the lake bottom of 7.3 meters (Figure 41e). Due to equipment failure, there is no profile data available for the summer sampling interval. When D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered supported based on dissolved oxygen data collected in the first three sampling intervals. Because the summer profile data is missing an assessment for that season cannot be made at this time. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

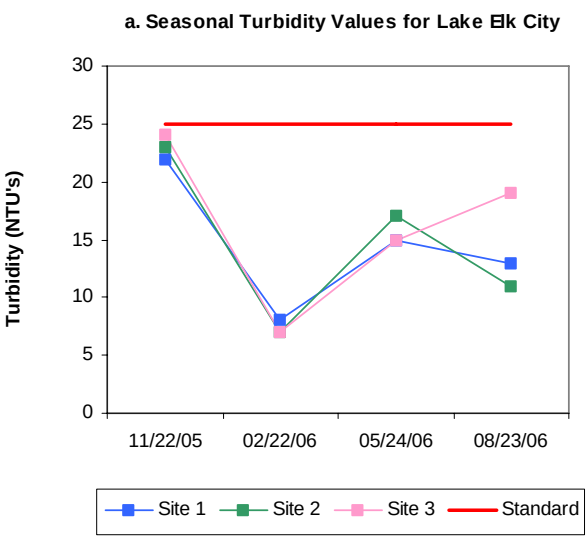
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

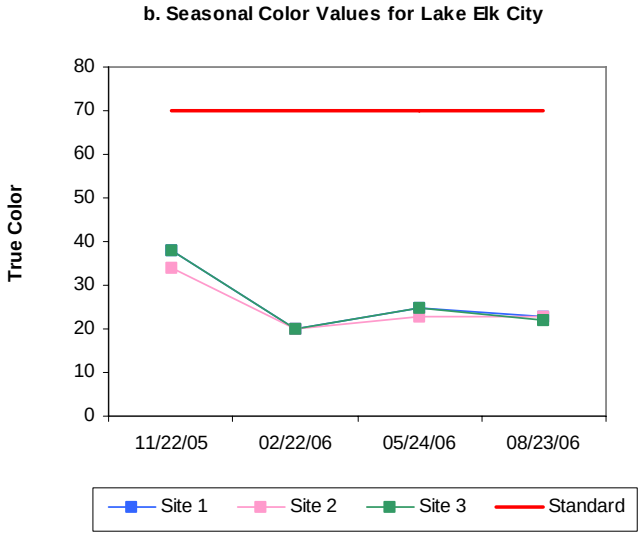
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.91 mg/L during the study period. The TN at the surface ranged from 0.74 mg/L to 1.08 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was recorded at site 3 in the spring quarter. The lake-wide total phosphorus (TP) average for 2005-2006 was 0.055 mg/L. The TP ranged from 0.037 mg/L to 0.067 mg/L at the lake surface. Similar to TN the lowest total phosphorus value was recorded at site 3 in the spring; however the highest values occurred in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 17:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

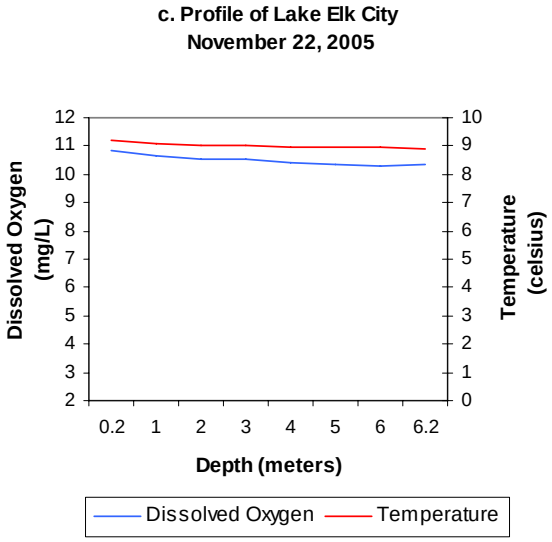
Lake Elk City was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

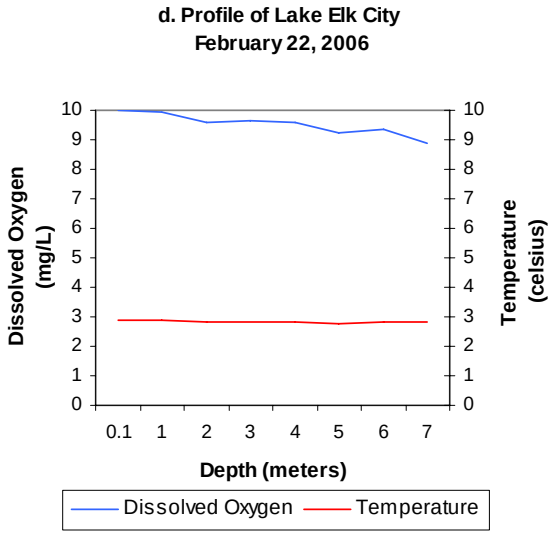
In summary, Lake Elk City was as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 33). This is consistent with historical data collection efforts in 2004 (TSI=56), indicating no significant increase or decrease in productivity has occurred over time. The lake is fully supporting its FWP beneficial based turbidity pH and D.O. concentrations recorded throughout the study period. With 100% of the true color values below the WQS of 70 units, Elk City Lake is fully supporting its Aesthetics beneficial as it relates to color. Based on the current NLW listing the lake is considered nutrient threatened and should be studied more intensively to confirm the Aesthetics beneficial use non-support status as well as understand the nutrient dynamics at work in the system. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through

September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.









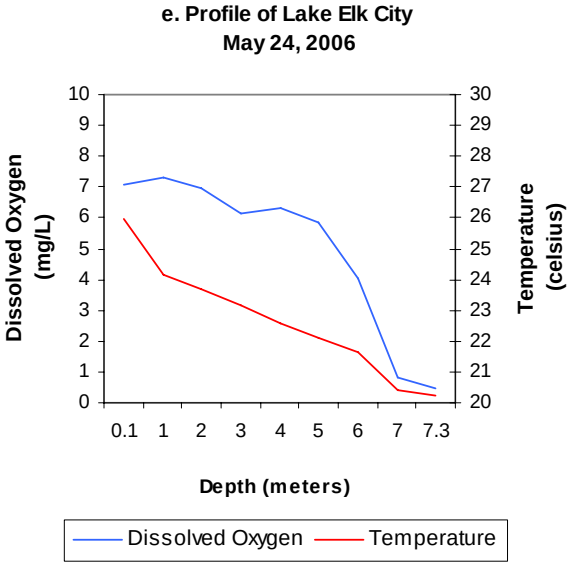


Figure 41a-41e. Graphical representation of data results for Lake Elk City.

Lake Data	
Owner	City of Elk City
County	Beckham
Constructed in	1970
Surface Area	240 acres
Volume	2,583 acre/feet
Shoreline Length	5 miles
Mean Depth	10.76 feet
Watershed Area	23 square miles

Plate 33 - Lake Water Quality for
Elk City Lake

Lake Ellsworth

Lake Ellsworth was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites as well as 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 35 NTU (Plate 34), true color was 22 units, and secchi disk depth was 43 centimeters. Based on these three parameters, Lake Ellsworth had fair to poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 54 (Plate 34), indicating the lake was eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values varied seasonally with meso-eutrophic values present in the fall and winter and mesotrophy in the spring to upper eutrophic. Hypereutrophic values present in the summer quarter. Turbidity values for site 1 were all below the Oklahoma Water Quality Standard (WQS) of 25 NTU; however, at site 2 25% of the collected values exceeded the criteria and the vast majority of the data collected at sites 3-5 exceeded the criteria (see Figure 42a). According to Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The FWP beneficial use is considered not supported at Lake Ellsworth with 50% of the sample values exceeding the criteria. All true color values were below the aesthetics WQS of 70 units (see Figure 42b). Applying the same default protocol, the Aesthetics beneficial use is supported based on true color values collected during the sample year.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were performed at all sample sites and yielded the following results. Salinity readings ranged from 0.27 parts per thousand (ppt) to 0.35 ppt, which is slightly higher than the expected range of values recorded for Oklahoma reservoirs. Readings for specific conductivity were within the range of expected values recorded for most Oklahoma reservoirs. Specific conductivity ranged from 544.3 µS/cm in the spring quarter to 671.8 µS/cm in the summer quarter. This indicates moderate to slightly elevated concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials ranged from 128 mV to 492 mV, indicating reducing conditions were absent present during 2003-2004 sampling. Lake pH values were neutral to slightly alkaline, ranging from 7.06 to 8.47 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The FWP beneficial use is fully supported based on pH with all values within the acceptable range. The lake was not thermally stratified during the fall or spring quarters (see Figure 42c-42d) and the water column was evenly mixed and oxygenated. After reviewing the data collected during the winter it appears

that there was a probe malfunction and dissolved oxygen (D.O.) values appear to be erroneous. Due to seasonality and historical data available, it is likely that stratification was not present and the water column was well oxygenated. In the summer quarter the lake was thermally stratified first between the 3 to 4 meter depths, with dissolved oxygen (D.O.) concentrations dropping below 2.0 mg/L from 7 meters to the lake bottom at 12.2 meters (see Figure 42e). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With approximately 50% of the water column experiencing anoxic conditions, the FWP beneficial use according to USAP (OAC 785:46-15-5) is partially supported. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

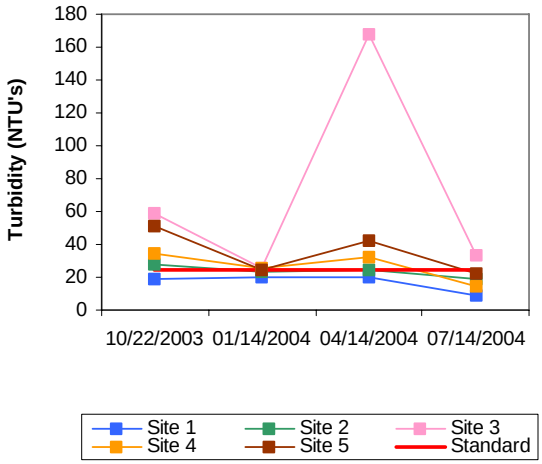
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 samples collected none exceeded the prescribed screening level or geometric mean. The PBCR beneficial use is therefore considered supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.80 mg/L at the lake surface. The TN at the surface ranged from 0.50 mg/L to 1.25 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.070 mg/L at the lake surface. The TP ranged from 0.048 mg/L to 0.115 mg/L at the lake surface. The highest surface TP values were reported in the spring quarter and the lowest were in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 12:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

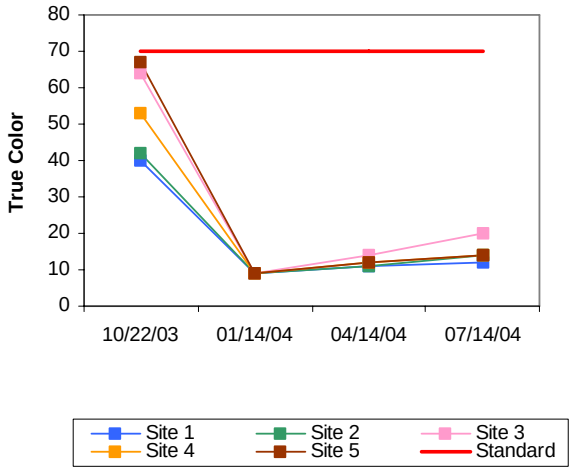
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1997 as part of their Toxics Monitoring Program and detected no compounds at the FDA Action level, ODEQ warning level, or ODEQ concern level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Ellsworth was as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 34). The FWP beneficial use is considered not supported for turbidity at Lake Ellsworth with 50% of the sample values exceeding the criteria. The Aesthetics beneficial use is supported based on true color and trophic status values collected during the sample year. The FWP beneficial use is supported for pH and partially supported based on dissolved oxygen. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 samples collected none exceeded the prescribed screening level or geometric mean. The PBCR beneficial use is therefore considered supported. Lake Ellsworth is owned and operated by the City of Lawton and the lake was constructed in 1962. The lake was constructed to serve as a water supply for the city and provide recreational opportunities to the public.

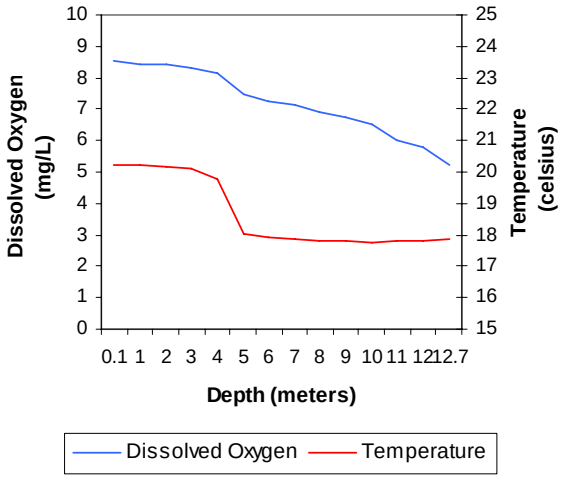
a. Seasonal Turbidity Values for Lake Ellsworth



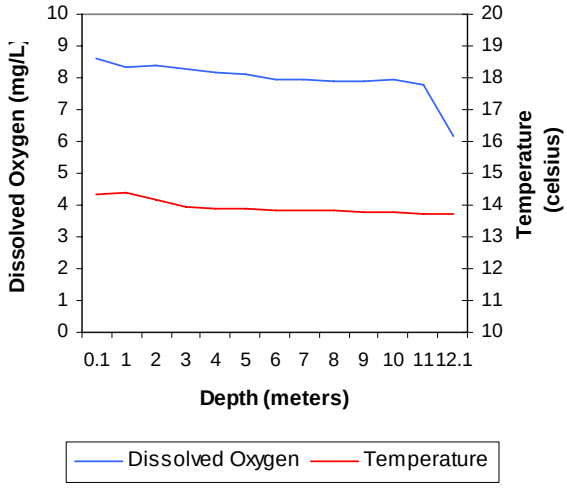
b. Seasonal Color Values for Lake Ellsworth



c. Profile of Lake Ellsworth October 22, 2003



d. Profile of Lake Ellsworth April 14, 2004



e. Profile of Lake Ellsworth July 14, 2004

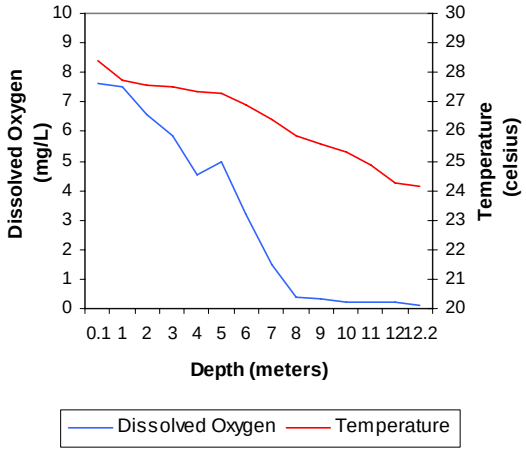


Figure 42a-42e. Graphical representation of data results for Lake Ellsworth.

Lake Ellsworth and Watershed

Lake Ellsworth Location

Turbidity 2004

Trophic State 2004

Lake Data	
Owner	City of Lawton
County	Comanche
Constructed	1962
Surface Area	5,600 acres
Volume	95,200 acre/feet
Shoreline Length	43 miles
Mean Depth	17.00 feet
Watershed Area	247 square miles

Plate 34 - Lake Water Quality for
Lake Ellsworth

Elmer Thomas Lake

Elmer Thomas Lake was sampled for four quarters from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity was 1 NTU (Plate 35), true color was 11 units and secchi disk depth was 417 centimeters. Water clarity was excellent at Elmer Thomas Lake and is similar to results from the 2003 evaluation. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 33 (Plate 35), indicating the lake was oligotrophic, with low primary productivity and nutrient levels in sample year 2004-2005. The TSI values for all sites were consistent with all values in the oligotrophic category. This value is similar to the one calculated in 2003 (TSI=34), indicating no significant increase or decrease in productivity. Seasonal turbidity values are displayed in Figure 43a. Turbidity values were all well below the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the values recorded below the WQS of 25 NTU the Fish & Wildlife Propagation (FWP) beneficial use considered fully supported at Elmer Thomas Lake. Seasonal true color values are displayed in Figure 43b. Similar to turbidity, recorded true color values were very low with all values below the Aesthetics WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is fully supported based on true color.

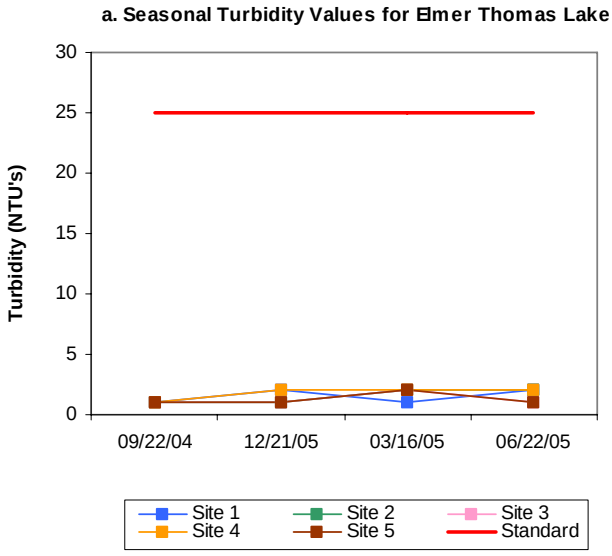
In 2004-2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.04 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductivity ranged from 52.1 µS/cm to 98.6 µS/cm, indicative of minimal levels of current conducting ions (chlorides and salts) in the lake system. The values for pH were generally neutral to slightly alkaline ranging from 6.76 to 8.63. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of collected values within the acceptable range Elmer Thomas Lake is meeting its FWP beneficial based on pH. Oxidation-reduction potentials (ORP) ranged from 321mV in the fall to 480 mV in the spring. In general, reducing conditions were not present at this reservoir, with all values above 100 mV. Elmer Thomas Lake was not thermally stratified during the fall, winter and spring quarters and dissolved oxygen (D.O.) levels were generally above 6.0 mg/L (see Figure 43c-43e). During the summer quarter the lake was thermally stratified however D.O. never dropped below 2.0 mg/L (Figure 43f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O.

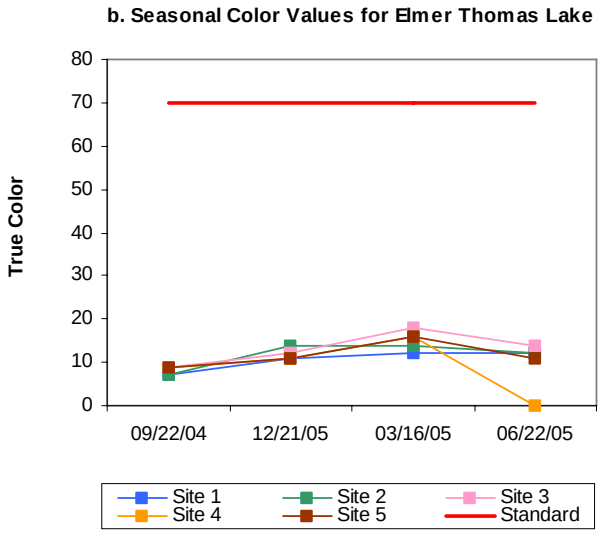
concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With an absence of anoxic conditions present during the study period, the FWP beneficial use is considered supported at Elmer Thomas Lake. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

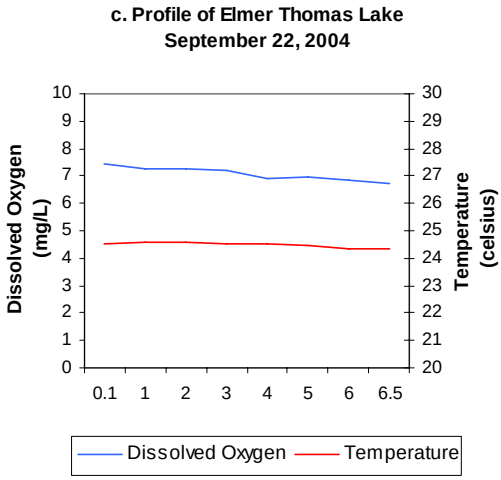
Bacteriological samples were not collected during the recreation season during sample year 2004-2005, therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made.

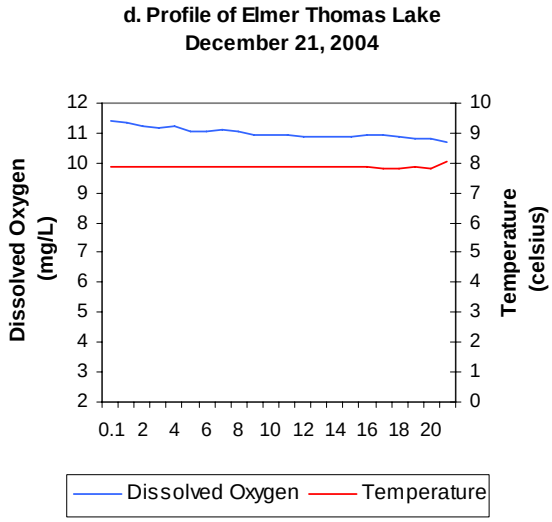
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.29mg/L at the surface. Surface TN ranged from 0.19 mg/L to 0.43 mg/L with the highest values recorded in the fall quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.009 mg/L at the surface. Surface TP was highest in the spring quarter and lowest in the fall with values ranging from 0.006 mg/L to 0.012 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 31:1 for sample year 2005. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

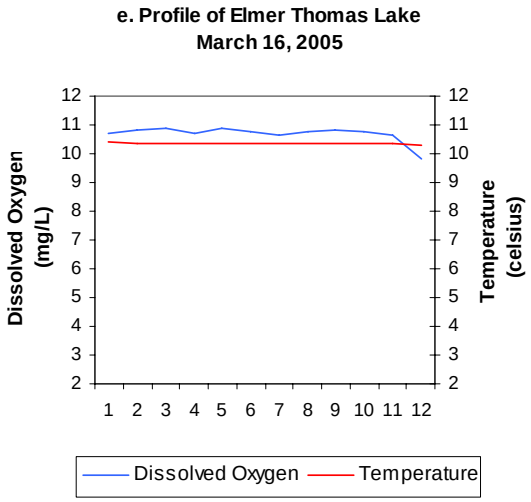
In summary, Elmer Thomas Lake was classified as oligotrophic with low primary productivity and nutrient levels in 2004-2005. This value is similar to the one calculated in 2003 (TSI=34), indicating no significant increase or decrease in productivity has taken place. Water clarity continues to be excellent based on turbidity, true color and secchi disk depth. The lake is currently supporting the FWP beneficial use based on pH, turbidity and dissolved oxygen values recorded during the sample year. The Aesthetics beneficial use is also supported based on the trophic status and for true color. Bacteriological samples were not collected during the recreation season during sample year, therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made. Elmer Thomas Lake, located in Comanche County, was constructed by the U.S. Department of Interior for the purpose of recreation.











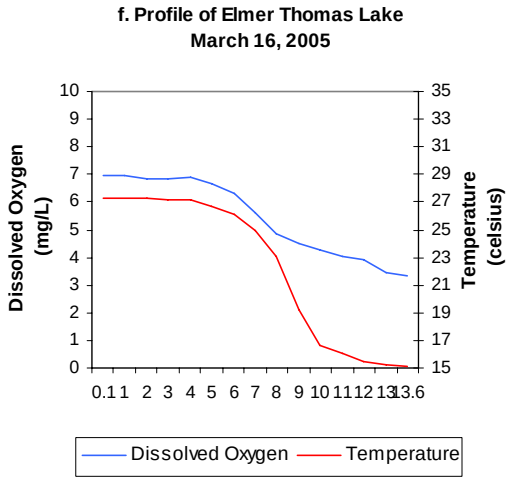
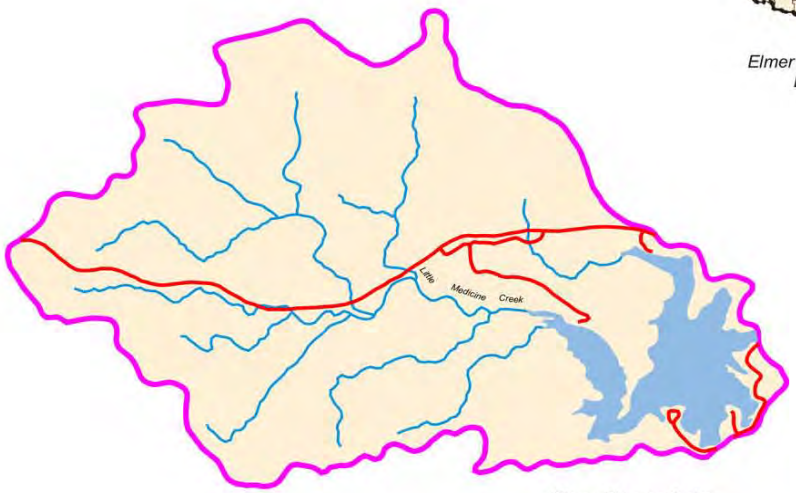
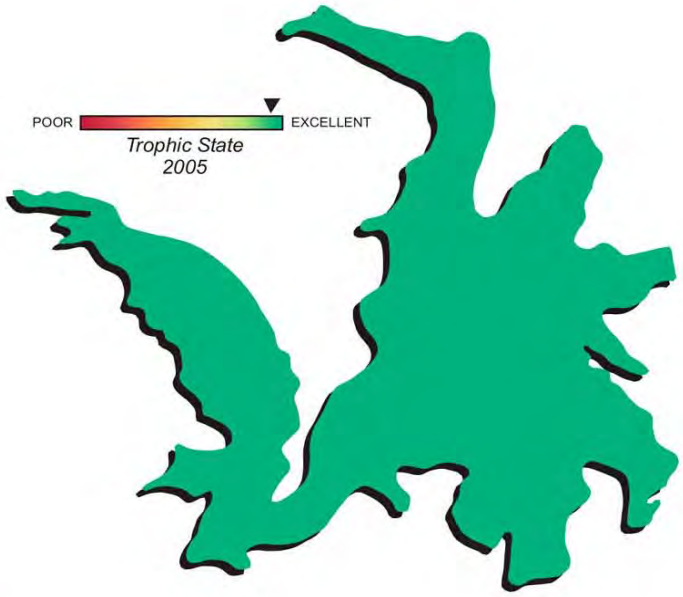


Figure 43a-43f. Graphical representation of data results for Elmer Thomas Lake.

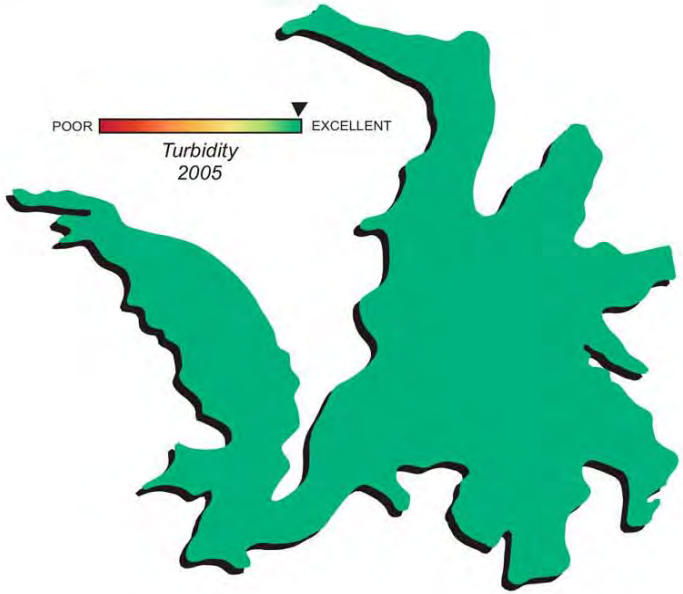
Elmer Thomas Lake Location



Elmer Thomas Lake and Watershed



Trophic State 2005



Turbidity 2005

Lake Data	
Owner	U.S. Dept. of the Interior
County	Comanche
Constructed in	N/A
Surface Area	334 acres
Volume	12,000 acre/feet
Shoreline Length	8 miles
Mean Depth	35.92 feet
Watershed Area	4,377 acres

Plate 35 - Lake Water Quality for
Elmer Thomas Lake

LAKES MONITORING PROGRAM

Lake Etling

Lake Etling was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at 3 sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites. Due to drought conditions and low lake levels a bottom sample was not taken at any point during the sample year. The lake-wide annual turbidity value was 65 NTU (Plate 36), true color was 18 units, and secchi disk depth was 22 centimeters in 2004. Based on these three parameters, Lake Etling had fair water clarity in comparison to other Oklahoma reservoirs. Water clarity differed from 2001 with both an increase in turbidity and a decline in the average secchi disk depth. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 72, indicating the lake was hypereutrophic, indicative of excessive levels of productivity and nutrient rich conditions. This value is greater than the TSI in 2001 (TSI=57), indicating a significant increase in trophic status since previous data collection efforts were conducted as is likely related to the decrease in lake levels. The TSI values were hypereutrophic at all sites throughout the study period. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Seasonal turbidity values are displayed in (Figure 44a). Only three of the twelve turbidity values were below the WQS of 25 NTU, constituting a listing as not supporting the Fish & Wildlife Propagation (FWP) beneficial use. According to USAP (Oklahoma Administrative Code 785:46-15-5), a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. All true color values were below the aesthetics WQS of 70 units for all four seasons at all sites (Figure 44b). Applying the same default protocol for determining the short-term average for true color, the Aesthetics beneficial use is considered supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.9 parts per thousand (ppt) to 1.4 ppt, which is higher than the expected range for most Oklahoma lakes. Salinity values indicate a moderate to high presence of chlorides or other salts in the lake. Specific conductivity values exhibited a similar pattern and were somewhat higher than most Oklahoma reservoirs, with values ranging from 1688 µS/cm in the fall to 2596 µS/cm in the summer, which is indicative of a high content of electrical current conducting compounds or salts throughout the lake system. Oxidation-reduction potentials (redox) ranged from 269 mV to 499 mV, indicating reducing conditions were not present during the study period. The pH was alkaline in nature with values ranging from 8.18 to 9.42 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Etling is not supporting the FWP use, with

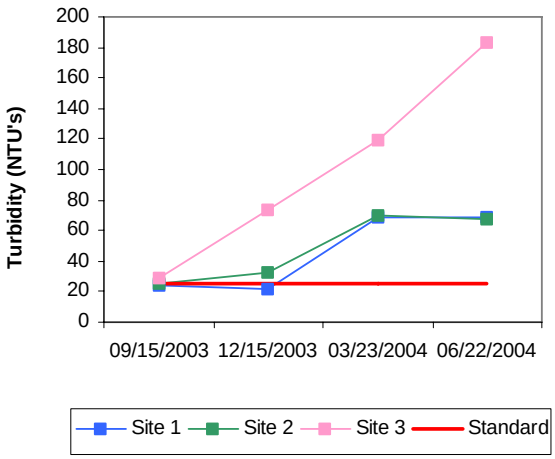
28% of the collected values falling outside the acceptable range. Slightly alkaline conditions seem to be common in the western part of the state and may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in this portion of the state. The lake was not thermally stratified during any of the four quarters sampled (see Figure 44c-44f). The water column was evenly mixed and oxygenated during the entire study period, which may be attributed to the shallow nature of the lake. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Lake Etling based on dissolved oxygen values. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 samples none exceeded the prescribed screening level or geometric mean listed in the WQS. The PBCR beneficial use is therefore considered supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 3.50 mg/L at the lake surface, much higher than seen in most Oklahoma lakes and reservoirs. The TN at the surface ranged from 2.31 mg/L to 4.51 mg/L. The highest was reported in the summer quarter and lowest surface TN value was reported in the fall quarter. The lake-wide total phosphorus (TP) average was 0.213 mg/L at the lake surface. The TP ranged from 0.122 mg/L to 0.293 mg/L at the lake surface. The highest surface TP values were reported in the spring quarter and the lowest were in the fall quarter. The total nitrogen phosphorus ratio (TN:TP) was 16:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

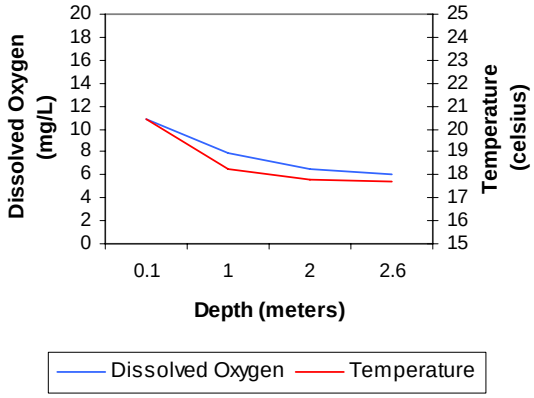
In summary, Lake Etling was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels (Plate 36). Based on secchi disk depth, turbidity and true color, Lake Etling had fair water clarity in 2003-2004. The FWP beneficial use was fully supported based on dissolved oxygen; however the use is not supported as it relates to turbidity. The lake was also found to be “provisionally not supporting” the FWP use as it relates to pH with 28% of the values outside the 6.5 to 9 range listed in the WQS. The lake was fully supporting its Aesthetics beneficial use for true color. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 samples none exceeded the prescribed screening level or geometric mean listed in the WQS. The PBCR beneficial use is therefore considered supported. Lake Etling is owned and operated by the State of Oklahoma for the purpose of providing recreational opportunities to the citizens of Oklahoma.

a. Seasonal Turbidity Values for Lake Etling

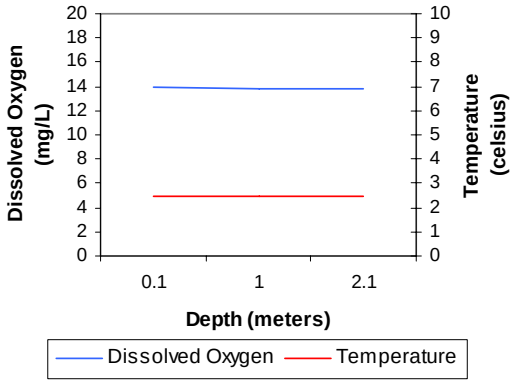


b. Seasonal Color Values for Lake Etling

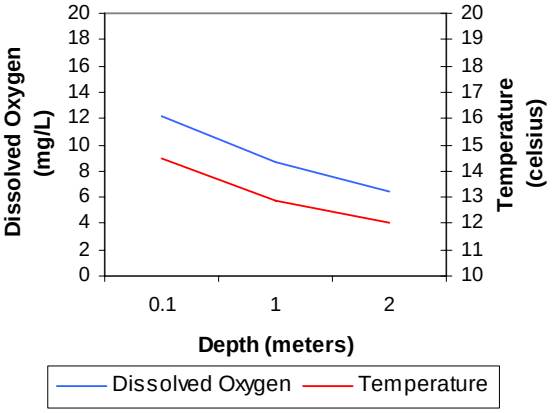
c. Profile of Lake Etling
September 15, 2003



d. Profile of Lake Etling
December 15, 2003



e. Profile of Lake Etling
March 23, 2004



f. Profile of Lake Etling
June 22, 2004

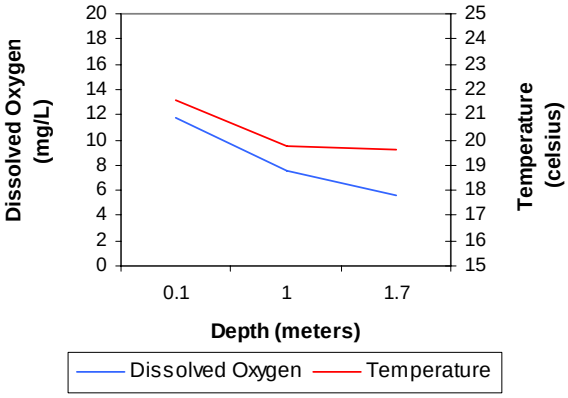


Figure 44a-44f. Graphical representation of data results for Lake Etling.

Etling Lake
and
Watershed

Turbidity
2004

Trophic State
2004

Lake Data	
Owner	State of Oklahoma
County	Cimarron
Constructed in	1958
Surface Area	159 acres
Volume	1,717 acre/feet
Shoreline Length	5 miles
Mean Depth	10.80 feet
Watershed Area	37 square miles (OK only)

Plate 36 - Lake Water Quality for
Lake Etling

LAKES MONITORING PROGRAM

Eucha Lake

Eucha Lake was sampled for four quarters from October 2004 through July 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the lake. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site1, the dam site. The average lake-wide turbidity was 9 NTU (Plate 37), true color was 19 units, and secchi disk depth was 98 centimeters. Based on these three parameters water clarity at Eucha Lake was good in comparison to other Oklahoma reservoirs. Results for these parameters are similar to those observed 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 56 (Plate 37), indicating the lake was eutrophic, indicative of high primary productivity and nutrient levels in sample year 2004-2005. The TSI values varied seasonally and generally ranged from mesotrophic in the winter to eutrophic the remainder of the year. The exception being site three, which had very low chlorophyll-a values, reported in both winter and spring and dipped down to oligotrophic. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (WQS). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Seasonal turbidity values are displayed in Figure 45a. Turbidity values ranged from a low of 2 NTU to a maximum of 30 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 5% of the recorded values exceeding 25 NTU the Fish and Wildlife Propagation (FWP) beneficial use is considered fully supported. Seasonal true color values were all well below the WQS of 70 units and are displayed in Figure 45b. Applying the same default protocol, the Aesthetics beneficial use is considered supported.

In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.05 parts per thousand (ppt) to 0.13 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductivity ranged from 121.6 µS/cm to 275.1 µS/cm, indicative of minimal levels of current conducting ions (salts) in the lake system. The values for pH ranged from 6.9 to 9.05 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only two values greater than 9 pH units, Eucha Lake is fully supporting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from 12 mV in the hypolimnion in the fall to 429 mV in the spring quarter. In general, reducing conditions were not present at this reservoir, with all values above 100 mV, with the exception of the fall quarter when anoxic conditions were present for much of the water column (see Figure 45c). The lake was stratified and anoxic conditions were present in the hypolimnion during both

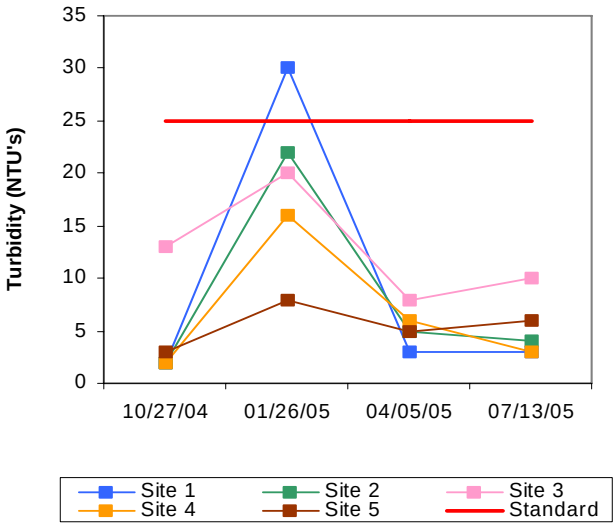
fall and summer sampling intervals. In the fall stratification occurred between 7 and 8 meters with dissolved oxygen levels dropping below 2.0 mg/L from 10 meters for the remainder (55%) of the water column at site 1, the dam site. During the summer sampling interval, stratification occurred between 3 and 4 meters at site 1 accounting for 84% of the water column being anoxic. Anoxic conditions were also present at sites 2,4, and 5 where D.O. was below 2.0 mg/L for 38 to 70% of the water column at these sample sites. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With anoxic conditions present for 55% of the water column in the fall and 84% of the water column in the summer Eucha Lake is considered to be not supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

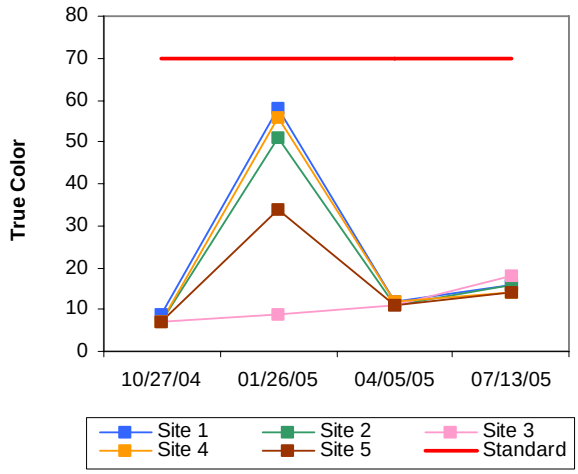
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.92 mg/L at the surface. Surface TN ranged from 0.55 mg/L to 4.25 mg/L with the highest values recorded in the winter quarter and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.047mg/L at the surface. Similar to total nitrogen surface TP was highest in the winter quarter however lower values were reported in the spring quarter with values ranging from 0.021 mg/L to 0.108 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 41:1 for sample year 2004-2005. This value is much higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Eucha Lake was classified as eutrophic, with high primary productivity and nutrient levels in 2004-2005. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (WQS) and is considered nutrient threatened and a nutrient impairment study should be conducted to determine if uses are impaired. Several studies have been conducted in Eucha/Spavinaw complex by the OWRB and other state agencies and can be referenced for further information. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on pH and turbidity values, however the use is considered not supported supporting with 84% of the water column experiencing anoxic conditions during the summer quarter. With 100% of the true color values well below the WQS of 70 units the Aesthetics beneficial use is supported based on this parameter. Eucha Lake, located in Delaware County, is owned by the city of Tulsa utilized for a water supply and recreation. In 1999, the Tulsa Municipal Authority contracted the OWRB to conduct a bathymetric survey of Eucha Lake (Figure 46) to determine current lake volume, capacity and sedimentation rates. The survey information was used to support numerical modeling of proposed water quality improvements by the OWRB. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Paul Koenig at (405) 530-8800.

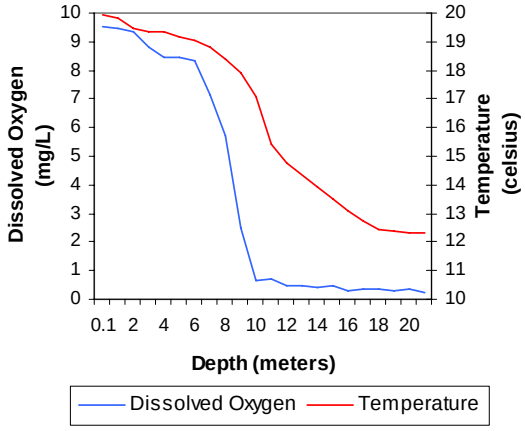
a. Seasonal Turbidity Values for Eucha Lake



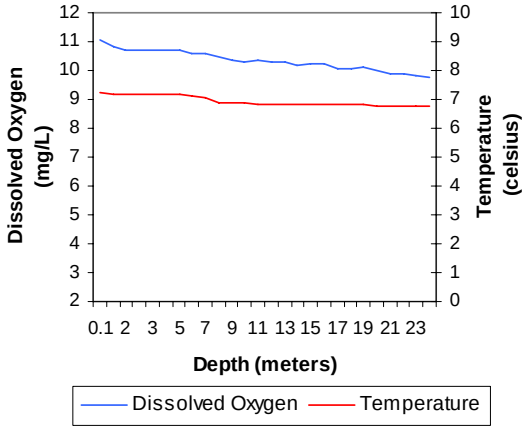
b. Seasonal Color Values for Eucha Lake



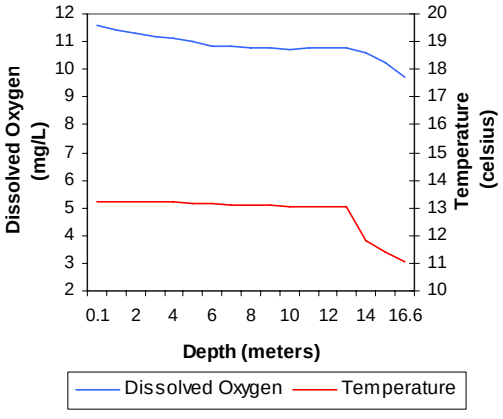
c. Profile of Eucha Lake
October 27, 2004



d. Profile of Eucha Lake
January 26, 2005



e. Profile of Eucha Lake
April 05, 2005



f. Profile of Eucha Lake
July 13, 2005

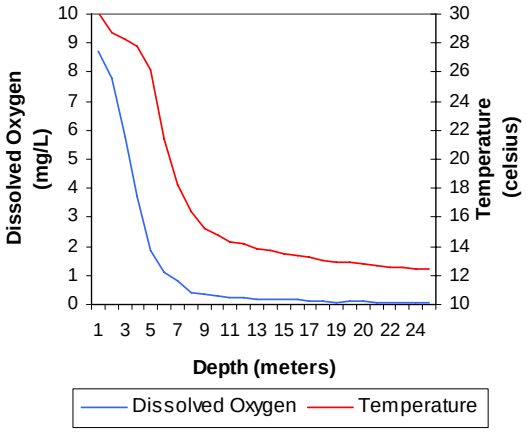
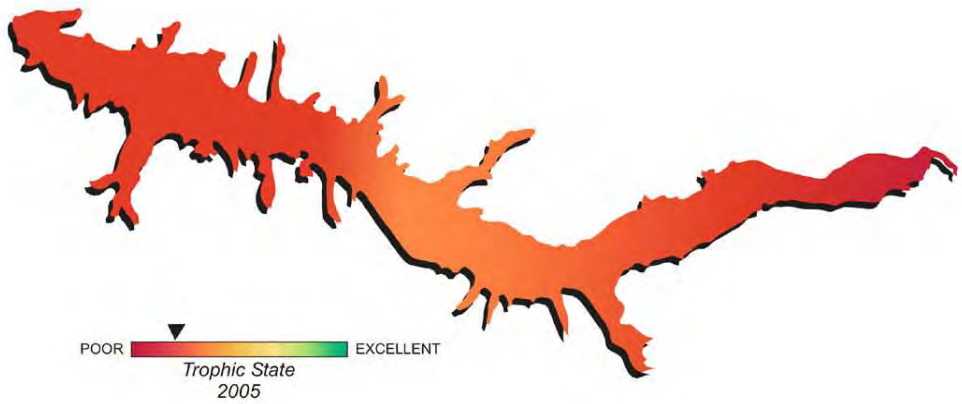


Figure 45a-45f. Graphical representation of data results for Eucha Lake.

Lake Data	
Owner	City of Tulsa
County	Delaware
Constructed	1952
Surface Area	2,860 acres
Volume	79,600 acre/feet
Shoreline Length	49 miles
Mean Depth	27.83 feet
Watershed Area	216 square miles



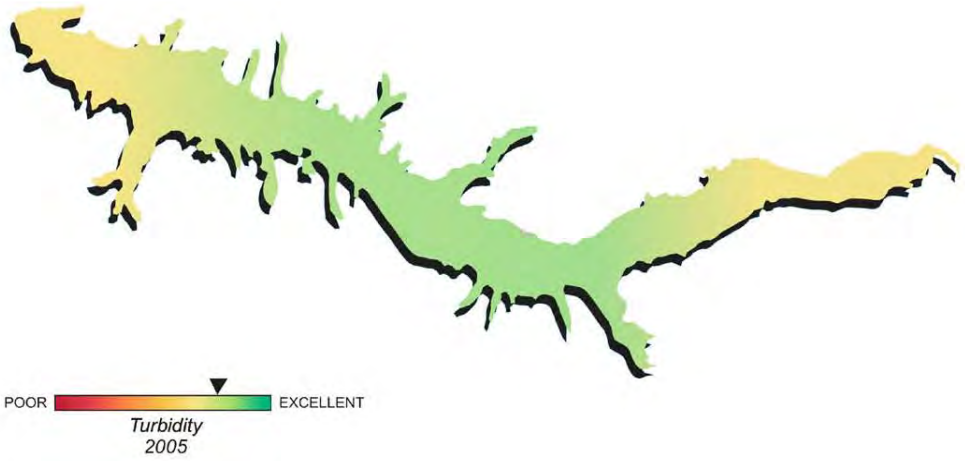


Plate 37- Lake Water Quality for
Lake Eucha

LAKES MONITORING PROGRAM

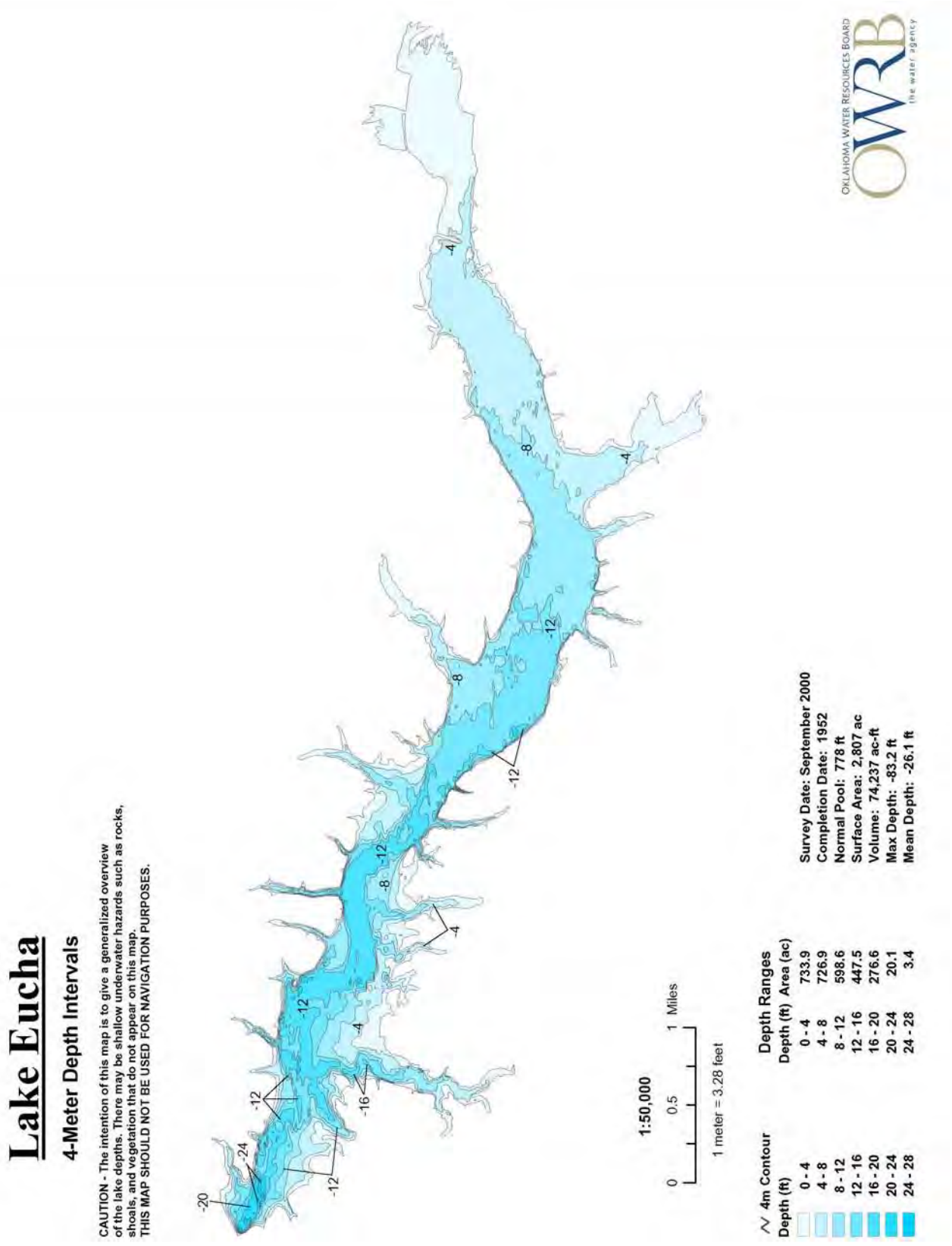


Figure 46. Bathymetric Map of Eucha Lake.

Eufaula Lake

Eufaula Lake was sampled for four quarters from November 2004 through August 2005. Water quality samples were collected at seventeen (17) sites to represent the riverine, transition and lacustrine zones, and major arms of the reservoir. This is the largest lake monitored by BUMP in both surface acres and number of sites sampled. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 7, the dam. The lake-wide average turbidity was 38 NTU (Plate 38), true color was 90 units, and secchi disk depth was 57 centimeters. Water clarity was average at Eufaula Lake in comparison to other Oklahoma reservoirs based on these three parameters, and results are higher than those of the 2003 evaluation. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=68). The TSI was 52 (Plate 38), indicating the lake was eutrophic, indicative of high primary productivity and nutrient levels in sample year 2004-2005. This value is identical to that calculated in 2003, (TSI=52), indicating no significant increase or decrease in productivity has occurred. The TSI values varied seasonally and ranged from oligotrophic to hypereutrophic. Turbidity values varied by site and by season, but were typically above the Oklahoma Water Quality Standard (WQS) of 25 NTU in the more riverine portions of the lake and below the standard in the lacustrine portions of the lake. The highest turbidity values throughout the year occurred at sites 14-17, the Gaines Creek arm. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 53% of the turbidity values above the standard, the Fish and Wildlife Propagation (FWP) beneficial use is not supported based on turbidity (see Figure 47a). Seasonal true color values are displayed in Figure 47b. True color values followed the same trend as turbidity, with values exceeding the WQS of 70 units in the more riverine portions of the lake with the highest values recorded at sites 14-17 throughout the year except for the summer quarter. Of the values collected, 44.1% exceeded 70 units. Applying the same default protocol, the Aesthetic beneficial use is not supported based on true color.

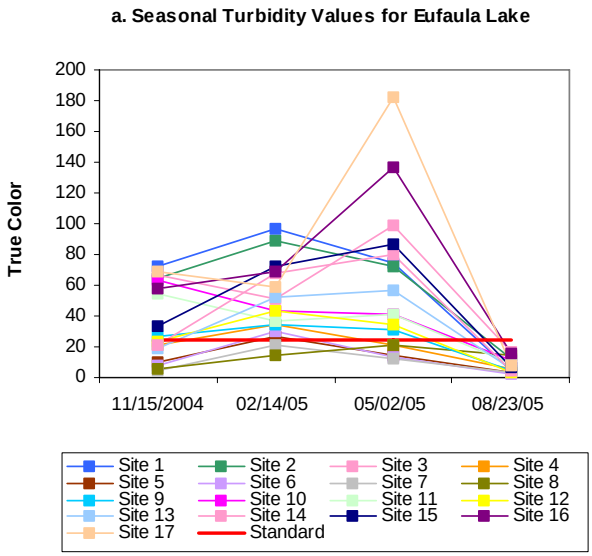
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the 2004-2005-sample year. Salinity values at Eufaula Lake varied by site and season, but generally ranged from 0.04 (fall, site 17) to 0.67parts per thousand (spring, site 10). The lowest salinity values occurred in the fall (site 17), and throughout the year were generally lowest in the Gaines Creek arm of the reservoir (sites 14-17). The highest values were in the spring (site 10) and were always highest in the Canadian River arm (sites 10 and 11) throughout the year. Specific conductivity ranged from 50.4 µS/cm to 908.7 µS/cm, indicative of moderate to high levels of current conducting ions (salts) in the lake system. The trend for conductivity was similar to salinity, as the Canadian arms were always higher and the Gaines Creek arm sites had the lowest values throughout the year. The recorded values for pH ranged from 7.04 to 8.55 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if

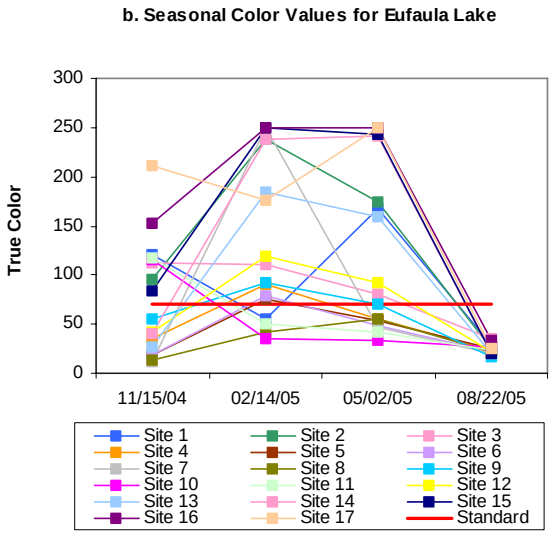
25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of collected values within the acceptable range, Eufaula Lake is supporting its FWP beneficial use for pH. In general, the lake was not thermally stratified during the fall, winter, and spring sampling quarters and the water column was mixed (see Figure 47c-47e). Dissolved oxygen (D.O.) remained above 6.0 mg/L in this time period. In the summer, the lake was stratified throughout at different depths depending on the site. Dissolved oxygen levels below the thermocline were less than 2.0 mg/L for the remainder of the water column (Figure 47f). Anoxic conditions were present at sites 5-9 and 11-14, which are generally deeper sites, accounting for 18 to 56% of the water column having oxygen levels below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With anoxic conditions present in up to 56% of the water column in the summer Eufaula Lake is considered to be partially supporting the FWP beneficial use. These conditions could, however, pose a serious concern, threatening fish and wildlife propagation and the lake should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

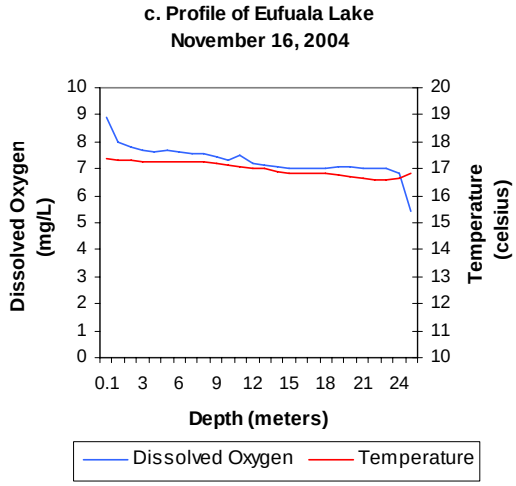
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

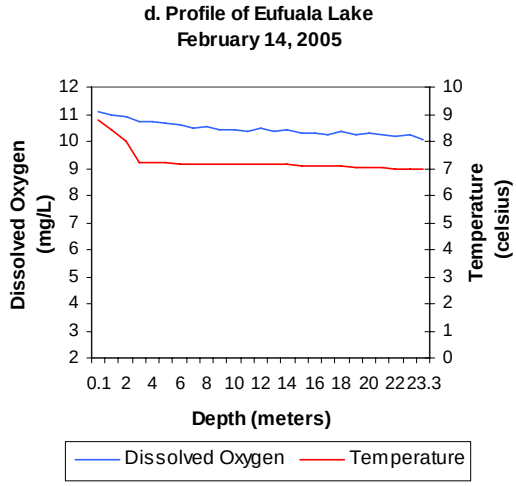
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.70 mg/L at the surface. Surface TN ranged from 0.29 mg/L to 1.16 mg/L with the highest values recorded in the winter and lowest in the summer quarter. The lake-wide total phosphorus (TP) average was 0.076 mg/L at the surface. TP values at the surface ranged from 0.019 mg/L to 0.165 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 9:1 for sample year 2004-2005. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

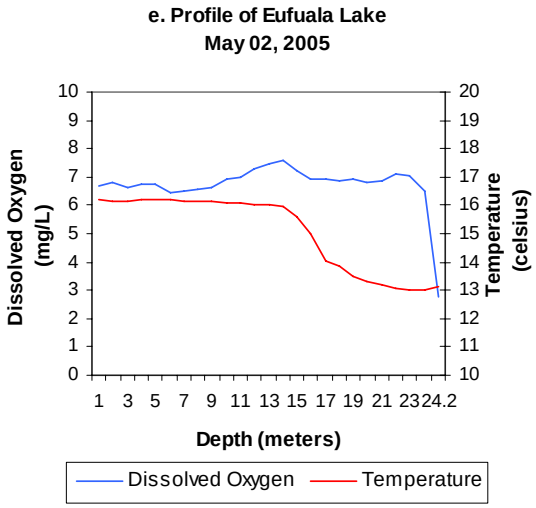
In summary, Eufaula Lake was classified as eutrophic with high primary productivity and nutrient rich conditions. This is the same classification as 2003 (TSI=52), indicating no significant increase or decrease in productivity has occurred. Water clarity was average in comparison to other Oklahoma reservoirs based on turbidity, true color, and secchi disk depth. The lake is considered not supporting the FWP beneficial use based on turbidity, and partially supporting based on dissolved oxygen levels. Anoxic conditions present throughout the lake in the summer could pose a threat to fish and wildlife propagation and should be monitored closely in the future. With 100% of collected values within the acceptable range, Eufaula Lake is supporting its FWP beneficial use for pH. The Aesthetics baneful use is supported based on trophic status, but not supported based on true color values as 44.1% of the collected values exceed the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Eufaula Lake, located in Haskell County, was constructed by the United State Army Corps of Engineers (USACE) for flood control, water supply, hydroelectric power and navigational purposes.











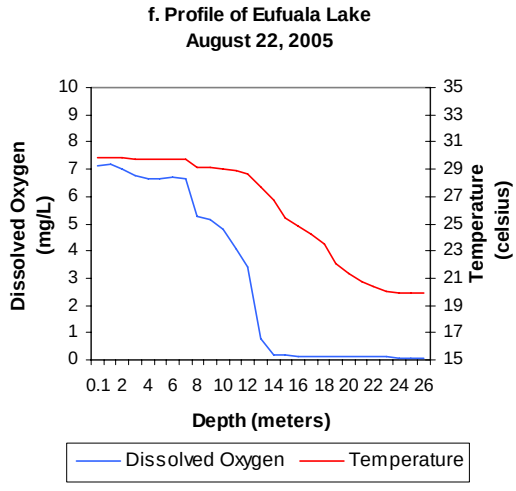
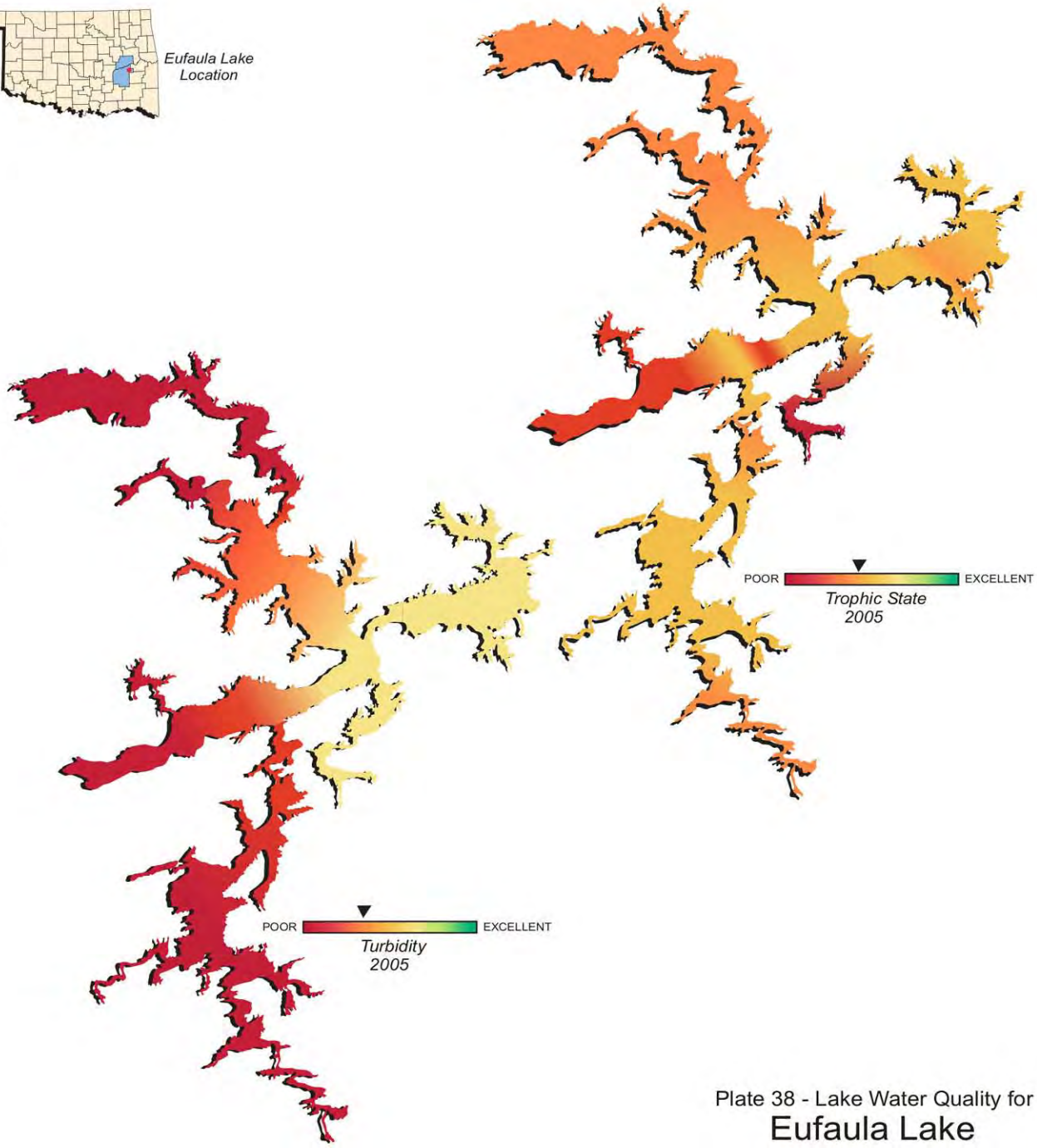


Figure 47a-47f. Graphical representation of data results for Eufaula Lake.

Eufaula Lake Location

Eufaula Lake and Watershed



Lake Data	
Consrtucted by	Corps of Engineers
County	McIntosh (Dam)
Constructed	1964
Surface Area	105,500 acres
Volume	2,314,600 acre/feet
Shoreline Length	600 miles
Mean Depth	21.94 feet
Watershed Area	47,522 square miles

Plate 38 - Lake Water Quality for
Eufaula Lake

LAKES MONITORING PROGRAM

Fairfax City Lake

Fairfax City Lake was sampled for four seasons, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 12 NTU (Plate 39), true color was 25 units, and secchi disk depth was 91 centimeters. Based on these three parameters, Fairfax City Lake had good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 47 (Plate 39), indicating the lake was mesotrophic, indicative of moderate levels of productivity and nutrient conditions. The TSI values were mesotrophic in the first three seasons and lower eutrophic during the summer. Turbidity values were well below the Oklahoma Water Quality Standard (WQS) of 25 NTU in all seasons, with the exception of the spring quarter (See Figure 48a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 16.6% of the samples exceeded 25 NTU, the Fish & Wildlife Propagation (FWP) beneficial use is considered supported as the spike in turbidity it likely the result of seasonal storm events. Seasonal true color values are displayed in Figure 48b. Similar to turbidity there was a spike in recorded true color values in the spring; however only one (8%) of the twelve values exceeded 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the true color values.

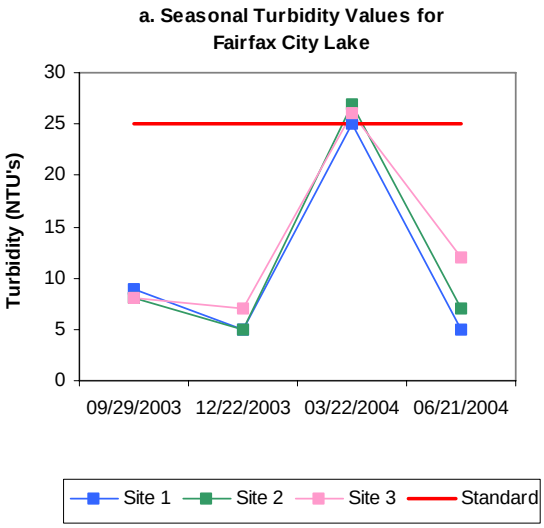
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity values ranged from 0.10 parts per thousand (ppt) to 0.16 ppt, within the expected range for Oklahoma reservoirs. Readings for specific conductivity were also well within the range of expected values for most Oklahoma reservoirs. Conductivity ranged from 217.2 µS/cm recorded in the spring quarter to 326.1 µS/cm recorded in the winter quarter of 2003, indicating moderate concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 352 mV to 501 mV, indicating reducing conditions were not a concern during 2003-2004 sampling. Lake pH values were neutral to slightly alkaline with values ranging from 7.06 in the summer quarter to 8.07 in the winter quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The FWP beneficial use was fully supported based on pH values collected during the study period. The lake was not thermally stratified in the fall or winter quarters and the water column was well mixed (See Figure 48c-48d). The lake was weakly stratified in the spring however anoxic conditions were not present (Figure 48e). Fairfax Lake was strongly thermally stratified in the summer quarter

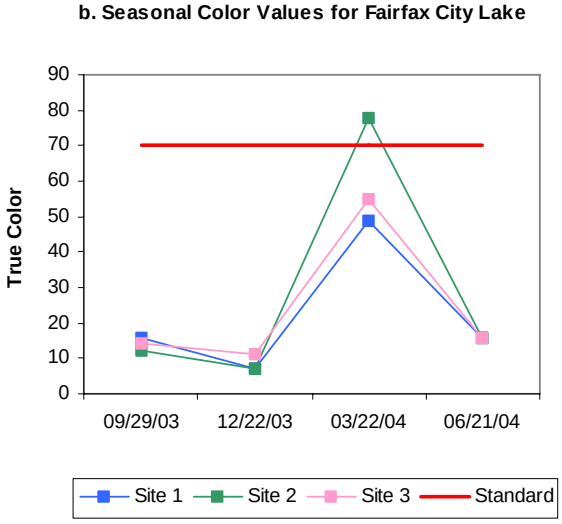
between the 3 and 4 meters depths at which point D.O. values fell below 2.0 mg/L to the lake bottom of 10 meters (see Figure 48f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With approximately 64% of the water column less than 2.0 mg/L the lake is partially supporting its FWP beneficial use based on D.O. values. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

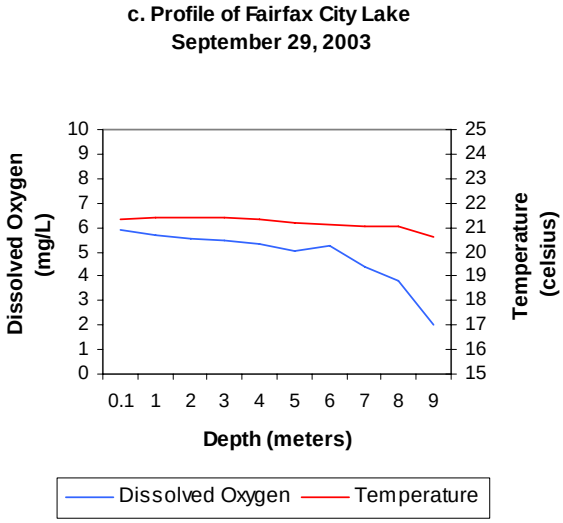
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected two or 20% exceeded the prescribed screening level for enterococci and *E. coli*, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

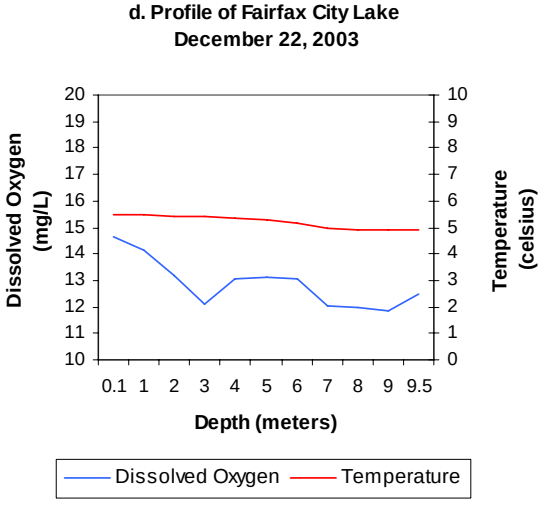
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.51 mg/L at the lake surface. The TN at the surface ranged from 0.40 mg/L to 0.62 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.030 mg/L at the lake surface. The TP ranged from 0.020 mg/L to 0.058 mg/L. The highest surface TP values were reported in the spring quarter and the lowest were in the remaining three quarters. The nitrogen to phosphorus ratio (TN:TP) was approximately 17:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

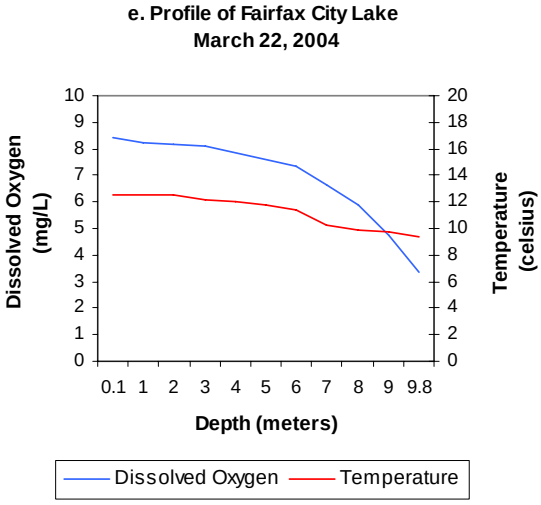
In summary, Fairfax City Lake was classified as mesotrophic indicative of moderate primary productivity and nutrient conditions (Plate 39). The Aesthetics beneficial use was fully supported based on true color values and the lakes trophic state. Fairfax City Lake was fully supporting the FWP beneficial use based on pH and partially supporting based and dissolved oxygen concentrations in the water column. Although 16.6% of the samples exceeded 25 NTU, the Fish & Wildlife Propagation (FWP) beneficial use is considered supported as the spike in turbidity is likely the result of seasonal storm events. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected two or 20% exceeded the prescribed screening level for enterococci and *E. coli* however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Fairfax City Lake is owned and operated by the City of Fairfax and is managed as a water supply reservoir and recreational outlet for the city and the public. In conclusion, the water quality of Fairfax City Lake is very good when compared to other lakes across the state and is one of the nicer smaller municipal lake resources available to the public.











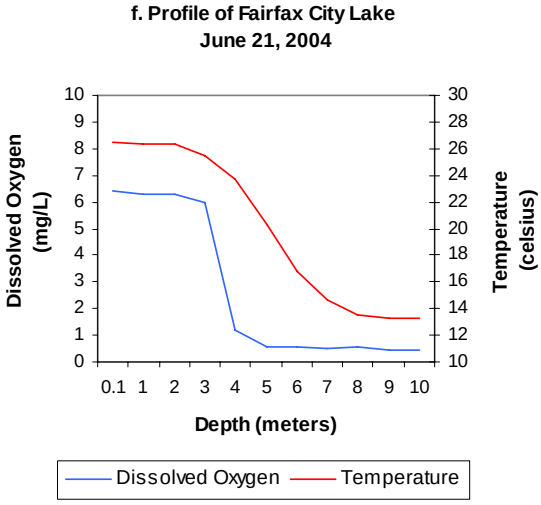
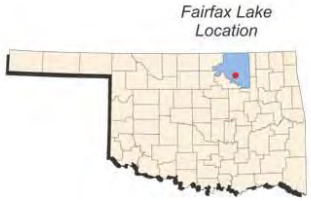
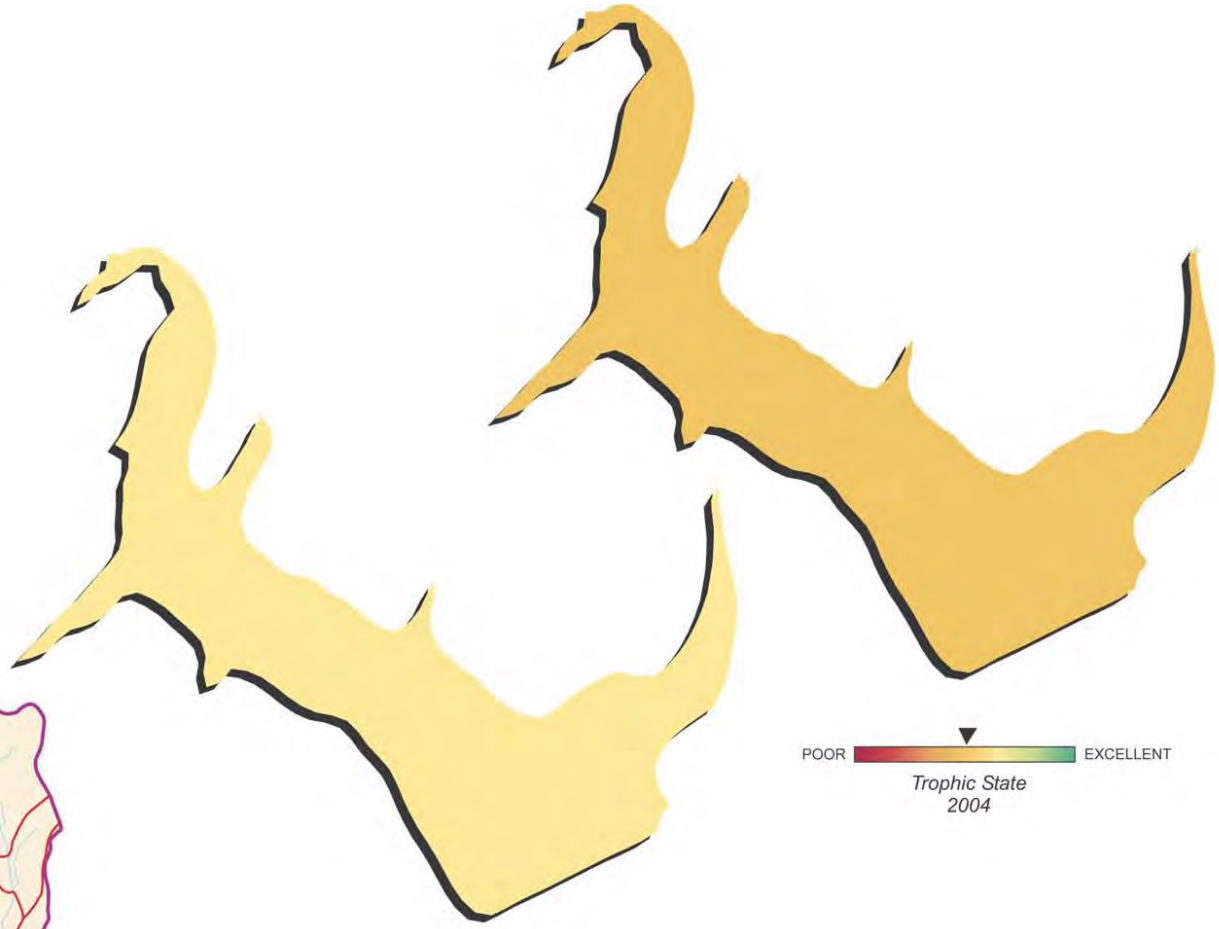


Figure 48a-48f. Graphical representation of data results for Fairfax City Lake.



Fairfax Lake
and
Watershed



Lake Data	
Owner	City of Fairfax
County	Osage
Constructed	1936
Surface Area	111 acres
Volume	1,795 acre/feet
Shoreline Length	4 miles
Mean Depth	16.17 feet
Watershed Area	9 square miles

Plate 39- Lake Water Quality for
Fairfax Lake

LAKES MONITORING PROGRAM

Fort Cobb Reservoir

Fort Cobb Reservoir, located in Caddo County, is situated on Cobb Creek approximately 14 miles northwest of the town of Anadarko. The reservoir is owned and operated by Bureau of Reclamation and was impounded in 1959. The lake serves multiple uses including municipal water supply, flood control, and recreational purposes. Fort Cobb Reservoir was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at six (6) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as any major arms and tributaries. Samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 13 NTU (Plate 40), true color was 20 units, and secchi disk depth was 62 centimeters. Based on these three parameters, Fort Cobb Reservoir had fairly good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=24). The average TSI was 65 (Plate 40), indicating the lake was hypereutrophic, indicative of excessive levels of productivity and nutrient rich conditions. This finding is consistent with historical data collection efforts and supports the listing of the lake as a Nutrient Limited Watershed (NLW) as listed in the Oklahoma Water Quality Standards (WQS). At this time Fort Cobb is considered threatened due to nutrients until a non-support status can be confirmed. The TSI values varied from mid and upper eutrophic in the fall and winter to hypereutrophic in the spring and summer quarters. Site 4 was the only site consistently hypereutrophic throughout the sample year. Only three (12.5%) of the twenty-four turbidity values exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 49a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Fort Cobb reservoir is partially supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Seasonal true color values are displayed in Figure 49b. All true color values were below the Aesthetics WQS of 70 units for all four quarters at all sites thus meeting the Aesthetics beneficial use for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity values ranged from 0.23 parts per thousand (ppt) to 0.58 ppt, slightly higher than the expected range for most Oklahoma reservoirs. Readings for specific conductivity were within the expected range for Oklahoma reservoirs. Specific conductivity ranged from 451.5 µS/cm in the summer to 1111 µS/cm in the winter quarter, indicating moderate to elevated concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 249 mV near the lake bottom in the summer quarter to 429 mV in the fall quarter, indicating reducing conditions were not present in the lake system during 2005-2006 sampling. Lake pH values were neutral to slightly alkaline with values ranging from 7.26 units to 10.69 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as

not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Fort Cobb Reservoir was fully supporting its FWP beneficial use with only 5.6% of the recorded values falling outside the acceptable range. The lake was not thermally stratified in the fall, winter or spring quarters and the lake was well mixed and oxygenated, with dissolved oxygen values above 6.0 mg/L except at the very bottom of the lake (see Figure 49c-49e). During the summer the lake was thermally stratified and anoxic conditions were present. Stratification occurred between 9 and 10 meters below the surface at site 2, at which point dissolved oxygen (D.O.) concentrations fell below 2.0 mg/L and remained below 1.0 mg/L all the way to the lake bottom at 11.7 meters (see Figure 49f). Site three was also stratified with anoxic conditions present in 27% of the water column. When D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With only 23 to 27% of the water column below 2.0 mg/L during the summer quarter the lake is considered to be fully supporting its FWP beneficial use based on D.O. concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

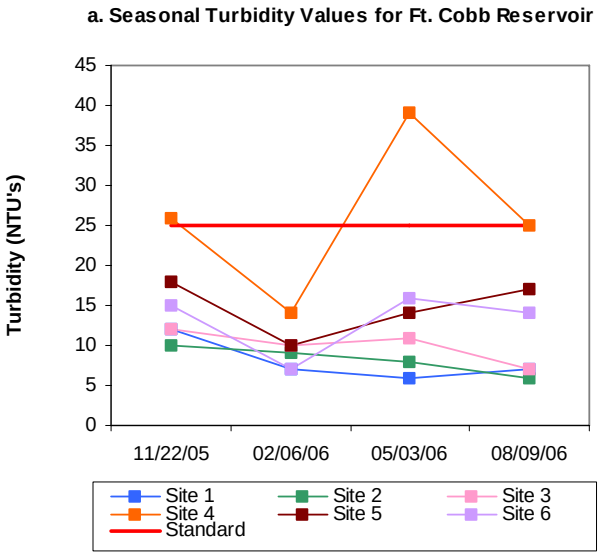
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September of 2006. All sample results were below both the screening level and geometric mean. The PBCR beneficial use is therefore considered supported.

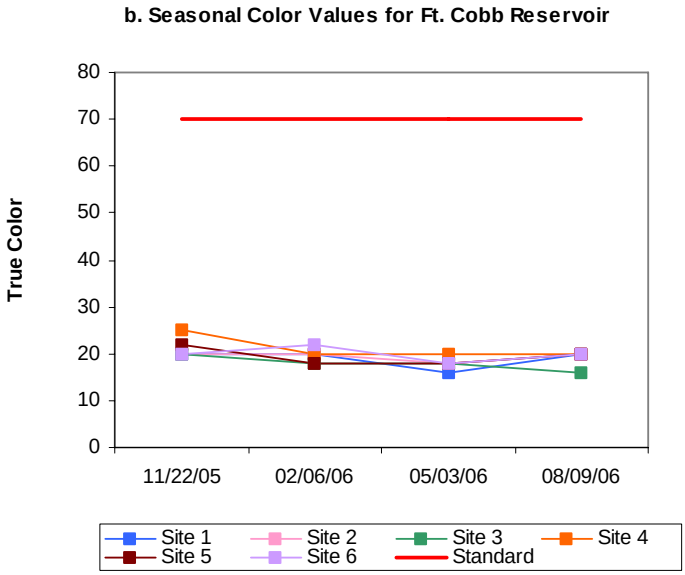
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.11 mg/L during the study period. The TN at the surface ranged from 0.77 mg/L in the spring quarter to 1.52 mg/L recorded in the summer quarter. The lake-wide total phosphorus (TP) average was 0.097 mg/L. The TP ranged from 0.050 mg/L to 0.210 mg/L. The highest surface TP values were reported in the summer and the lowest were in the winter sampling interval. The nitrogen to phosphorus ratio (TN:TP) was 11:1 for sample year 2005-2006 . This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

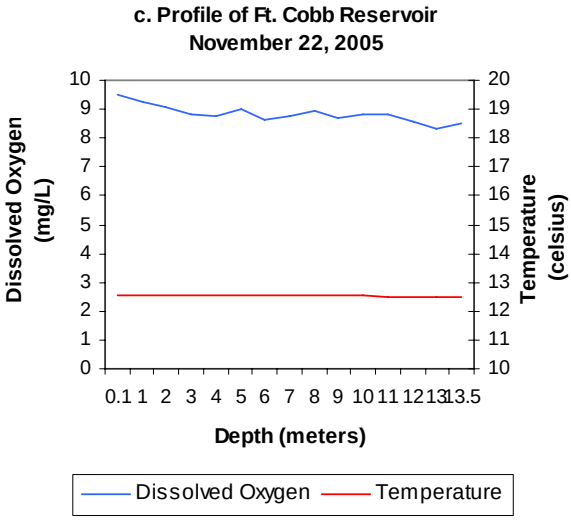
Fort Cobb Reservoir was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

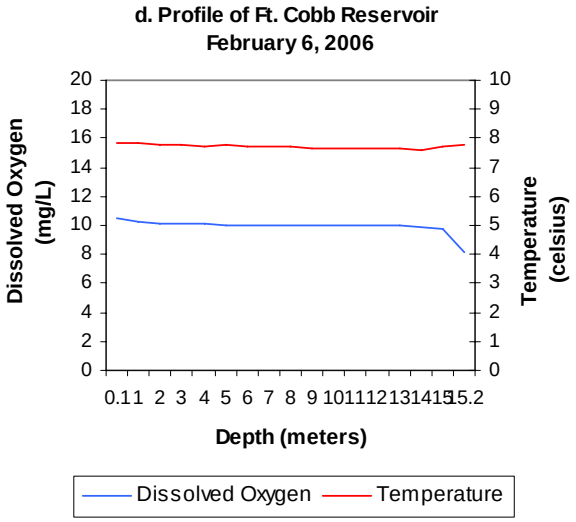
In summary, Fort Cobb Reservoir was classified as hypereutrophic indicative of excessive primary productivity and nutrient rich conditions (Plate 40). This is consistent with findings from previous data collection efforts and further supports the listing of the lake in the WQS as NLW waterbody with nutrient threats present. The high levels of nutrients in the water column, coupled with the relatively good water quality, serves to fuel primary productivity in the lake. The Oklahoma Department of Environmental Quality (ODEQ) recently conducted a Total Maximum Daily Load (TMDL) study on the lake for nutrients and made recommendations for a reduction of both nitrogen and phosphorus. The lake was fully supporting its Aesthetics beneficial use based on true color. With only 23-27% of the water column experiencing anoxic conditions during the summer, the lake is considered supporting the FWP beneficial use as it relates to dissolved oxygen; however the lake is partially supporting the FWP beneficial use for turbidity with 12.5% of the collected values above the WQS criteria of 25 NTU. Fort Cobb Reservoir is fully

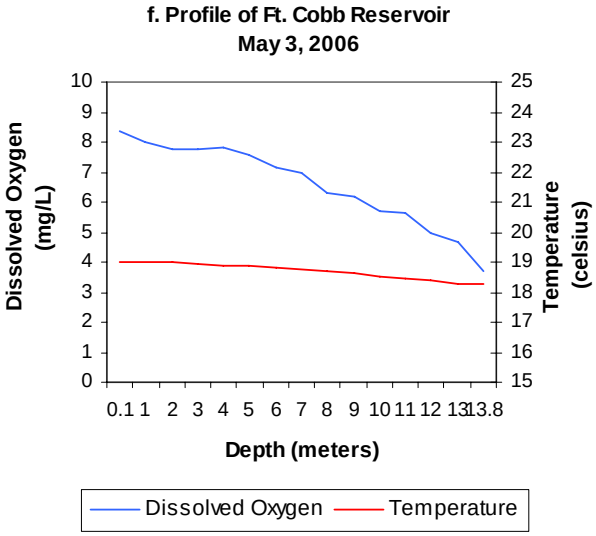
supporting its FWP beneficial use as it relates to pH with only 5.6% of the recorded values falling outside the acceptable range of 6.5 to 9 pH units. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September of 2006. All sample results were below both the screening level and geometric mean. The PBCR beneficial use is therefore considered supported.











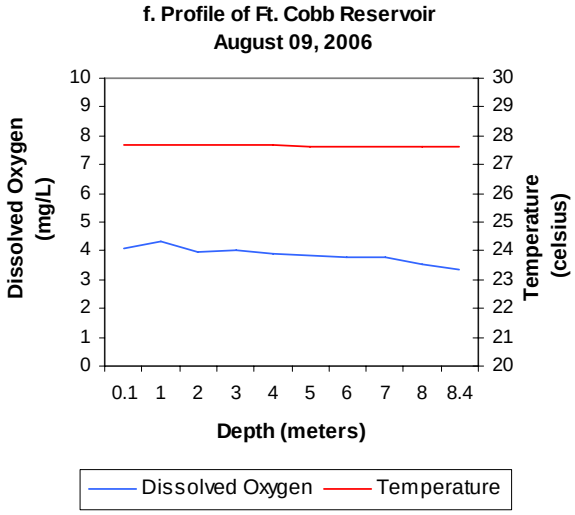
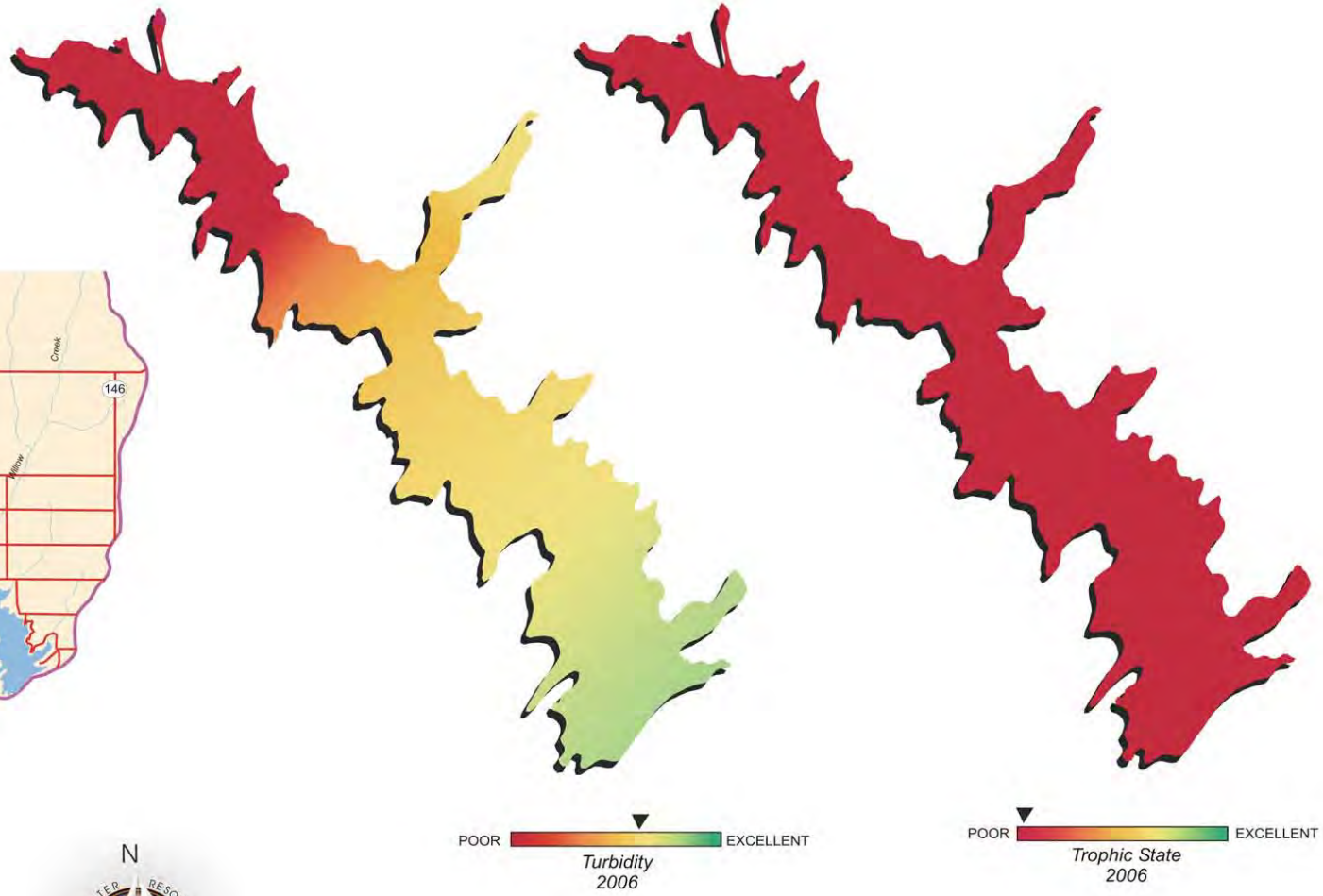


Figure 49a-49f. Graphical representation of data results for Fort Cobb Reservoir.

Fort Cobb Lake Location

Fort Cobb Lake and Watershed



Lake Data	
Consrtucted by	Bureau of Recalmation
County	Caddo
Constructed	1959
Surface Area	4,100 acres
Volume	80,010 acre/feet
Shoreline Length	45 miles
Mean Depth	19.48 feet
Watershed Area	314 square miles

Plate 40 - Lake Water Quality for
Fort Cobb Lake

LAKES MONITORING PROGRAM

Fort Gibson Lake

Fort Gibson Lake was sampled for four quarters, from November 2003 through August 2004. Water quality samples were collected at eight (8) sites to represent the riverine, transitional, and lacustrine zones of the lake as well as any major arms of the reservoir. Samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 12 NTU (Plate 41), true color was 24 units, and secchi disk depth was 85 centimeters in 2004. Based on these three parameters, Fort Gibson Lake had good water clarity in 2004. Water clarity is very similar to 2000-2001, as secchi disk depth has improved while true color and turbidity are about the same as previously reported. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=32). The average TSI was 58, classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is lower than the TSI in 2002 (TSI=64). Based on previous data collection efforts, the lake is listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The TSI values were primarily hypereutrophic or eutrophic at all sites although the TSI at several sites in the winter were mesotrophic or oligotrophic. Only two of the 32 turbidity values exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU (See Figure 50a). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 6% of the reported values above the standard the FWP use is considered supported based on turbidity. All true color values were below the aesthetics WQS of 70 units throughout the sample year (Figure 50b). Applying the same default protocol, the Aesthetics beneficial use is still considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.17 ppt, well within the expected range for most Oklahoma reservoirs. Readings for specific conductivity were within the expected range for Oklahoma reservoirs. Specific conductivity ranged from 234 µS/cm in the summer quarter to 309.5 µS/cm in the fall quarter, indicating low to moderate concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 282mV near the lake bottom in the fall quarter to 544 mV in the summer quarter, indicating reducing conditions were not present in the lake system during 2003-2004 sampling. Lake pH values were neutral to slightly alkaline with values ranging from 7.25 units to 8.65 all within the WQS range of 6.5-9.0 units, therefore the FWP beneficial use was supported based on pH. The lake was not thermally stratified in the fall, winter or spring quarters and the lake was well mixed and oxygenated, with dissolved oxygen values above 5.0 mg/L except at the very bottom of the lake (see Figure 50c-50e). Fort Gibson Lake was thermally stratified during

the summer quarter between 10 and 11 meters below the surface at site 1, at which point dissolved oxygen (D.O.) concentrations fell below 2.0 mg/L and remained below 1.0 mg/L all the way to the lake bottom at 17.3 meters (see Figure 50f). Site 1 was the only sample station to have D.O. concentrations less than 5.0 mg/L at the lake surface. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With approximately 28% of the water column violating the criteria the lake is considered to be fully supporting its FWP beneficial use based on D.O. concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61cfu/ml however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

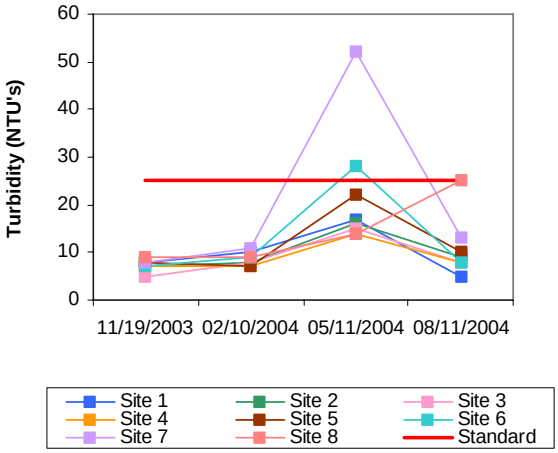
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.97 mg/L at the lake surface and 0.94 mg/L at the lake bottom. The TN at the surface ranged from 0.49 mg/L in fall quarter to 1.77 mg/L recorded in the spring quarter. The lake-wide total phosphorus (TP) average was 0.100 mg/L at the lake surface to 0.097 mg/L at the lake bottom. The TP ranged from 0.048 mg/L to 0.149 mg/L. The highest surface TP values were reported in the fall and the lowest were in the winter. The nitrogen to phosphorus ratio (TN:TP) was 10:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

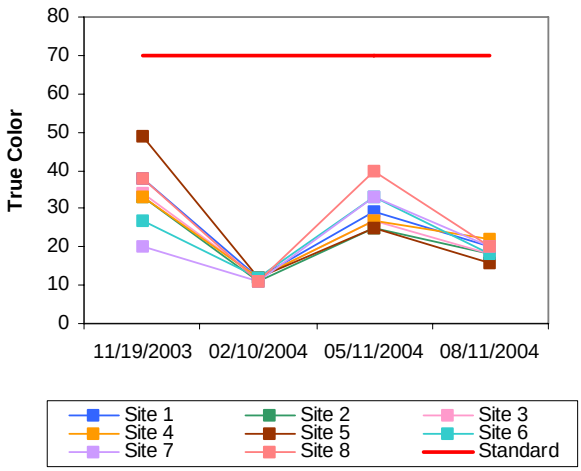
In summary, Fort Gibson Lake was classified as eutrophic indicative of high primary productivity and nutrient rich conditions (Plate 41). The lake was fully supporting its Aesthetics beneficial use based on true color. Based on previous from previous data collection efforts the lake is currently listed in the WQS as Nutrient Limited Watershed (NLW) water. This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. With only 6.3% of the collected values above the WQS criteria for turbidity, the lake is fully supporting its FWP beneficial use for turbidity and with 28% of the experiencing anoxic conditions at site 1 during the summer, the lake is also supporting the FWP beneficial use as it relates to dissolved oxygen. There are high levels of nutrients in the water column, which coupled with the relatively good water quality serves to fuel primary productivity in the lake. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61cfu/ml however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Fort Gibson Lake, constructed by the USACE, was built for flood control and hydroelectric

power purpose. The lake also provides many recreational opportunities for the citizens of Oklahoma to enjoy.

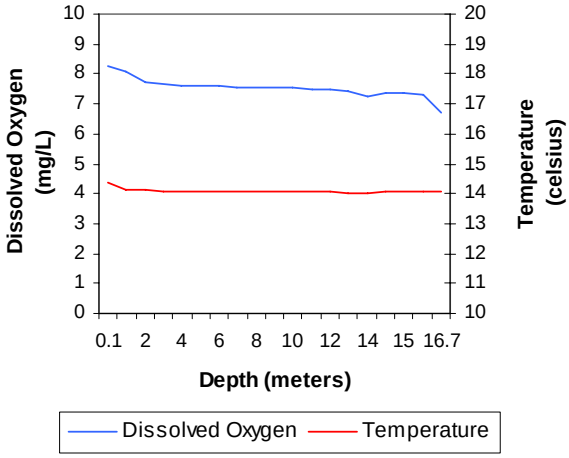
a. Seasonal Turbidity Values for Ft. Gibson Lake



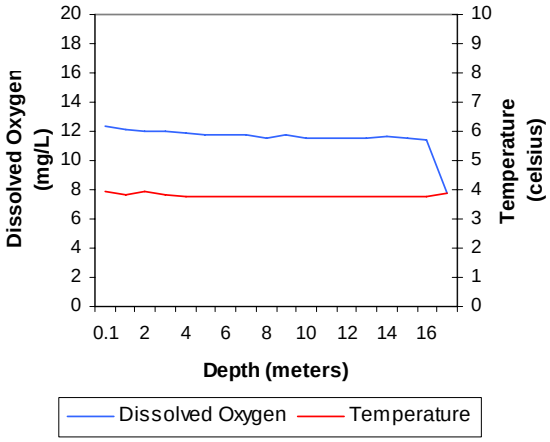
b. Seasonal Color Values for Ft.Gibson Lake



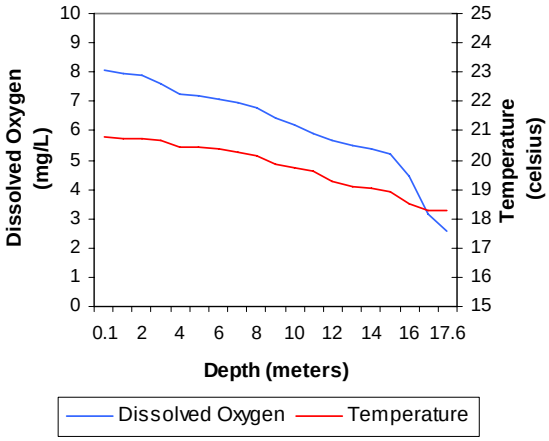
c. Profile of Ft. Gibson Lake
November 19, 2003



d. Profile of Ft. Gibson Lake
February 10, 2004



e. Profile of Ft. Gibson Lake
May 11, 2004



f. Profile of Ft. Gibson Lake
August 16, 2004

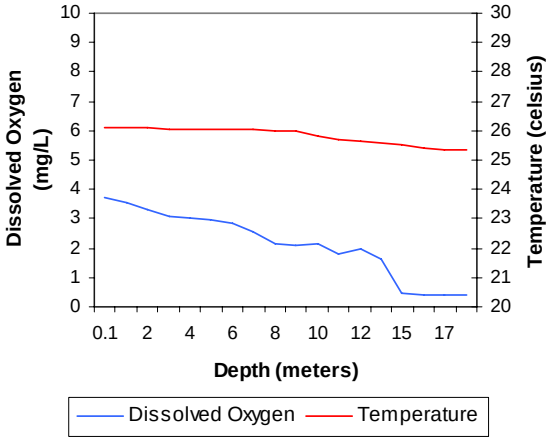


Figure 50a-50f. Graphical representation of data results for Ft. Gibson Lake.

Fort Gibson Lake Location

Fort Gibson Lake and Watershed

Lake Data	
Consrtucted by	Corps of Engineers
County	Cherokee (Dam)
Constructed	1953
Surface Area	19,900 acres
Volume	365,200 acre/feet
Shoreline Length	225 miles
Mean Depth	23.84 feet
Watershed Area	12,492 square miles

Turbidity 2004

Trophic State 2004

Plate 41 - Lake Water Quality for
Fort Gibson Lake

LAKES MONITORING PROGRAM

Fort Supply Lake

Fort Supply Lake, located in Woodward County, is approximately 1 mile south of the town of Fort Supply. The United States Army Corps of Engineers built the reservoir in 1942 for flood control and hydroelectric power purposes. Fort Supply Lake was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 45 NTU (Plate 42), true color was 46 units, and secchi disk depth was 34 centimeters. Based on these three parameters, Fort Supply Lake had fair to poor water clarity in 2005-2006, similar to findings in previous data collection efforts. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 57 (Plate 42), classifying the lake in the upper end of eutrophy, indicative of high levels of productivity and high nutrient conditions. This is the same as the TSI calculated in 2004, indicating no significant change in productivity has occurred since the last evaluation. Currently Fort Supply Lake is listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The TSI values were primarily eutrophic throughout the year with low hypereutrophic conditions observed at half the sites in both the fall and summer quarters. Turbidity values are displayed in Figure 51a. According to the Use Support Assessment Protocols (USAP) detailed in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The Fish & Wildlife Propagation (FWP) beneficial use is not supporting with 74% of the collected values exceeding the numeric criteria of 25 NTU. Seasonal true color values are shown in Figure 51b. Applying the same default protocol, the Aesthetics beneficial use is considered supporting with 5% of the true color values exceeding the WQS of 70 units.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.45 parts per thousand (ppt) to 0.55 ppt, which is much higher than the range of expected values for Oklahoma lakes, reflecting elevated levels of chlorides or other salts in the lake. Specific conductivity values were also above the expected range for Oklahoma reservoirs, coinciding with the high salinity concentrations. Values ranged from 867.2 µS/cm in the fall to 1053 µS/cm recorded in the summer. Oxidation-reduction potentials (redox) ranged from 345 mV in the summer quarter to 424 mV in the spring, indicating reducing conditions were not present at the time of sampling. Lake pH values were neutral to slightly alkaline with values ranging from 7.33 in the spring to 8.39 in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With

100% of the pH values recorded within the acceptable range, the lake is supporting its FWP beneficial use as it relates to pH. Thermal stratification was not evident in any quarterly sampling events due to the shallow nature of the reservoir and fact that wind mixing prevents a thermocline from developing (see Figure 51c-51f). Dissolved oxygen (D.O.) values were above 3.5 mg/L throughout the water column at all sites during the study period, indicating the water column was well oxygenated and well mixed. When D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered fully supported at Fort Supply Lake based on D.O. values. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.93 mg/L at the lake surface. The TN at the surface ranged from 0.76 mg/L to 1.36 mg/L. Both the highest and lowest surface TN values were reported in the summer sampling interval. The lake-wide total phosphorus (TP) average was 0.077 mg/L at the lake surface. The TP ranged from 0.035 mg/L to 0.123 mg/L. The highest surface TP value was reported in the summer and the lowest was in the winter. The nitrogen to phosphorus ratio (TN:TP) was 12:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2004 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening or consumption advisory levels. Fort Cobb Reservoir was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Fort Supply Lake was classified as eutrophic, bordering hypereutrophic, indicative of high primary productivity and high nutrients (Plate 42). The TSI of 57 is consistent with that of previous data collection efforts in 2004, indicating that no significant increase or decrease in productivity has occurred. Water clarity continues to be fair to poor based on turbidity, true color and secchi disk depth. With only 5% of the true color values exceeding the WQS of 70 units, the lake is supporting its Aesthetics beneficial use as it relates to color. Fort Supply Lake is currently listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The FWP beneficial use is not supporting with 74% of the turbidity values exceeding the WQS of 25 NTU; however the use is supported based on pH and dissolved oxygen concentrations in the lake. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results

were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

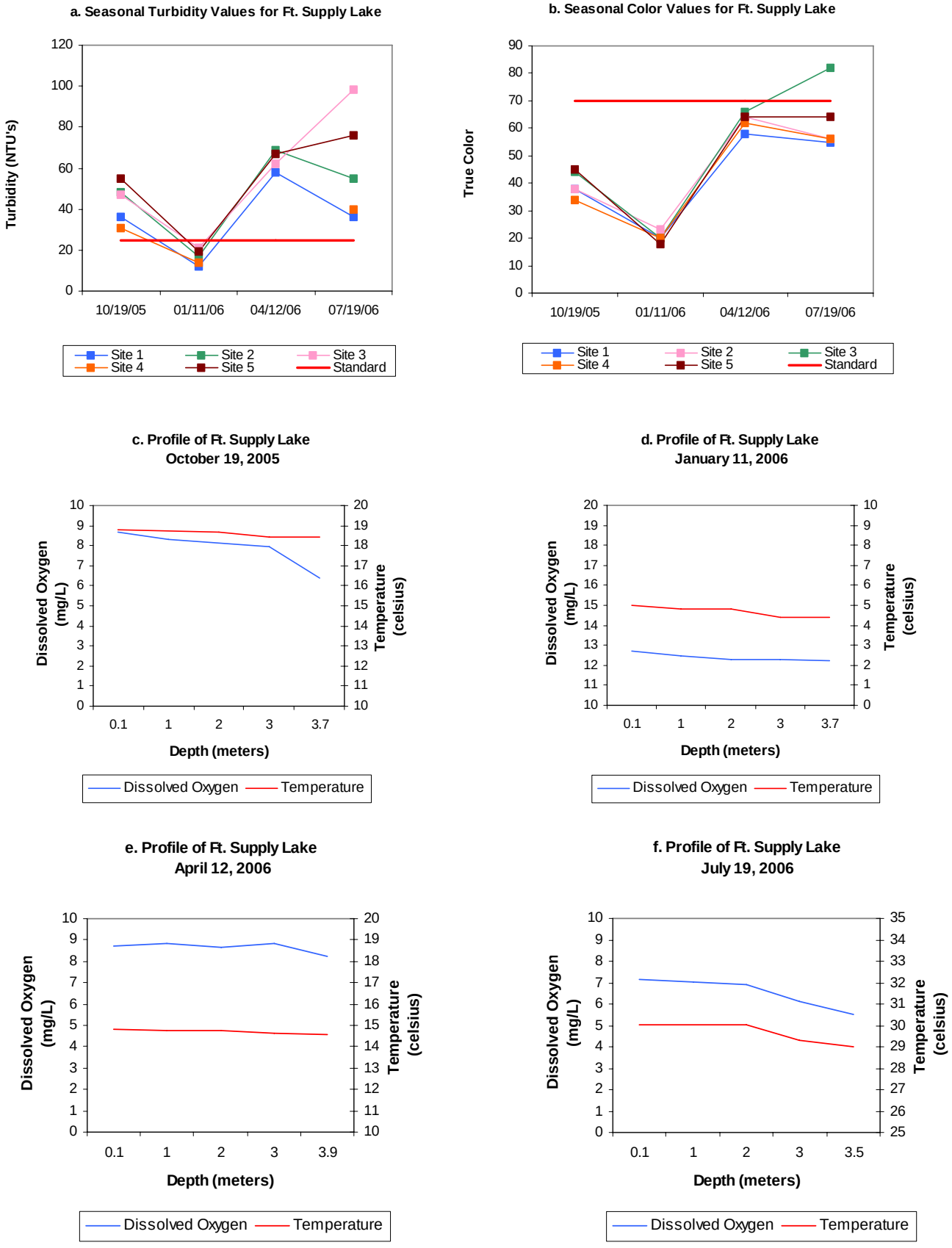
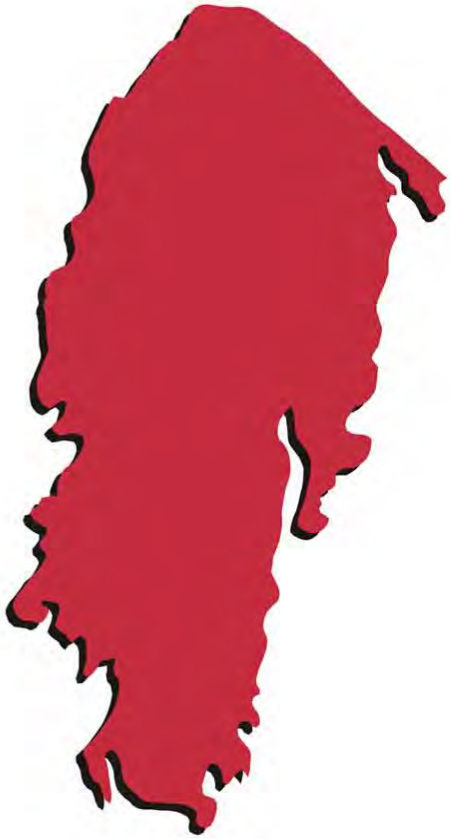
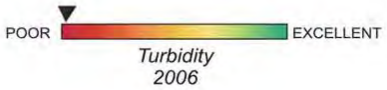


Figure 51a-51f. Graphical representation of data results for Fort Supply Lake.



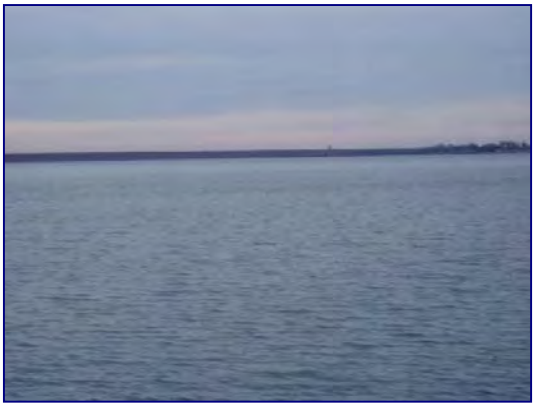


Lake Data	
Consrtucted by	Corps of Engineers
County	Woodward
Constructed	1942
Surface Area	1,820 acres
Volume	13,900 acre/feet
Shoreline Length	26 miles
Mean Depth	7.64 feet
Watershed Area	1,735 square miles

Plate 42 - Lake Water Quality for

Fort Supply Lake

Foss Reservoir



Foss Reservoir was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition and lacustrine zone of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 9 NTU (Plate 43), true color was 8 units, and average secchi disk depth was 97 centimeters in sample year 2004-2005. Water clarity was good at Foss Reservoir based on these three parameters. Results for turbidity, true color, and secchi disk depth are similar to those recorded in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The current TSI of 52 (Plate 43) is higher than that calculated in 2003 (TSI=48) placing the lake in a different trophic category. The TSI of 52 indicates the lake was eutrophic, with high levels of productivity and nutrient conditions for sample year 2005. The TSI values for all sites varied seasonally and ranged from oligotrophic in the summer to mesotrophic in the winter and spring with eutrophic values in the fall. The only exception to this pattern occurred at site 5, which generally had higher TSI values through out the year and was even hypereutrophic in the fall. Seasonal turbidity values by site are displayed in Figure 52a. Turbidity values ranged from a low 4 NTU to a maximum of 30 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is considered supported at Foss Reservoir with only 1(5)% of the values above the turbidity standard of 25 NTU. Seasonal true color values are displayed in Figure 52b. All color values are well below the aesthetics WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered supported based on true color data collected during the study period.

In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Foss Reservoir ranged from 1.06 parts per thousand (ppt) to 1.24 ppt, which is higher than most Oklahoma reservoirs. Specific conductivity was also high ranging from 1963 (summer) µS/cm to 2320 µS/cm (fall), indicating extremely high concentrations of current conducting compounds (chlorides and salts) in the lake, consistent with higher salinity concentrations. The pH values were generally neutral to slightly alkaline ranging from 6.68 at the lake bottom in the spring to 8.3 at the surface in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values recorded within the acceptable range the lake supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 357 mV at the surface in the fall to 577 mV during the spring, indicating reducing conditions

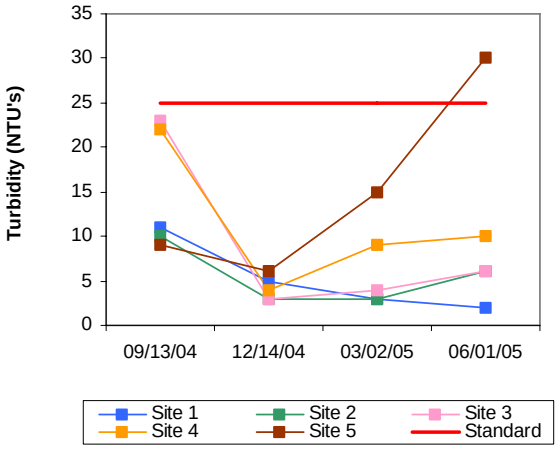
were not present during any of the sampling intervals. During the fall, winter, and spring thermal stratification was not present and the lake was well mixed with dissolved oxygen values remaining above 6.0 mg/L (see Figure 52c-52e). The lake was thermally stratified during the summer sampling interval however anoxic conditions were not present at any sites at the time of sampling. Stratification generally occurred between 7 and 8 meters at sites 1-3, the deepest sites in the reservoir. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With D.O. greater than 2.0 mg/L in all sampling intervals, Foss Reservoir is considered supporting the FWP beneficial use for sample year 2004-2005. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

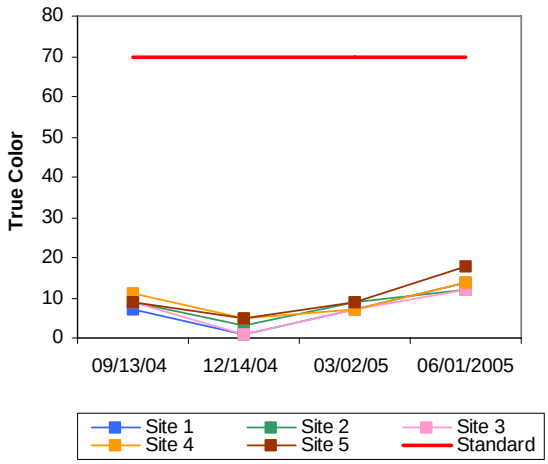
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.67 mg/L at the surface. Surface TN ranged from 0.49 mg/L to 1.12 mg/L with both the highest and lowest values recorded in the winter quarter. The lake-wide total phosphorus (TP) average was 0.022 mg/L at the surface. TP values at the surface ranged from 0.014 mg/L to 0.039 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 30:1 for sample year 2004-2005. This value is much higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Foss Reservoir was classified as eutrophic with high primary productivity and nutrient conditions. The current TSI of 52 (Plate 43) is higher than that calculated in 2003 (TSI=48) placing the lake in a different trophic category. Water clarity was good based on turbidity, true color and secchi disk depth. The FWP beneficial use is supported based on pH, turbidity and dissolved oxygen levels recorded throughout the study period. The Aesthetics beneficial use is also considered supported at Foss Reservoir based on its trophic status and true color. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Foss Reservoir was constructed by Bureau of Reclamation to serve as a flood control, water supply and a fish and wildlife recreation reservoir. Foss State Park is located in western Oklahoma in Custer County.

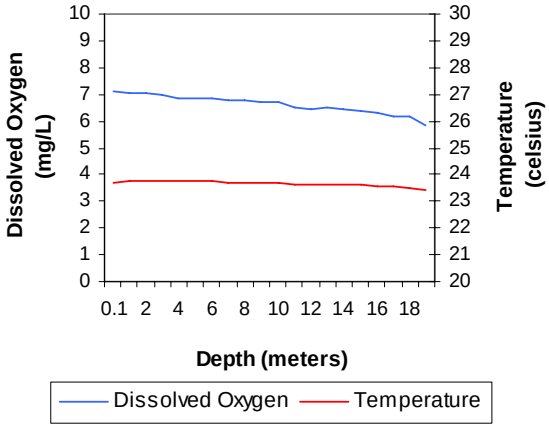
a. Seasonal Turbidity Values for Foss Reservoir



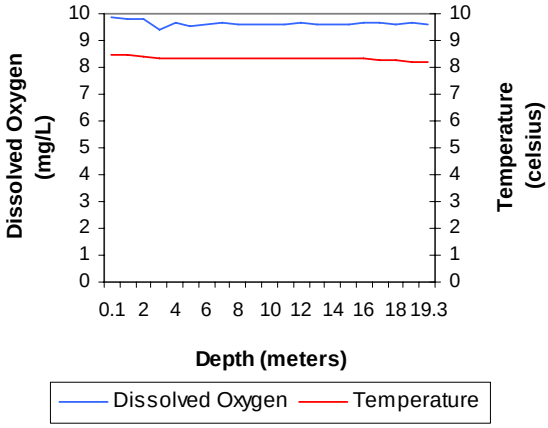
b. Seasonal Color Values for Foss Reservoir



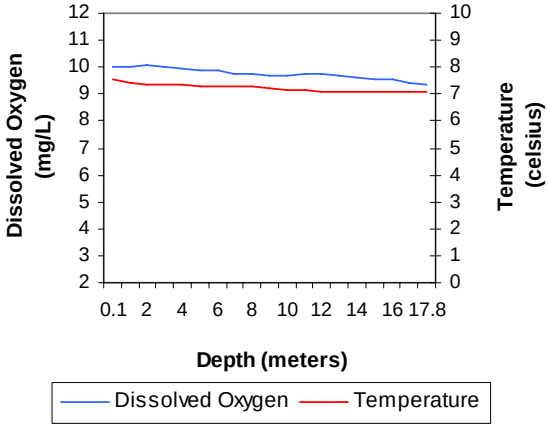
c. Profile of Foss Reservoir
September 13, 2004



d. Profile of Foss Reservoir
December 14, 2004



e. Profile of Foss Reservoir
March 02, 2005



f. Profile of Foss Reservoir
June 01, 2005

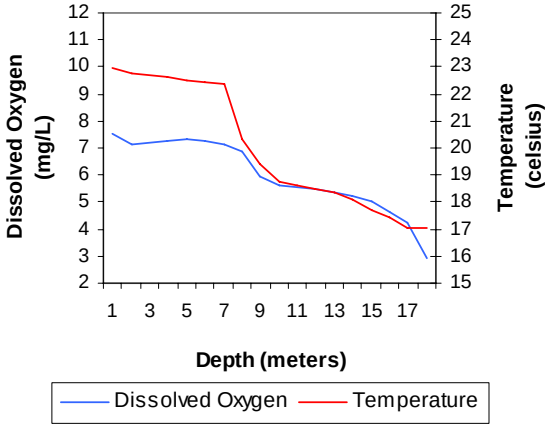
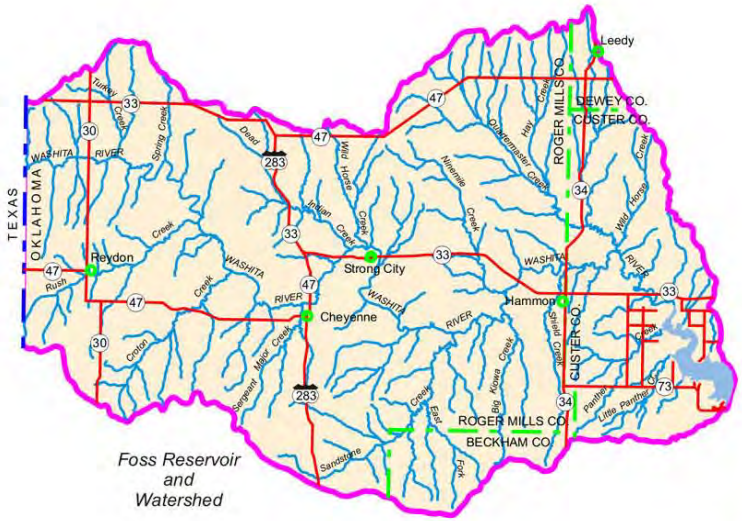
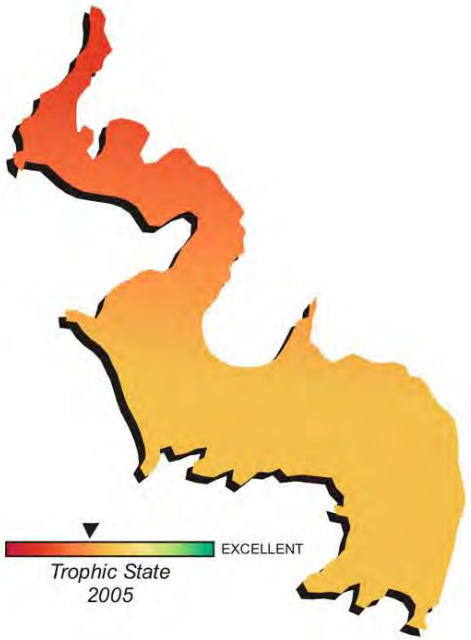
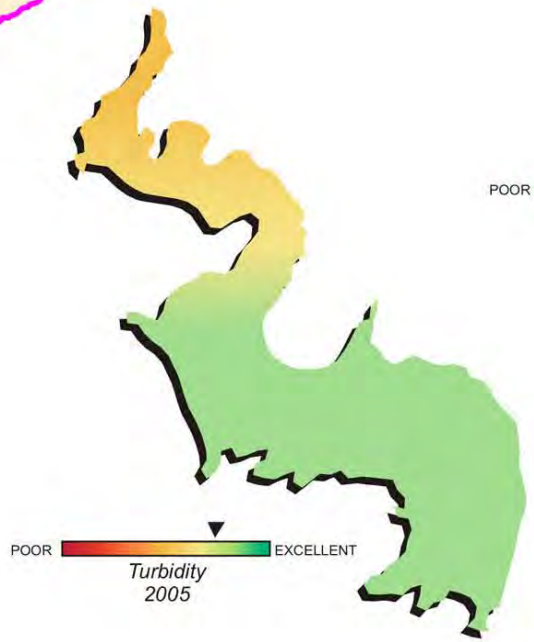


Figure 52a-52f. Graphical representation of data results for Foss Reservoir.







Lake Data	
Owner	U.S. Dept. of the Interior
County	Custer
Constructed in	1961
Surface Area	8,800 acres
Volume	256,220 acre/feet
Shoreline Length	63 miles
Mean Depth	23.15 feet
Watershed Area	1,496 square miles

Plate 43 - Lake Water Quality for

Foss Reservoir

LAKES MONITORING PROGRAM

Lake Frederick

Frederick Lake was sampled for four quarters from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 78 NTU (Plate 44), true color was 108 units, and secchi disk depth was 15 centimeters. Based on these three parameters, Frederick Lake had poor water clarity in 2005. Water clarity was similar to historical data and is likely always poor based on the soil composition and nature of this lake. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 51 (Plate 44), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. This value is consistent with the TSI in 2003 (TSI=51) indicating no significant increase or decrease in productivity has occurred since the previous evaluation. The TSI values ranged from upper mesotrophic bordering eutrophic in the fall and winter to eutrophic in the spring with mesotrophic values at all sites in the summer quarter. Seasonal turbidity values are displayed in Figure 53a. All turbidity values were well above the turbidity standard of 25 NTU with the lowest recorded value of 37 NTU and the maximum value of 212 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥ 25% of the samples exceed the Oklahoma Water Quality Standard (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. With 100% of turbidity values exceeding 25 NTU, the Fish and Wildlife Propagation (FWP) beneficial use is not supported at Lake Frederick. Seasonal true color values are displayed in Figure 53b. Of the twenty values collected eleven (55%) exceeded the WQS of 70 units. Applying the same default protocol, the Aesthetic beneficial is not supported.

In 2004-2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Lake Frederick ranged from 0.21 parts per thousand (ppt) to 0.25 ppt, which is within the range of expected values for most Oklahoma reservoirs in this part of the state. Specific conductivity ranged from 417.2 µS/cm to 484.5 µS/cm, indicating moderate concentrations of current conducting compounds (chlorides and salts) in the lake system. The pH values were neutral to slightly alkaline in nature, ranging from 7.61 at the lake bottom in the summer to 8.28 at the surface in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values recorded within the acceptable range the Lake Frederick is supporting the FWP beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 327 mV in the spring to 482 mV in the hypolimnion during the fall. All ORP values were positive and above 100 mV indicating reducing conditions were not present in the lake at the time of sampling. Thermal stratification was not present and the lake was well mixed with dissolved oxygen (D.O) values remaining above 4.0 mg/L (see Figure 53c-53f) throughout the entire sample year. The absence

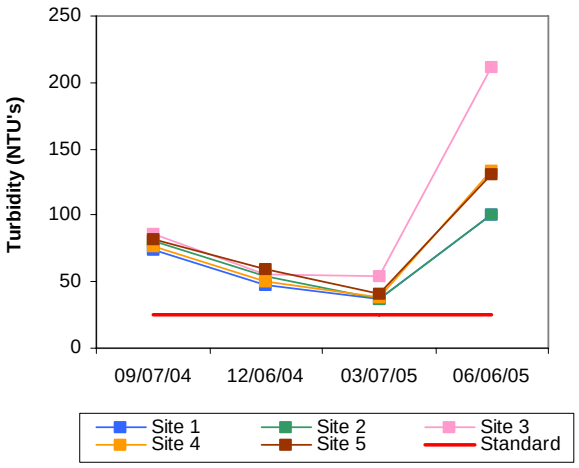
of stratification may be attributed to the shallow nature of this reservoir where wind and wave action keep the lake well mixed. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 100% of the dissolved oxygen values above 2.0 mg/L, Lake Frederick is considered to be supporting the FWP beneficial use. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

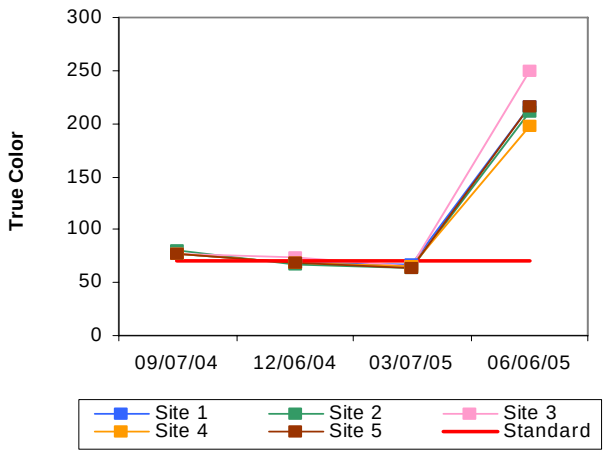
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.70 mg/L at the surface. Surface TN ranged from 0.54 mg/L to 0.86 mg/L with the highest values recorded in the fall quarter. The lake-wide total phosphorus (TP) average was 0.060 mg/L at the surface. TP values at the surface ranged from 0.043 mg/L to 0.085 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 12:1 for sample year 2004-2005. This value is much higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Lake Frederick was classified as eutrophic (TSI=51), indicative of high primary productivity and nutrient rich conditions (Plate 44). This is consistent with the TSI calculated in 2003, indicating no significant change has occurred over time. Productivity in the lake is kept in check due to light limitation driven by high turbidity. Water clarity is poor based on turbidity, true color, and secchi disk depth and will likely to always be poor based on soil composition of the area. The Fish and Wildlife Propagation beneficial use is supported based on dissolved oxygen and pH, but is not supported based on high turbidity values. The Aesthetics beneficial use is supported based on its trophic status, however it is considered not supported for true color with 55% of the reported values exceeding the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Due to the lake's use as a municipal water supply reservoir and past and present drought conditions, the city of Frederick was concerned with sedimentation and current lake volumes. During the summer of 2000 the city of Frederick contracted the OWRB to conduct a bathymetric survey of the lake to generate a bathymetric map (Figure 54) and determine current lake volume. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800. Frederick Lake was constructed in 1974 by the Soil Conservation Service and is located in Tillman County.

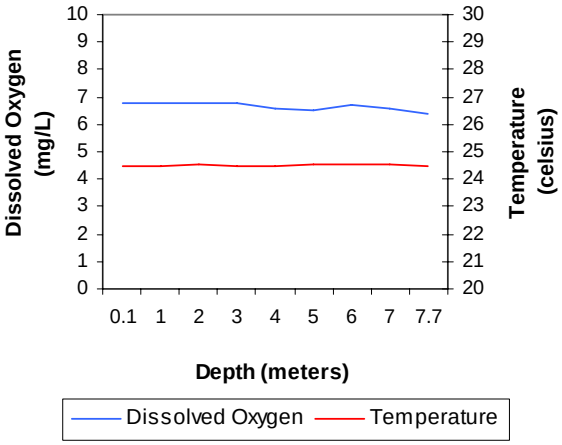
a. Seasonal Turbidity Values for Lake Frederick



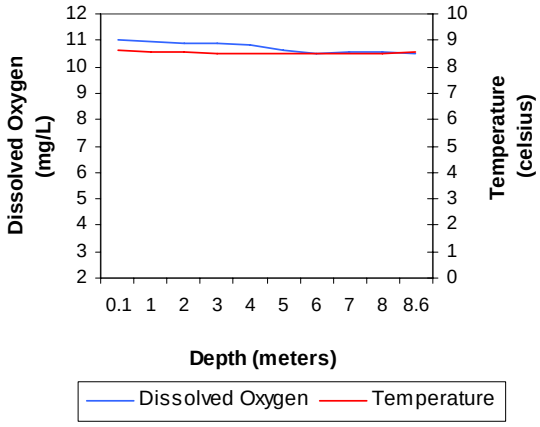
b. Seasonal Color Values for Lake Frederick



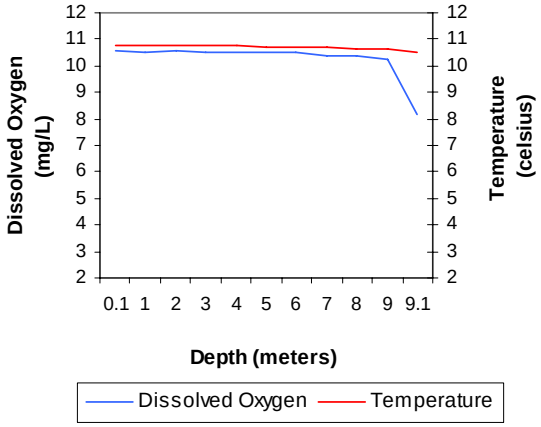
c. Profile of Lake Frederick
September 07, 2004



d. Profile of Lake Frederick
December 06, 2004



e. Profile of Lake Frederick
March 07, 2005



f. Profile of Lake Frederick
March 07, 2005

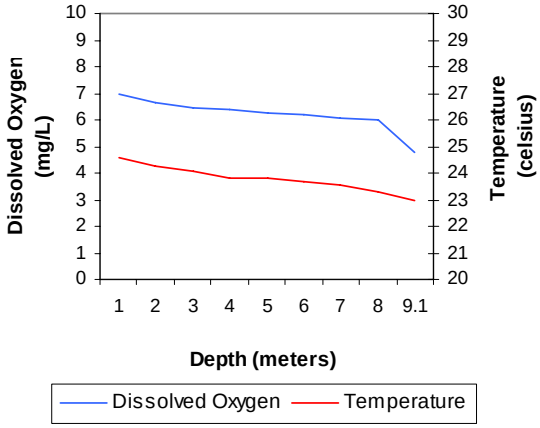


Figure 53a-53f. Graphical representation of data results for Lake Frederick.

Plate 44 - Lake Water Quality for

Lake Frederick

Frederick Lake and Watershed

Lake Data	
Owner	City of Frederick
County	Tillman
Constructed in	1974
Surface Area	876.8 acres
Volume	9,715 acre/feet
Shoreline Length	18.9 miles
Mean Depth	10.83 feet
Watershed Area	57 square miles

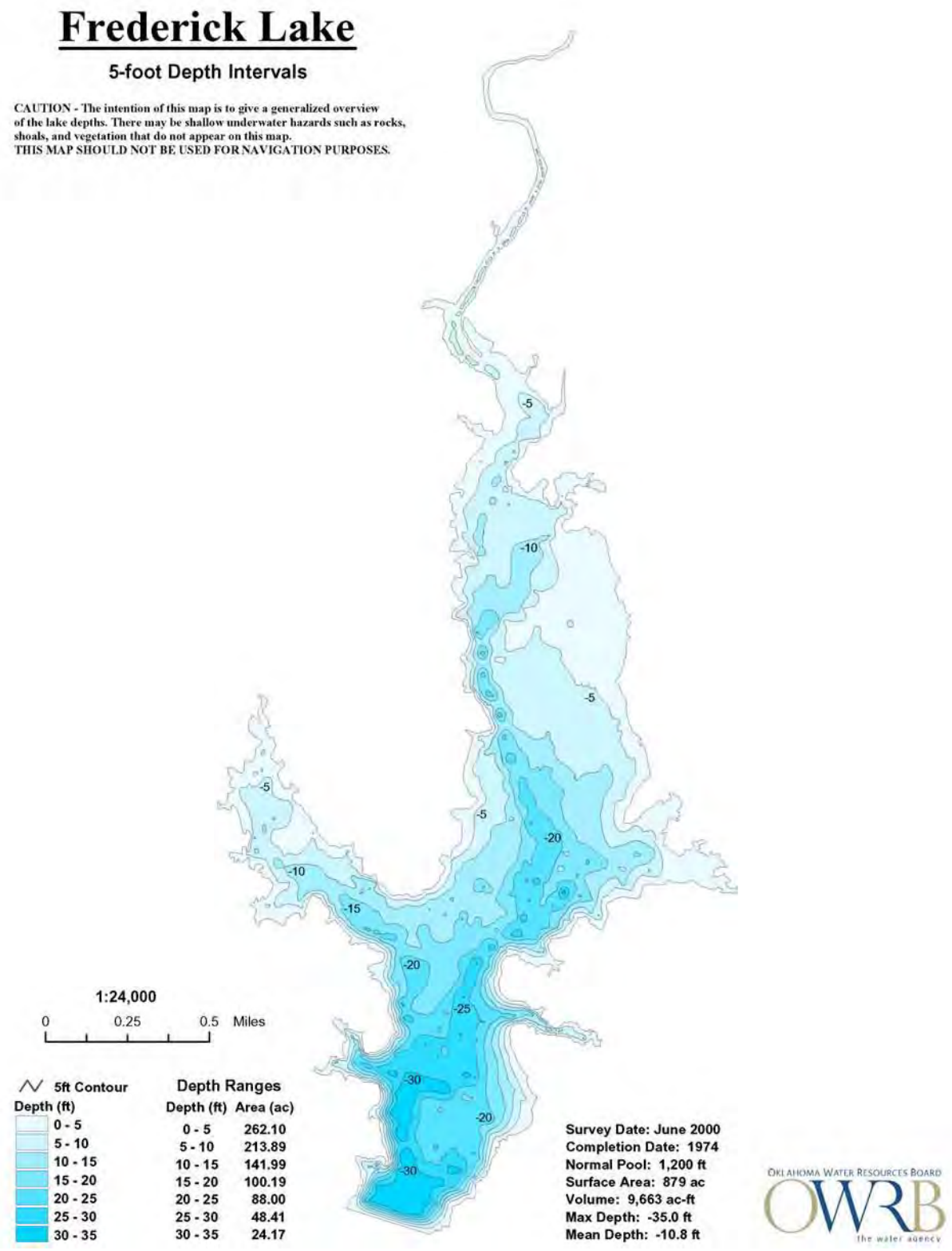


Figure 54. Bathymetric Map of Lake Frederick.

Fuqua Lake

Fuqua Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones and major arms of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 12 NTU (Plate 45), true color was 12 units, and secchi disk depth was 86 centimeters. Based on these three parameters, Fuqua Lake had good water clarity in 2005, similar to than observed in the 2003 evaluation. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 48 (Plate 45), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is similar to the one in 2003 (TSI=47), indicating no significant increase or decrease in productivity has occurred. The TSI values varied seasonally from eutrophic in both fall and winter to mesotrophic in the spring and summer. The only exception to this was during the spring quarter when sites 1-3 had very low chlorophyll-a concentrations reported and the TSI for these sites was oligotrophic. Seasonal turbidity values are displayed in Figure 55a. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standard (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Of the twenty values collected, only one (5%) exceeded 25 NTU, therefore the lake is considered supporting the Fish and Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 55b. All true color values were well below the WQS of 70 units with values ranging from 10-16 color units thought the year. Applying the same default protocol the Aesthetic beneficial use is fully supported based on true color.

In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Fuqua Lake ranged from 0.26 parts per thousand (ppt) to 0.32ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 514 µS/cm to 625.6 µS/cm, indicating moderate concentrations of current conducting compounds or other analogous material (salts) in the lake system. The pH values ranged from 7.2 in the summer to 8.44 during the fall quarter fall representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values recorded within the acceptable range the lake supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 147 mV in the summer to 453 mV in the in the winter. Reducing conditions were not present in the lake during the study period. Thermal stratification was not present and the lake was well mixed with dissolved oxygen (D.O) values remaining above 6.0 mg/L (see Figure 55c-55e) during the first three sampling quarters. Thermal stratification was evident and anoxic conditions present in the summer. During the summer quarter the lake

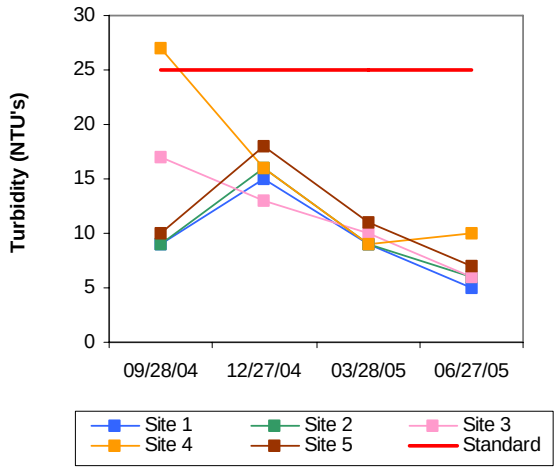
exhibited thermal stratification between 3 and 4 meters with dissolved oxygen dropping below 2.0 mg/L from the 6 meters in depth to the lake bottom of 9.4 meters (see Figure 55f). Sites 2-4 were also stratified between 3 and 4 meters however D.O. was higher throughout the entire water column due to the shallow nature of these sites. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With only 36% of the water column at site 1 less than 2.0 mg/L in the summer Fuqua Lake is considered supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

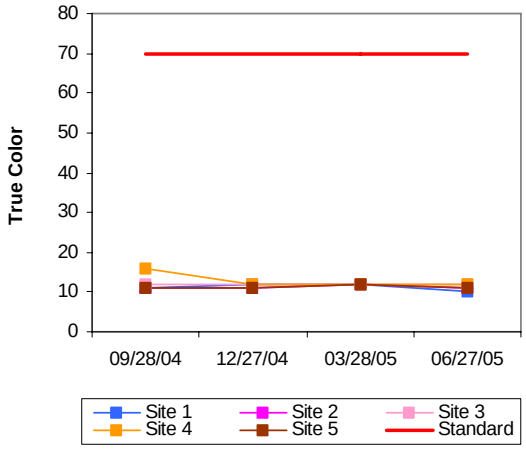
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.37 mg/L at the surface. Surface TN ranged from 0.21 mg/L to 0.88 mg/L with both the highest recorded in the fall quarter. The lake-wide total phosphorus (TP) average was 0.019mg/L at the surface. TP values at the surface ranged from 0.016 mg/L in the winter to 0.039 mg/L in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was 19:1 for sample year 2004-2005. This value is much higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Fuqua Lake was classified as mesotrophic with moderate primary productivity and nutrient levels in 2004-2005 (Plate 45). The TSI in 2003 was also mesotrophic, indicating no increase or decrease in productivity. Water clarity was good based on turbidity, true color, and secchi disk depth, similar to that observed in the 2003 evaluation. The lake is supporting its FWP beneficial use based on pH, turbidity and dissolved oxygen values recorded during the study period. The Aesthetics beneficial use is considered supported based on its trophic status and true color values. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the PBCR beneficial use cannot be made at this time. Fuqua Lake is owned by the city of Duncan and serves as a municipal water supply and recreational reservoir.

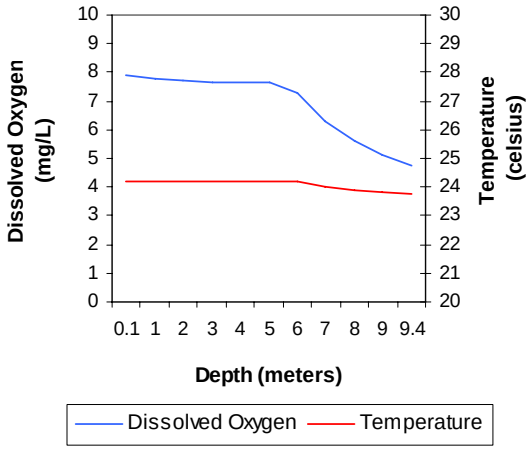
a. Seasonal Turbidity Values for Fuqua Lake



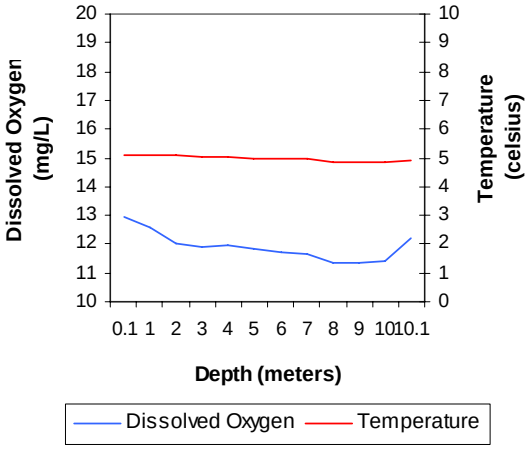
b. Seasonal Color Values for Fuqua Lake



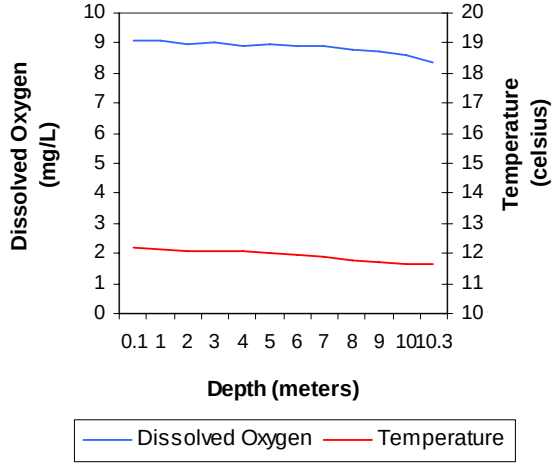
c. Profile of Fuqua Lake
September 28,2004



d. Profile of Fuqua Lake
December 27, 2004



e. Profile of Fuqua Lake
December 27, 2004



f. Profile of Fuqua Lake
December 27, 2004

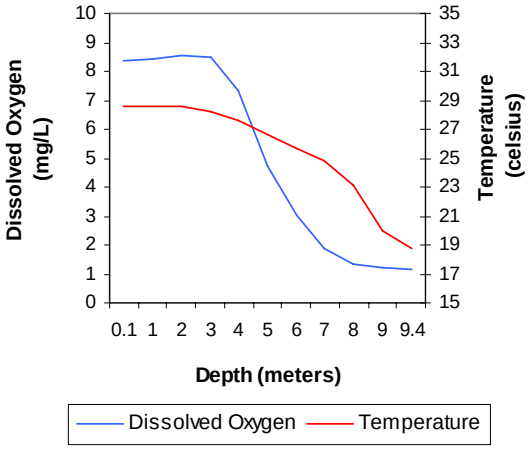


Figure 55a-55f. Graphical representation of data results for Fuqua Lake.

Fuqua Lake and Watershed

Fuqua Lake Location

Lake Data	
Owner	City of Duncan
County	Stephens
Constructed in	1962
Surface Area	1,500 acres
Volume	21,100 acre/feet
Shoreline Length	18 miles
Mean Depth	14.07 feet
Watershed Area	38 square miles

Turbidity 2005

Trophic State 2005

Plate 45- Lake Water Quality for
Fuqua Lake

Grand Lake

Grand Lake, located in Mayes County, is approximately 13 miles southeast of Vinita. The Grand River Dam Authority (GRDA) constructed Grand Lake, the third largest reservoir in Oklahoma, for flood control and hydro-electrical power and is also utilized for various recreational purposes. Grand Lake was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at 13 sites to represent the riverine, transition, and lacustrine zones as well as major arms and tributaries of the reservoir. Samples were collected from the lake surface at all sites during the study period. Grand Lake is a large dendritic reservoir and has been broken into three management segments, upper lake, mid-lake and lower lake to represent the riverine, transition, and lacustrine zones of the reservoir. The following discussion will briefly summarize each segment with a lake-wide summary included at the end of the narrative.

Upper Lake:

The upper part of Grand Lake (segment # 121600030040) extends from the Elk River arm up-lake up to the Twin Bridges area and includes BUMP sites 10-13 (see Figure 57). The segment-wide average turbidity was 13 nephelometric turbidity units (NTU), true color was 25 units, and Secchi disk depth was 69 centimeters. Based on these three parameters water clarity for this segment was average for sample year 2006. This is not unusual for this part of the lake since it is more riverine than other lacustrine sites. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=16). The average TSI was 62, classifying the segment as hypereutrophic, indicative of excessive primary productivity and nutrient conditions. Chlorophyll-a values among the sites were consistently upper eutrophic to mid-hypereutrophic during the sample year. Turbidity values ranged from a low of 5 NTU (site 10) to a maximum of 22 NTU (sites 12 and 13). All true color values were below the Aesthetics criteria 70 units with values ranging from 16 to 42 units.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites within the upper segment. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.23 ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 233.4 µS/cm to 453.7 µS/cm, indicating low to moderate concentrations of current conducting compounds or other analogous material (salts) in the lake system. The pH values ranged from 6.75 to 8.34 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its Fish and Wildlife Propagation (FWP) beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range, this portion of the lake is considered supporting the beneficial use based on pH. Thermal stratification was not present during the fall, winter or spring quarters and the water column was well mixed. During the summer anoxic conditions were present at all sites to varying degrees accounting for 25-43% of the water column to be below 2.0 mg/L. If D.O. values are less than

2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With up to 43% of the water column less than 2.0 mg/L in the summer, the upper segment of Grand Lake is considered supporting the FWP beneficial use.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of (Nutrient Limited Watershed) NLW lakes and nutrient criteria development for lakes and reservoirs. In the upper lake the average total nitrogen (TN) was 0.89 mg/L, with values ranging from 0.45 mg/L in the fall to 1.79 mg/L in the spring quarter. The average total phosphorus (TP) was 0.115, with values ranging from 0.042 mg/L in the winter to 0.212 mg/L in the summer. The nitrogen to phosphorus ratio (TN:TP) was 8:1, This value is the close to 7:1, characterizing this portion of the lake as possibly co-limited (Wetzel, 1983).

Mid- Lake

The mid-lake portion of Grand Lake (segment # 121600030030) extends from the Elk River arm downward including both Horse creek Cove and the Honey Creek arm of the lake and includes BUMP sites 4-9. The segment average turbidity was 9 NTU, true color was 25 units, and secchi disk depth was 91 centimeters. Based on these three parameters water clarity for this segment was average to good for sample year 2006. This is not unusual as you move through the lake and sediment and other materials are starting to settle out. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=16). The average TSI was 60, classifying the segment as eutrophic, indicative of high primary productivity and nutrient conditions. Chlorophyll-a values among the sites were generally upper eutrophic to mid-hypereutrophic during the sample year. Turbidity values were all below the Oklahoma Water Quality Standard (WQS) of 25 NTU with values ranging from a low of 2 NTU (site 7) to a maximum of 17 NTU (site 8). True color for this portion of the lake ranged from 18 to 44 units.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites within the mid-lake segment. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.15 ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 235.5 µS/cm to 354 µS/cm, indicating low to moderate concentrations of current conducting compounds or other analogous material (salts) in the lake system. The pH values ranged from 6.53 to 8.59 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range, this portion of the lake is considered supporting the beneficial use based on pH. Thermal stratification was not present during the fall or winter and the water column was well mixed. During the spring sampling interval the water column was weakly stratified with dissolved oxygen only falling below 2.0 mg/l at sites 6 (Honey Creek arm) and 7 near the sediment-water interface. In the summer quarter thermal stratification was more evident and anoxic conditions were present at all sites to varying degrees accounting for 22-47% of the water column to be below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 7-11% of the water column in the spring and 22 to 43% of the water column in the summer

less than 2.0 mg/L, the mid-lake portion of Grand Lake is considered supporting the FWP beneficial use.
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. Total nitrogen (TN) in the mid-lake portion ranged from 0.50 mg/L in the winter to 1.54 mg/L in the spring with a segment average of 0.71 mg/L. TP values ranged from 0.031 in the summer to 0.103 mg/L in the fall with an average of 0.075 mg/l. The nitrogen to phosphorus ratio (TN:TP) was 9:1. This value is slightly higher than 7:1, characterizing this portion of the lake as phosphorus limited or possibly co-limited (Wetzel, 1983).

Lower Lake

The lower portion of Grand Lake (segment # 121600030020) extends from Horse Creek Cove downward to the dam and includes BUMP sites 1-3. The segment-wide average turbidity was 5 NTU, true color was 21 units, and secchi disk depth was 134 centimeters. Based on these three parameters water clarity for this segment was excellent for sample year 2006. This is not unusual as you move through the lake towards the dam area and sediment and other materials have had time to settle out. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=16). The average TSI was 50, classifying the segment as mesotrophic bordering eutrophic, indicative of moderate to high primary productivity and nutrient conditions. Chlorophyll-a values among the sites were generally upper eutrophic to mid-hypereutrophic during the sample year. Turbidity values were all below the Oklahoma Water Quality Standard (WQS) of 25 NTU ranging from a low of 2 NTU (site 1) to a maximum of 7 NTU (site 2). Like turbidity, true color was also low with values ranging from 16-23 units, well below the Aesthetics criteria of 70 units.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites within the lower lake segment. Salinity values ranged from 0.13 parts per thousand (ppt) to 0.19 ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 264 µS/cm to 374 µS/cm, indicating low to moderate concentrations of current conducting compounds or other analogous material (salts) in the lake system. The pH values ranged from 7.07 to 8.68 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range, this portion of the lake is considered supporting the beneficial use based on pH. In the fall, site 1 was weakly stratified with dissolved oxygen (D.O.) below 2.0 mg/l from 25 meters below the surface to the lake bottom of 33.4 meters. Thermal stratification was not present during the winter quarter and the water column was well mixed. During the spring sampling interval the water column was weakly stratified however dissolved oxygen remained above 2.0 mg/L at three sites 6 in this segment. In the summer quarter thermal stratification was more evident and anoxic conditions were present at all sites to varying degrees accounting for 47-62% of the water column to be below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With up to 62% of the water column in the summer less than 2.0 mg/L, the lower lake portion of Grand Lake is considered partially supporting the FWP beneficial use.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. In the lower portion of the lake the average total nitrogen (TN) was 0.60 mg/L, with values ranging from 0.46 mg/L in the spring to 0.77 mg/l in the winter quarter. The average total phosphorus (TP) was 0.059, with values ranging from 0.023 mg/L in the summer to 0.107 mg/L in the fall. The nitrogen to phosphorus ratio (TN:TP) was 10:1, This value is the close to 7:1, characterizing this portion of the lake as phosphorus limited or possibly co-limited (Wetzel, 1983).

Lake Summary

The lake was also sampled for chlorides and sulfates, to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported in all three management segments based on numerical criteria located in OAC 785:45 – Appendix F.

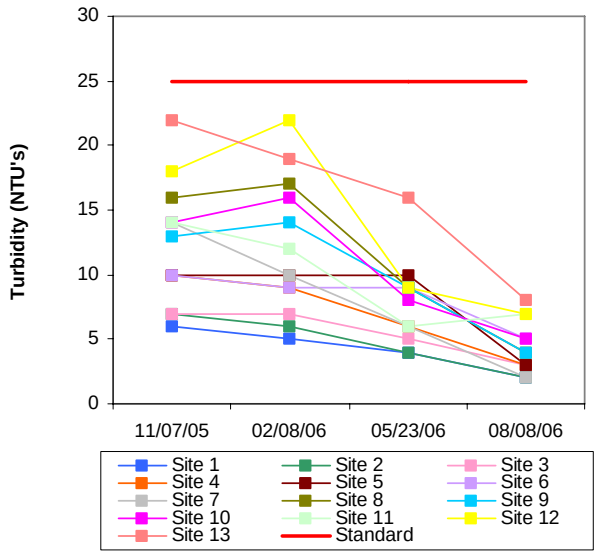
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites throughout the lake for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. Although all sample results were below both the screening level and geometric mean, the minimum data requirements for each segment were not met and an assessment of the PBCR beneficial use cannot be made at this time.

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2002 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. Grand Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

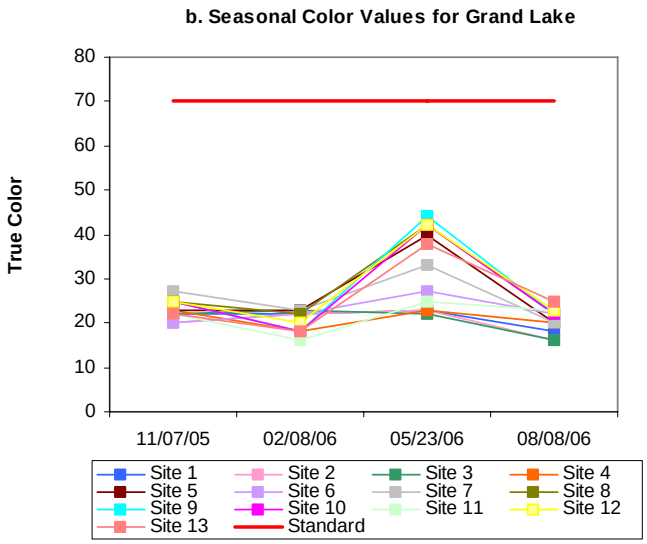
In summary, Grand Lake is classified as eutrophic, with high primary productivity and nutrient rich conditions (Plate 46). The lake-wide annual turbidity value was 9 NTU (Plate 46), true color was 24 units, and secchi disk depth was 93 centimeters. Based on these three parameters, Grand Lake had average to good water clarity, slightly better than that observed in 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=52). The average TSI was 59 (Plate 46), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is similar to that calculated in 2004 (TSI=57) and 2001 (TSI=59), placing the lake within the same trophic category. Chlorophyll-a values were varied by site and season during the study period at this reservoir. The TSI values ranged from oligotrophic (2%) to hypereutrophic (33%), although most values were in the mesotrophic (21%) or eutrophic category (44%). As expected, the lowest TSI average was at the lower end of the lake (site 1) as well as sites 2 and 3 and the most productive sites were in the tributary arms, Honey Creek (site 6) and Spring/Neosho River arm (sites 12 and 13). Seasonal turbidity values are displayed in Figure 56a. Turbidity values were also variable between sites and seasonally with lower values observed in the more lacustrine areas of the lake. All 52 turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU. With 100% of the recorded turbidity values below the numeric criteria, the Fish & Wildlife Propagation (FWP) beneficial use is considered fully supported for sample year 2006. Seasonal true color values are displayed in Figure 56b. Like turbidity, none of the 52 true color values exceeded the numeric criteria of 70 units; therefore, the Aesthetics beneficial use is considered fully supported. Based on anoxic conditions present in the summer (Figure 56f), the FWP is considered partially supported at Grand Lake as it relates to dissolved

oxygen. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites throughout the lake for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. Although all sample results were below both the screening level and geometric mean, the minimum data requirements for each segment were not met and an assessment of the PBCR beneficial use cannot be made at this time.

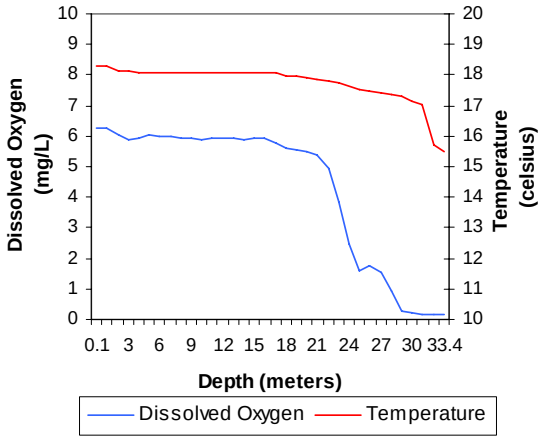
a. Seasonal Turbidity Values for Grand Lake



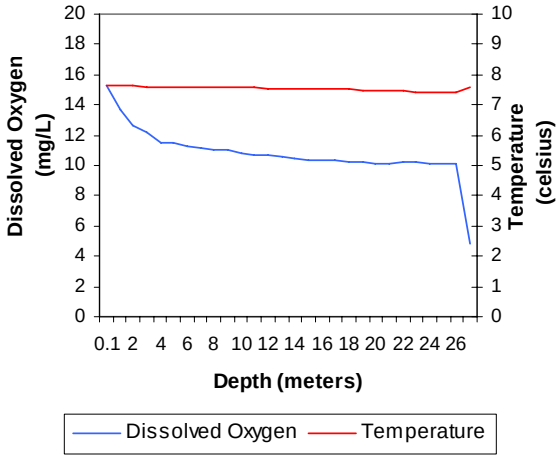
b. Seasonal Color Values for Grand Lake



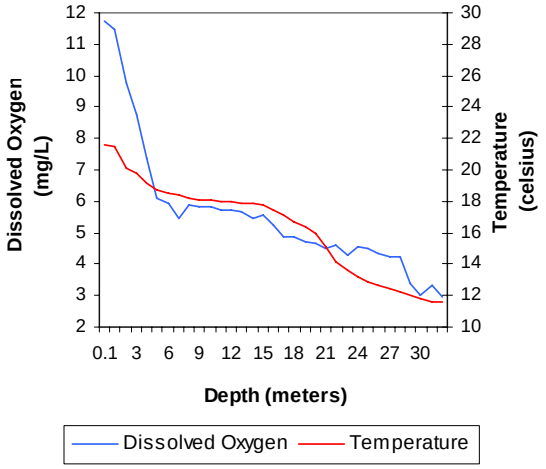
c. Profile of Grand Lake
November 7, 2005



d. Profile of Grand Lake
February 08, 2006



e. Profile of Grand Lake
May 23, 2006



f. Profile of Grand Lake
August 08, 2006

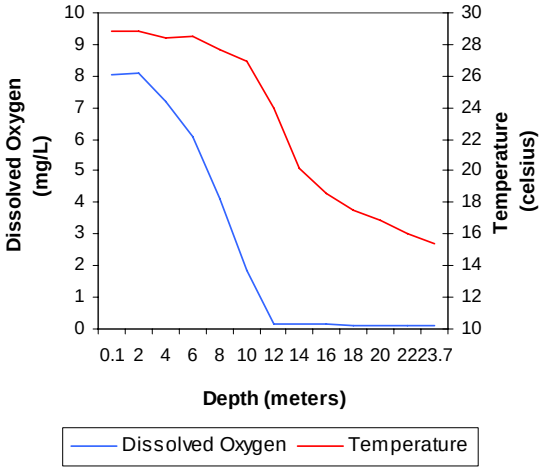
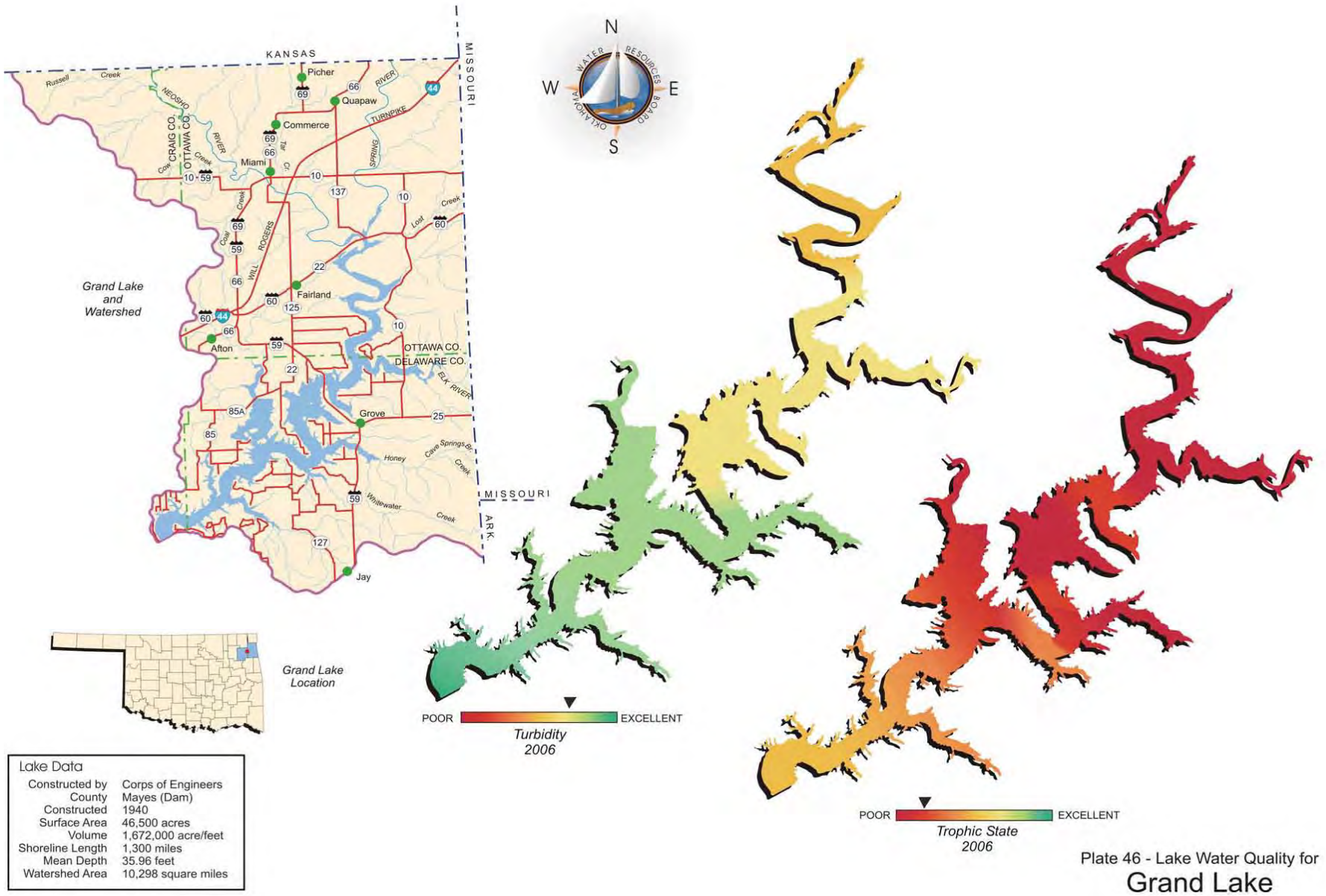


Figure 56a-56f. Graphical representation of data results for Grand Lake.



Lake Data	
Constructed by	Corps of Engineers
County	Mayes (Dam)
Constructed	1940
Surface Area	46,500 acres
Volume	1,672,000 acre/feet
Shoreline Length	1,300 miles
Mean Depth	35.96 feet
Watershed Area	10,298 square miles

Plate 46 - Lake Water Quality for
Grand Lake

LAKES MONITORING PROGRAM

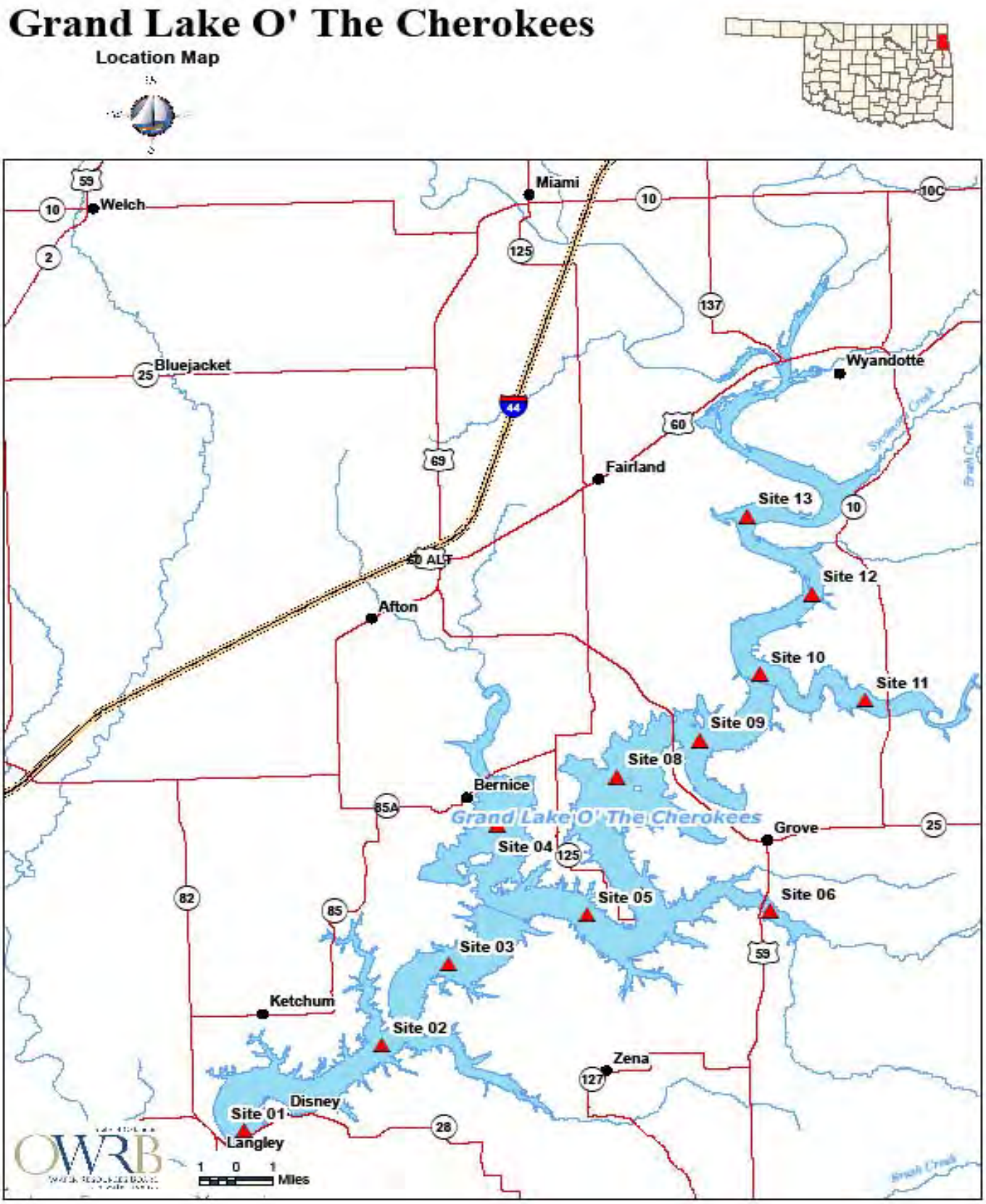


Figure 57. Grand Lake Site Map

Great Salt Plains Lake

Great Salt Plains Lake is located in Alfalfa County on the Salt Fork of the Arkansas River. The lake and state park are just a few miles north of the town of Jet. The United States Army Corps of Engineers constructed the lake in 1941 for flood control and other conservation purposes and is a popular spot for birding related activities. Great Salt Plains Lake was sampled for two quarters from October 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water samples were collected from the lake surface at all five sites during the study period. Due to low lake levels, OWRB staff was unable to access the lakes in both the winter and summer sampling intervals. The following data discussion is based on the data collected in October 2005, April 2006 and was aggregated with past historical data collected since the beginning of the BUMP program in 1998. The lake-wide average turbidity value was 193 NTU (Plate 47), true color was 62 units, and secchi disk depth was 10 centimeters. Based on these three parameters, Great Salt Plains Lake had poor water clarity and is likely to always be poor based on the soil composition and shallow morphometry of this lake. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites (n=57). The average TSI was 71 (Plate 47), classifying the lake as hypereutrophic, indicative of excessive levels of primary productivity and nutrients. Currently the lake is listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Fifty-nine of the sixty turbidity values (98%) exceeded the WQS of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Great Salt Plains Lake is currently not supporting its Fish & Wildlife Propagation (FWP) beneficial use based on high turbidity. Of the fifty-one true color values collected, nine (17%) exceed the WQS standard of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered partially supported in regards to true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were also recorded at all sample sites during the period of record. Salinity ranged from 0.02 to 5.67 parts per thousand (ppt), which is much higher than the range of expected values for Oklahoma lakes, reflecting the presence of large amounts of chlorides or other salts in the lake. Specific conductivity values ranged from 494.6 µS/cm to 10,016 µS/cm, which also indicated extremely high levels of current conducting ionic compounds (or other analogous materials) present in the water column. Oxidation-reduction potentials (redox) ranged from 93 mV to 490 mV, indicating an absence of reducing conditions at any time in the water column during the course of lake sampling. The pH values were generally neutral to slightly alkaline, ranging from 5.11 to 8.80 units. In the summer of 2002, all recorded pH values were below 6.5 pH units however this is the only instance that this has occurred. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the

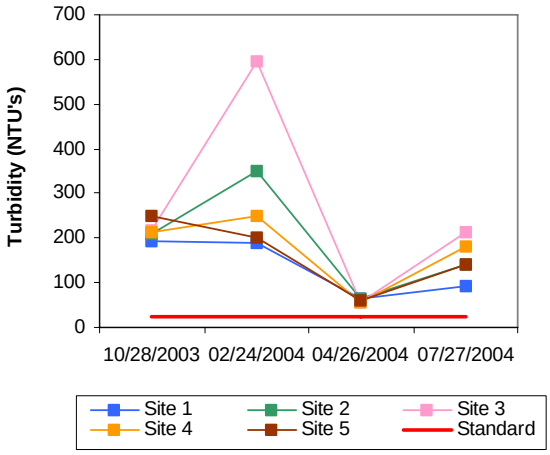
range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only 6.4% of the collected values below 6.5 units, the lake is supporting its FWP beneficial use based on pH. Due to the shallow nature of the reservoir thermal stratification was not present in this reservoir at any point during the period of record, and dissolved oxygen (D.O.) concentrations were above 2.0 mg/L at all times and were generally above 6.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported and If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the use is deemed partially supported. Based on D.O. concentrations the FWP beneficial use is fully supported at Great Salt Plains Lake. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. With both chlorides and sulfate exceeding the numerical criteria located in OAC 785:45 – Appendix F the Agriculture beneficial use is considered not supported. In accordance with EPA guidance, states may develop site-specific criteria on the basis of natural background conditions. Because the extremely high chloride conditions are due to natural causes; the Water Board is looking at the applicability of developing site-specific criteria for Great Salt Plains Lake.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.64 mg/L at the lake surface. The TN at the surface ranged from 0.75 mg/L to 2.85 mg/L, which is a considerable amount of nitrogen to be present in the water column. The lake-wide total phosphorus (TP) average was 0.290 mg/L at the lake surface, which was also very high value in comparison to other lakes in Oklahoma. The TP ranged from 0.046 mg/L to 1.783 over the period of record. The nitrogen to phosphorus ratio (TN:TP) was approximately 6:1. This value is the just under 7:1, characterizing the lake as nitrogen or possibly co-limited (Wetzel, 1983).

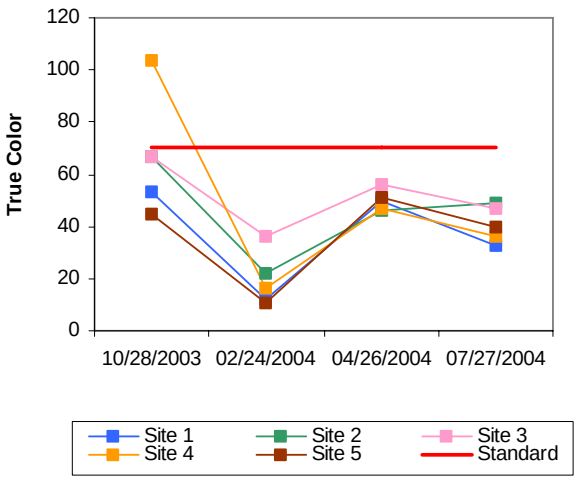
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 and again in 2005 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening or consumption advisory levels.

In summary, Great Salt Plains Lake was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels (Plate 47). The lake is currently listed in the WQS as NLW waterbody and should be studied intensively in the future to verify beneficial use non-support status. Although the lake has very high turbidity, this does not appear to limit productivity and an intensive study would help to better understand the nutrient dynamics at work in the reservoir. Until such time, the Aesthetics beneficial use is partially supported based on true color values and considered threatened due to nutrients. Water clarity is consistently poor at this lake and is likely to always be poor based on the soil composition and shallow morphometry of this lake. The lake was not supporting its FWP beneficial use based on extremely high turbidity and is supporting its FWP beneficial use for pH concentrations. The FWP is fully supported based on D.O. concentrations. There was a major fish kill recorded at the reservoir during the summer of 2006. Low lake levels combined with triple digit temperatures are blamed for this event. For further information please contact the Oklahoma Department of Wildlife Conservation. With both chlorides and sulfate exceeding the numerical criteria located in OAC 785:45 – Appendix F the Agriculture beneficial use is considered not supported. In accordance with EPA guidance, states may develop site-specific criteria on the basis of natural background conditions. Because the high chloride levels are due to natural causes, the Water Board is looking at the applicability of developing site-specific criteria for Great Salt Plains Lake.

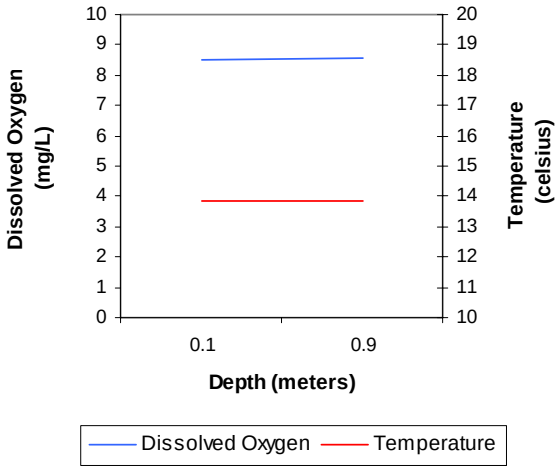
a. Seasonal Turbidity Values for Gt. Salt Plains Lake



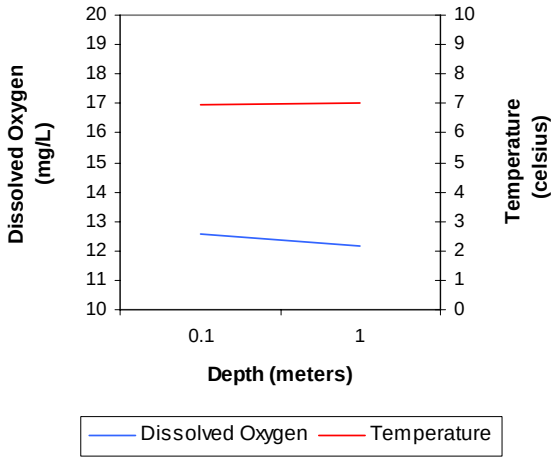
b. Seasonal Color Values for Gt. Salt Plains Lake



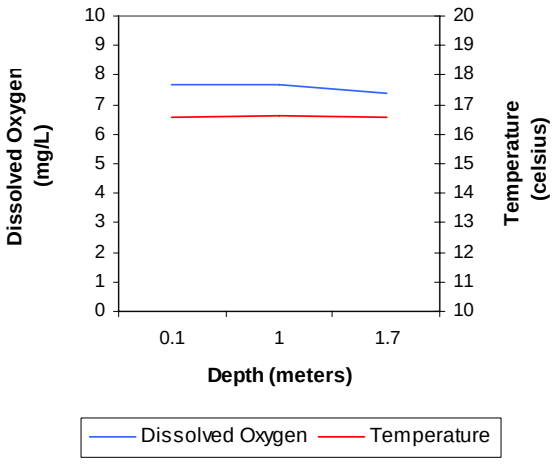
c. Profile of Gt. Salt Plains Lake October 28, 2003



d. Profile of Gt. Salt Plains Lake Febraury 24, 2004



e. Profile of Gt. Salt Plains Lake April 26, 2004



f. Profile of Gt. Salt Plains Lake July 27, 2004

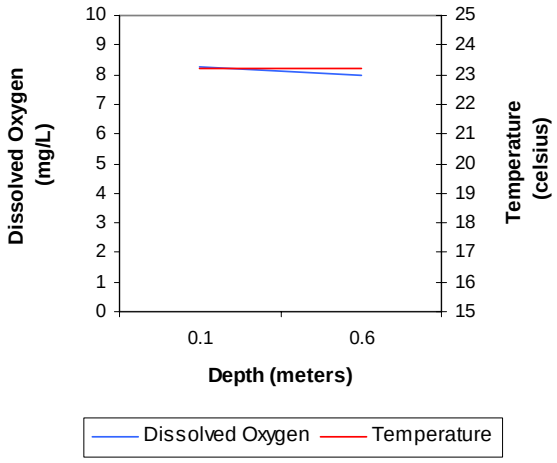
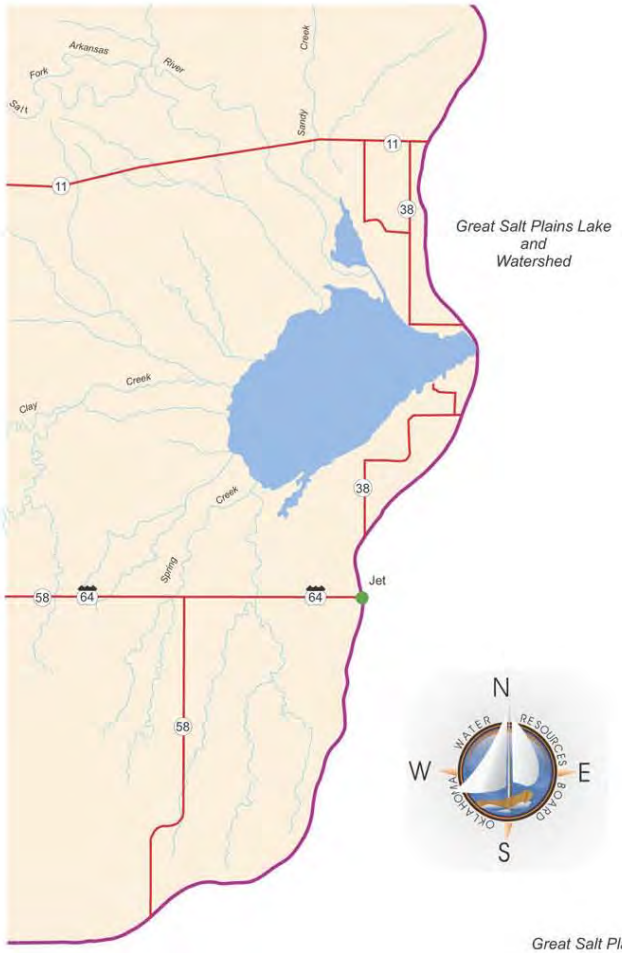
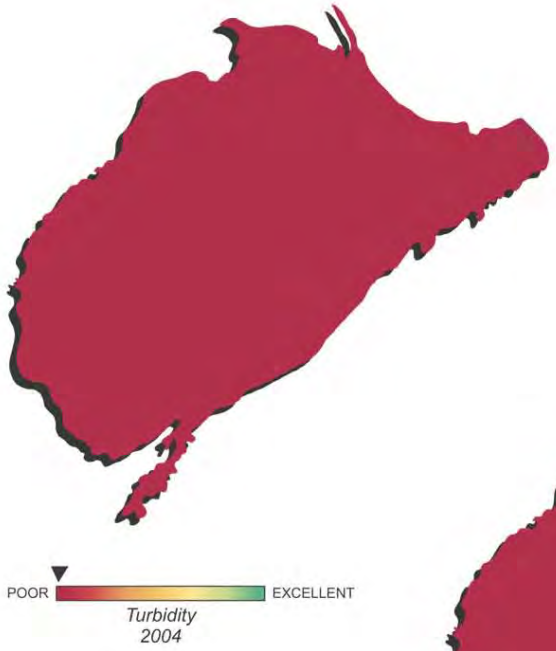
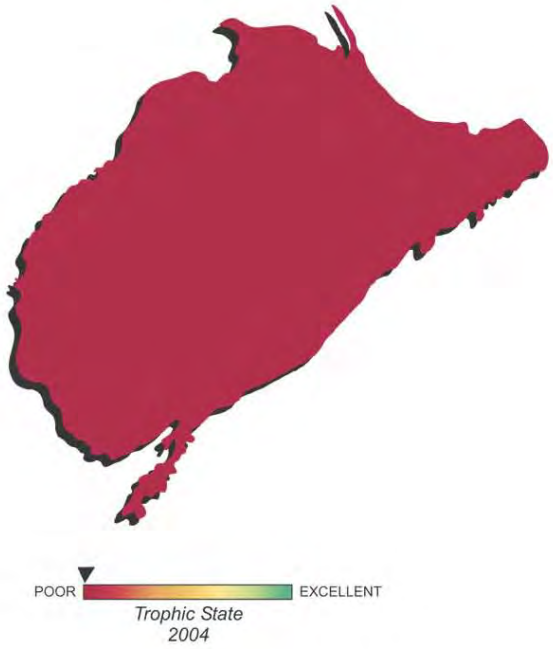


Figure 58a-58f. Graphical representation of data results for Great Salt Plains Lake.







Lake Data	
Constructed by	Corps of Engineers
County	Alfalfa
Constructed in	1941
Surface Area	8,690 acres
Volume	31,420 acre/feet
Shoreline Length	41 miles
Mean Depth	4.22 feet
Watershed Area	3,200 square miles

Plate 47 - Lake Water Quality for
Great Salt Plains Lake

Greenleaf Lake

Greenleaf Lake, located in Muskogee County, is just a few miles south of the town of Braggs. The lake was built in 1939 and is leased to the State of Oklahoma for recreational purposes and is within Greenleaf State Park in the eastern part of the state. Greenleaf Lake was sampled for four quarters, from November 2005 through September 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 7 NTU (Plate 48), true color was 15 units, and secchi disk depth was 111 centimeters. Based on these three parameters, Greenleaf Lake had good water clarity in 2006. These results are slightly better than those in 2004 although very similar. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 52 (plate 48), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is the similar to the one calculated in 2004 (TSI=54), indicating no change in trophic status over time. The TSI values varied seasonally with meso-eutrophic conditions in the fall and winter to upper eutrophic in the spring quarter. The exception to this occurred in September when both mesotrophic and oligotrophic conditions were present. The annual TSI of 54 seems representative of conditions at Greenleaf Lake and is consistent with historical data collection efforts conducted in 2001 and 2004. Turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU with values ranging from a low of 5 NTU to a maximum of 10 NTU (Figure 59a). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the turbidity values below the WQS of 25 NTU, Greenleaf Lake is supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in (Figure 59b). Similar to turbidity, 100% of the samples collected were below the WQS numeric criteria of 70 units. Applying the same default protocol the Aesthetics beneficial use is considered supported at Greenleaf Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity values ranged from 0.06 parts per thousand (ppt) to 0.14 ppt, well within the expected range for most Oklahoma reservoirs if not slightly lower. Readings for specific conductivity were within the expected range for Oklahoma reservoirs. Specific conductivity ranged from 143.6 µS/cm in the spring quarter to 297 µS/cm in the summer quarter, indicating low concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 55mV in the summer quarter near the water to sediment interface near the lake bottom to 511 mV also in the summer quarter. Although all redox values were positive, these near reducing conditions are consistent with anoxic conditions present in a large portion of the water column during the summer sampling interval. Lake pH values were neutral to slightly alkaline with values ranging from 6.81 units to 8.31 all within the WQS range of 6.5-9.0

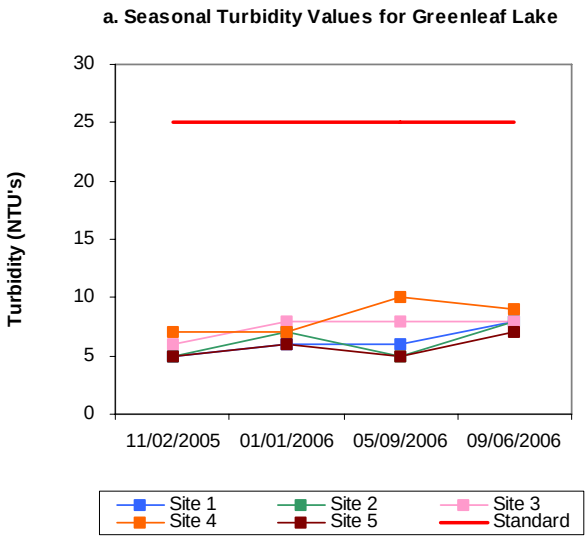
units, therefore the FWP beneficial use was supported as it relates to pH. Thermal stratification was not evident in either the fall or winter quarters and the water column was well mixed (Figure 59c-59d). During the spring the lake was thermally stratified with 13 to 43% of the water column experiencing anoxic conditions at sites 1,2 and 5, the three deepest sites (Figure 59e). During the summer the lake exhibited strong thermal stratification with dissolved oxygen (D.O.) concentrations less than 1.0 mg/L from 6 meters below the surface to the lake bottom of 12.3 meters at both sites 1 and 2 (see Figure 59f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With up to 71% of the water column in the summer violating the criteria the lake is considered to be not supporting its FWP beneficial use based on D.O. concentrations for sample year 2006. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

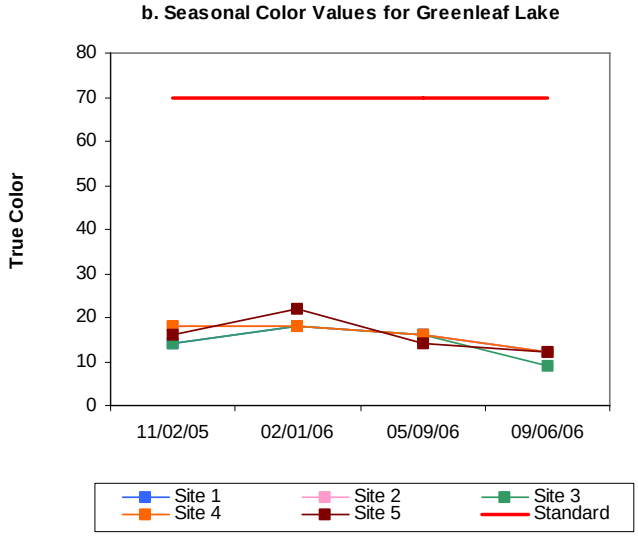
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

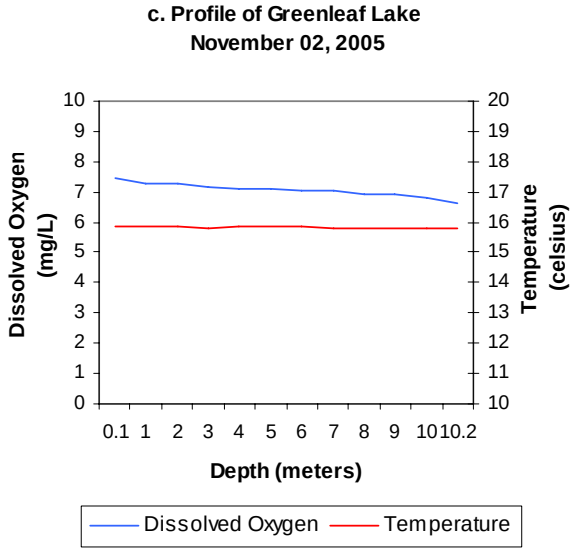
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.58 mg/L at the lake surface. The TN at the surface ranged from 0.42 mg/L in the fall and spring quarters to 0.83 mg/L recorded during the summer quarter. The lake-wide total phosphorus (TP) average was 0.039 mg/L at the lake surface. The TP ranged from 0.025 mg/L to 0.067 mg/L. The highest surface TP values were reported in the spring and the lowest were in the winter. The nitrogen to phosphorus ratio (TN:TP) was 15:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

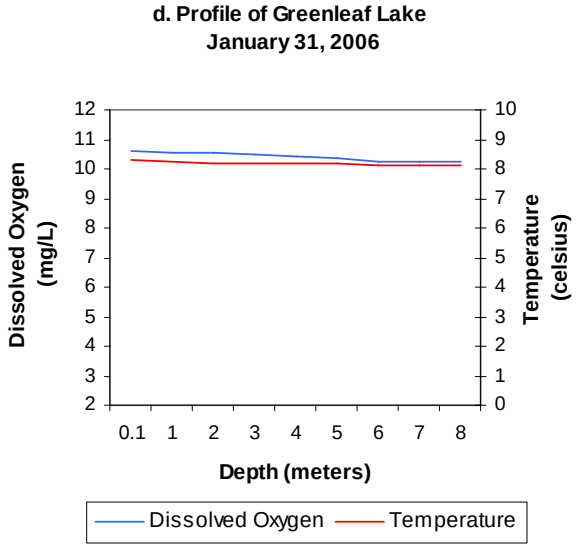
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2000 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. Greenleaf Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

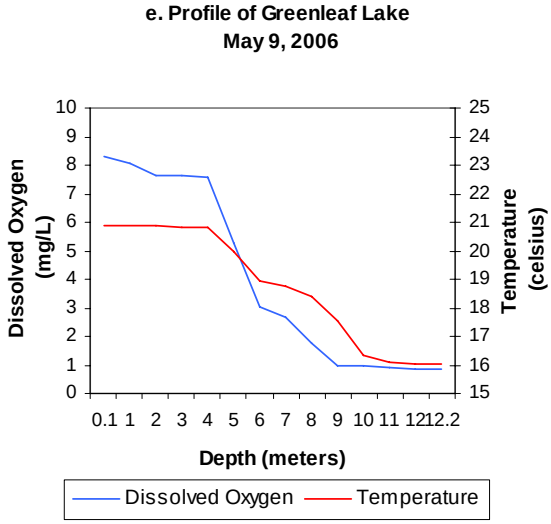
In summary, Greenleaf Lake is classified as eutrophic with high primary productivity and nutrient rich conditions (Plate 48). This classification is consistent previous data collection efforts conducted in 2001 and 2004. Water clarity is good in comparison to other Oklahoma lakes and reservoirs based turbidity, true color and Secchi disk depth readings. The Aesthetics beneficial use is supported based on trophic status and with 100% of the true color values below the WQS of 70 units the beneficial use is also considered supported as it relates to color. The lake is supporting the FWP use as it relates to pH and turbidity however is not supporting with anoxic conditions present in 71% of the water column during the summer sampling interval. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.











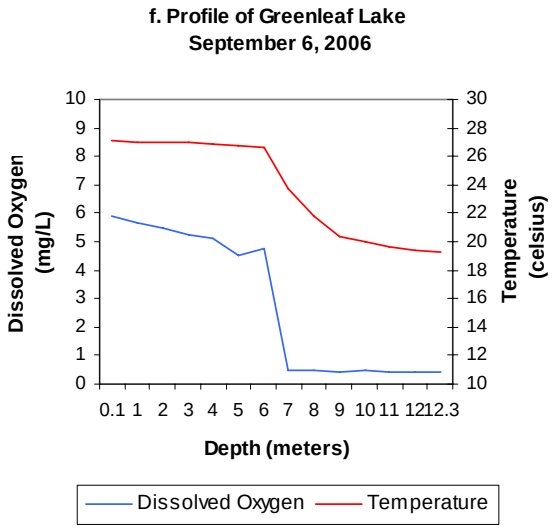


Figure 59a-59f. Graphical representation of data results for Greenleaf Lake.

Greenleaf Lake Location

Greenleaf Lake and Watershed

Lake Data	
Owner	Leased to State of Oklahoma
County	Muskogee
Constructed in	1939
Surface Area	920 acres
Volume	14,720 acre/feet
Shoreline Length	18 miles
Mean Depth	16.00
Watershed Area	86 square miles

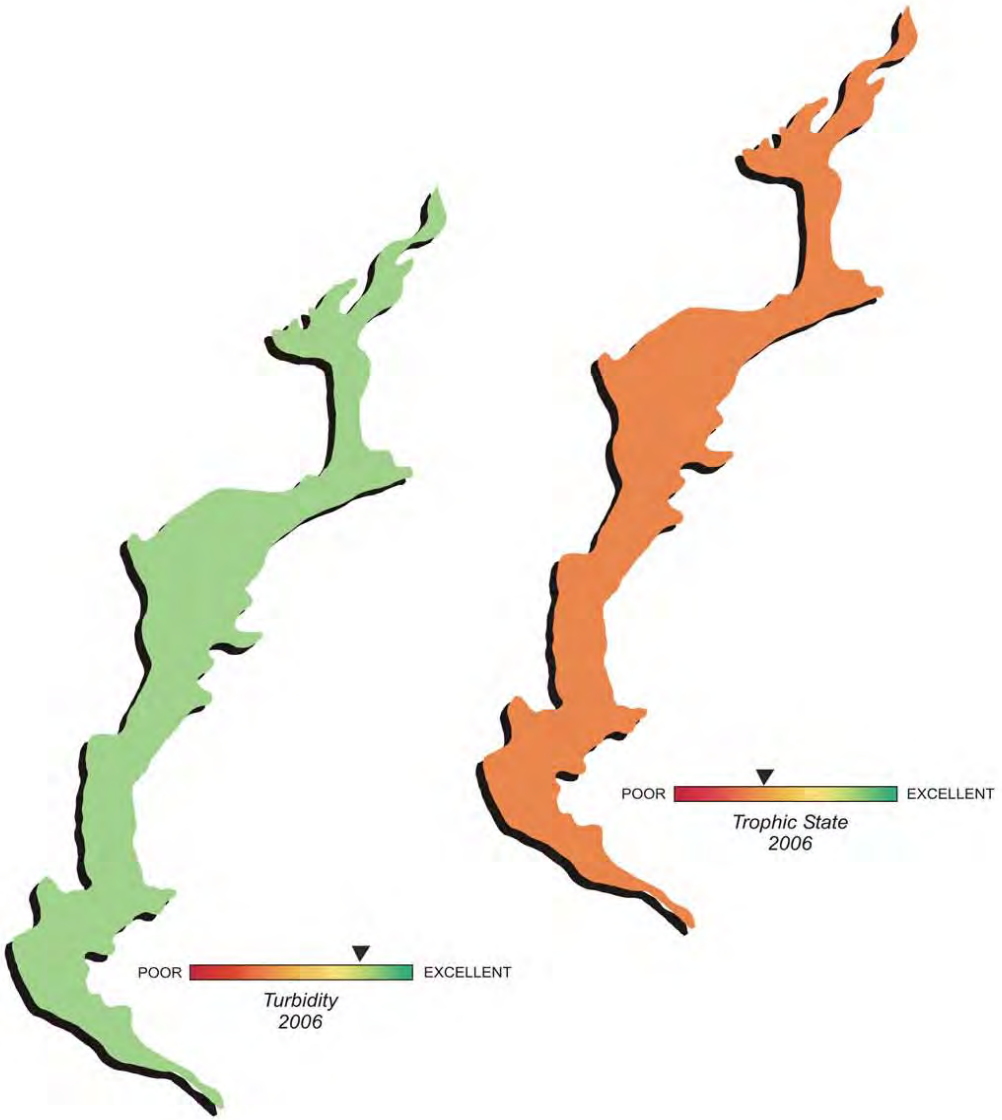


Plate 48 - Lake Water Quality for
Greenleaf Lake

LAKES MONITORING PROGRAM

Guthrie Lake

Guthrie Lake, located in Logan County, is approximately 4 miles south of Guthrie. The lake was constructed in 1919 and is owned and operated by the City of Guthrie and is utilized for water supply and recreational purposes. Guthrie Lake was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 19 NTU (Plate 49), true color was 21 units, and secchi disk depth was 52 centimeters. Based on these three parameters, Guthrie Lake had average to fairly good water clarity in 2005-2006. Findings for these parameters are similar to those of the 2004 evaluation. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 61 (Plate 49), classifying the hypereutrophic, indicative of excessive primary productivity and nutrient levels. The TSI values ranged from hypereutrophic in the fall and summer quarters with eutrophic conditions in the winter to meso-eutrophic conditions in the spring quarter. This pattern is almost identical to that seen in the 2004 evaluation. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Of the twenty turbidity values collected, four (20%) exceeded the WQS of 25 NTU (see Figure 60a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Available flow and rainfall data suggest that the peak in turbidity, which occurred in October is likely due to seasonal storm events, therefore the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) based on turbidity. Seasonal true color values are displayed in Figure 60b. None of the true color values exceeded the numeric criteria of 70 units. Applying the same default protocol for determining the short-tem average for true color, the Aesthetics beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity ranged from 0.32 to 0.43 parts per thousand (ppt), which is slightly higher than the expected range for Oklahoma lakes. Readings for specific conductivity ranged from 623.1 µS/cm to 821 µS/cm, indicating moderate to slightly elevated concentrations of electrical current conducting compounds (salts) present in the water column throughout the sample year. In general, pH values were neutral to alkaline, ranging from 7.78 in the spring quarter to 8.14 units in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Guthrie Lake is

meeting its FWP beneficial use as it realties to pH. Oxidation-reduction potentials (redox) ranged from 357mV in the summer to 470mV in the fall, indicating that reducing conditions were not present in the water column during the course of sampling. The lake was not thermally stratified at any point during 2005-2006 and dissolved oxygen (D.O.) concentrations were generally above 5.0 mg/L throughout the water column (see Figure 60c-60f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is fully supported at Guthrie Lake with the absence of anoxic conditions. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

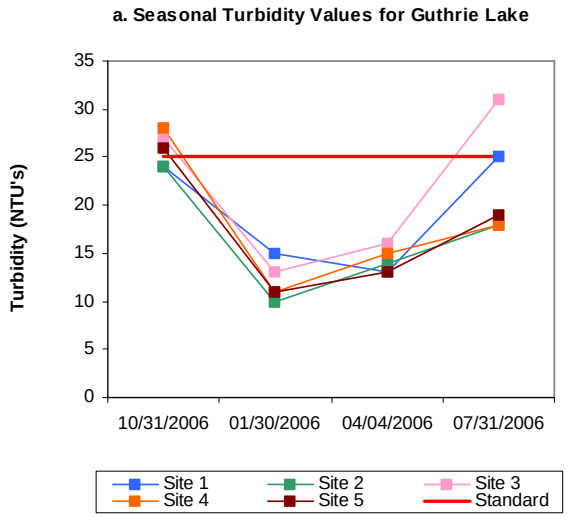
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

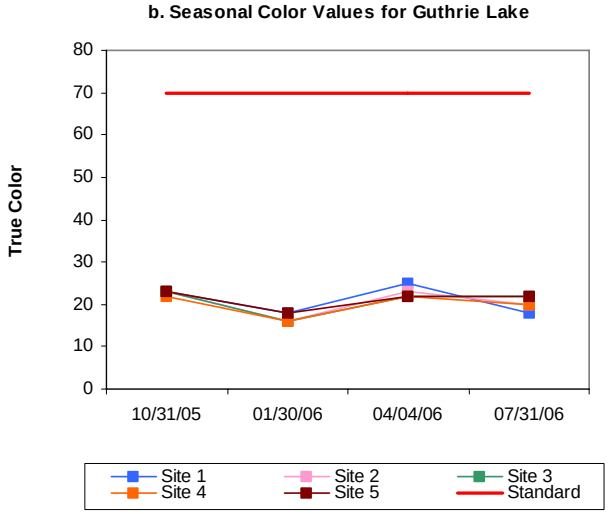
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.01 mg/L at the lake surface during the sample year. The TN at the surface ranged from 0.61 mg/L to 1.34 mg/L. The highest surface TN values were reported in the summer and fall quarters and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.067 mg/L at the lake surface. The TP ranged from 0.041 mg/L to 0.103 mg/L. The highest surface TP value was reported in the summer quarter and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 15:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

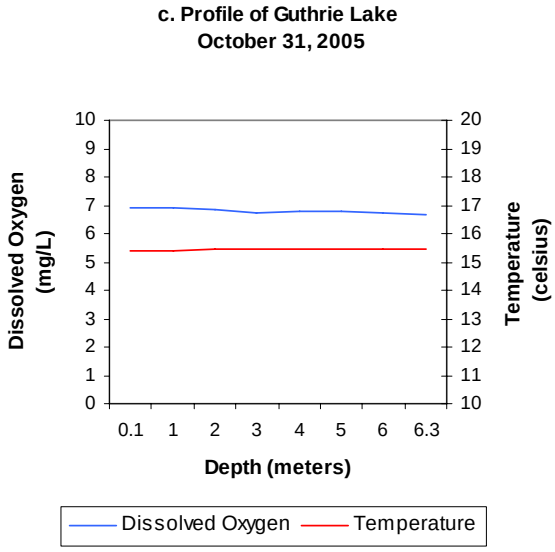
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2001 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. Guthrie Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

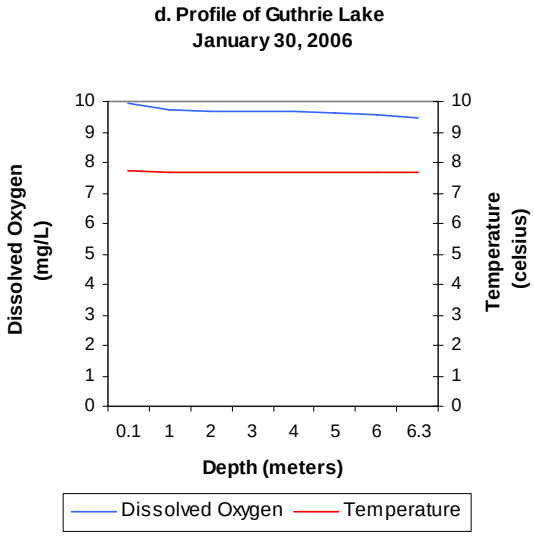
In summary, Guthrie Lake was classified as eutrophic bordering hypereutrophic in 2005-2006, indicating excessive primary productivity and nutrient levels (Plate 49). Water clarity was average to fairly good based on turbidity, true color, and secchi disk depth. The Aesthetics beneficial use is considered supported based on true color and not supported in regards to trophic status. Based on the calculated TSI, the lake will be recommended for listing as a Nutrient Limited Watershed (NLW) in the next WQS revision process and its Aesthetic beneficial use considered threatened until a study can be conducted to confirm non-support status. Guthrie Lake is meeting its FWP beneficial use based on pH and dissolved oxygen concentrations recorded during the sample year. Although 20% of the collected turbidity values exceeded the WQS of 25 NTU, available flow and rainfall data suggest that the peak in turbidity, which occurred in October, is likely due to seasonal storm events, therefore the lake will be listed as supporting its FWP use. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through

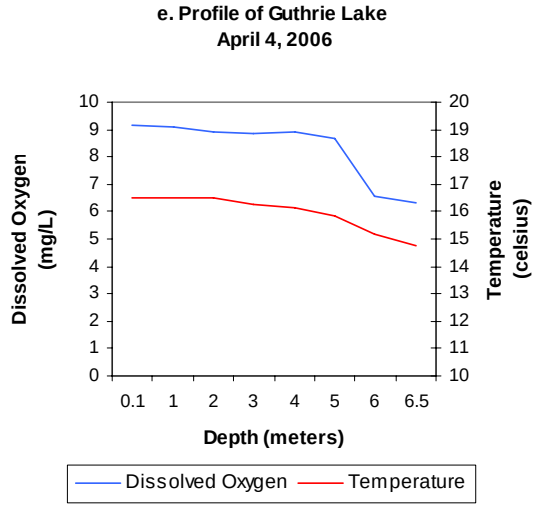
September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.











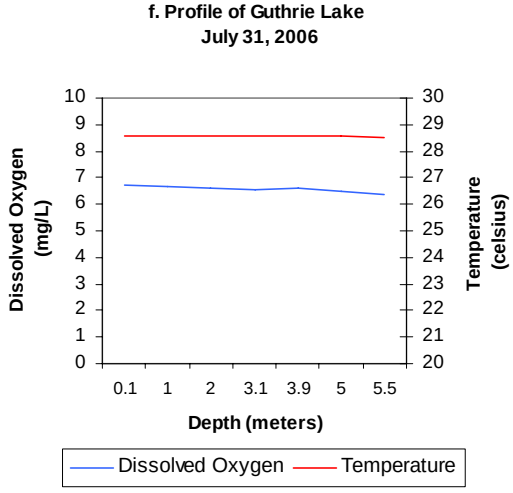
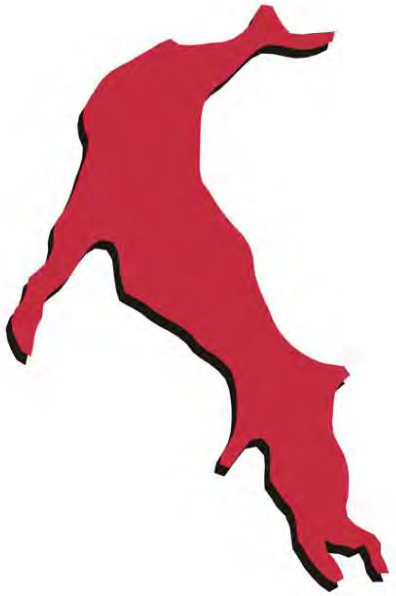
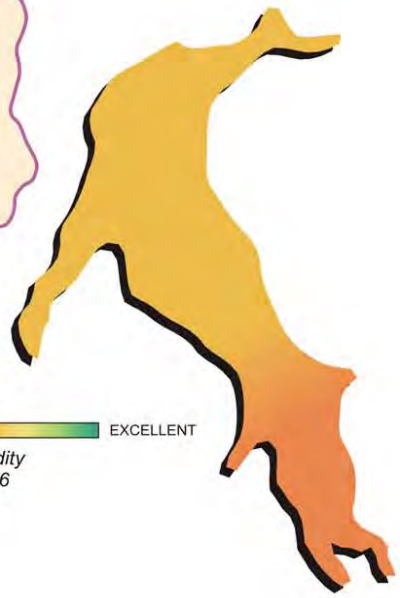


Figure 60a-60f. Graphical representation of data results for Guthrie Lake.



POOR EXCELLENT

Trophic State
2006



POOR EXCELLENT

Turbidity
2006

Lake Data	
Owner	City of Guthrie
County	Logan
Constructed in	1919
Surface Area	274 acres
Volume	3,875 acre/feet
Shoreline Length	4 miles
Mean Depth	14.14 feet
Watershed Area	13 square miles

N W E S

OKLAHOMA WATER RESOURCES BOARD

Plate 49 - Lake Water Quality for
Guthrie Lake

LAKES MONITORING PROGRAM

Healdton City Lake

Healdton City Lake, located in Carter County, was constructed in 1979 and is owned and operated by the City of Healdton and is utilized for water supply, flood control and recreational purposes. Healdton City Lake was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 48 NTU (Plate 50), true color was 159 units, and secchi disk depth was 34 centimeters. Based on these three parameters, Healdton City Lake had poor water clarity in 2006, which is consistent with historical data collection efforts. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=17). The average TSI was 49, classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. Due to lightening in the area, OWRB staff was unable to continue sampling past the first two sites during the May sampling trip. As a result no samples for sites 3-5 were submitted for analysis from spring data collection efforts. The current TSI value is consistent with previous monitoring results from 2003-2004 where the calculated TSI was also mesotrophic (TSI=45). This value is consistent with findings in 2001 (TSI=42), indicating no significant increase or decrease in productivity has occurred. The TSI values were primarily mesotrophic with eutrophic conditions present at sites 3-5 in the summer. Seasonal turbidity values are displayed in Figure 61a. All turbidity values were above the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 100% of the turbidity samples collected were above the standard, an assessment of the FWP use cannot be made, as minimum data requirements were not met. True color values are displayed in (Figure 61b). All true color values were also above the Oklahoma Water Quality Standard (WQS) of 70 throughout the sample year. Like turbidity, minimum data requirements were not met and an assessment of the Aesthetics beneficial use is considered cannot be made at this time. In reviewing past data for both turbidity and true color it us unlikely that either beneficial use would be found supporting for these parameters.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity ranged from 0.13 to 0.19 parts per thousand (ppt), well within the expected range for Oklahoma lakes. Readings for specific conductivity ranged from 275.6 µS/cm to 378.5 µS/cm, indicating moderate concentrations of electrical current conducting compounds (salts) present in the water column throughout the year. In general, pH values were neutral, ranging from 7.05 in the spring quarter to 7.86 units in the fall quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall

outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range, Healdton City Lake is meeting its FWP beneficial use as it relates to pH. Oxidation-reduction potentials (redox) ranged from 304 mV at the sediment-water interface in the fall to 450 mV also in the fall, indicating the absence of reducing conditions in the lake system. The lake was not thermally stratified in the fall or winter sampling intervals and dissolved oxygen (D.O.) concentrations were generally above 6.0 mg/L throughout the water column (see Figure 61c-61d). In the spring quarter, the lake was stratified between 4 and 5 meters below the surface with D.O. values below 2.0 mg/L from 5 meters to the lake bottom of 7.3 meters (Figure 61e). The lake was also thermally stratified in the summer and anoxic conditions were present in 33% of the water column (Figure 61f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is fully supported at Healdton City Lake based with only 33%(summer) to 44%(spring) of these dissolved oxygen levels below 2.0 mg/L. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

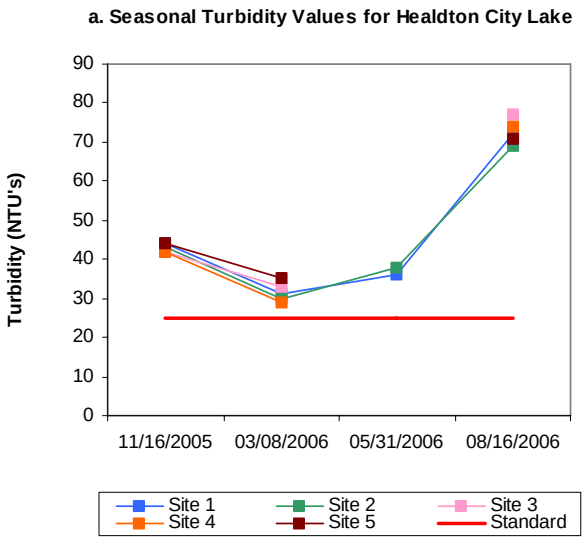
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

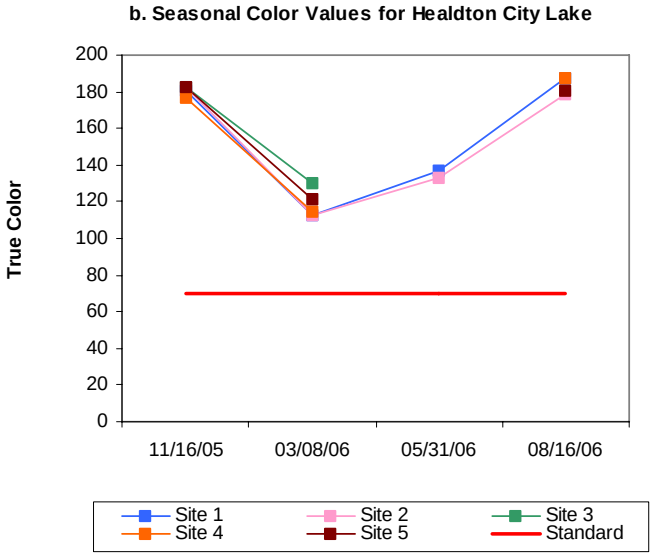
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.74 mg/L at the lake surface. The TN at the surface ranged from 0.59 mg/L to 0.94 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average was 0.066 mg/L at the lake surface. The TP ranged from 0.043 mg/L to 0.100 mg/L. The highest surface TP value was reported in the summer quarter however the lowest was reported in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 11:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

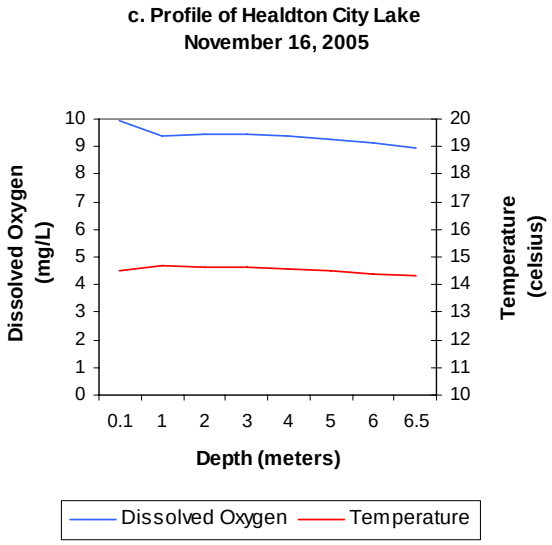
Healdton City Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

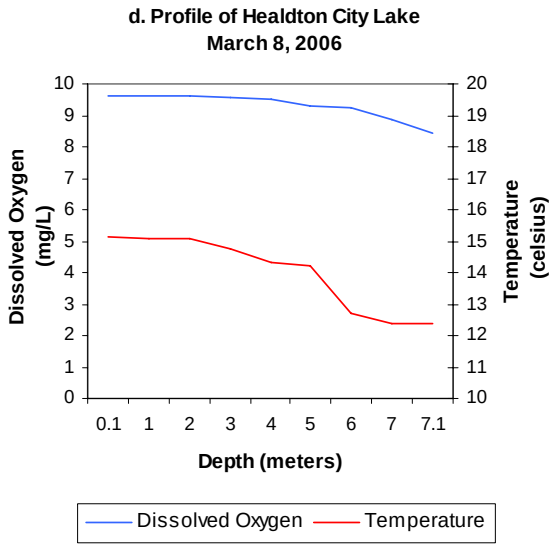
In summary, Healdton City Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 50). Water clarity was poor based on turbidity, true color, and secchi disk depth. The Aesthetics beneficial use is considered supported based on trophic status, however an assessment based on true color cannot be made due to minimum data requirements not being met. Healdton Lake is considered meeting its FWP beneficial use based on pH and dissolved oxygen concentrations. Like true color, minimum data requirements were not met and an assessment of the FWP beneficial use as it relates to turbidity cannot be made at this time. In reviewing past data for both turbidity and true color it us unlikely that either beneficial use would be found supporting for these parameters. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation

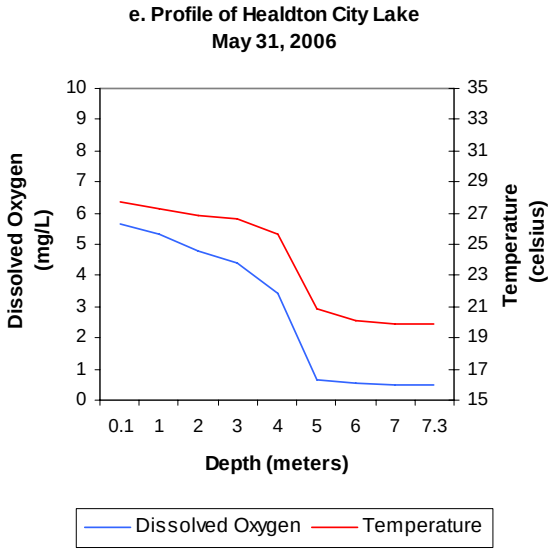
season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.











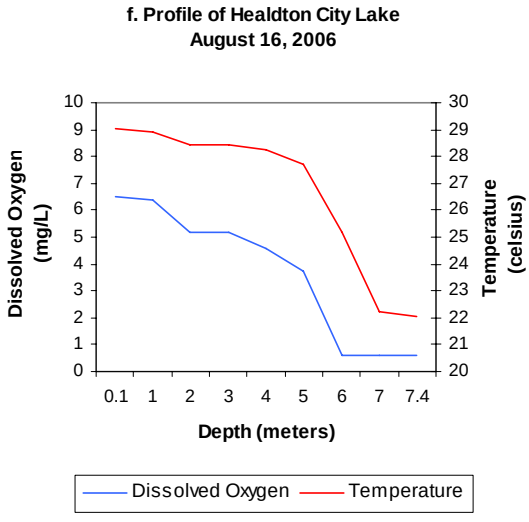


Figure 61a-61f. Graphical representation of data results for Healdton City Lake

Healdton Lake
Location

Healdton Lake
and
Watershed

Lake Data	
Owner	City of Healdton
County	Carter
Constructed in	1979
Surface Area	370 acres
Volume	3,766 acre/feet
Shoreline Length	7 miles
Mean Depth	10.18 feet
Watershed Area	11 square miles

Turbidity
2006

Trophic State
2006

Plate 50 - Lake Water Quality for
Healdton Lake

LAKES MONITORING PROGRAM

Lake Hefner

The lake is owned and operated by the City of Oklahoma City and was constructed in 1947. It serves as a water supply for Oklahoma City and also offers a recreational outlet for the public. Hefner is one of the premier sailing lakes in the United States. Lake Hefner was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 7 NTU (Plate 51), true color was 19 units, and secchi disk depth was 92 centimeters. Based on these three parameters, Lake Hefner had good water clarity very similar to that of previous sampling efforts. This is not unexpected as the lake is an off-channel reservoir, meaning that the lake is not located along a stream course. The lake is "filled" through runoff immediately adjacent to the lake with the bulk of the water in the lake being transported from the North Canadian River via diversion into the Bluff Creek canal, which flows into Lake Hefner. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 63 (Plate 51), classifying the lake as hypereutrophic, indicative of excessive primary productivity and nutrient rich conditions. This value is greater than that of 2004 (TSI=55) and 2002 (TSI=56). Although the current TSI is greater than 62, which normally triggers consideration to be included as an NLW, this is the first time since 1999 that this threshold had been crossed and is likely attributable to the low lake levels (approx. 10 ft. below normal) and not an actual change in productivity therefore the lake will not be recommended for inclusion as an NLW during the next Oklahoma Water Quality Standards revision process, but will be monitored closely in the future. Chlorophyll-a values were variable with the lake generally being eutrophic during the winter and spring and hypereutrophic in both fall and summer quarters. The exception to this was site 5 in the spring, which was hypereutrophic. Turbidity values were all well below the Oklahoma Water Quality Standard (WQS) of 25 NTU with values ranging from 4 to 13 NTU (see Figure 62a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Hefner is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use for sample year 2006 based on turbidity. Seasonal true color values are displayed in Figure 62b. None of the collected true color values exceeded the numeric criteria of 70 units; therefore the Aesthetics beneficial is fully supported for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample during the study period. Salinity ranged from 0.50 to 0.68 parts per thousand (ppt), which was higher than the expected range of values reported for Oklahoma lakes. Specific conductivity ranged from 959 µS/cm in the fall quarter to 1314 µS/cm in the summer quarter, indicating moderate to elevated concentrations of electrical conducting compounds (salts) were present in the water column. In general, pH values were

neutral to alkaline, ranging from 7.77 units in the spring quarter to 8.68 units in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Hefner is fully supporting its FWP beneficial use based on pH values. Oxidation-reduction potentials (redox) ranged from 47 mV near the sediment-water interface in the summer at site 1 to 460 mV in the winter quarter. Although all redox values were positive, near reducing conditions were present in the summer near the sediment-water, which is not uncommon when a large portion of the water column is anoxic. The lake was not thermally stratified during the fall, winter or spring the sampling intervals with dissolved oxygen (D.O.) concentrations generally above 6.0 mg/L throughout the water column at all sites (see Figure 62c-62e). In the summer thermal stratification was evident and anoxic conditions were present at both sites 1 and 5, the deepest sites. Stratification occurred at several 1-meter intervals at site1, with dissolved oxygen (D.O.) falling below 2.0 mg/L from 9 meters to the lake bottom of 16.6 meters (Figure 62f). Similarly at site 5, D.O. was below 2.0mg/L from 9 meters below the surface to the bottom of 12.6 meters with anoxic condition comprising 36% of the water column. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is partially supported at Lake Hefner with anoxic conditions present in 50% of the water column during the summer at site 1. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.79mg/L at the lake surface during the study period. The TN at the surface ranged from 0.69 mg/L to 1.06 mg/L. The highest surface TN value was in the summer quarter and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average was 0.082 mg/L. The TP ranged from 0.055 mg/L to 0.120 mg/L. Similar to TN the lowest surface TP value was reported in the winter however the highest was in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2001 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. Lake Hefner was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Lake Hefner was classified as hypereutrophic (TSI=63), indicative of excessive productivity and nutrient rich conditions (Plate 51) for sample year 2005-2006. Although the current TSI is greater than 62, which normally triggers consideration to be included as an NLW, this is the first time since 1999 that this threshold had been crossed. It is hard to say if this increase is due to the lower lake levels brought on by the drought the state is experiencing or an actual change in productivity therefore the lake will not be recommended for inclusion during the next Oklahoma Water Quality Standards revision process, but will be monitored closely in the future. Water clarity is good based on turbidity, true color and Secchi depth readings. The lake is fully supporting its Aesthetics beneficial use true color with 100% of the values below the WQS of 70 units. Lake Hefner is fully supporting its FWP beneficial use based on turbidity and pH values. With 50% of the water column less than 2.0mg/L during the summer, the FWP beneficial use is only partially supported at Lake Hefner. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

In 1997 the Oklahoma Legislature directed the OWRB to conduct a study on the impact of Confined Animal Feeding Operations (CAFO) in watersheds that supply potable water to municipalities with a population over 250,000. As part of this study a bathymetric survey was completed on Oklahoma City's water supply reservoirs. A bathymetric map (Figure 63) was generated to determine current storage capacity and identify areas of extreme sedimentation. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800.

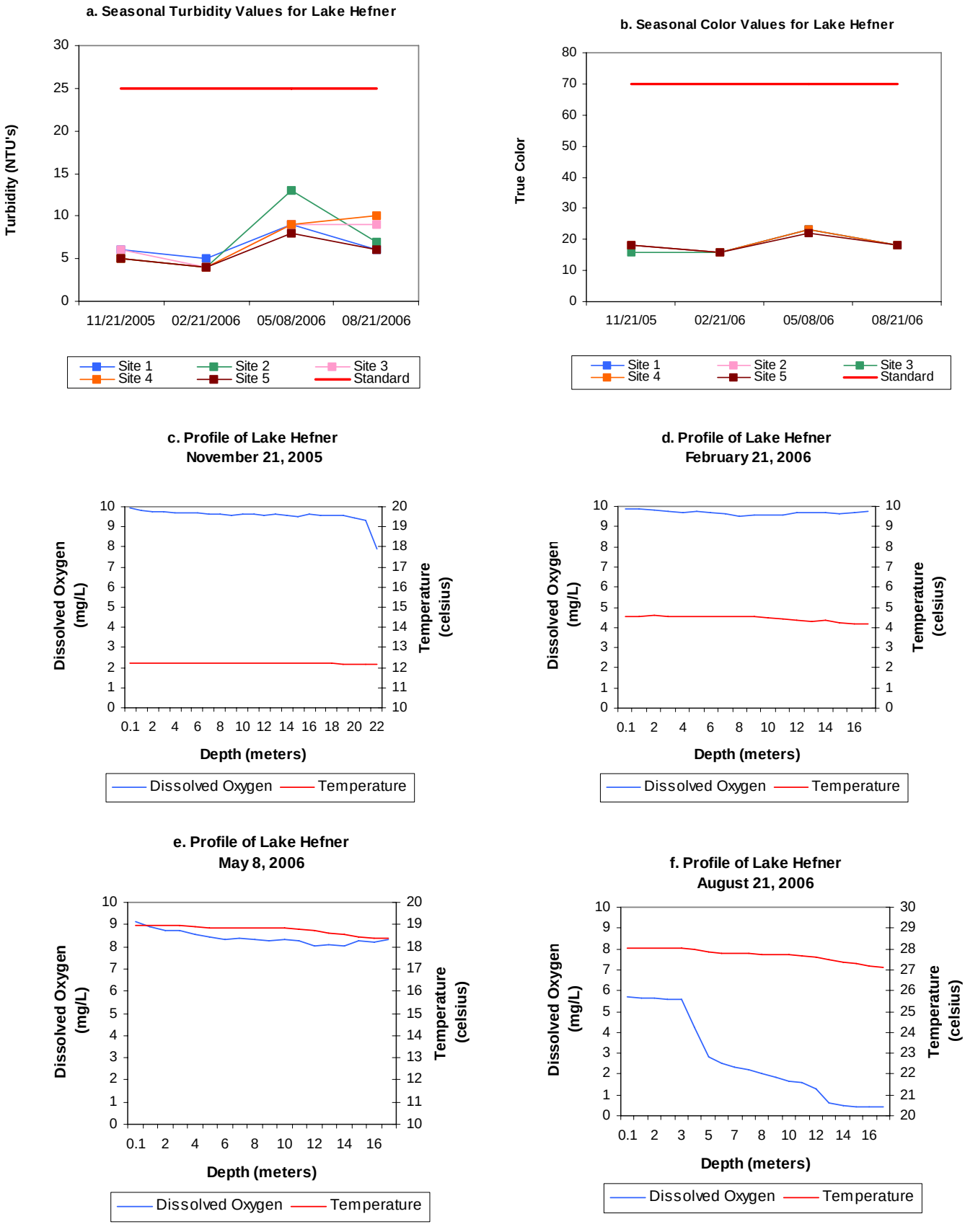
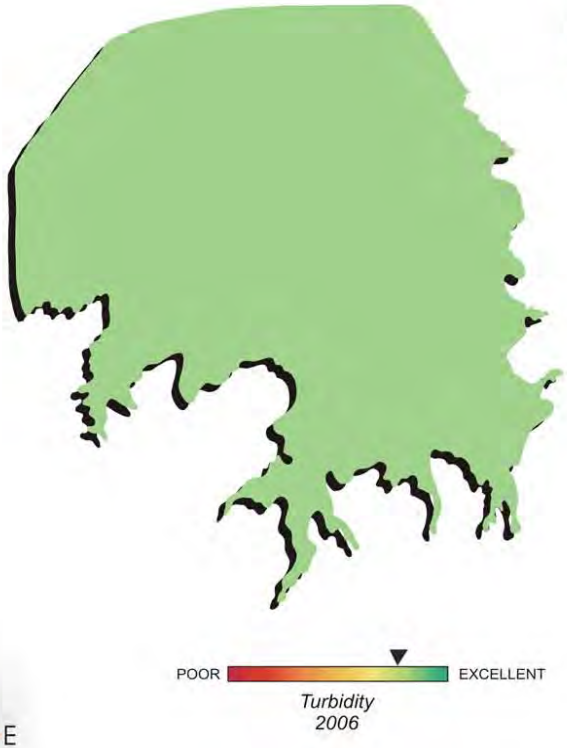


Figure 62a-62f. Graphical representation of data results for Lake Hefner.

Hefner Lake Location

Hefner Lake and Watershed



Turbidity 2006

Trophic State 2006

Lake Data

Owner	City of Oklahoma City
County	Oklahoma
Constructed in	1947
Surface Area	2,537.9 acres
Volume	68,867 acre/feet
Shoreline Length	15.8 miles
Mean Depth	27.13 feet
Watershed Area	9 square miles

Plate 51 - Lake Water Quality for
Hefner Lake

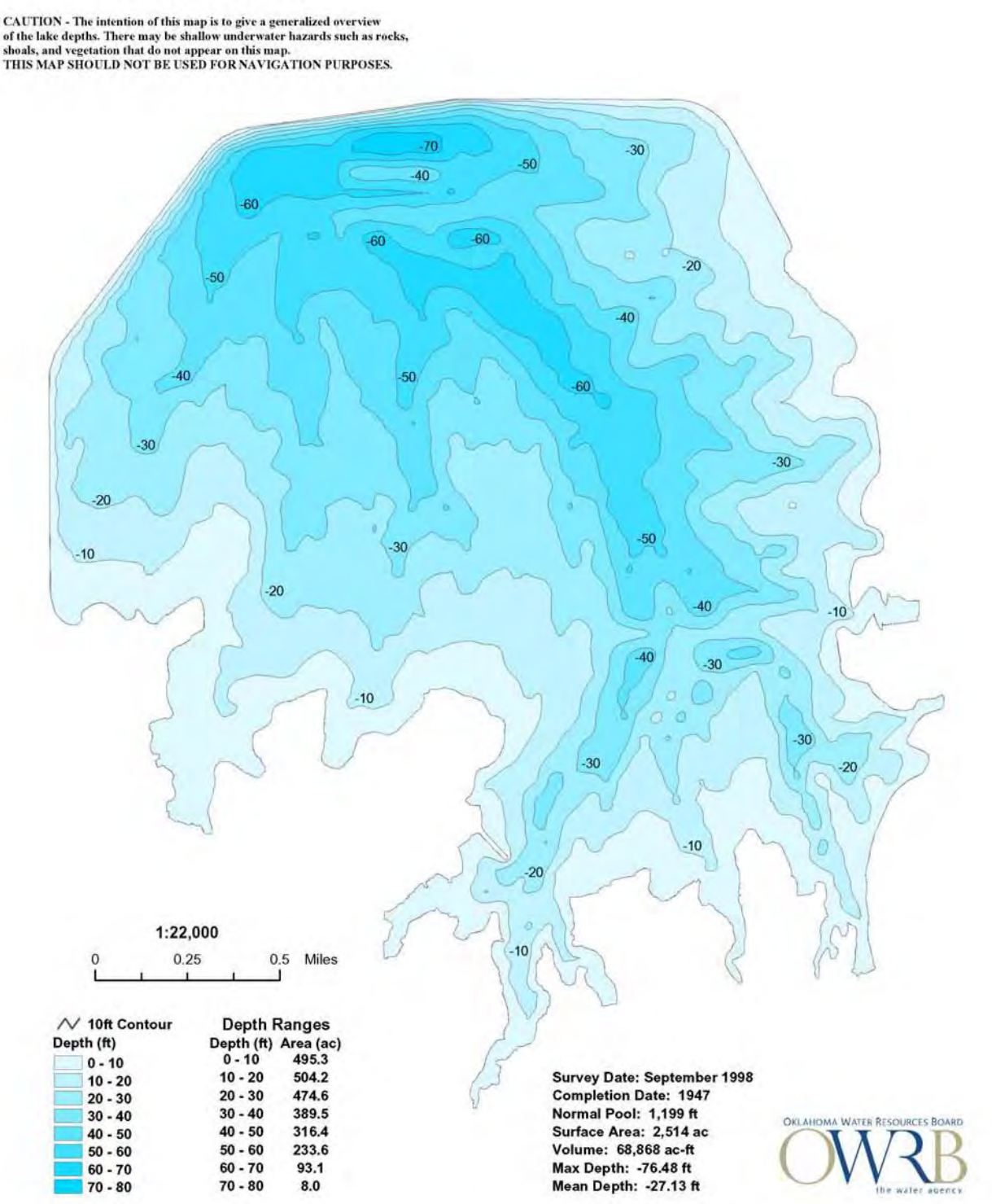


Figure 63. Bathymetric map of Hefner Lake.

Lake Henryetta

Lake Henryetta was sampled for four quarters from November 2004 through August 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 57 NTU (Plate 52), true color was 237 units and average secchi disk depth was 23 centimeters. Based on these parameters water clarity was poor at Lake Henryetta. Results are similar to those calculated in 2003 indicating no significant increase or decrease over time. The trophic state index (TSI) was calculated using values collected at all sites for four quarters (n=20). The result was a TSI of 47 (Plate 52), indicating the lake was mesotrophic with moderate primary productivity and nutrient conditions. This value is higher than that in 2003 (TSI=43), however, the trophic category is the same. The TSI values were fairly consistent and ranged seasonally from oligotrophic in the fall and winter to mesotrophic and lower eutrophy in the spring and summer. The only exception was a spike in chlorophyll concentration that resulted in a hypereutrophic value at site 5 during the fall quarter. Seasonal turbidity values are displayed in Figure 64a. All turbidity values were well above the turbidity standard of 25 NTU and ranged from a low of 45 NTU to a maximum of 70 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the turbidity values above the standard, the Fish and Wildlife Propagation (FWP) beneficial use is considered not supported Seasonal true color values are displayed in Figure 64b. True color values followed the same trend as turbidity, with all values exceeding the WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is supported at Lake Henryetta.

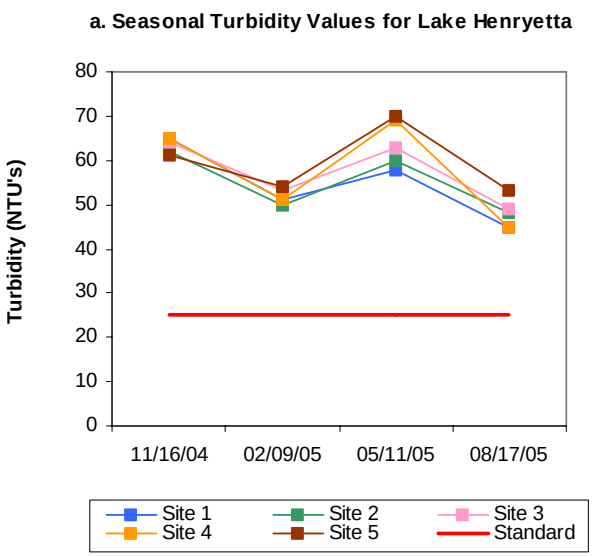
In 2004-2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were performed at all five-sample sites. The salinity ranged from 0.01 parts per thousand (ppt) to 0.04 ppt, which is lower than that seen in most Oklahoma reservoirs. Specific conductivity ranged from 51.4 µS/cm in the fall to 100.2 µS/cm in the summer, indicating the minimal presence of current conducting ions (salts and chlorides) in the lake system. The pH values ranged from 6.28 to 7.77 representing a neutral to slightly acidic system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Low pH values were recorded during the summer at sites 1,2, and 4. With only 5.5% of the values outside the acceptable range, the FWP beneficial use is considered supported based on pH. Oxidation-reduction potential ranged from 269 mV at the surface in the winter to 527 mV in the hypolimnion in the fall. In general, reducing conditions were not present during the study period. Thermal stratification was not present during the fall, winter, or spring quarters and the lake was well mixed with dissolved oxygen (D.O) levels remaining above 7.0 mg/L (Figure 64c-64e). In

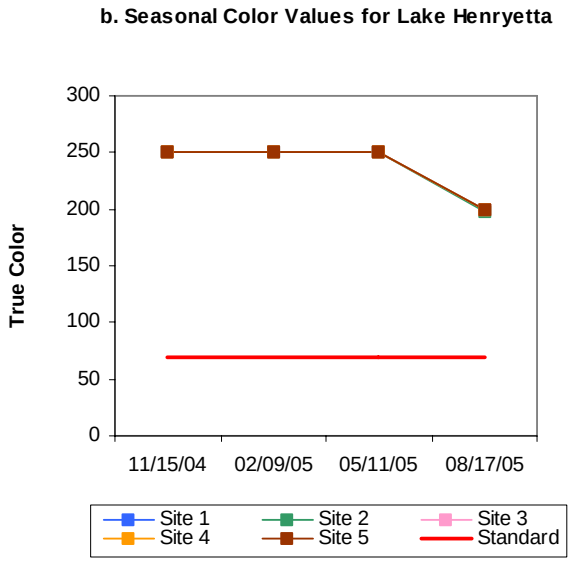
the summer the lake exhibited weak thermal stratification between 3 and 4 meters with dissolved oxygen dropping below 2.0 mg/L from 4 meters to the lake bottom of 5.6 meters, accounting for 28.6% of the water column to be anoxic at site 1 (Figure 64f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Lake Henryetta is considered supporting the FWP beneficial use based on dissolved oxygen. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

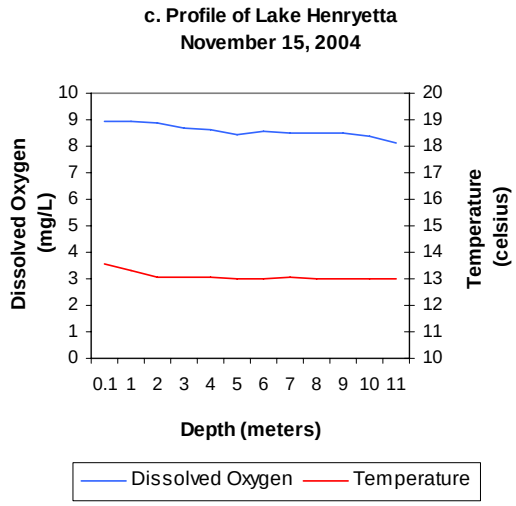
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

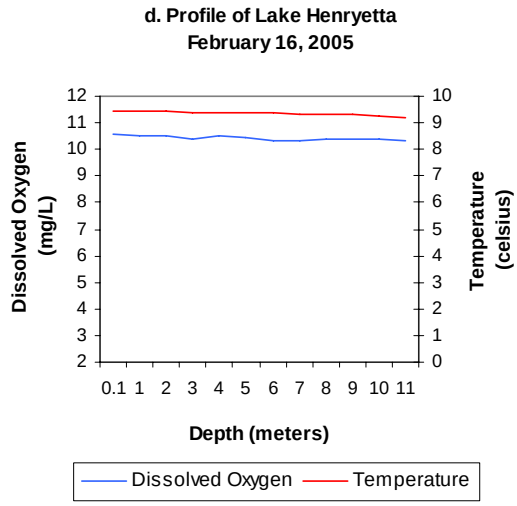
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.71 mg/L at the surface. Surface TN ranged from 0.44 mg/L in the summer to 1.07 mg/L in the spring quarter. The lake-wide total phosphorus (TP) average was 0.089 mg/L at the surface. TP values at the surface ranged from 0.067 mg/L in the summer to 0.228 mg/L in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 8:1 for sample year 2004-2005. This value slightly higher than 7:1, characterizing the lake phosphorus limited or possibly co-limited (Wetzel, 1983).

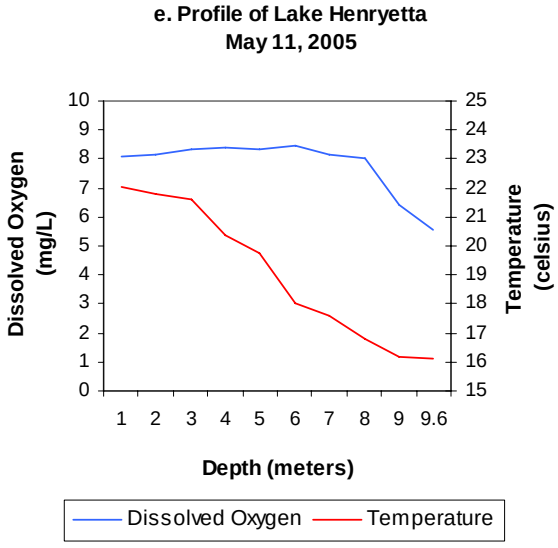
In summary, Lake Henryetta was classified as mesotrophic (TSI=47) with moderate primary productivity and nutrient conditions (Plate 52). Although the current value is higher than that of 2003 (TSI = 43), it is within the same trophic category. Water clarity is poor based on true color, turbidity and low secchi disk depth, which is consistent with historical findings. The FWP beneficial use is considered supported based on pH and dissolved oxygen levels recorded during the study period. With 100% of the values exceeding 25 NTU, the lake is not meeting the FWP based high turbidity. The lake is supporting the Aesthetics beneficial use based on its trophic status, however not supporting based on true color with values ranging from 199-250 color units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake Henryetta, located in Okmulgee County, constructed in 1928 serves as municipal water supply and recreation reservoir.











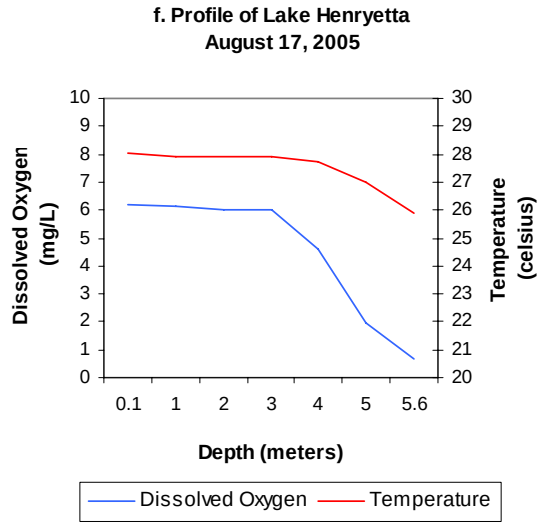


Figure 64a-64f. Graphical representation of data results for Lake Henryetta.

Lake Henryetta
Location

Lake Henryetta
and
Watershed

Lake Data	
Owner	City of Henryetta
County	Okmulgee
Constructed in	1928
Surface Area	450 acres
Volume	6,660 acre/feet
Shoreline Length	11 miles
Mean Depth	14.80 feet
Watershed Area	21 square miles

POOR EXCELLENT

Turbidity
2005

POOR EXCELLENT

Trophic State
2005

Plate 52 - Lake Water Quality for
Lake Henryetta

LAKES MONITORING PROGRAM

Heyburn Lake

Heyburn Lake was sampled for four quarters from October 2004 through July 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitions and lacustrine zone of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 40 NTU (Plate 53), true color was 111 units and average secchi disk depth was 37 centimeters. Based on these parameters Heyburn Lake had poor water clarity in comparison to other Oklahoma reservoirs. These values are similar to those calculated in 2003 indicating no significant increase or decrease over time. The trophic state index (TSI) was calculated using values collected at all sites for four quarters (n=20). The result was a TSI of 47 (Plate 53), indicating the lake was mesotrophic during the study period. This value is the similar to that calculated in 2003 (TSI=46), indicating that no significant increase or decrease in productivity has occurred. The TSI values were fairly consistent and varied seasonally from oligotrophic in the winter to upper meso-eutrophic in the fall, with mesotrophic values in both spring, and summer quarters. Seasonal turbidity values are displayed in Figure 65a. Turbidity values ranged from a low of 27 NTU to a maximum of 61 NTU. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the turbidity values above 25 NTU, the Fish and Wildlife Propagation (FWP) beneficial use is not supported based on turbidity. Seasonal true color values are displayed in Figure 65b. Of the twenty values collected 80% were above the WQS of 70 units. Applying the same default protocol, the Heyburn Lake is considered not supporting the Aesthetics beneficial use.

In 2004-2005Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were performed at all sample sites. Salinity values at Heyburn Lake ranged from 0.08 parts per thousand (ppt) to 0.16 ppt. This is within the average recorded for most Oklahoma reservoirs. Specific conductivity ranged from 174.5 µS/cm to 325.9 µS/cm indicating the minimal presence of current conducting ions (salts and chlorides) in the lake system. The pH values ranged from 6.87 to 8.01 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the FWP beneficial use is supported based on pH. Oxidation-reduction potential (ORP) ranged from 318 mV to 480 mV. In general, reducing conditions were not present at any time during the study period. Thermal stratification was not present during any of the first three quarters and the lake was well mixed. (Figure 65c-65e). Thermal stratification was evident and anoxic conditions were present during the summer sampling interval. Stratification occurred between 1 and 2 meters at which point the dissolved oxygen dropped below 2.0 mg/L to bottom of the lake (5.5 meters) accounting for 71% of the water column to be experiencing anoxic conditions. Sites 2 and 5 were also stratified between 1

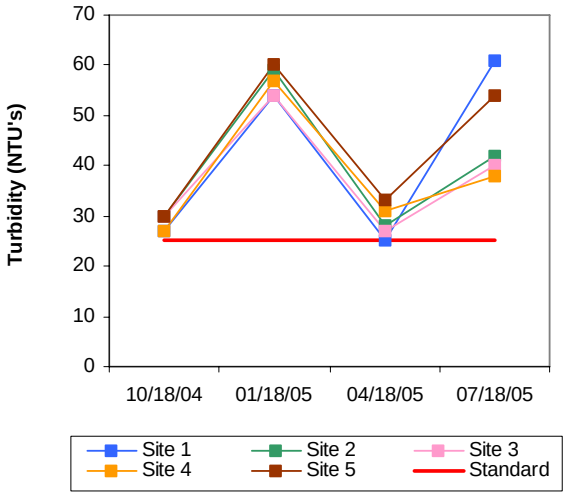
and 2 meters with 33 and 50% of the water column below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Heyburn Lake is considered not supporting the FWP beneficial use based on low D.O. values in the summer. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

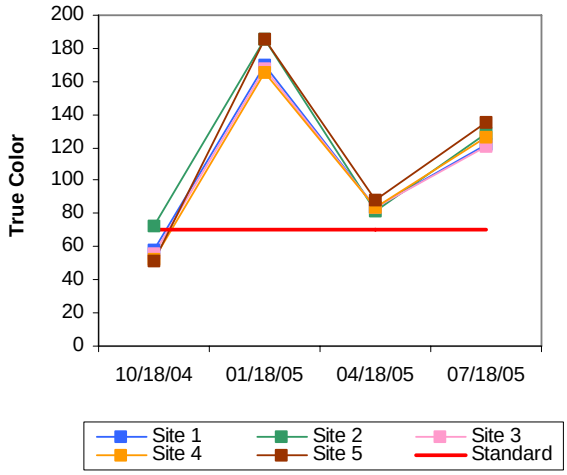
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.60 mg/L at the surface. Surface TN ranged from 0.39 mg/L in the fall to 0.80 mg/L in the summer quarter. The lake-wide total phosphorus (TP) average was 0.043 mg/L at the surface. Similar to total nitrogen, TP values at the surface ranged from 0.029 mg/L in the fall to 0.067 mg/L in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was 14:1 for sample year 2004-2005. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Heyburn Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels. This current TSI is similar to that calculated in 2003 (TSI=46), indicating that no significant increase or decrease in productivity has occurred. Water clarity was poor based on turbidity, true color, and low secchi disk depth readings. Light limitation driven by the high turbidity may play a role in keeping nutrients at bay. The FWP beneficial use is supported based on pH, but not supported based on low dissolved oxygen and on high turbidity values recorded during the sample year. The Aesthetics beneficial use is supported based on its trophic status. With 80% of the true color values exceeding the WQS of 70 units the Aesthetics beneficial use is considered not supported as it relates to color. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. The Oklahoma Department of Environmental Quality (ODEQ) sampled Heyburn Lake in 2002 as part of the Toxics and Reservoirs program. Mercury residue exceeding the advisory level was found in fish tissue and the ODEQ recommends continued sampling. The United States Army Corps of Engineers (USACE) constructed Heyburn Lake for flood control and other recreation purposes.

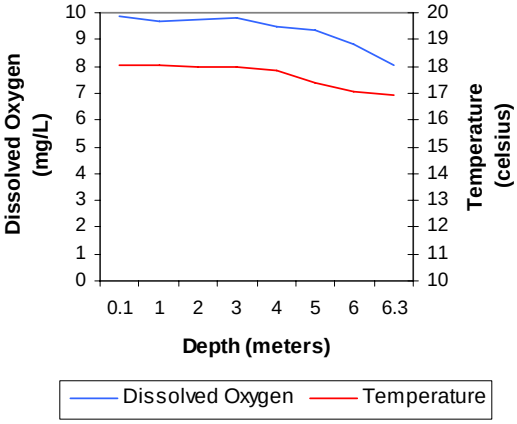
a. Seasonal Turbidity Values for Heyburn Lake



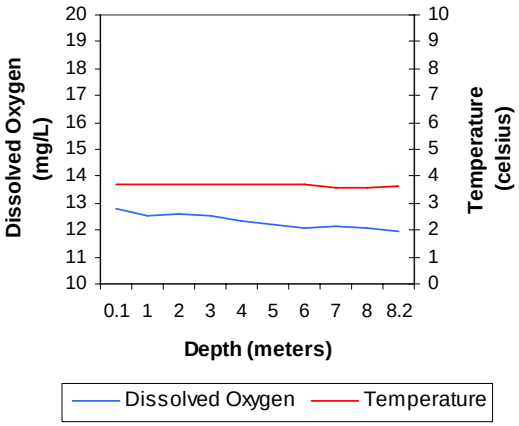
b. Seasonal Color Values for Heyburn Lake



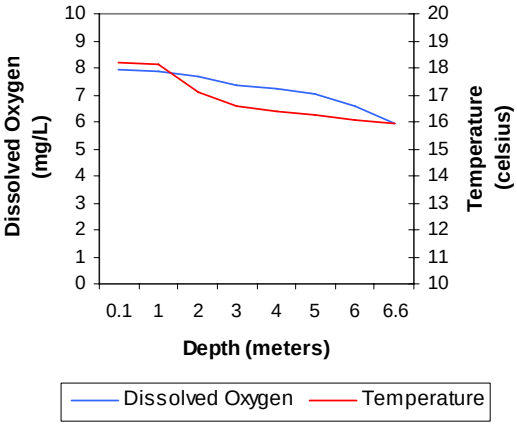
c. Profile of Heyburn Lake
October 18, 2004



d. Profile of Heyburn Lake
January 18, 2005



e. Profile of Heyburn Lake
April 18, 2005



f. Profile of Heyburn Lake
July 18, 2005

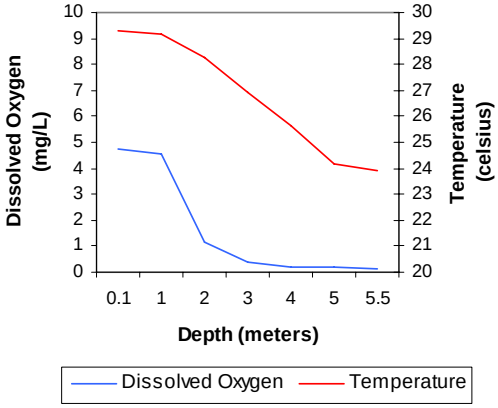
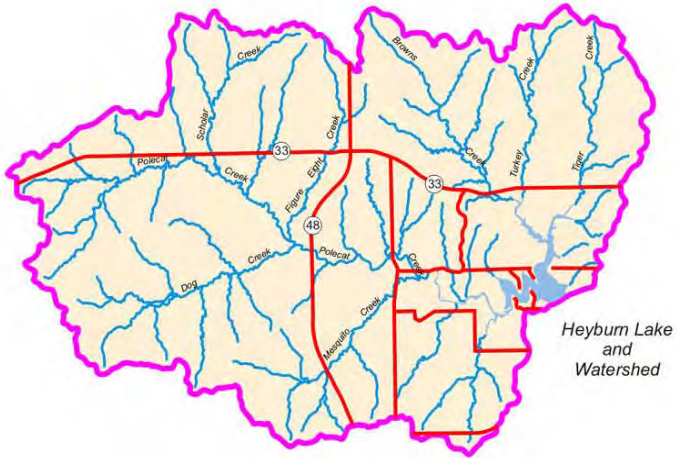
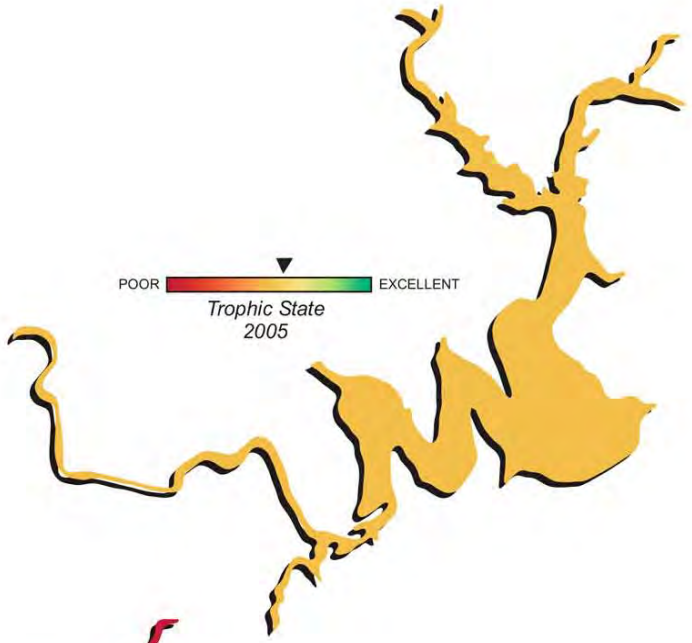


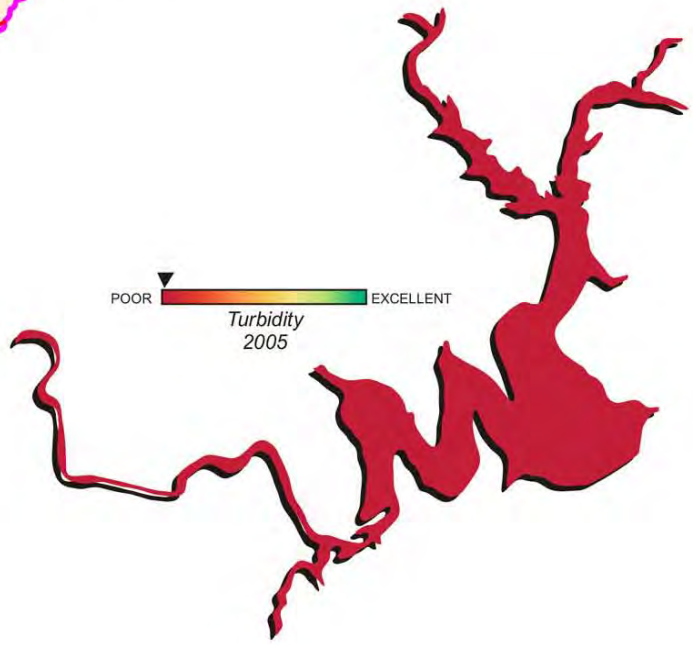
Figure 65a-65f. Graphical representation of data results for Heyburn Lake.

Heyburn Lake Location



Heyburn Lake and Watershed





Lake Data	
Owner	Corps of Engineers
County	Creek
Constructed in	1950
Surface Area	880 acres
Volume	7,101 acre/feet
Shoreline Length	50 miles
Mean Depth	8.37 feet
Watershed Area	123 square miles

Plate 53 - Lake Water Quality for
Heyburn Lake

LAKES MONITORING PROGRAM

Holdenville Lake

Holdenville Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 18 NTU (Plate 54), true color was 26 units, and secchi disk depth was 61 centimeters. Based on these three parameters, Holdenville Lake had average to good water clarity in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 50 (Plate 54), classifying the lake as mesotrophic bordering eutrophic, indicative of moderate to high levels of productivity and nutrient conditions. The TSI values varied seasonally from eutrophic in the fall and mid to upper mesotrophic in the winter and spring quarters. Eutrophic conditions were again present during the summer sampling interval. Six of the twenty turbidity values collected were above the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 66a). According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 30% of the samples collected in 2003-2004 were above the standard, it is likely that the peak seen in March is due to seasonal rain events. Holdenville Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial as it relates to turbidity. Seasonal true color values are displayed in Figure 66b. All true color values were below the aesthetics WQS of 70 units. Applying the same default protocol for determining the short-term average for true color the Aesthetics beneficial use is considered fully supported at Holdenville Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity ranged from 0.06 parts per thousand (ppt) to 0.08, well within the range of expected values for Oklahoma lakes. Reflecting the minimal presence of chlorides or other salts in the lake. Specific conductivity values were also well within the expected range for Oklahoma reservoirs, coinciding with the low salinity values seen for the lake. Values ranged from 142.7 µS/cm in the spring quarter to 183.1 µS/cm in the winter quarter. Oxidation-reduction potentials (redox) ranged from 392 mV near the sediment-water interface at the lake bottom in the summer to 577 mV in the fall in the water column. Reducing conditions were absent in all sampling intervals. Lake pH values were neutral with values ranging from 7.11 to 7.92 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Holdenville Lake is fully supporting its FWP beneficial use based on pH. Thermal stratification was not evident in the fall, winter or spring quarters and dissolved oxygen (D.O.) remained above 4.0 mg/L at all times and was generally above 7.0 mg/L (see Figure 66c-66e). In the summer, both thermal stratification was evident

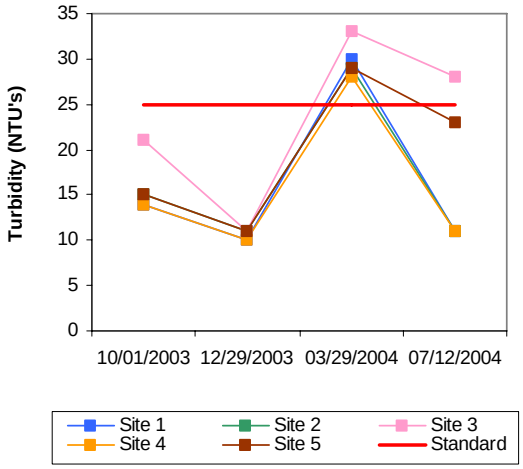
and anoxic conditions were present. The lake was stratified between 4 and 5 meters below the surface and D.O. concentrations were 1.0 mg/L or less from 5 meters to the lake bottom at 11.2 meters (see Figure 66f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial is considered partially supported at Holdenville Lake with approximately 62% of the water column having D.O. concentrations less than 2.0 mg/L at site 1, in the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected four (40%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (36.7 cfu/ml) exceeds the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

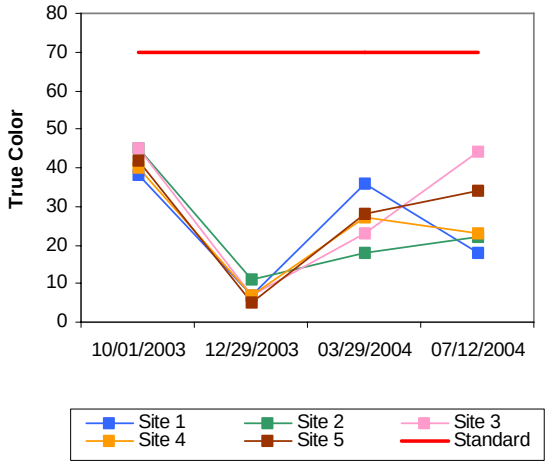
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.55 mg/L at the lake surface. The TN at the surface ranged from 0.24 mg/L to 0.72 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average was 0.031 mg/L at the lake surface. The TP ranged from 0.023 mg/L to 0.046 mg/L. The highest surface TP value was reported in the summer quarter and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 18:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Holdenville Lake is currently mesotrophic bordering eutrophic, indicative of high primary productivity and nutrient conditions (Plate 54). Holdenville Lake is fully supporting its FWP beneficial use for pH. Although 30% of the samples collected in 2003-2004 were above the standard, it is likely that the peak seen in March is due to seasonal rain events, therefore Holdenville Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial as it relates to turbidity. Anoxic conditions were present in the summer therefore the lake is partially supporting its FWP beneficial used based on recorded D.O. values (OAC 785:46). The lake is fully supporting its Aesthetics beneficial use based on its trophic status and true color. Water clarity is average to good based on turbidity, true color and secchi disk depth. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected four (40%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (36.7 cfu/ml) exceeds the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported. Holdenville Lake was constructed in 1931 and is owned and operated by the City of Holdenville. The lake is managed to serve as the Holdenville's municipal water supply and also offers a recreational outlet for the general public to utilize.

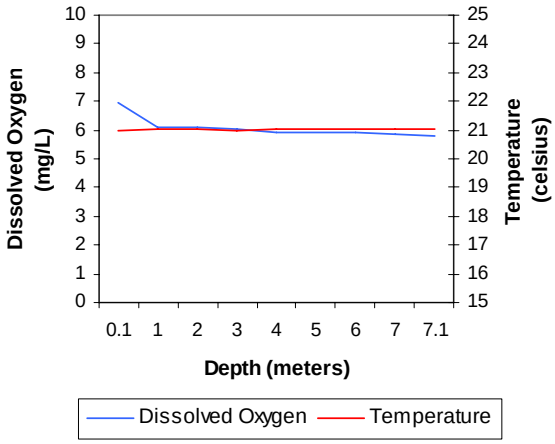
a. Seasonal Turbidity Values for Holdenville Lake



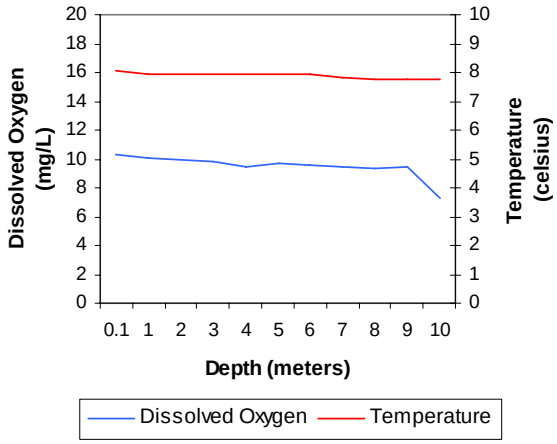
b. Seasonal Color Values for Holdenville Lake



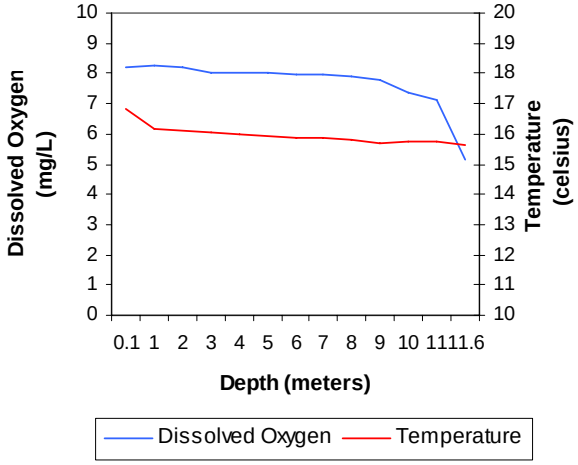
c. Profile of Holdenville Lake
October 01, 2003



d. Profile of Holdenville Lake
December 29, 2003



e. Profile of Holdenville Lake
March 29, 2004



e. Profile of Holdenville Lake
July 12, 2004

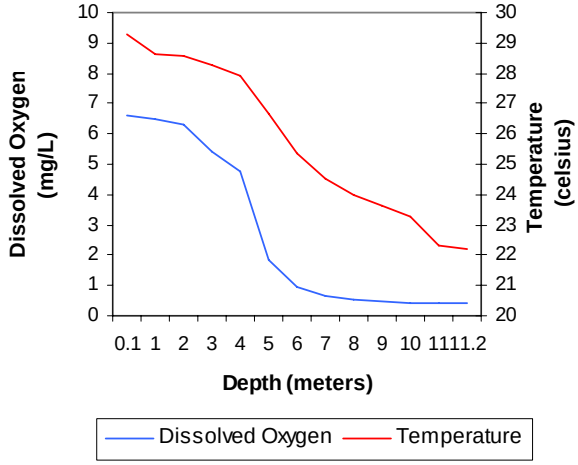


Figure 66a-66f. Graphical representation of data results for Holdenville Lake.

Plate 54 - Lake Water Quality for Holdenville Lake

Holdenville Lake
Location

Lake Data	
Owner	City of Holdenville
County	Hughes
Constructed in	1931
Surface Area	550 acres
Volume	11,000 acre/feet
Shoreline Length	11 miles
Mean Depth	20.00 feet
Watershed Area	9 square miles

Hominy Municipal Lake

Hominy Municipal Lake was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites with an additional sample collected at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 9 NTU (Plate 55), true color was 17 units, and secchi disk depth was 114 centimeters. Based on these three parameters, Hominy Municipal Lake had excellent water clarity in 2003-2004 and is one of the nicer small municipal lakes in Oklahoma. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 49 (Plate 55), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. The TSI values were generally mesotrophic with eutrophic conditions present during the spring sampling interval. All turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 67a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the samples below the standard, the Fish & Wildlife Propagation (FWP) beneficial use is fully supported. Seasonal true color values are displayed in Figure 67b. True color values were fairly consistent between seasons and were all below the aesthetics WQS of 70 units (see Figure 67b). Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the true color values.

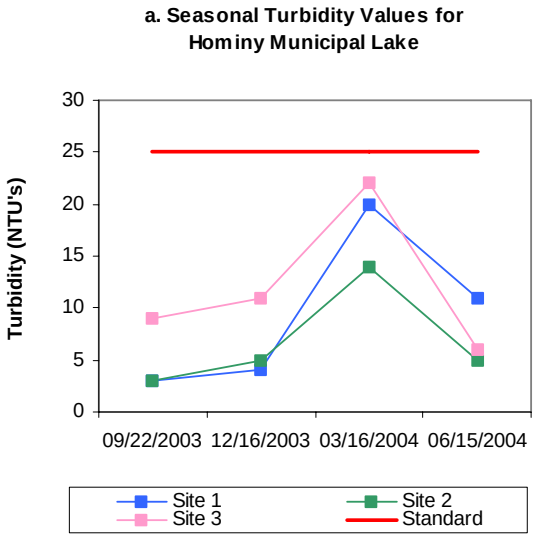
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity values ranged from 0.08 parts per thousand (ppt) to 0.15 ppt, which is within the expected range for Oklahoma reservoirs. Readings for specific conductivity were also within the normal range of values recorded in most Oklahoma lakes, ranging from 177 µS/cm in the spring to 307 µS/cm in the winter quarter. These values indicate low concentrations of electrical current conducting materials (salts) were present in the lake system, which corresponds with the low salinity values. In general, pH values were neutral to slightly alkaline, ranging from 6.81 to 8.17 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Hominy Municipal Lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 309 mV in the spring quarter to 513 mV in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir in during the sampling period. The lake was thermally stratified in the fall quarter between 6 and 7 meters below the surface at which point dissolved oxygen (D.O.) concentrations in the water column were below 2.0 mg/L to the lake bottom at 11 meters (Figure 67c). In both winter and spring quarters the lake was well mixed and oxygenated with D.O. values above 8.0 mg/L (Figure 67d-67e). In the summer the

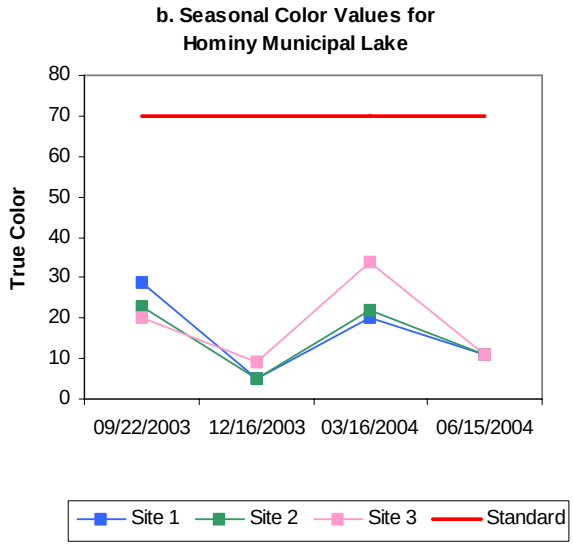
lake was strongly thermally stratified between 4 and 5 meters, at site 1, with D.O. values falling below 2.0 mg/L from 6 meters to the lake bottom of 13.4 meters (see Figure 67f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use could be considered partially supported at Hominy Municipal Lake because approximately 60% of the water column was anoxic at site 1 in the summer quarter. During the fall quarter, only 33% of the water column has D.O. concentrations of less than 2.0 mg/L. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

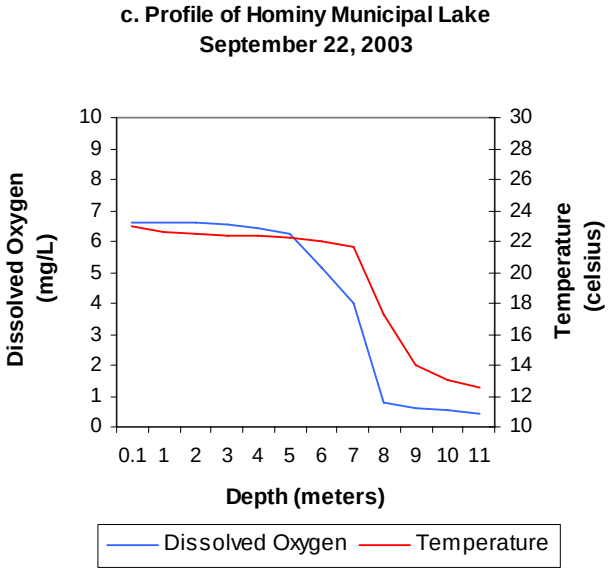
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 samples collected one (10%) exceeded the prescribed screening level of 235 cfu/ml for *E. coli*, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

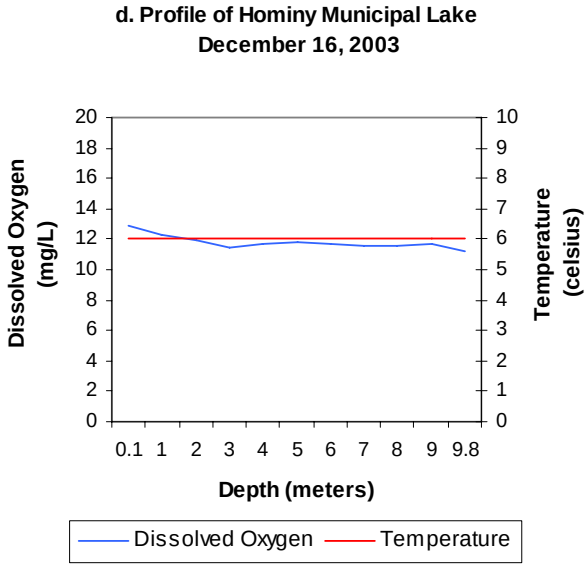
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.41 mg/L at the lake surface. The TN at the surface ranged from 0.29 mg/L to 0.63 mg/L. The highest surface TN value was reported in the winter quarter and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average was 0.019 mg/L at the lake surface. The surface TP ranged from 0.012 mg/L to 0.28 mg/L. The highest surface TP value was reported in the spring and the lowest was recorded in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 22:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

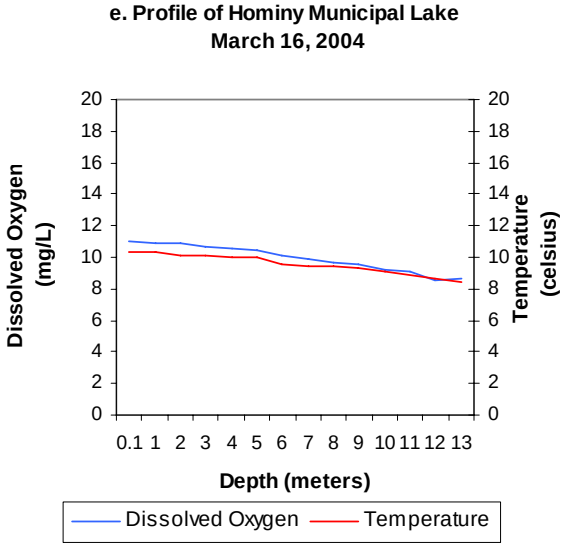
In summary, Hominy Municipal Lake was classified as mesotrophic, indicating moderate productivity and nutrient levels (Plate 55). The FWP beneficial use is fully supporting based on turbidity and pH values, however the use is partially supported based on the collected D.O. values in the water column. The Aesthetics beneficial use was supported based on true color values as well as the trophic status. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 235 cfu/ml for *E. coli*, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. In general, the lake is one of the nicer small municipal lakes in Oklahoma and has good water quality. Hominy Municipal Lake is the municipal water supply for the City of Hominy and is owned and operated by the city. The lake was constructed in 1940 and is also utilized for recreational purposes.











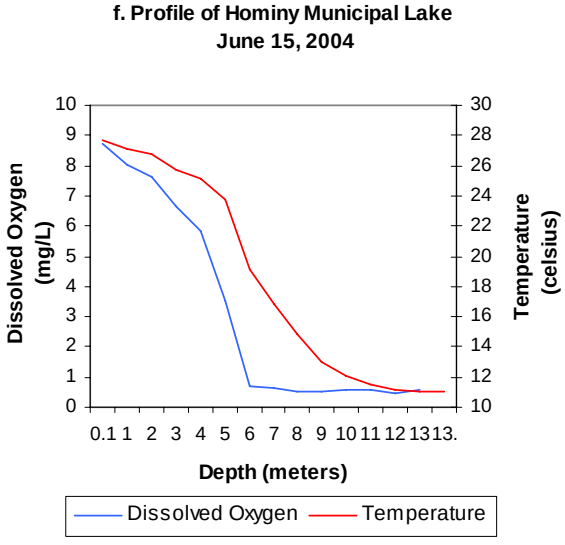


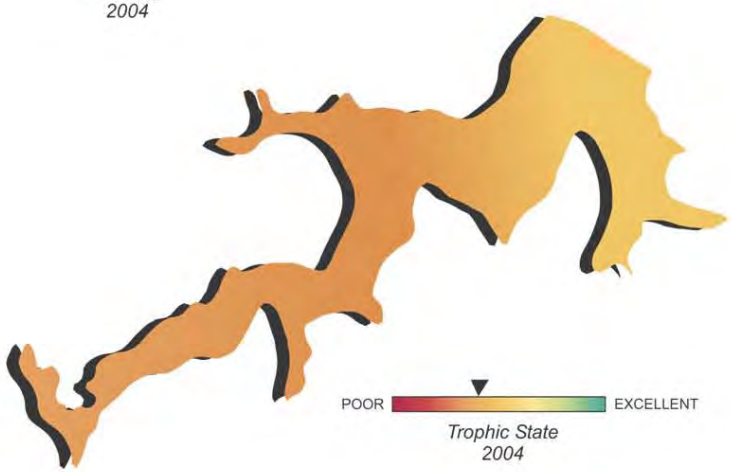
Figure 67a-67f. Graphical representation of data results for Hominy Municipal Lake.

Hominy Lake Location

Hominy Lake and Watershed

POOR — EXCELLENT

Turbidity 2004



POOR — EXCELLENT

Trophic State 2004

Lake Data	
Owner	City of Hominy
County	Osage
Constructed in	1940
Surface Area	165 acres
Volume	5,000 acre/feet
Shoreline Length	6 miles
Mean Depth	30.30 feet
Watershed Area	3,282 acres

Plate 55 - Lake Water Quality for
Hominy Lake

Hudson Lake (Osage County)

Hudson Lake (Osage County), is owned and operated by the City of Bartlesville and was constructed in 1949 to serve as a municipal water supply for the city and to offer recreational opportunities for the public. Hudson Lake was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 8 NTU (Plate 57), true color was 21 units, and secchi disk depth was 98 centimeters. Based on these three parameters, Hudson Lake (Osage County) had good water clarity in 2005-2006, slightly better than that of the previous evaluation in 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 57 (Plate 57), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This is very similar to the TSI in 2004 (TSI=54), indicating no significant increase or decrease in productivity has occurred over time. The TSI values varied seasonally at Hudson Lake (Osage County) from mesotrophic in the winter, to upper mesotrophic in the spring and eutrophic in the fall and even hypereutrophic conditions in the summer quarter. All turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU with values ranging from a low of 5 NTU to a maximum of 16 NTU (see Figure 68a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the collected values below the WQS of 25 NTU, the lake is considered supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 68b. Similar to turbidity, all true color values were well below the standard throughout the sample year. The Aesthetics beneficial use is therefore considered supported based on true color concentrations in the water column.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.08 parts per thousand (ppt) to 0.14 ppt, which is within the range of values reported for Oklahoma lakes. Readings for specific conductivity ranged from 178.3 µS/cm to 297.4 µS/cm, indicating low to moderate concentrations of electrical current conducting compounds (salts) were present in the water column throughout the year. These values also corresponded with the recorded salinity values. In general, pH values were neutral to very slightly alkaline, ranging from 6.84 to 8.75 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the recorded values within the acceptable range, Hudson Lake is fully supporting its FWP beneficial use based on pH values. Oxidation-reduction potentials (redox) ranged from 61 mV at the

water-sediment interface in the summer to 442 mV in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir, in fact; only 5 readings were less than 200 mV in 2005-2006. In the fall quarter the lake exhibited thermal stratification at several 1-meter intervals at site 1, with dissolved oxygen (D.O.) recorded as less than 2.0 mg/L from 8 meters to the lake bottom of 9.2 meters (Figure 68c). The lake did not exhibit thermal stratification in the winter or spring quarters (see Figure 68d-68e). In the summer the lake was stratified between 4 and 5 meters at sites 1 and the D.O. concentration was less than 2.0 mg/L below 5 meters extending to the lake bottom at 7.7 meters (see Figure 68f). Anoxic conditions were present in approximately 33 (site 2) to 44% (site 1) of the water column during the summer sampling interval. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With up to 44% of the water column at site 1 experiencing anoxic conditions in the summer, the FWP beneficial use is considered supported at Hudson Lake (Osage County). The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

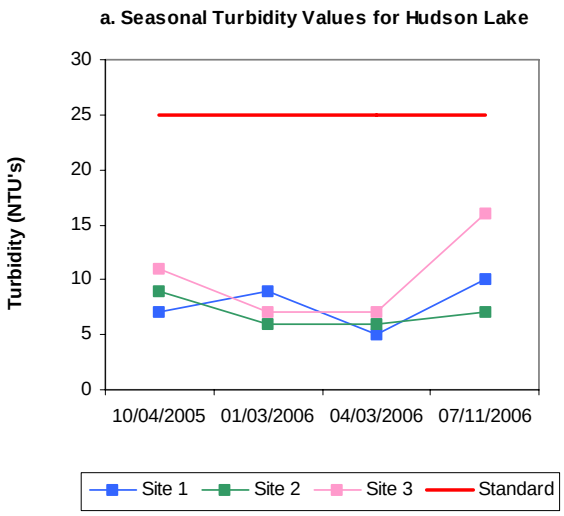
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

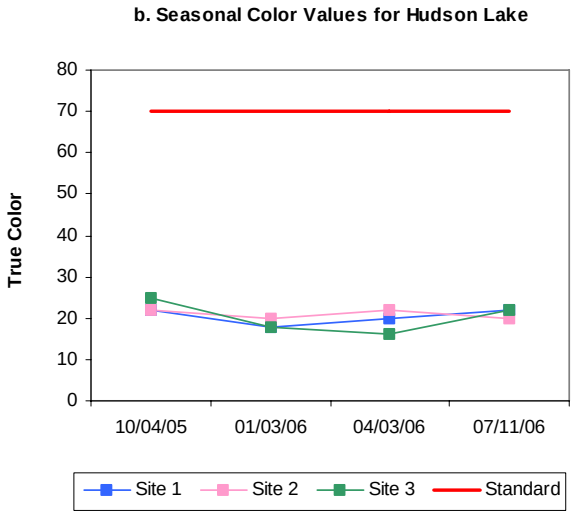
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.62 mg/L at the lake surface and ranged from 0.45 mg/L to 1.01 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average was 0.034 mg/L at the lake surface. The surface TP ranged from 0.021 mg/L to 0.073 mg/L. Similar to TN, the highest surface TP value was reported in the summer however the lowest was in the winter. The nitrogen to phosphorus ratio (TN:TP) was approximately 18:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

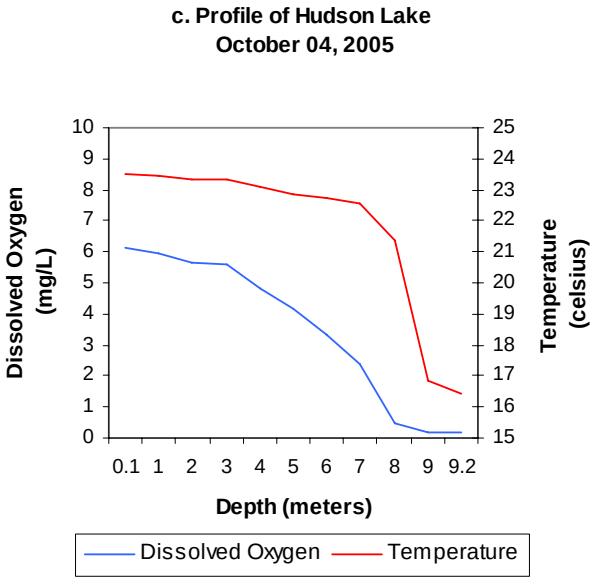
Hudson Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

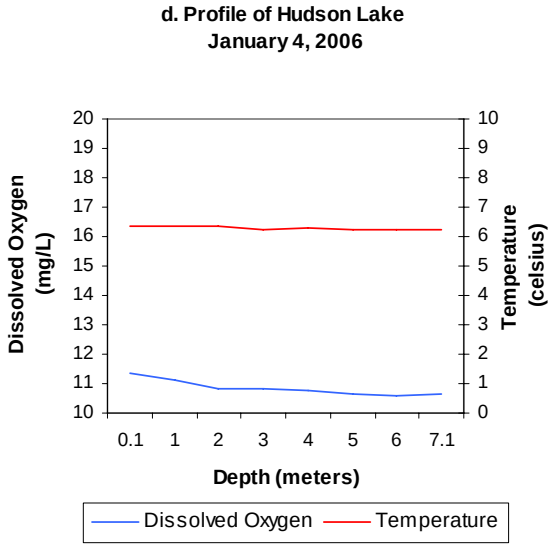
In summary, Hudson Lake (Osage County) was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 57). This is consistent with past data collection efforts in 2001 and 2004, which also found the lake to be eutrophic. Water clarity was good based on turbidity, true color and secchi depth. The FWP beneficial use was fully supported based on pH, turbidity and dissolved oxygen levels recorded throughout the sample year. The Aesthetics beneficial use was fully supported based on trophic status. With 100% of the reported values below the WQS of 70 units, the Aesthetics beneficial use is also considered supported based on true color concentrations in the water column. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the

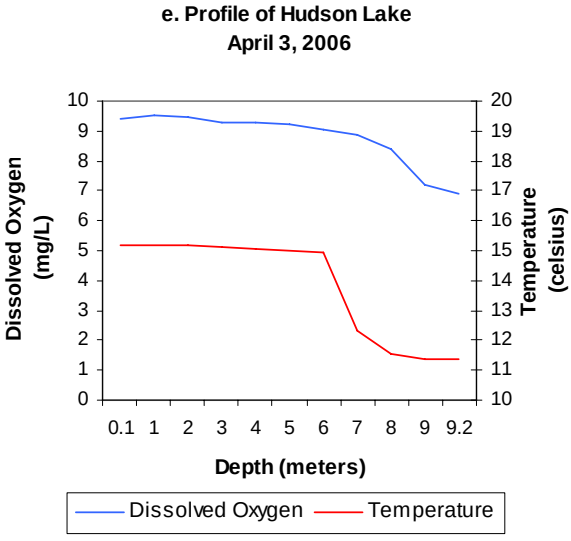
screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.











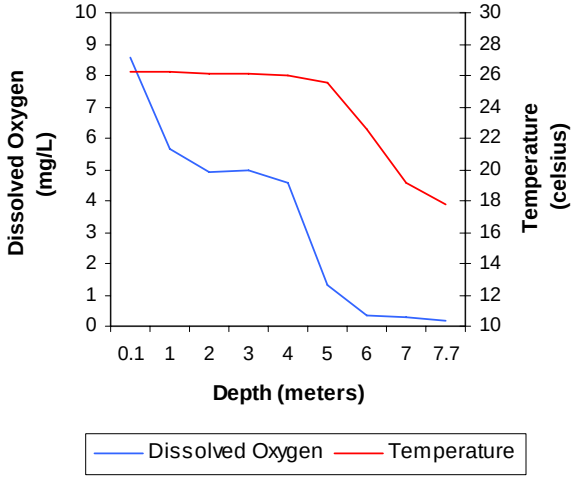
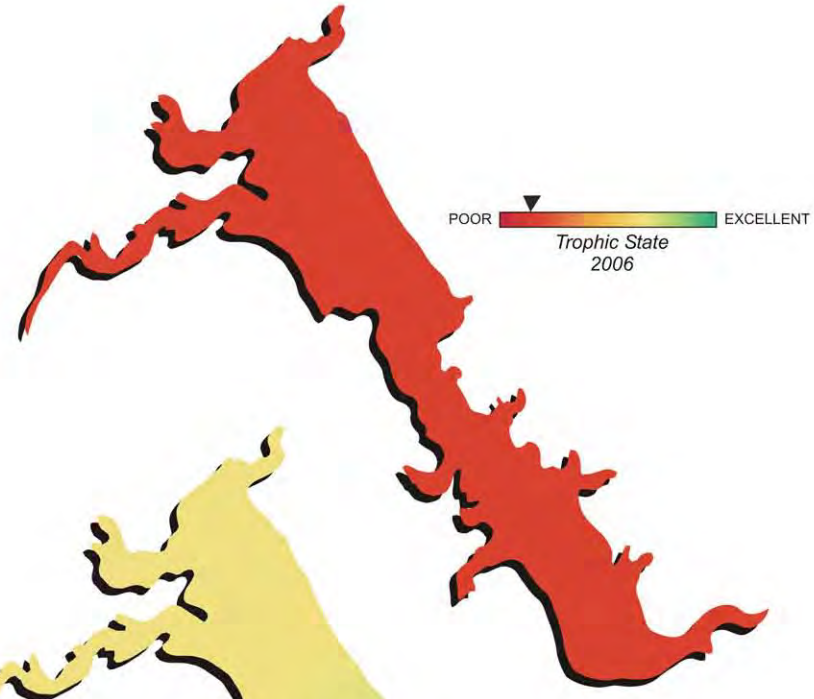


Figure 68a-68f. Graphical representation of data results for Hudson Lake (Osage County).

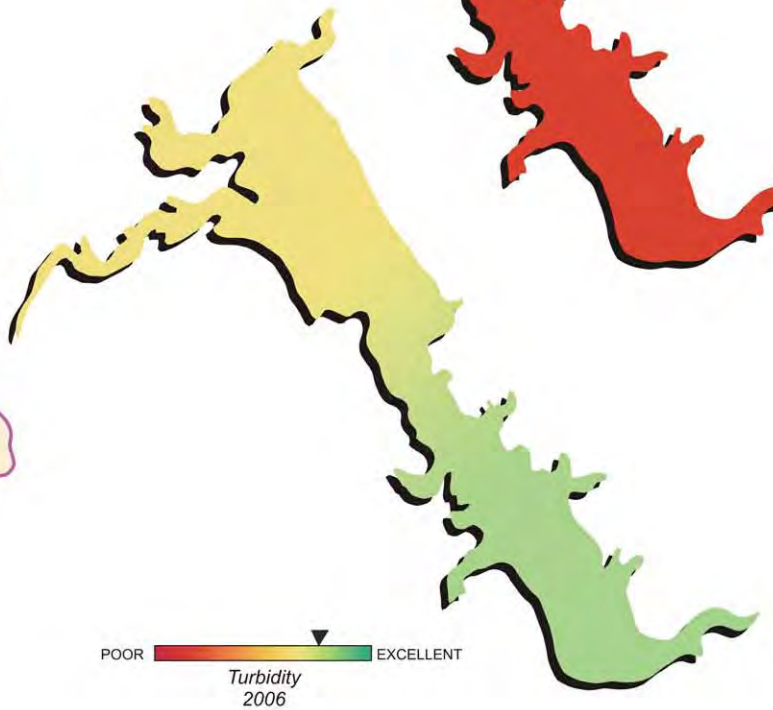
Hudson Lake
Location

Hudson Lake
and
Watershed

Lake Data	
Owner	City of Bartlesville
County	Osage
Constructed in	1949
Surface Area	250 acres
Volume	4,000 acre/feet
Shoreline Length	8 miles
Mean Depth	16.00 feet
Watershed Area	14 square miles



Trophic State
2006



Turbidity
2006

Plate 57 - Lake Water Quality for
Hudson Lake (Osage Co.)

LAKES MONITORING PROGRAM

Lake Hudson (Mayes Co.)

Lake Hudson was sampled for four quarters from October 2004 through July 2005. Water quality samples were collected at eight (8) sites to represent the riverine, transition and lacustrine zones and arms of the reservoir. Samples were collected at the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 11 NTU (Plate 56), true color was 25 units and average secchi disk depth was 65 centimeters. Based on these three parameters Lake Hudson had good water clarity in 2005. These values are similar to the values reported in 2003 although secchi disk depth has decreased some the last evaluation. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a) was calculated using values at all site for four quarters (n=32). The TSI was 60 (Plate 56), indicating the lake was eutrophic with high primary productivity and nutrient levels. Although this differs from the value reported in 2003, (TSI= 55), the trophic classification is the same. The TSI values varied seasonally ranging from eutrophic during the fall to mesotrophic in the winter quarter. All sites were hypereutrophic in the spring and equally divided between hypereutrophic and eutrophic during the summer quarter. Seasonal turbidity values are displayed in Figure 69a. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the values below the standard the Fish and Wildlife Propagation beneficial use is deemed fully supported. Seasonal true color values are displayed in Figure 69b. Similar to turbidity, all true color values were well below the WQS of 70 units for all quarters during the sample year. Applying the same default protocol the Aesthetics beneficial use is supported based on true color.

In 2004-2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity; oxidation-reduction potential and salinity were recorded at all five sample sites. Salinity ranged from 0.10 parts per thousand (ppt) to 0.14 ppt for this sample year, which is within the average range of values reported for Oklahoma lakes. Specific conductivity values ranged from 229.5 µS/cm in the fall to 295.7 µS/cm indicating a moderate level of current conducting ions (salts) were present in the system. The pH values were neutral to slightly alkaline at Lake Hudson ranging from 7.02 to 8.72. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the FWP beneficial use is considered supported based as it relates to pH. Oxidation-reduction potentials ranged from 206 mV in the winter to 539 mV in the hypolimnion during the summer sampling interval. Reducing conditions were not present in this reservoir during the 2004-2005-sample year. During the fall and spring sampling intervals stratification was not present and the lake was well mixed with dissolved oxygen concentrations remaining above 5.0 mg/L throughout the water column (Figure 69c-69d). Due

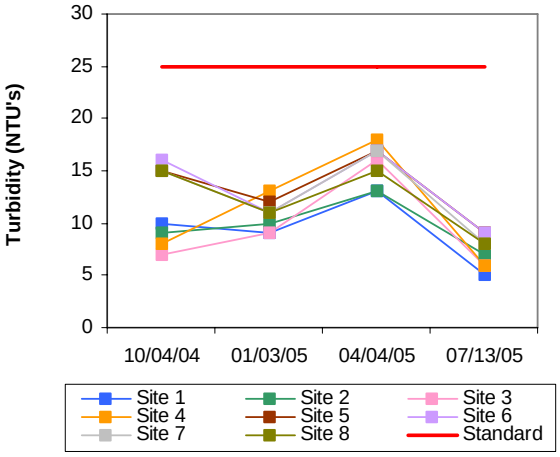
to an equipment malfunction in the winter all recorded D.O. values appear to be erroneous and an assessment cannot be made, however based on the time of year anoxic conditions are generally not present. In the summer quarter, thermal stratification was evident and occurred at several 1-meter intervals throughout the water column. Dissolved oxygen ranged from 9.83 mg/L at the surface to 1.22 mg/l at the lake bottom of 10.9 meters at site 1, accounting for approximately 17 % of the water column to be anoxic (Figure 69e). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 17% of the water column in the summer falling below 2.0 mg/L the FWP beneficial use is considered supported at Lake Hudson. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

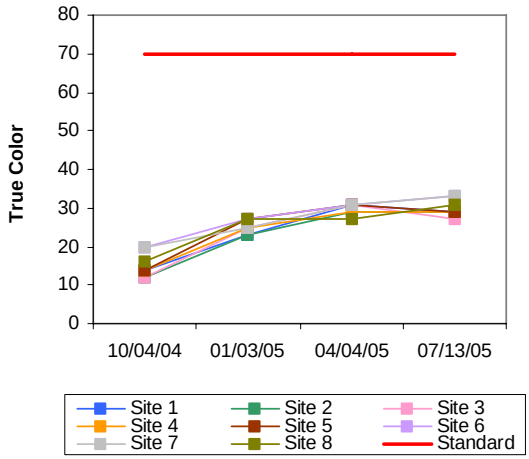
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.95 mg/L at the surface. Surface TN ranged from 0.39 mg/L to 1.50 mg/L, with the highest values reported in the spring and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.91 mg/L at the surface Total phosphorus at the surface ranged from 0.066 mg/L to 0.125 mg/L. Surface TP was highest in the fall quarter and lowest during the summer. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2004-2005. This is slightly higher than 7:1, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Lake Hudson was classified as eutrophic, indicative of high primary productivity and nutrient conditions (Plate 56). Although this differs from the classification reported in 2003, (TSI= 55), the trophic classification is the same. Water clarity is good based on true color, turbidity and secchi disk depth and is similar to findings from previous sampling efforts. The FWP beneficial use is supported based on turbidity and pH values reported during the study period. With only 17% of the water column experiencing anoxic conditions during the summer quarter, the FWP beneficial use is also supported as in regards to dissolved oxygen levels. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. The Oklahoma Department of Environmental Quality (ODEQ) sampled Lake Hudson in 2002 as part of the Toxics and Reservoirs program and found no problems with toxic organic or metal residues in the fish tissue they analyzed. Lake Hudson was constructed by the Grand River Dam Authority (GRDA) for flood control and hydroelectric purposes and is located in Mayes County.

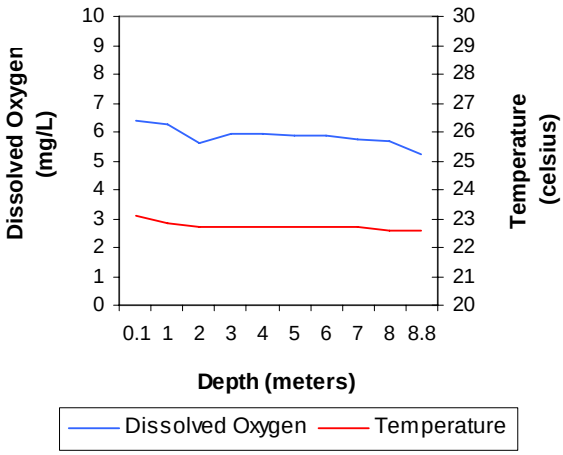
a. Seasonal Turbidity Values for Lake Hudson (Mayes Co.)



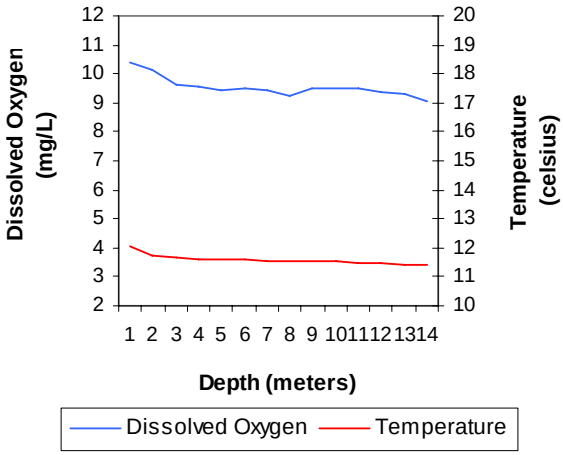
b. Seasonal Color Values for Lake Hudson (Mayes Co.)



c. Profile of Lake Hudson (Mayes Co.) October 04, 2004



d. Profile of Lake Hudson (Mayes Co.) April 04, 2005



e. Profile of Lake Hudson (Mayes Co.) July 13, 2005

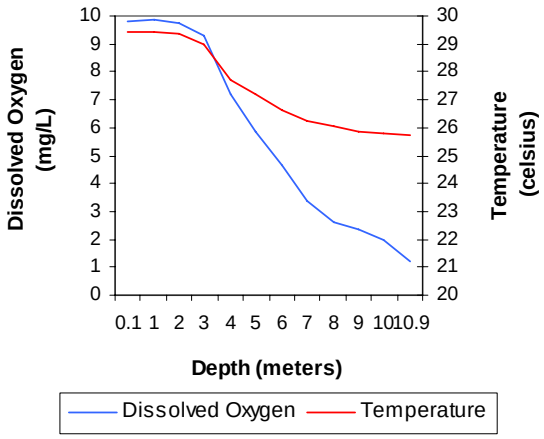
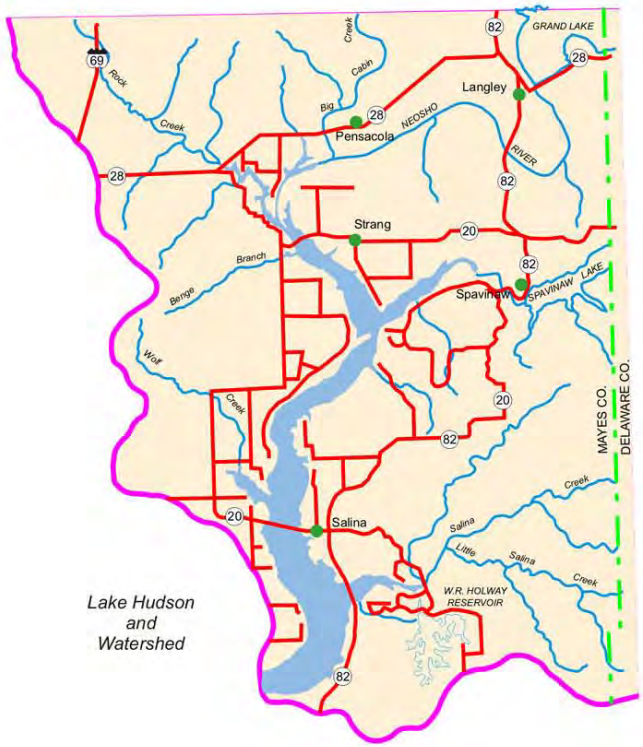


Figure 69a-69e. Graphical representation of data results for Lake Hudson (Mayes Co.).

Lake Hudson Location



Lake Hudson and Watershed

Lake Data	
Constructed by	Grand River Dam Authority
County	Mayes
Constructed in	1964
Surface Area	10,900 acres
Volume	200,300 acre/feet
Shoreline Length	200 miles
Mean Depth	19.38 feet
Watershed Area	11,533 square miles

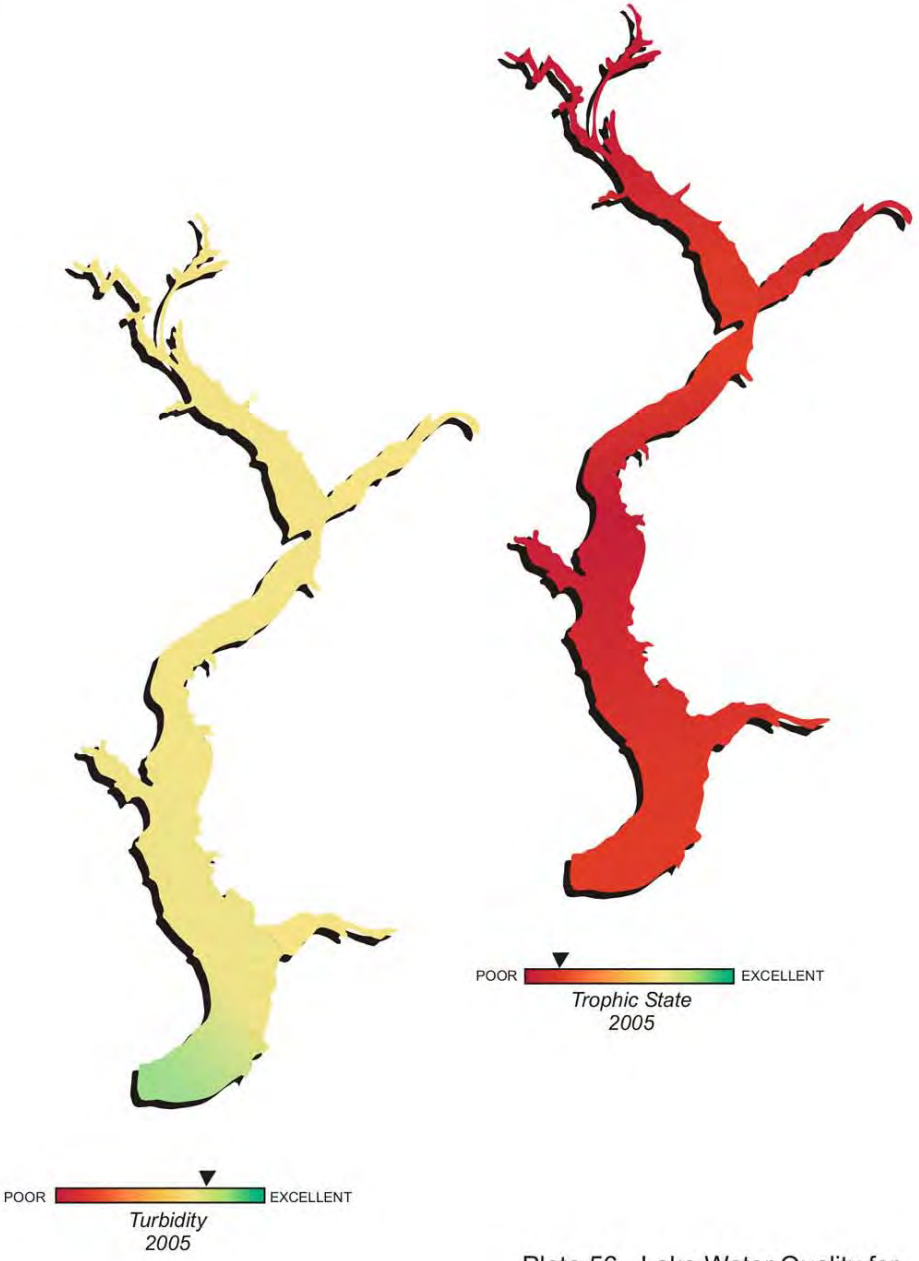


Plate 56 - Lake Water Quality for
Lake Hudson (Mayes Co.)

LAKES MONITORING PROGRAM

Hugo Lake

Hugo Lake was sampled for four quarters from November 2004 through August 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 42 NTU (Plate 58), true color was 123 units, and secchi disk depth was 36 centimeters. Based on these three parameters, Hugo Lake had poor water clarity in comparison to other Oklahoma reservoirs. Water clarity is similar to historical data and is likely always poor based on the soil composition and nature of this lake. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 53 (Plate 58), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. This value is the similar to the TSI in 2003 (TSI=55), indicating no significant change in productivity has occurred since the last evaluation. The values varied seasonally and were generally eutrophic with mesotrophic values observed in the spring quarter. The only exception to this was sites 4 and 5, which also had lower TSI values during the winter. Seasonal turbidity values are displayed in Figure. In general turbidity values exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU with the exception of sites 1-2 in the fall (see Figure 70a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is not supported at Hugo Lake with 90% of the collected values exceeding the standard. Seasonal true color values are displayed in Figure 70b. Like turbidity, all true color values were greater than the aesthetics WQS of 70 units with the exception of sites 1 and 3 in the fall quarter. With 90% of the collected values exceeding the standard the lake is not supporting the Aesthetics beneficial use.

In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Hugo Lake ranged from 0.01 parts per thousand (ppt) to 0.05 ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 41.4 µS/cm to 130.7 µS/cm, indicating minimal concentrations of current conducting compounds (chlorides and salts) in the lake system. The pH values ranged from 6.49 to 8.22 in the fall representing a neutral to slightly acidic system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Low pH values were recorded only recorded at site 5 in the winter. With only 2.1% of the values falling outside the acceptable range the lake is considered supporting the beneficial use based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of

developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potential (ORP) ranged from 171 mV in the fall to 489 mV in during the summer. All ORP values were positive and above 100 mV indicating reducing conditions were not present in the lake at the time of sampling. Thermal stratification was not present during the fall, winter and spring and the lake was well mixed with dissolved oxygen (D.O) values remaining above 5.0 mg/L (see Figure 70c-70e). The lake was stratified in the summer at sites 2 and 4 between 7 and 9 meters in depth at which point the dissolved oxygen (D.O) fell below 2.0 mg/L to the lake bottom of 11.9 meters, accounting for 38 and 31%, respectively of the water column to be anoxic. Site 1 also showed a gradual stratification however D.O. remained greater than 2.0 mg/L (see Figure 70f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 31 to 38 % of the water column less than 2.0 mg/L, therefore the FWP beneficial use is considered supported at Hugo Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2004-2005 found the Agriculture beneficial use to be fully supported bases on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

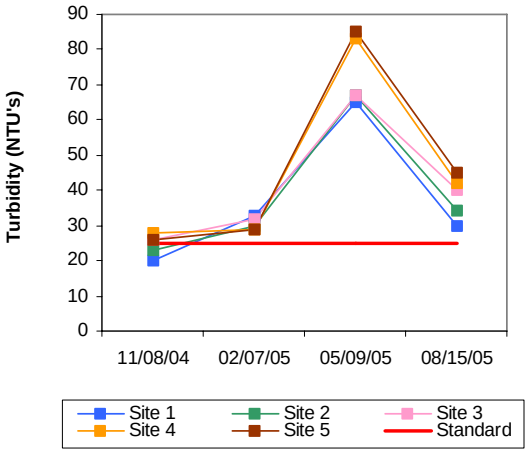
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.54 mg/L at the surface. Surface TN ranged from 0.27 mg/L to 1.06 mg/L, with the highest values seen in the fall and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.063 mg/L at the surface. Total phosphorus at the surface ranged from 0.042 mg/L to 0.097 mg/L. Surface TP was highest in the spring quarter and lowest during the winter. The nitrogen to phosphorus ratio (TN:TP) was approximately 9:1 for sample year 2004-2005. This is only slightly higher with the 7:1 ratio used to determine the limiting nutrient, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

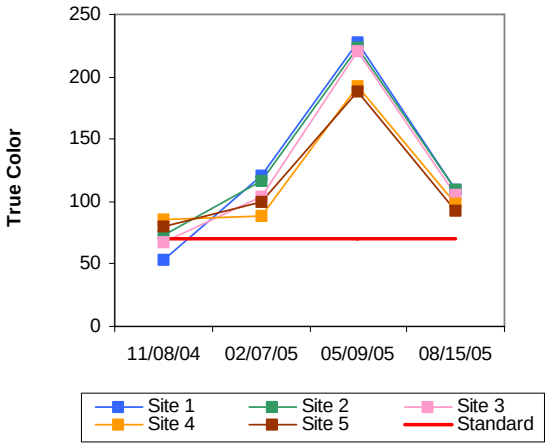
In summary, Hugo Lake was classified as eutrophic, indicative of high primary productivity and nutrient conditions. This is consistent with the 2003 evaluation indicating little to no change in productivity has occurred. Water clarity was poor based on turbidity, true color and low secchi disk depth and is likely to always be poor based on the soil composition and nature of this lake. The lake is supporting the FWP beneficial use based on pH and dissolved oxygen, but not supporting based turbidity. The Aesthetics beneficial use is supported based on its trophic status, and not supporting the use with 90% of the true color values of the reported exceeding the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. In 1999, a bathymetric survey was conducted at Hugo Lake (Figure 71) as part of the Kiamichi River Development Project. The purpose of the survey was to generate a 3-D simulation of water level changes within the reservoir in response to concerns local citizens had regarding the potential transfer of water to other areas of the state and /or the north Texas area. Specific concerns included fluctuating lake levels and the subsequent impacts on fish/wildlife, recreation, tourism and economic development in the area. For further information about this study or bathymetric mapping visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800. The United States Army Corps of Engineers (USACE) constructed Hugo Lake for flood control, water supply, fish and wildlife and

recreational purposes. The lake is located in Choctaw County approximately 7 miles east of the city of Hugo.

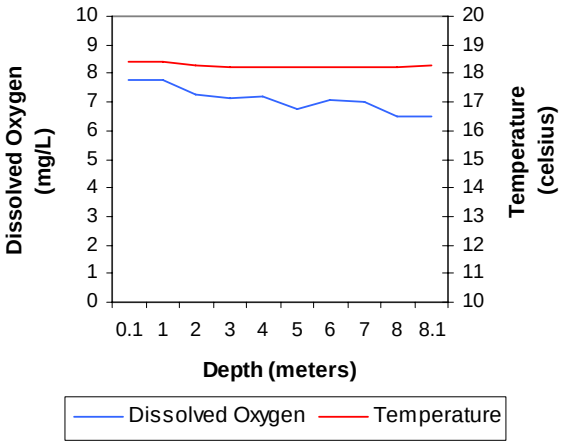
a. Seasonal Turbidity Values for Hugo Lake



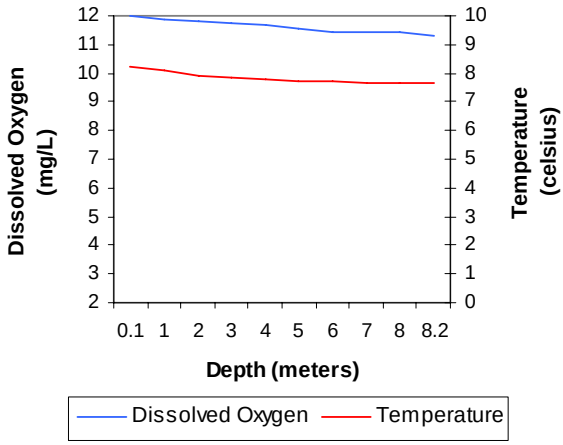
b. Seasonal Color Values for Hugo Lake



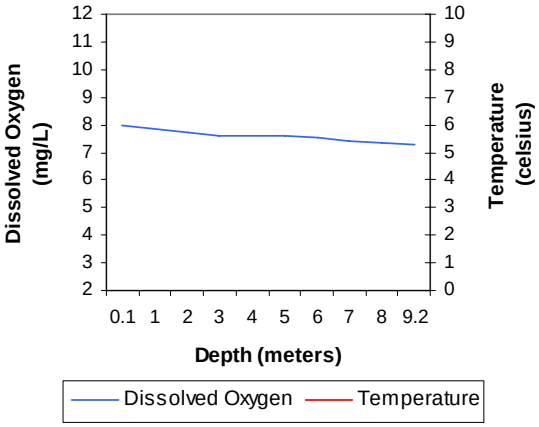
c. Profile of Hugo Lake
November 08, 2004



d. Profile of Hugo Lake
February 07, 2005



e. Profile of Hugo Lake
May 09, 2005



f. Profile of Hugo Lake
August 16, 2005

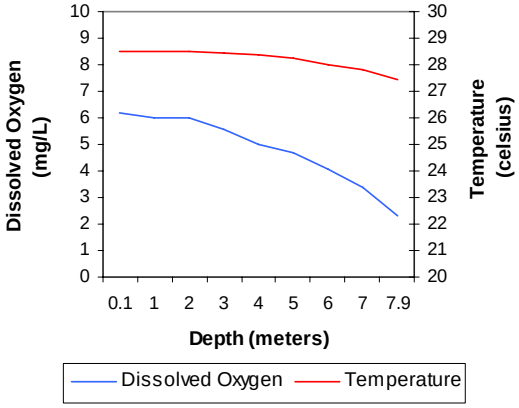


Figure 70a-70f. Graphical representation of data results for Hugo Lake.

Hugo Lake Location

Hugo Lake and Watershed

Lake Data	
Constructed by	Corps of Engineers
County	Choctaw
Constructed in	1974
Surface Area	11,592 acres
Volume	126,740 acre/feet
Shoreline Length	71.33 miles
Mean Depth	10.56 feet
Watershed Area	1,709 square miles

Turbidity 2005

Trophic State 2005

Plate 58 - Lake Water Quality for
Hugo Lake

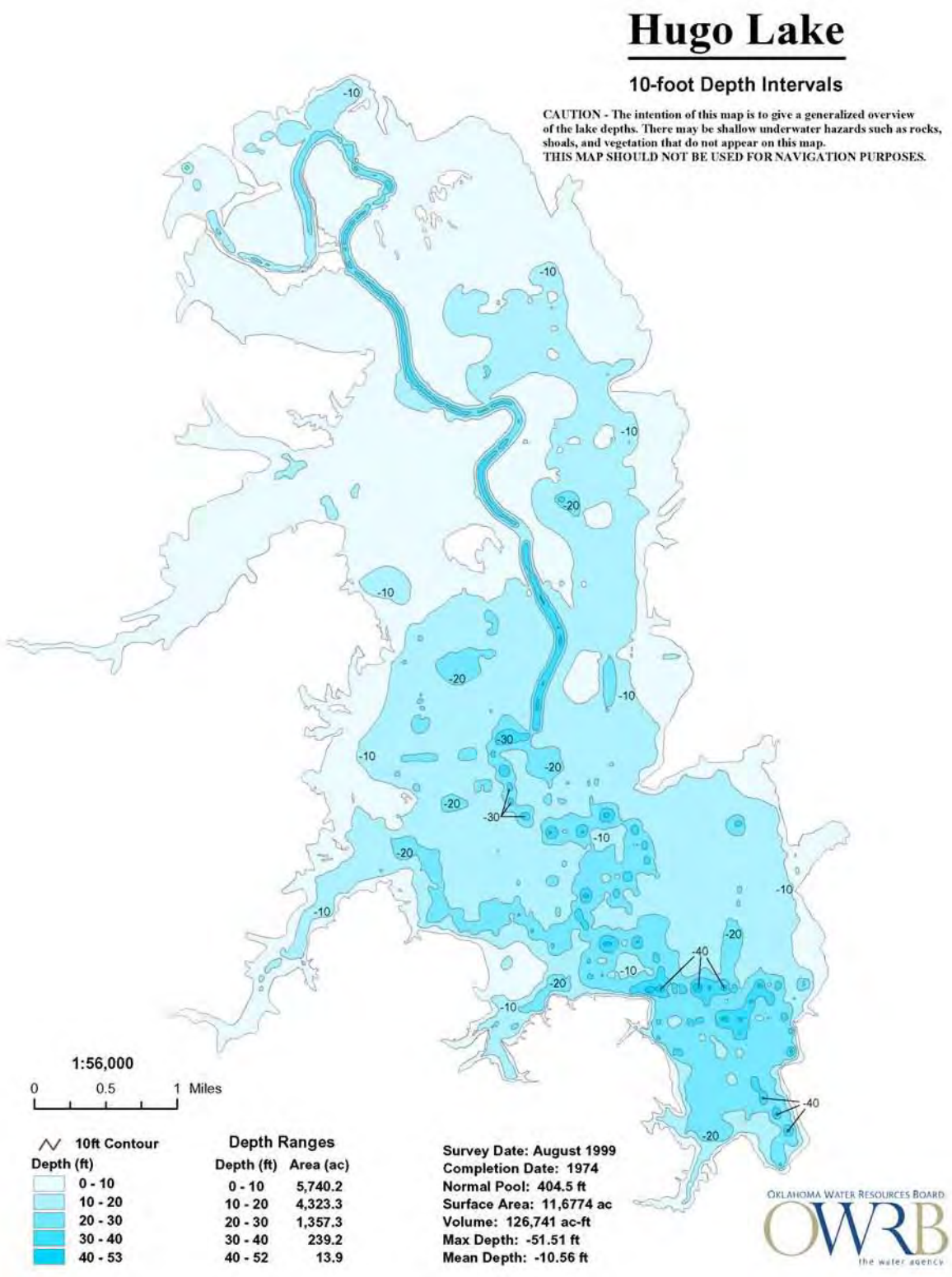


Figure 71. Bathymetric Map of Hugo Lake.

Hulah Lake

Hulah Lake was sampled for four quarters from October 2004 through July 2005. Water quality samples were collected from five (5) sites to represent the riverine, transition and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam site. The average lake-wide turbidity was 45 NTU (Plate 59), true color was 48 units and average secchi disk depth was 28 centimeters in sample year 2003. Based on these three parameters water clarity was poor at Hulah Lake in 2005, consistent with results from 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=15). Due to a post-processing error no samples were submitted to lab for analysis from the fall data collection efforts. The average TSI was 54 (Plate 59), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. Although based on only three quarters, this value is the similar to the TSI in 2003 (TSI=55), indicating no significant change in productivity has occurred since the previous evaluation. The TSI values for all sites were mesotrophic in the winter and eutrophic during both spring and summer. The only exception was site 3, which was oligotrophic in the winter quarter. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (WQS). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Seasonal turbidity values are displayed in Figure 72a. Only one of the twenty values collected was below the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the WQS of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. With 95% of the collected values exceeding the numerical criteria of 25 NTU, the Fish and Wildlife Propagation (FWP) beneficial use is not supported. Seasonal true color values are displayed in Figure 72b. True color values ranged from 25 to 84 units. Applying the same default protocol the Aesthetics beneficial use is considered as only 5% of the reported values exceeded the WQS of 70 units.

In 2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Hulah Lake ranged from 0.11 parts per thousand (ppt) to 0.23 ppt. This is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 242.3 µS/cm to 358.3 µS/cm, indicating moderate concentrations of electrical current conducting compounds (chlorides and salts) in the lake system. The pH values ranged from 7.23 to 8.43 representing a neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all values within the acceptable range the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 184 mV in the hypolimnion during the fall to 487 mV during the spring quarter. All ORP values were positive indicating reducing conditions

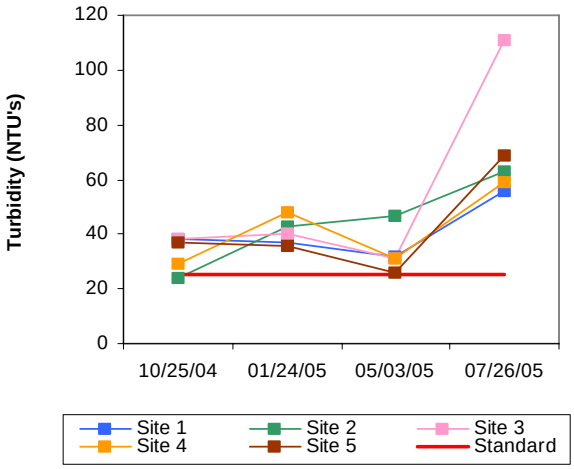
were not present in the lake. Thermal stratification was not present during the fall, winter and spring sampling intervals and the lake was well mixed (see Figure 72c-72e). In the summer dissolved oxygen (D.O) only fell below 2.0 mg/L at the sediment-water interface, which may be the result of the Hydrolab probe resting on the lake bottom (see Figure 72f). This lake is very shallow and generally stays well mixed due to wind and wave action. If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered supported at Hulah Lake with only 1D.O. reading below 2.0 mg/L during the summer. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2004-2005 found the Agriculture beneficial use to be fully supported bases on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

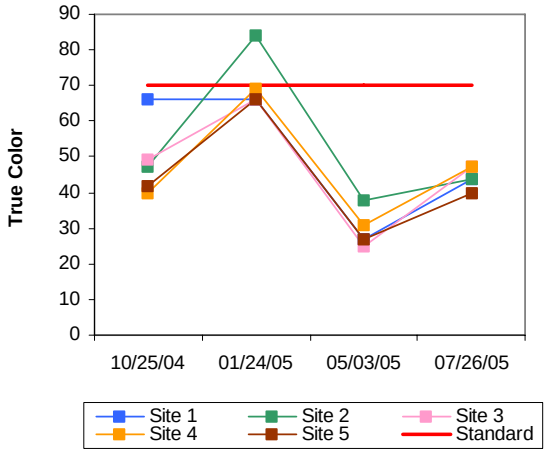
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.62 mg/L at the surface. Surface TN ranged from 0.31 mg/L to 1.44 mg/L, with the highest values seen in the summer and lowest in the spring quarter. The lake-wide total phosphorus (TP) average was 0.080 mg/L at the surface. Total phosphorus at the surface ranged from 0.056 mg/L to 0.129 mg/L. Similar to TN surface TP was highest in the summer and lowest during the spring. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2004-2005. This is only slightly higher with the 7:1 ratio used to determine the limiting nutrient, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Hulah Lake was eutrophic, indicative of high primary productivity and nutrient levels in 2004-2005. This is consistent with the evaluation in 2003, indicating no significant change in productivity has occurred since the lake was last sampled. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards. This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Water clarity was poor based on true color, turbidity and secchi disk depth. The lake is supporting the FWP beneficial use based on pH and dissolved oxygen values, but not supporting based on high turbidity levels. With only 5% of the values exceeding the WQS of 70 units, the Aesthetics beneficial is considered supported based on true color. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Hulah Lake, located in Osage County, was constructed by the United States Army Corps of Engineers (USACE) for the purpose of flood control, water supply, low-flow regulation and conservation.

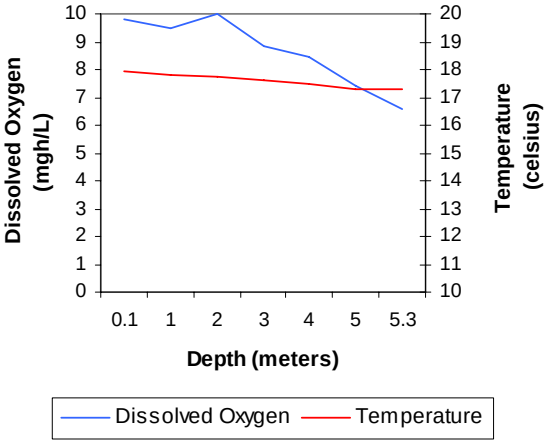
a. Seasonal Turbidity Values for Hulah Lake



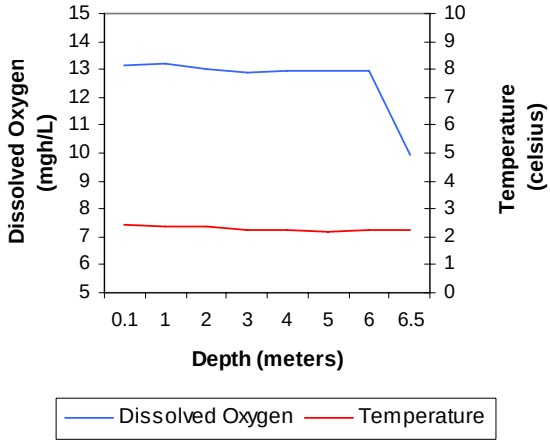
b. Seasonal Color Values for Hulah Lake



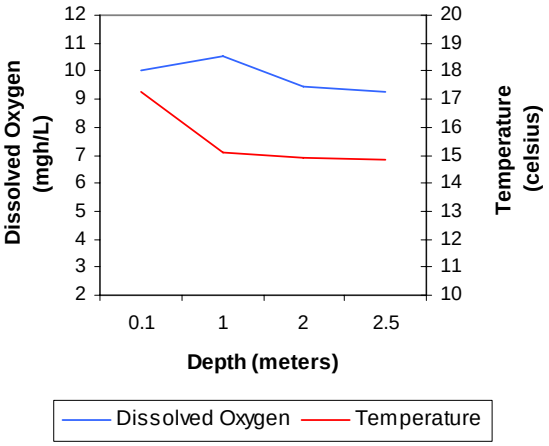
c. Profile of Hulah Lake
October 25, 2004



d. Profile of Hulah Lake
January 25, 2005



e. Profile of Hulah Lake
May 03, 2005



f. Profile of Hulah Lake
July 26, 2005

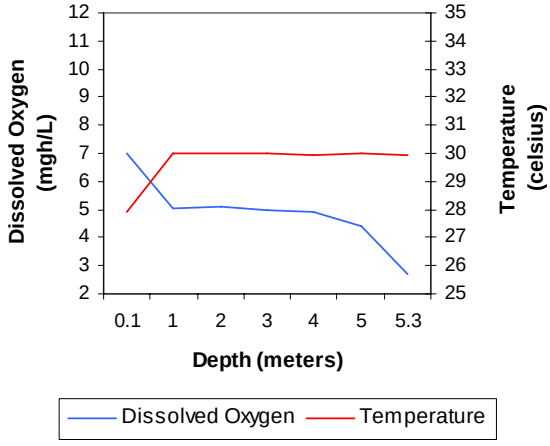
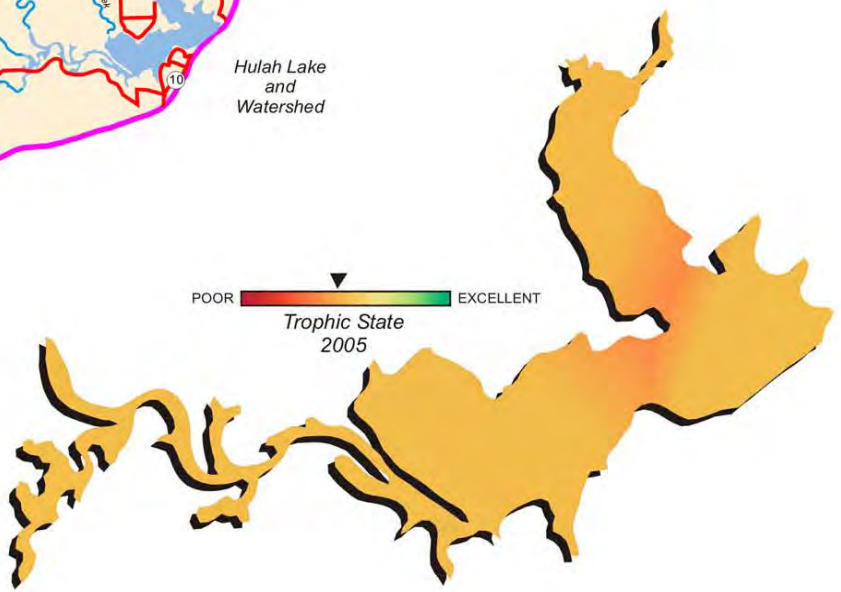


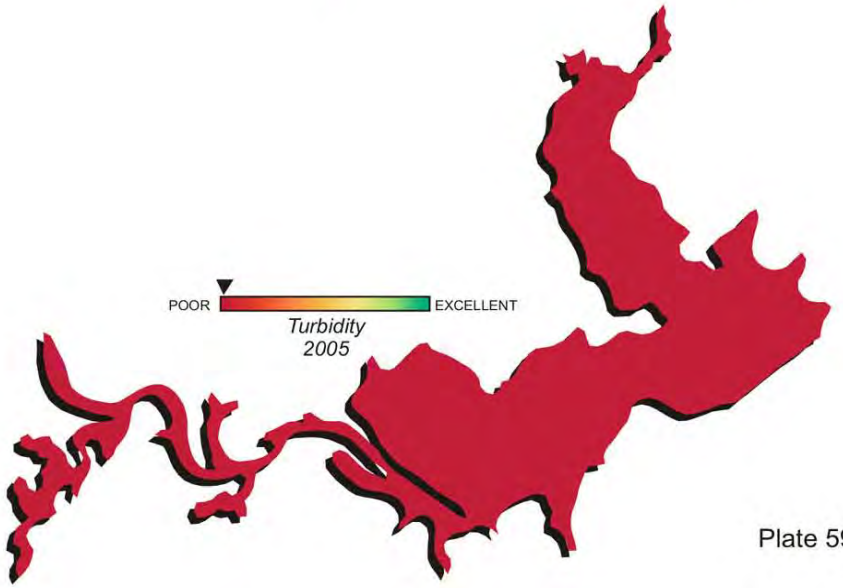
Figure 72a-72f. Graphical representation of data results for Hulah Lake.

Hulah Lake and Watershed

Hulah Lake Location



Trophic State 2005



Turbidity 2005

Lake Data	
Constructed by	Corps of Engineers
County	Osage
Constructed in	1951
Surface Area	3,570 acres
Volume	31,160 acre/feet
Shoreline Length	62 miles
Mean Depth	9.64 feet
Watershed Area	732 square miles

Plate 59 - Lake Water Quality for
Hulah Lake

LAKES MONITORING PROGRAM

Humphreys Lake

Humphreys Lake was sampled for four quarters, September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 9 NTU (Plate 60), true color was 12 units, and secchi disk depth was 92 centimeters. Based on these three parameters, Humphreys Lake had good water clarity in 2003. The water clarity was very similar, if not slightly better than observed in the 2003 evaluation. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 58 (Plate 60), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is similar to the one calculated in 2003 (TSI=56) indicating no significant increase or decrease in productivity has occurred. The TSI values ranged seasonally from hypereutrophic in the fall, upper-eutrophic in the winter and summer and mesotrophic values in the spring. The only exception to this occurred at site 4 when a low chlorophyll-a was reported in the spring. Seasonal turbidity values are displayed in Figure 73a. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. With 100% of the turbidity values below the WQS of 25 NTU the Fish and Wildlife Propagation beneficial use is considered supported. Seasonal true color values are displayed in Figure 73b. All true color values were below the WQS of 70 units. Applying the same default protocol the Aesthetics beneficial use is considered supported.

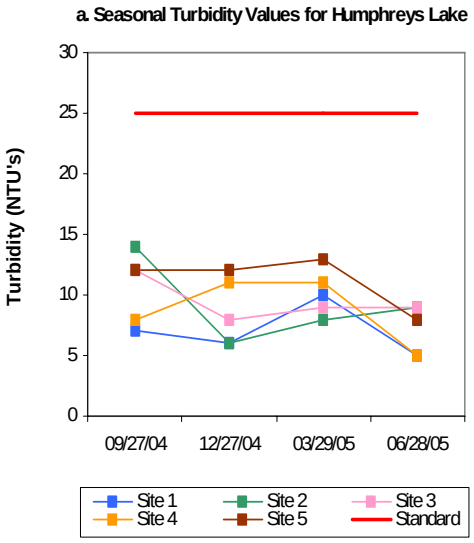
In 2004-2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Humphreys Lake ranged from 0.27 parts per thousand (ppt) to 0.36 ppt. This is within the average range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 501 µS/cm to 700.3 µS/cm, indicating moderate concentrations of electrical current conducting compounds (chlorides and salts) in the lake system, consistent with salinity readings. The pH values ranged from 7.1 to 8.61 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 69 mV in hypolimnion during the summer to 464 mV in the spring. In general, reducing conditions were not present with all recorded values above 100 mV with the exception the one value recorded at the lake bottom at the dam in the summer quarter. The lake was well mixed with dissolved oxygen levels above 7.0 mg/L in the winter and spring sampling intervals (see Figure 73d-73e). Thermal stratification and anoxic conditions were present in both fall and summer quarters. During the fall,

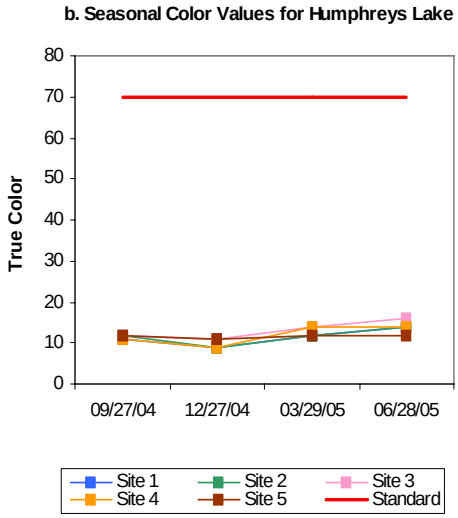
stratification occurred between 5 and 6 meters with dissolved oxygen (D.O.) less than 2.0 mg/L for approximately for 40% of the water column to be experiencing anoxic conditions. Similar conditions were observed in the summer, with stratification occurring between 4 and 5 meters with dissolved oxygen concentrations (D.O.) falling below 2.0 mg/L from 6 meters in depth to the lake bottom of 10 meters accounting for approximately 46 % of the water column at site 1 to be experiencing anoxic conditions (see Figure 73f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 40% (fall) and 46% (summer) of the water column experiencing anoxic conditions, the FWP beneficial use is considered supported at Humphreys Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2004-2005 found the Agriculture beneficial use to be fully supported bases on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

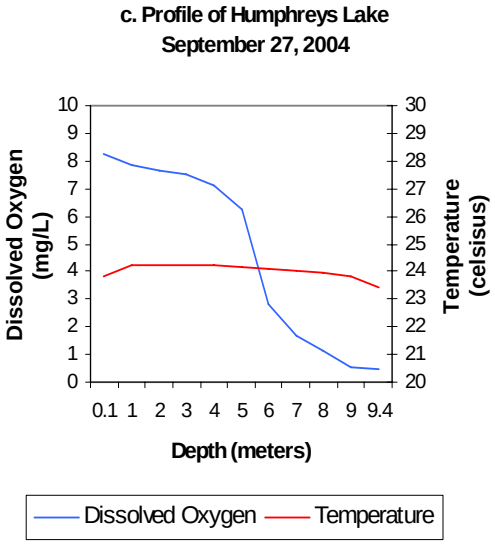
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

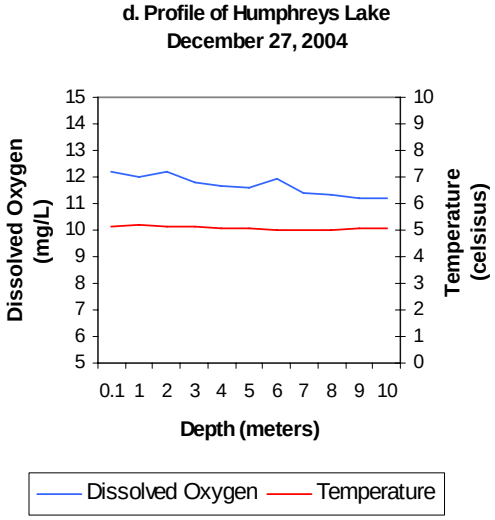
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.77 mg/L at the surface. Surface TN ranged from 0.54 mg/L to 1.11 mg/L, with the highest values occurring in the fall. The lake-wide total phosphorus (TP) average was 0.041 mg/L at the surface. Total phosphorus at the surface ranged from 0.028 mg/L to 0.067 mg/L. Surface TP was highest in the fall and lowest during the summer. The nitrogen to phosphorus ratio (TN:TP) was approximately 19:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

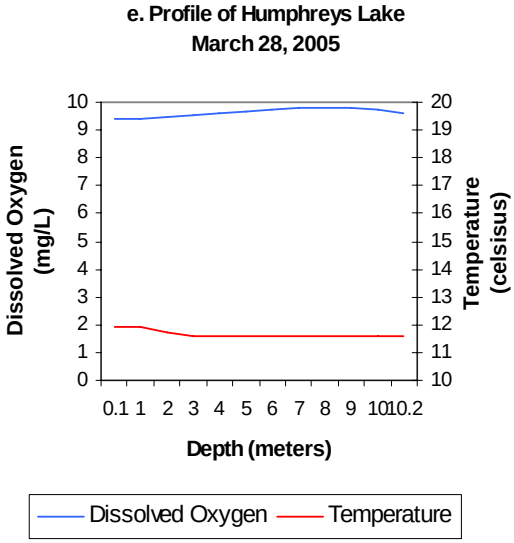
In summary, Humphreys Lake was classified as eutrophic, indicative of high primary productivity and nutrient conditions (Plate 60). This value is similar to the one calculated in 2003 (TSI=56) indicating no significant increase or decrease in productivity has occurred. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on turbidity, pH, and dissolved oxygen levels reported during the study period. The Aesthetics beneficial use is supported based on its trophic status and for true color with 100% of the values below the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Humphreys Lake is owned by the City of Duncan and serves as a flood control, water supply, and recreational reservoir.











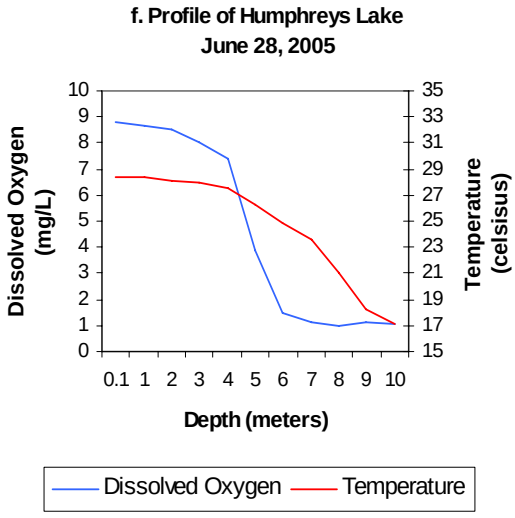
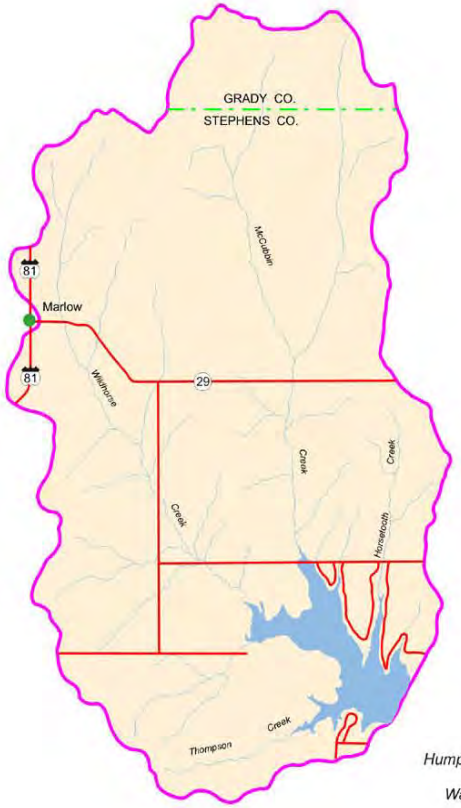


Figure 73a-73f. Graphical representation of data results for Humphreys Lake.

Humphreys Lake
Location



Humphreys Lake
and
Watershed

Trophic State
2005

Turbidity
2005

Lake Data	
Owner	City of Duncan
County	Stephens
Constructed in	1958
Surface Area	882 acres
Volume	14,041 acre/feet
Shoreline Length	17 miles
Mean Depth	15.92 feet
Watershed Area	31 square miles

Plate 60 - Lake Water Quality for
Humphreys Lake

Lake Jean Neustadt

Lake Jean Neustadt was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity was 13 NTU (Plate 61), true color was 22 units, and secchi disk depth was 76 centimeters. Based on these three parameters, Lake Jean Neustadt had good water clarity in 2005. Results are consistent with the 2003 data collection efforts. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 52 (Plate 61), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient conditions. This value is higher than the one calculated in 2003 (TSI=47) and places the lake in a different trophic category. The TSI values were fairly consistent with values ranging from lower mesotrophic in the winter and spring to the upper end of eutrophy during the fall and summer intervals. Seasonal turbidity values per site are displayed in Figure 74a. All turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU and ranged from a low 6 NTU to a high of 21 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. With 100% of the turbidity recorded below the standard, the FWP beneficial use is considered supported. Seasonal true color values are displayed in Figure 74b. All true color values were below the aesthetics WQS of 70 units at all sites. Applying the same default protocol, the Aesthetics beneficial use is fully supported at Lake Jean Neustadt.

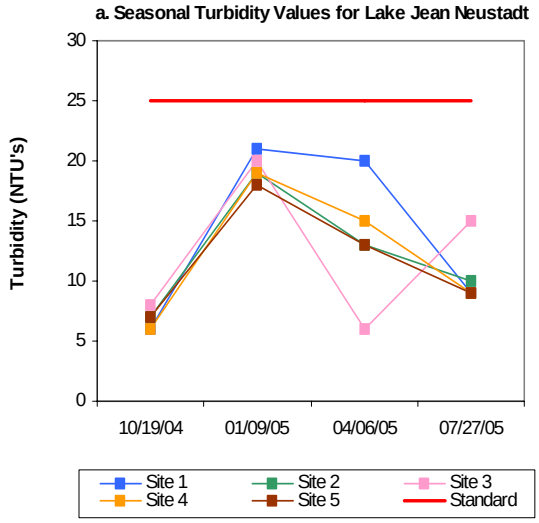
In 2004-2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values at Lake Jean Neustadt ranged from 0.13 parts per thousand (ppt) to 0.22 ppt. This is within the average range of values for most Oklahoma reservoirs. Specific conductivity ranged from 261.7 µS/cm in the summer to 430.8 µS/cm in the fall quarter, indicating minimal concentrations of electrical current conducting compounds (chlorides and salts) in the lake system consistent with salinity readings. The pH values ranged from 7.00 to 8.40 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 48 mV to 494 mV. Reducing conditions were not present with all recorded values, with the exception of one value recorded at the lake bottom at site 1, in the fall, above 100 mV. In general thermal stratification was not present during the first three sampling intervals and the lake appeared to be well mixed (see Figure 74c-74e). Dissolved oxygen remained above 7.0 mg/L during this time except for two readings recorded near the water-sediment interface at site 1 during the fall. Thermal

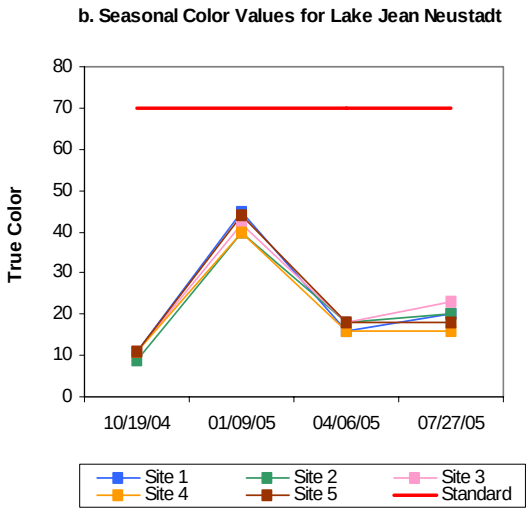
stratification was evident and anoxic conditions were present in the summer quarter. The lake was strongly stratified between 5 and 6 meters in depth at both sites 1 and 4, with anoxic conditions in approximately 33 to 50% of the water column. (see Figure 74f). If the D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered partially supported at Lake Jean Neustadt based anoxic conditions comprising 50 % of the water column during the summer months. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported bases on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

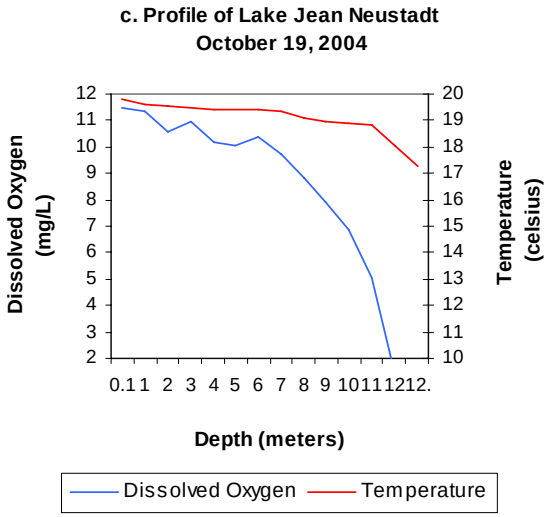
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

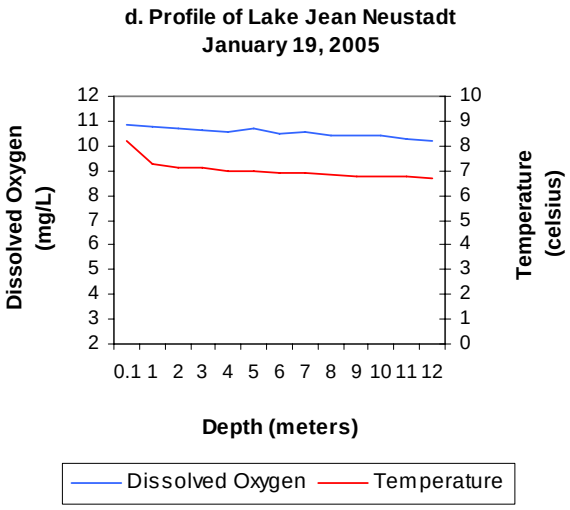
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.57 mg/L at the surface. Surface TN ranged from 0.47 mg/L to 0.74 mg/L, with the highest values reported in the summer and the lowest values in the spring. The lake-wide total phosphorus (TP) average was 0.035 mg/L at the surface. Total phosphorus at the surface ranged from 0.024 mg/L to 0.061 mg/L. TP was highest in the winter and lowest during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 16:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

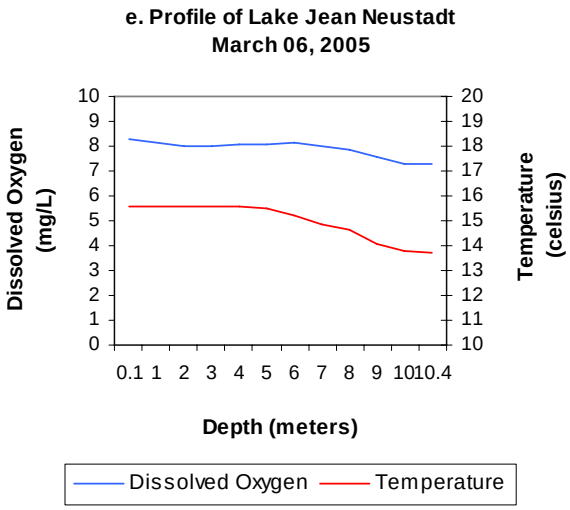
In summary, Lake Jean Neustadt was classified as eutrophic, indicative of high primary productivity and nutrient conditions (Plate 61). This value is higher than the one calculated in 2003 (TSI=47) and places the lake in a different trophic category. Water clarity was good based on true color, turbidity, and secchi disk depth. The FWP beneficial use is supported based on turbidity and pH values recorded during the sample year. With 50% of the water column experiencing anoxic conditions during the summer the FWP use is considered partially supported. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color as 100% of the color values were well below the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake Jean Neustadt, located in Carter County, serves as a recreational reservoir for the City of Ardmore.











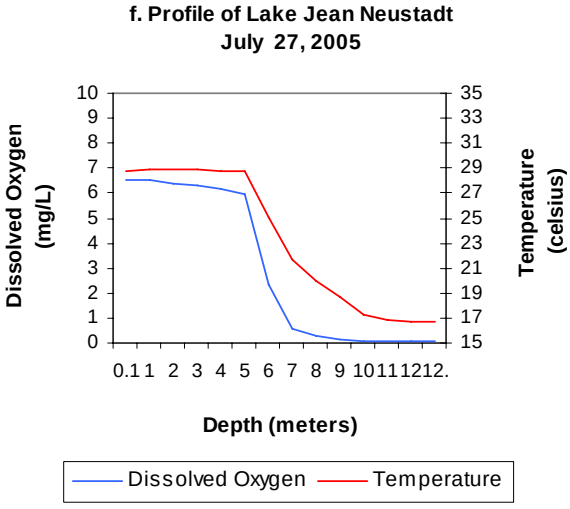
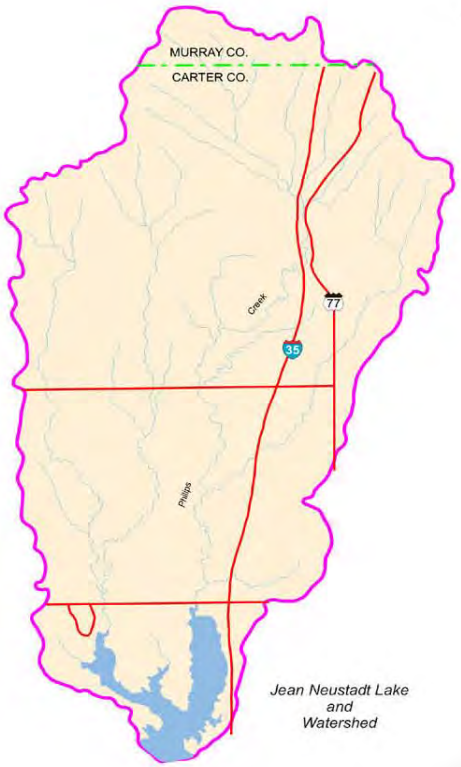


Figure 74a-74f. Graphical representation of data results for Lake Jean Neustadt.

Jean Neustadt Lake Location



Jean Neustadt Lake and Watershed

Lake Data	
Owner	City of Ardmore
County	Carter
Constructed in	1969
Surface Area	462 acres
Volume	6,106 acre/feet
Shoreline Length	10 miles
Mean Depth	13.22 feet
Watershed Area	17 square miles

Turbidity 2005

Trophic State 2005

Plate 61 - Lake Water Quality for
Lake Jean Neustadt

John Wells Lake

John Wells Lake is owned and operated by the City of Stigler and is used as a municipal water supply for Stigler and provides numerous recreational opportunities for the public. John Wells Lake was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 5 NTU (Plate 62), true color was 16 units, and secchi disk depth was 151 centimeters. Based on these three parameters, John Wells Lake had excellent water clarity in 2005-2006. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 46 (Plate 62), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. The TSI values were mesotrophic throughout the entire sample year. All turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 75a) with values ranging from a low of 4 NTU to a maximum of 10 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. John Wells Lake is considered fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity collected in sample year 2006. Seasonal true color values are displayed in Figure 75b. True color values were all well below the aesthetics WQS of 70 units at all sites. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the true color values. In general, John Wells Lake is one of the nicer small municipal reservoirs in Oklahoma.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.05 ppt, well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductivity ranged from 59.8 µS/cm to 117.9 µS/cm, indicating low concentrations of electrical current conducting compounds (salts) were present in the water column. In general, pH values were neutral to slightly alkaline, ranging from 6.40 in the winter to 8.38 units in the spring. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only 1% of the recorded values outside the acceptable range, the FWP use is considered supported as it relates to pH. Oxidation-reduction potentials (redox) ranged from 189 mV at the sediment-water interface in the spring to 483 mV in the winter. Redox readings indicated that reducing conditions were not present in the reservoir in an appreciable way. Values were generally above 200 mV only falling below this point when anoxic conditions were present in approximately 45% of the water column during spring

sampling. The lake was not thermally stratified in either the fall or winter sampling intervals and the water column was well mixed (Figure 75c-75d). In the spring the lake was thermally stratified at several 1-meter intervals with dissolved oxygen (D.O.) less than 2.0mg/L from 6 meters below the surface to the lake bottom of 9.2 meters (Figure 75e). In the summer the lake was again stratified however not to the same extent observed in the spring (Figure 75f). Lake levels in the summer quarter were about half of that recorded in the spring and this may explain the difference in the amount of the water column experiencing anoxic conditions. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at John Wells Lake with 45% of the water column being anoxic at site 1 in the spring quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

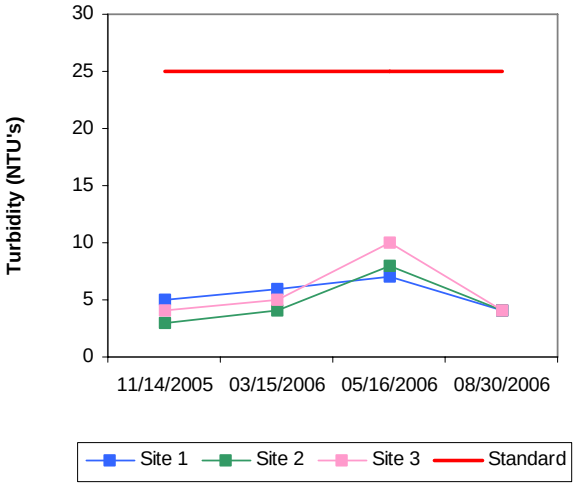
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the lake surface. The TN at the surface ranged from 0.20 mg/L to 0.56 mg/L. The highest surface TN value was reported in the winter quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average was 0.016 mg/L at the lake surface. The surface TP ranged from 0.013 mg/L to 0.020 mg/L. The highest surface TP value was reported in the summer quarter and the lowest was in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 27:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

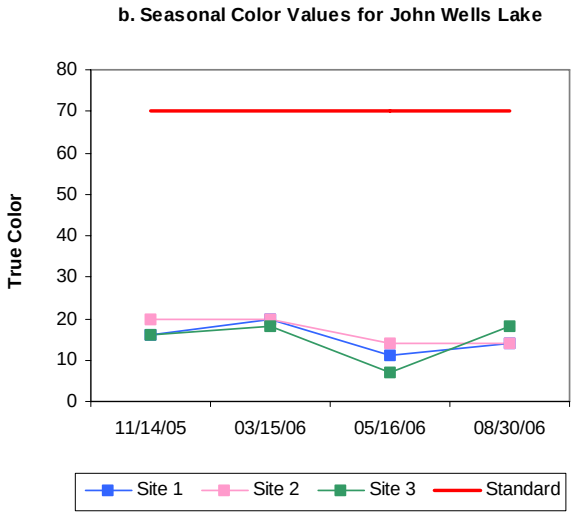
John Wells Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, John Wells Lake was classified as mesotrophic, indicative of moderate productivity and nutrient conditions (Plate 62). Water clarity was excellent based on true color, turbidity, and secchi disk depth. This is consistent with previous data collection efforts conducted in 2003-2004. Both true color and trophic status were fully supporting the Aesthetics beneficial use. John Wells Lake was fully supporting the FWP beneficial use based on pH and D.O. values as recorded during the study period. With 100% percent of the values below the WQS of 25 NTU, the lake was also fully supporting the FWP beneficial use for turbidity. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

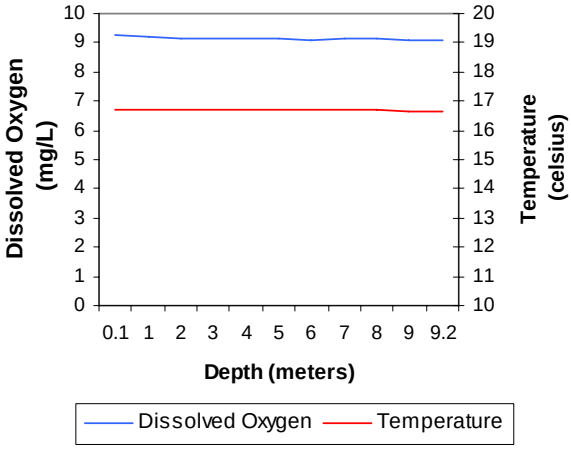
a. Seasonal Turbidity Values for John Wells Lake



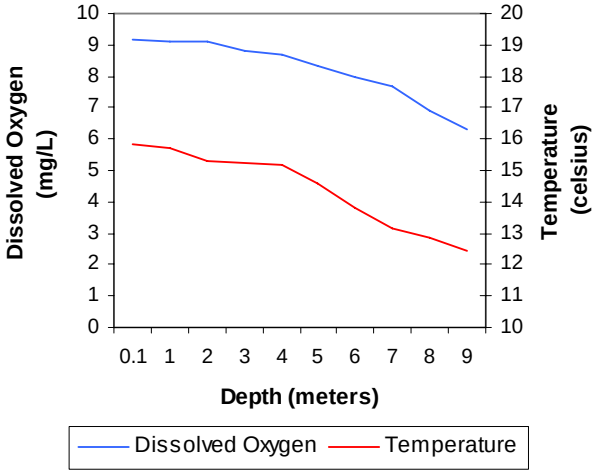
b. Seasonal Color Values for John Wells Lake



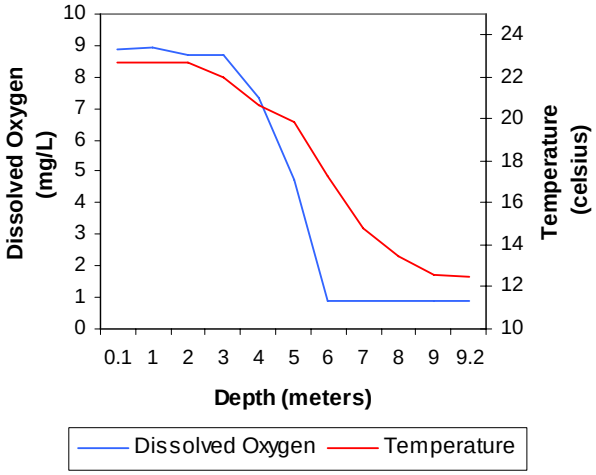
c. Profile of John Wells Lake
November 14, 2005



d. Profile of John Wells Lake
March 15, 2006



e. Profile of John Wells Lake
May 16, 2006



e. Profile of John Wells Lake
August 30, 2006

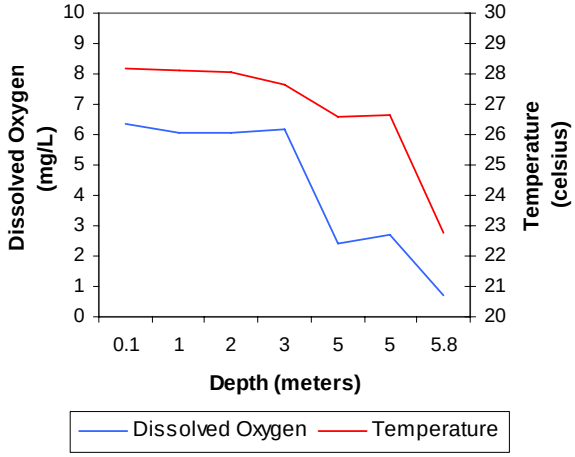
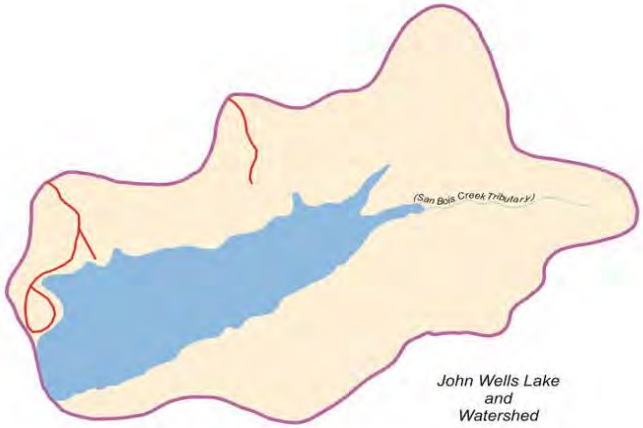


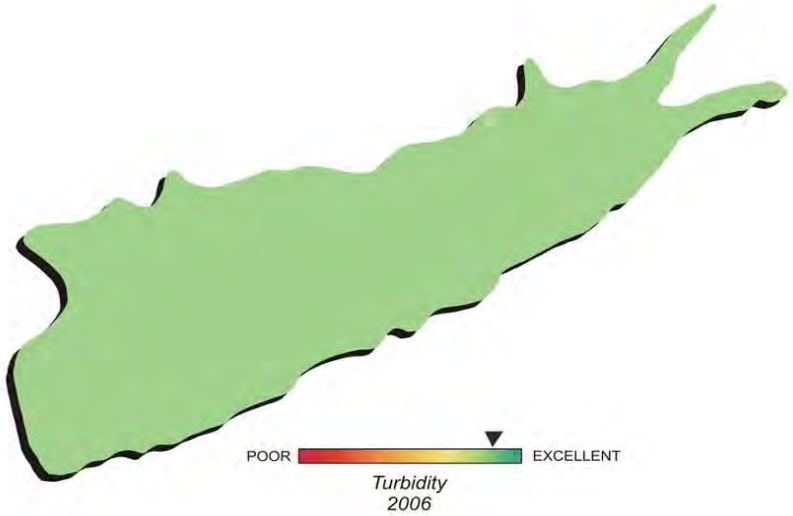
Figure 75a-75e. Graphical representation of data results for John Wells Lake.

John Wells Lake
Location

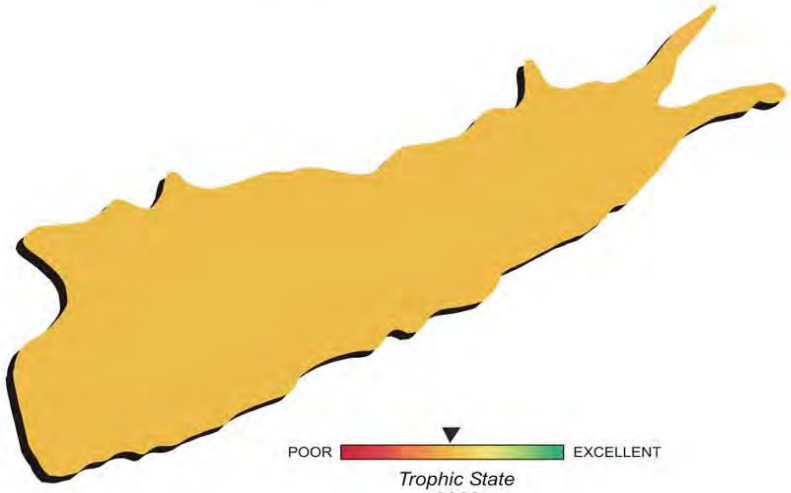


John Wells Lake
and
Watershed

Lake Data	
Owner	City of Stigler
County	Haskell
Constructed in	1936
Surface Area	194 acres
Volume	1,352 acre/feet
Shoreline Length	3 miles
Mean Depth	6.97 feet
Watershed Area	961 acres



Turbidity
2006



Trophic State
2006

Plate 62 - Lake Water Quality for
John Wells Lake

LAKES MONITORING PROGRAM

Kaw Lake

Kaw Lake was sampled for four quarters from November 2004 through August 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones and arms of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 17 NTU (Plate 63), true color was 37 units, and average secchi disk depth was 67 centimeters. Based on these three parameters Kaw Lake had average water clarity in sample year 2005, better than that observed in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 56 (Plate 63), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient conditions. This value is similar to that from 2003 (TSI=53), indicating no significant change in productivity has occurred since the last evaluation. Seasonal TSI values varied by site and season and spanned all trophic categories in sample year 2005. In the fall and winter sampling quarters values were generally oligotrophic to mesotrophic. In the spring, values ranged from oligotrophic at sites 1, eutrophic at site 2, and hypereutrophic at sites 3-5. TSI values in the summer were all hypereutrophic with the exception of site 1, which had the lowest TSI throughout the year. The highest values throughout the year occurred at site 5 in the upper end of the reservoir. Seasonal turbidity values per site are displayed in Figure 76a. Turbidity ranged from a low of 10 NTU to a maximum of 29 NTU in 2005. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 20% of the recorded values exceeding the WQS of 25 NTU, Kaw Lake is partially supporting its Fish and Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 76b. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is considered supported with 100% of the true color values were below the WQS of 70 units.

In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sites. Salinity values ranged from 0.23 parts per thousand (ppt) to 0.62 ppt, which is higher than most values reported for Oklahoma lakes. Specific conductivity ranged from 563.1 µS/cm to 1172 µS/cm indicating that very high concentrations of electrical current conducting compounds (salts) were present in the lake system, consistent with the elevated salinity readings. The highest salinity and specific conductivity values occurred at sites 3 and 5 in the Arkansas River arm during the spring and summer. The pH values at Kaw Lake ranged from 6.94 to 8.2, representing a to neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is considered supporting the FWP

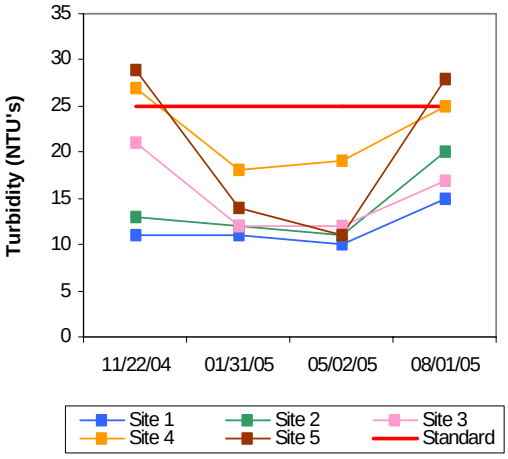
beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 157 mV in the hypolimnion in the fall to 420 mV in the winter. In general, reducing conditions were not present at this reservoir. During the fall, winter, and spring quarters, stratification was not present and the lake was well mixed with dissolved oxygen (D.O.) levels generally above 5.0 mg/L (Figure 76c-76e). Thermal stratification was evident in the summer and anoxic conditions were present. Stratification occurred at several 1-meter intervals throughout the entire lake with 14 to 61% of the water column experiencing anoxic conditions (Figure 76f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Kaw Lake, with 14 to 61% of the water column below 2.0 mg/L in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

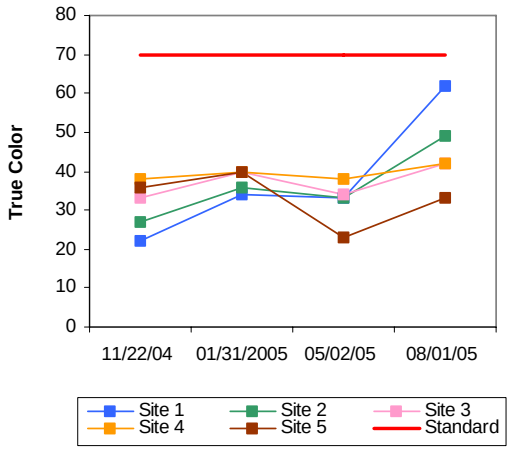
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.32 mg/L at the surface. Surface TN ranged from 0.61 mg/L to 1.99 mg/L, with the highest values reported in the fall and the lowest values in the summer quarter. The lake-wide total phosphorus (TP) average was 0.175 mg/L at the surface. Total phosphorus at the surface ranged from 0.124 mg/L to 0.236 mg/L. TP was highest in the summer and lowest at site 4 during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2004-2005 This is only slightly higher with the 7:1 ratio used to determine the limiting nutrient, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Kaw Lake was classified as eutrophic, indicative of high levels of primary productivity and nutrient conditions (Plate 63). This value is consistent with that from evaluation (TSI=53), indicating no significant change in productivity has occurred since the last evaluation. Water clarity was average at Kaw Lake based on true color, secchi disk depth and turbidity readings, better than that observed in 2003. The lake is considered supporting the FWP beneficial use based on pH, but partially supporting for dissolved oxygen and turbidity. The Aesthetics beneficial use is supported based on its trophic status as well as true color with 100% of the collected values below the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. The United States Army Corps of Engineers (USACE) constructed Kaw Lake for the purpose of flood control, water supply and quality, recreation and fish and wildlife. The lake is located in Osage County approximately 8 miles east of Ponca City.

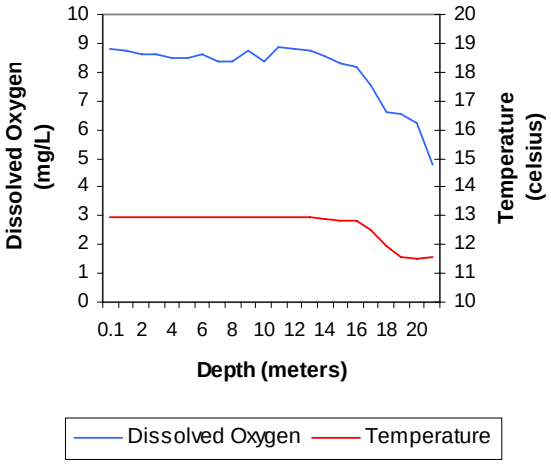
a. Seasonal Turbidity Values for Kaw Lake



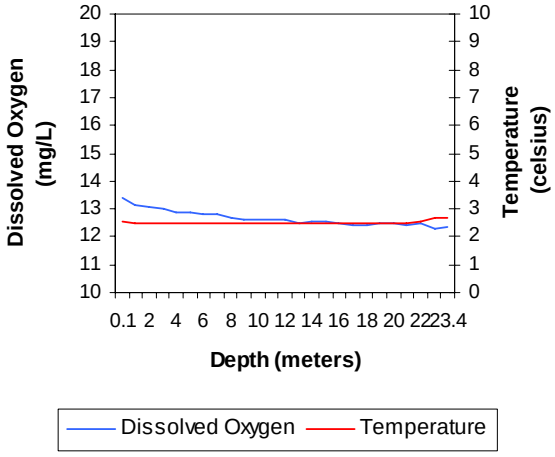
b. Seasonal Color Values for Kaw Lake



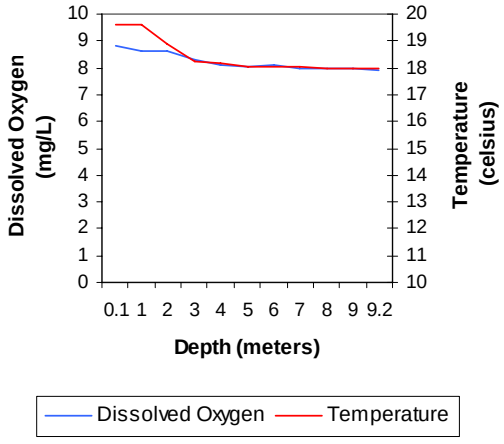
c. Profile of Kaw Lake
November 22, 2004



d. Profile of Kaw Lake
January 31, 2005



e. Profile of Kaw Lake
May 16, 2005



f. Profile of Kaw Lake
August 02, 2005

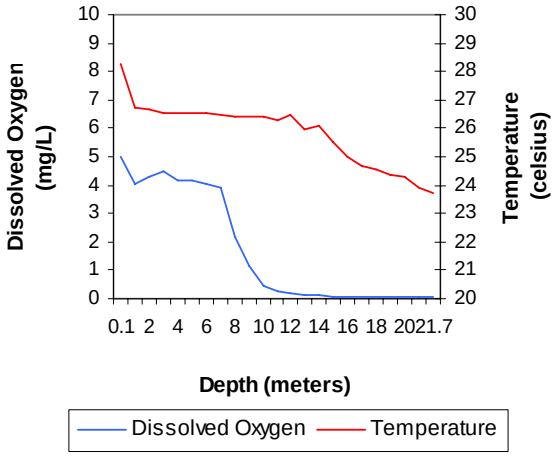
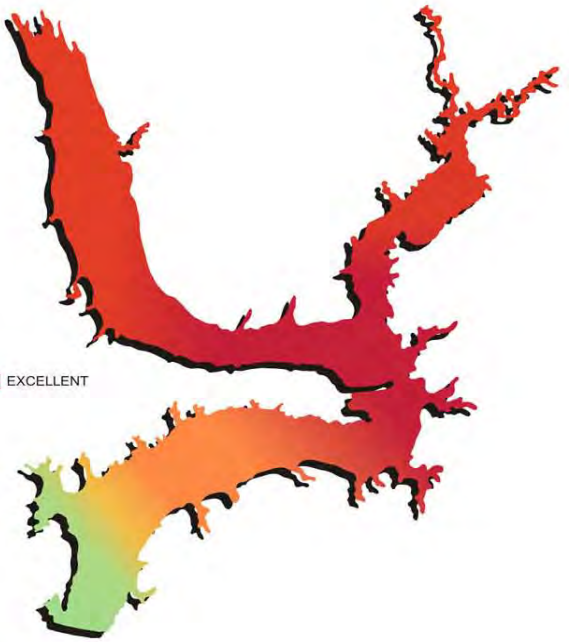
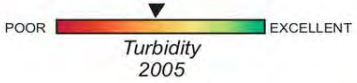
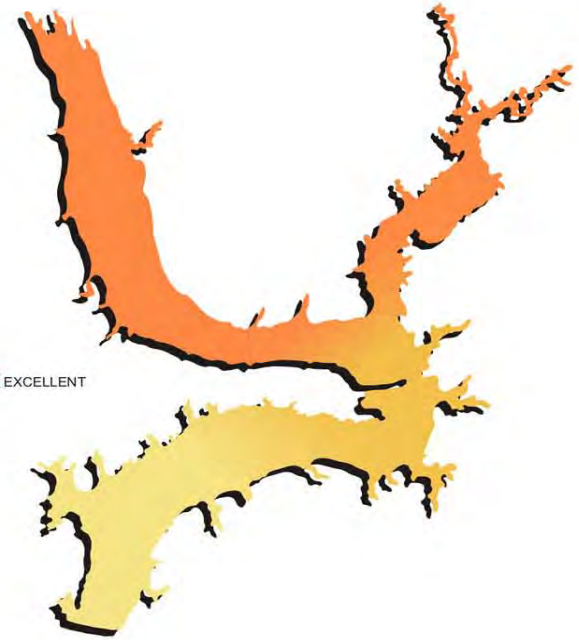


Figure 76a-76f. Graphical representation of data results for Kaw Lake.







Lake Data	
Constructed by	Corps of Engineers
County	Osage
Constructed in	1976
Surface Area	17,040 acres
Volume	428,600 acre/feet
Shoreline Length	168 miles
Mean Depth	25.21 feet
Watershed Area	46,530 square miles

Plate 63- Lake Water Quality for
Kaw Lake

LAKES MONITORING PROGRAM

Keystone Lake

Keystone Lake is managed by the United States Army Corps of Engineers and was constructed in 1964 to serve as a flood control, water supply, hydroelectric power, navigation, and fish and wildlife resource. Keystone Lake has the reputation as one of the "saltiest" lakes in Oklahoma. Keystone Lake was sampled for four quarters from October 2005 through July 2006.

Water quality samples were collected at twelve (12) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as major arms of the lake. Samples were collected from the lake surface at all 12 sites throughout the study period. Keystone Lake is large dendritic reservoir, which has both the Arkansas and Cimarron rivers flowing into the lake,. To better understand the influence these rivers has on the waterbody and the lake dynamics it has been broken into four management segments: Keystone Lake; Keystone Lake, Arkansas River arm; Keystone Lake, Cimarron River arm, lower and Keystone Lake, Cimarron River arm, upper. The following discussion will briefly summarize each segment with a lake-wide summary included at the end of the narrative.

Keystone Lake

This portion of Keystone Lake (segment # 621200010020) extends from the dam up to the Washington Irving Cove (S) area in the Arkansas River arm of the reservoir and includes BUMP sites 1 and 2 (see Figure 78). The segment-wide average turbidity was 13 nephelometric turbidity units (NTU), true color was 29 units and secchi disk depth was 91 centimeters in sample year 2006. Water clarity is good in this portion of the lake, based on these three parameters. This is expected since these sites are the farthest away from the inflow of both the Arkansas and Cimarron Rivers and materials have had more time to settle out. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=8). The average TSI was 54, classifying the segment as eutrophic, indicative of high primary productivity and nutrient conditions. Chlorophyll-a values varied among the seasons with the highest values reported in the spring and summer quarters. Turbidity values ranged from a low of 4 NTU to a maximum of 30 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered partially supported if 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 12.5% of the values exceeded 25 NTU an assessment of the Fish & Wildlife Propagation (FWP) beneficial use cannot be made, as minimum data requirements are not being met. All true color values were below the Aesthetics criteria 70 units however like turbidity there are not enough data for this segment to assess the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at both sample sites within this segment. Salinity values ranged from 0.45 to 4.03 parts per thousand (ppt) indicating moderate to very high salt content within the lake depending on the location of the sample site. Salinity readings were higher than the normal range of salinity values reported for most Oklahoma lakes. In general, salinity values

are very high in the Cimarron River arm of the reservoir. Readings for specific conductivity were also very high, ranging from 867 µS/cm to 7232 µS/cm, indicating extremely high amounts of electrical current conducting compounds (salts) in the lake system throughout the year. In general, pH values were slightly neutral to alkaline, ranging from 7.16 to 8.56 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of pH values falling within the acceptable range the FWP beneficial use is supported as it relates to pH. Thermal stratification was not evident during the fall, winter or spring sampling intervals and the water column appeared to be well mixed. In the summer, thermal stratification was evident and anoxic conditions present at both sites 1 and 2. At site 1, the temperature ranged from 27.84^0 C at the surface to 20.72^0 C at the bottom with dissolved oxygen (D.O.) less than 2.0 mg/L in approximately 62% of the water column. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Keystone Lake (segment # 621200010020) with 40% to 62% of the water column experiencing anoxic conditions in the summer quarter.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of (Nutrient Limited Watershed) NLW lakes and nutrient criteria development for lakes and reservoirs. In this segment of the lake the average total nitrogen (TN) was 0.86 mg/L, with values ranging from 0.65 mg/L in the summer to 1.10 mg/l in the fall quarter. The average total phosphorus (TP) was 0.106, with values ranging from 0.063 mg/L in the spring to 0.193 mg/L in the fall. The nitrogen to phosphorus ratio (TN:TP) was 8:1, this value is close to 7:1, characterizing for this portion of the lake as possibly co-limited (Wetzel, 1983).

Keystone Lake, Arkansas River Arm

This portion of Keystone Lake (segment # 621200010050) extends from Washington Irving Cove (S) up to the Osage Point area in the Arkansas River arm of the reservoir and includes BUMP sites 3, 4 and 5. The segment-wide average turbidity was 51 NTU, true color was 40 units and secchi disk depth was 47 centimeters in sample year 2006. Based on these three parameters water clarity is average in this portion of the lake. This is not unusual since this segment is more riverine and has greater tributary influence as well as the Arkansas River flowing in. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 64, classifying the segment as hypereutrophic, indicative of excessive primary productivity and nutrient conditions. Chlorophyll-a values were consistently upper eutrophic to mid-hypereutrophic in 3 of the 4 sampling intervals. Turbidity values ranged from a low of 7 NTU (site 3) to a maximum of 254 NTU (site 5). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered partially supported if 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although eight (12.5%) of the twelve values exceeded 25 NTU an assessment of the Fish & Wildlife Propagation (FWP) beneficial use cannot be made due to minimum data requirements are not being met. Only 1 (8.3%) of the true color values were below the Aesthetics criteria 70 units however like turbidity there are not enough data for this segment to assess the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites within this segment. Salinity values ranged from 0.28 to 1.24 parts per thousand (ppt) indicating moderate to high salt content within is segment of the waterbody. Salinity readings were higher than the normal range of salinity values reported for most Oklahoma lakes. Readings for specific conductivity were also high, ranging from 542 µS/cm to 2317 µS/cm, indicating high amounts of electrical current conducting compounds (salts) in the lake system throughout the year. In general, pH values were slightly neutral to alkaline, ranging from 7.34 to 8.96 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of pH values falling within the acceptable range the FWP beneficial use is supported as it relates to pH. Thermal stratification was not evident during the fall, winter or spring sampling intervals and the water column appeared to be well mixed. In the summer, the water column was weakly stratified with anoxic conditions present at both sites 3 and 4. At site 3, the temperature ranged from 28.58^0 C at the surface to 25.17^0 C at the bottom with dissolved oxygen (D.O.) less than 2.0 mg/L in approximately 20% of the water column. Site 5, is very shallow and did not stratify during this time period likely as a result of wind mixing. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Keystone Lake (segment # 621200010050) with only 18% to 20% of the water column experiencing anoxic conditions in the summer quarter.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of (Nutrient Limited Watershed) NLW lakes and nutrient criteria development for lakes and reservoirs. In the Arkansas River segment of the lake the average total nitrogen (TN) was 1.04 mg/L, with values ranging from 0.64 mg/L in the summer to 2.04 mg/l in the fall quarter. The average total phosphorus (TP) was 0.167, with values ranging from 0.094 mg/L in the winter to 0.362 mg/L in the fall. The nitrogen to phosphorus ratio (TN:TP) was 6:1; this value is the close to 7:1, characterizing for this portion of the lake as possibly co-limited (Wetzel, 1983).

Keystone Lake, Cimarron River, Lower Arm

This portion of Keystone Lake (segment # 620900010020) extends from the marina area to Salt Creek Cove (S) area and up to Sandy Park in the Cimarron River arm of the reservoir and includes BUMP sites 6 through 9. The segment-wide average turbidity was 14 NTU, true color was 28 units and secchi disk depth was 76 centimeters in sample year 2006. Water clarity is good in this portion of the lake, based on these three parameters as is expected since these sites are still a good distance away from the inflow of the Cimarron River and materials have had some time to settle out. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=16). The average TSI was 60, classifying the segment as eutrophic, indicative of high primary productivity and nutrient conditions. Chlorophyll-a values were generally upper eutrophic to mid-hypereutrophic during the sample year with the lowest values reported in the fall quarter. Turbidity values ranged from a low of 4 NTU (site 6) to a maximum of 28 NTU (site 9). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered partially supported if 10% to 25% of the turbidity values exceed

the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although three (18%) of the sixteen values exceeded 25 NTU an assessment of the Fish & Wildlife Propagation (FWP) beneficial use cannot be made due to minimum data requirements not being met. All true color values were below the Aesthetics criteria 70 units however like turbidity there are not enough data for this segment to assess the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites within this segment. Salinity values ranged from 0.15 to 2.66 parts per thousand (ppt) indicating moderate to high salt content within the lake depending where the sample site was located. Salinity readings were higher than the normal range of salinity values reported for most Oklahoma lakes. In general, salinity values are high in the Cimarron River arm of the reservoir. Readings for specific conductivity were also very high, ranging from 314 µS/cm to 4849 µS/cm, indicating extremely high amounts of electrical current conducting compounds (salts) in the lake system throughout the year. In general, pH values were slightly neutral to alkaline, ranging from 7.36 to 8.56 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of pH values falling within the acceptable range the FWP beneficial use is supported as it relates to pH. Thermal stratification was not evident during the fall, winter or spring sampling intervals and the water column appeared to be well mixed. In the summer, stratification was gradual and anoxic conditions present from 9 meters below the surface to the lake bottom. At site 6, the temperature ranged from 27.47^0 C at the surface to 25.21^0 C at the bottom with dissolved oxygen (D.O.) less than 2.0 mg/L in approximately 47% of the water column. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Keystone Lake (segment # 620900010020) with 27% to 47% of the water column experiencing anoxic conditions in the summer quarter.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of (Nutrient Limited Watershed) NLW lakes and nutrient criteria development for lakes and reservoirs. In the Lower Cimarron River segment of the lake the average total nitrogen (TN) was 0.84 mg/L, with values ranging from 0.61 mg/L in the summer to 1.20 mg/l in the fall quarter. The average total phosphorus (TP) was 0.101, with values ranging from 0.055 mg/L in the winter to 0.186 mg/L in the fall. The nitrogen to phosphorus ratio (TN:TP) was 8:1; this value is the close to 7:1, characterizing for this portion of the lake as possibly co-limited (Wetzel, 1983).

Keystone Lake, Cimarron River, Upper Arm

This portion of Keystone Lake (segment # 620900010090) extends from Appalachia Bay up to Pawnee Cove (S) area in the Cimarron River arm of the reservoir and includes BUMP sites 10 through 12. The segment-wide average turbidity was 41 NTU, true color was 40 units and secchi disk depth was 41 centimeters in sample year 2006. Based on these three parameters water clarity is average in this portion of the lake. This is not unusual since this segment is more riverine and has greater influence from the Cimarron River flowing in. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 63, classifying the segment as eutrophic, indicative of high primary productivity and nutrient conditions. Chlorophyll-a values were generally upper

eutrophic to mid-hypereutrophic throughout the sample year. Turbidity values ranged from a low of 7 NTU (site 10) to a maximum of 147 NTU (site 12). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered partially supported if 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although seven (58%) of the twelve values exceeded 25 NTU an assessment of the Fish & Wildlife Propagation (FWP) beneficial use cannot be made as minimum data requirements not being met. Only 2 (16.6%) of the true color values were below the Aesthetics criteria 70 units however like turbidity there are not enough data for this segment to assess the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites within this segment. Salinity values ranged from 0.73 to 6.34 parts per thousand (ppt) indicating moderate to very high salt content within this segment of the lake. Salinity readings were much higher than the normal range of salinity values reported for most Oklahoma lakes. In general, salinity values tend to be higher in the Cimarron River arm of the reservoir. Readings for specific conductivity were also very high, ranging from 1373 µS/cm to 11,134 µS/cm, indicating extremely high amounts of electrical current conducting compounds (salts) in the lake system throughout the year. The only other lake with values this high is Great Salt Plains Reservoir, near Jet. In general, pH values were slightly neutral to alkaline, ranging from 7.39 to 8.38 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of pH values falling within the acceptable range the FWP beneficial use is supported as it relates to pH. Thermal stratification was not evident during the fall, winter or spring sampling intervals and the water column appeared to be well mixed. In the summer, thermal stratification was minimal however anoxic conditions were still present. Site 10, which is the deepest site in this segment, had dissolved oxygen less than 2.0 mg/L from 9 meters below the surface to the lake bottom of 15 meters. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Keystone Lake (segment # 620900010090) with 25% to 31% of the water column experiencing anoxic conditions in the summer quarter.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of (Nutrient Limited Watershed) NLW lakes and nutrient criteria development for lakes and reservoirs. In the Upper Cimarron River segment of the lake the average total nitrogen (TN) was 1.08 mg/L, with values ranging from 0.66 mg/L in the spring to 1.77 mg/l in the fall quarter. The average total phosphorus (TP) was 0.143, with values ranging from 0.059 mg/L in the summer to 0.328 mg/L in the fall. The nitrogen to phosphorus ratio (TN:TP) was 8:1; this value is the close to 7:1, characterizing for this portion of the lake as possibly co-limited (Wetzel, 1983).

Lake Summary

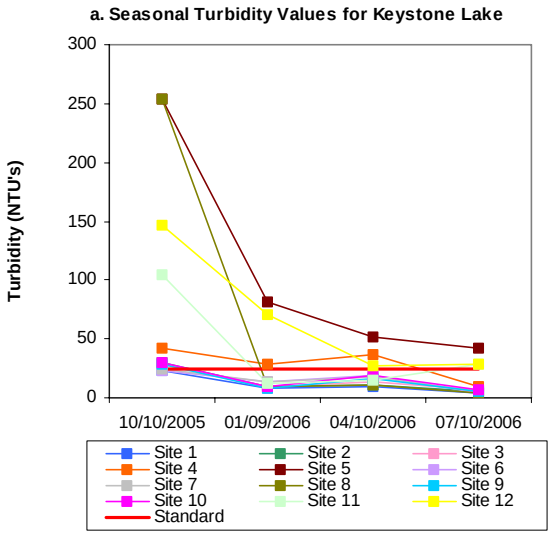
The lake was also sampled for chlorides and sulfates, to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported in the main lake and Arkansas River arm; however the use was not supported due to high chloride

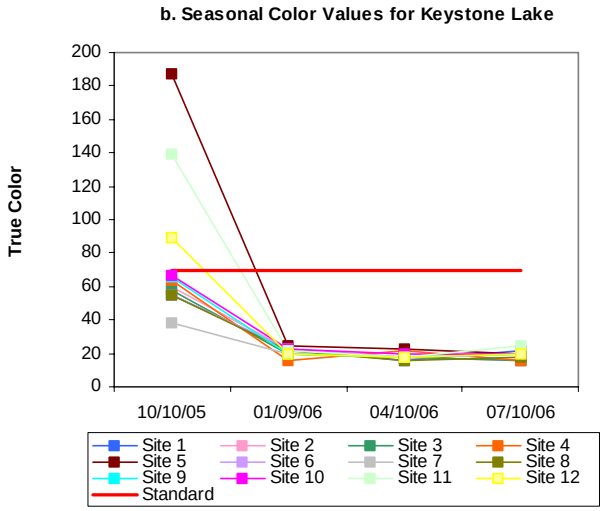
concentrations in the Cimarron River arms of the lake based on numerical criteria located in OAC 785:45 – Appendix F.

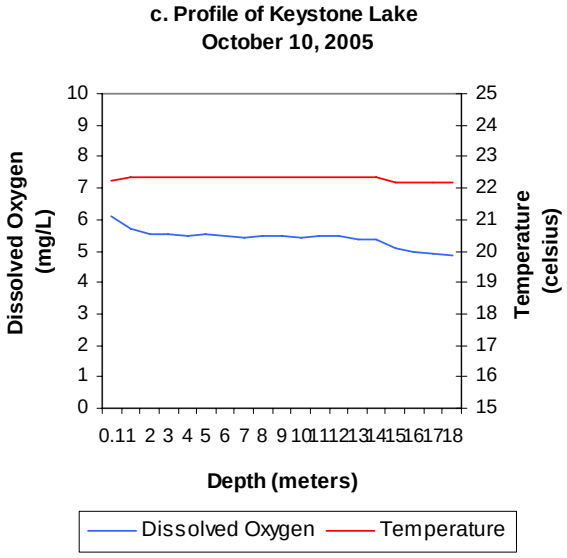
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites throughout the lake for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. Although all sample results were below both the screening level and geometric mean, however the minimum data requirements for each segment were not met and an assessment of the PBCR beneficial use cannot be made at this time.

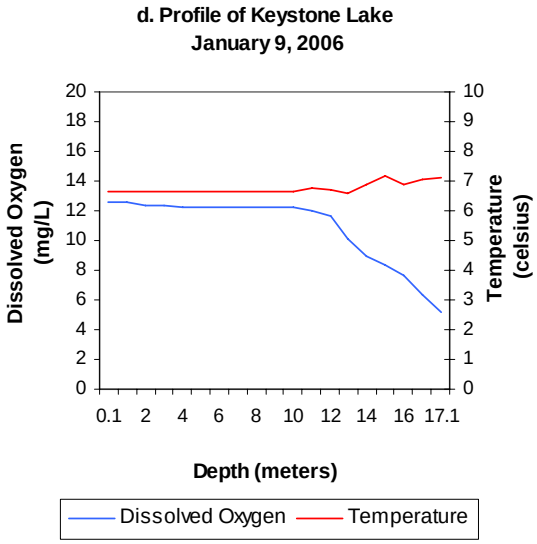
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake was re-sampled in 2005, however the results are not available at this time and will be included as they become available. Keystone Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

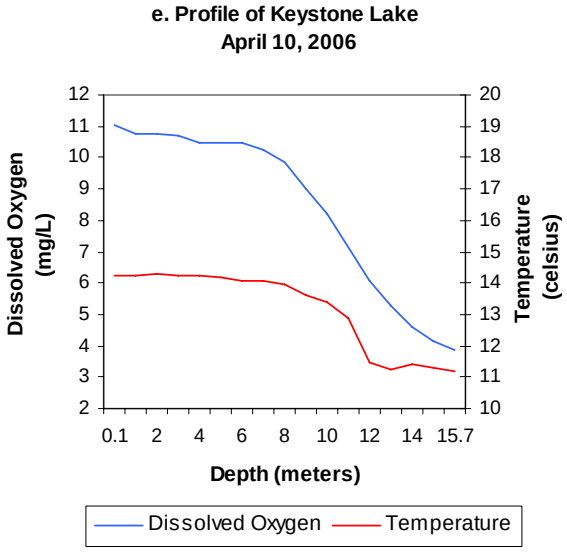
In summary, Keystone Lake was classified as hypereutrophic, indicative of excessive productivity and nutrient levels (Plate 64) for sample year 2005-2006. The lake-wide annual turbidity value was 35 NTU (Plate 64), true color was 34 units, and secchi disk depth was 62 centimeters in 2005-2006. Based on these three parameters, Keystone Lake had average water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=48). The average TSI was 61 (Plate 64), classifying the lake as hypereutrophic, indicative of excessive levels of productivity and nutrients. In the spring and summer quarters the vast majority of the lake was either eutrophic or hypereutrophic in nature. The sites in the upper most reaches of the lake (4, 5, 11, and 12) were the most productive throughout the entire year. Seasonal turbidity values are displayed in Figure 77a. Turbidity values were variable with lower values recorded in the more lacustrine areas of the lake. Eighteen of the 48 turbidity values exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU. With 37.5% of the recorded turbidity values above the numeric criteria, the Fish & Wildlife Propagation (FWP) beneficial use is considered not supported for sample year 2006. Seasonal true color values are displayed in Figure 77b. Only three (6.25%) of the 48 true color values exceeded the numeric criteria of 70 units; therefore, the Aesthetics beneficial use is considered fully supported. Based on anoxic condition present in the summer (Figure 77f), the FWP is considered partially supported at Keystone Lake as it relates to dissolved oxygen. Keystone is fully supporting its FWP beneficial with all pH values within the range of 6.5 to 9 pH units. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites throughout the lake for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. Although all sample results were below both the screening level and geometric mean, however the minimum data requirements for each segment were not met and an assessment of the PBCR beneficial use cannot be made at this time.











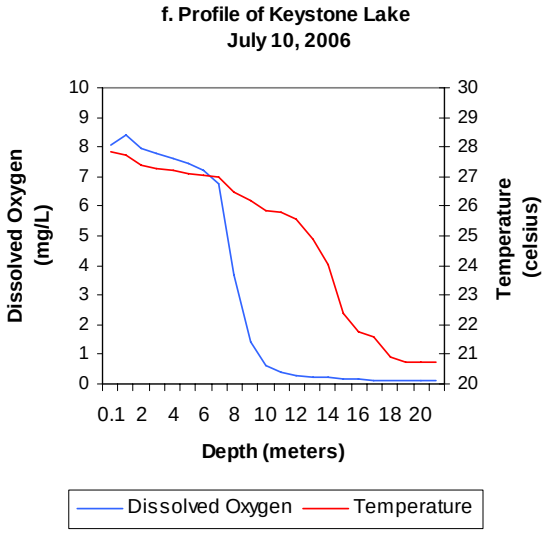
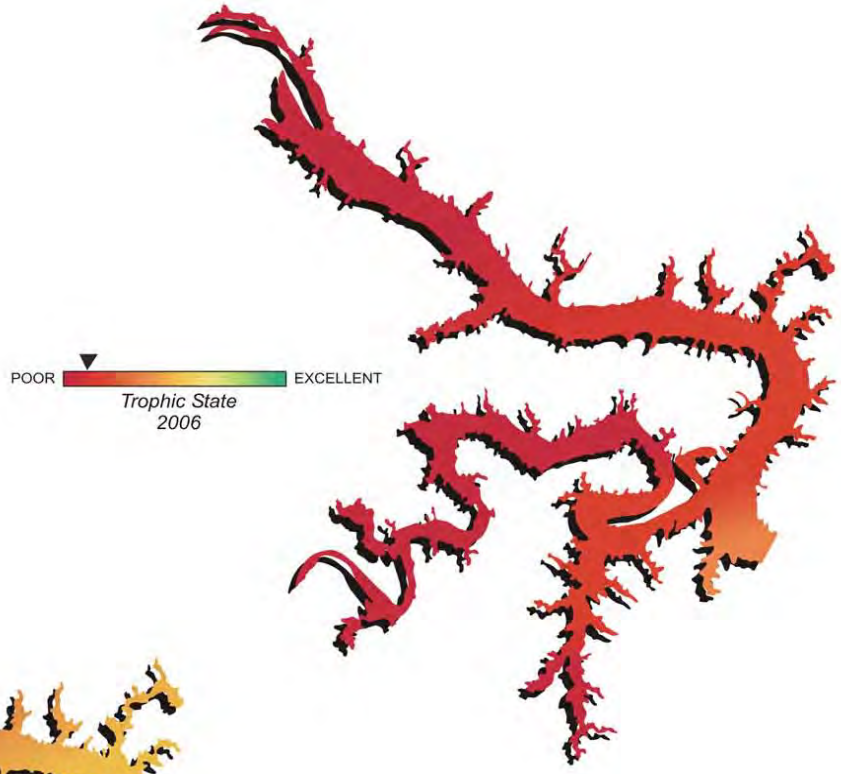
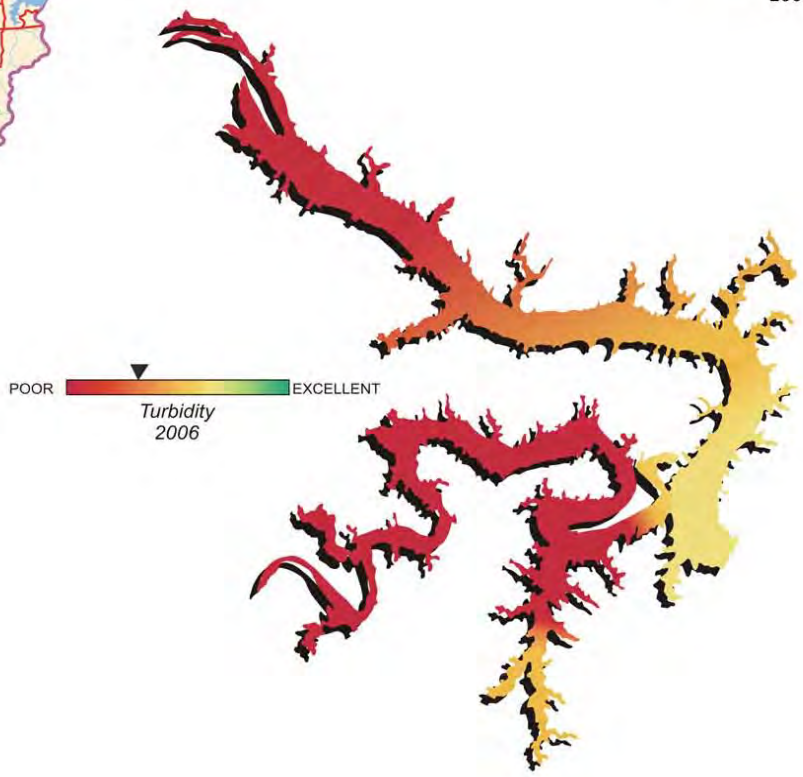


Figure 77a-77 f. Graphical representation of data results for Keystone Lake.

Keystone Lake and Watershed





Lake Data	
Constructed by	Corps of Engineers
County	Tulsa
Constructed in	1964
Surface Area	23,610 acres
Volume	557,600 acre/feet
Shoreline Length	330 miles
Mean Depth	23.62 feet
Watershed Area	74,506 square miles

Plate 64 - Lake Water Quality for
Keystone Lake

LAKES MONITORING PROGRAM

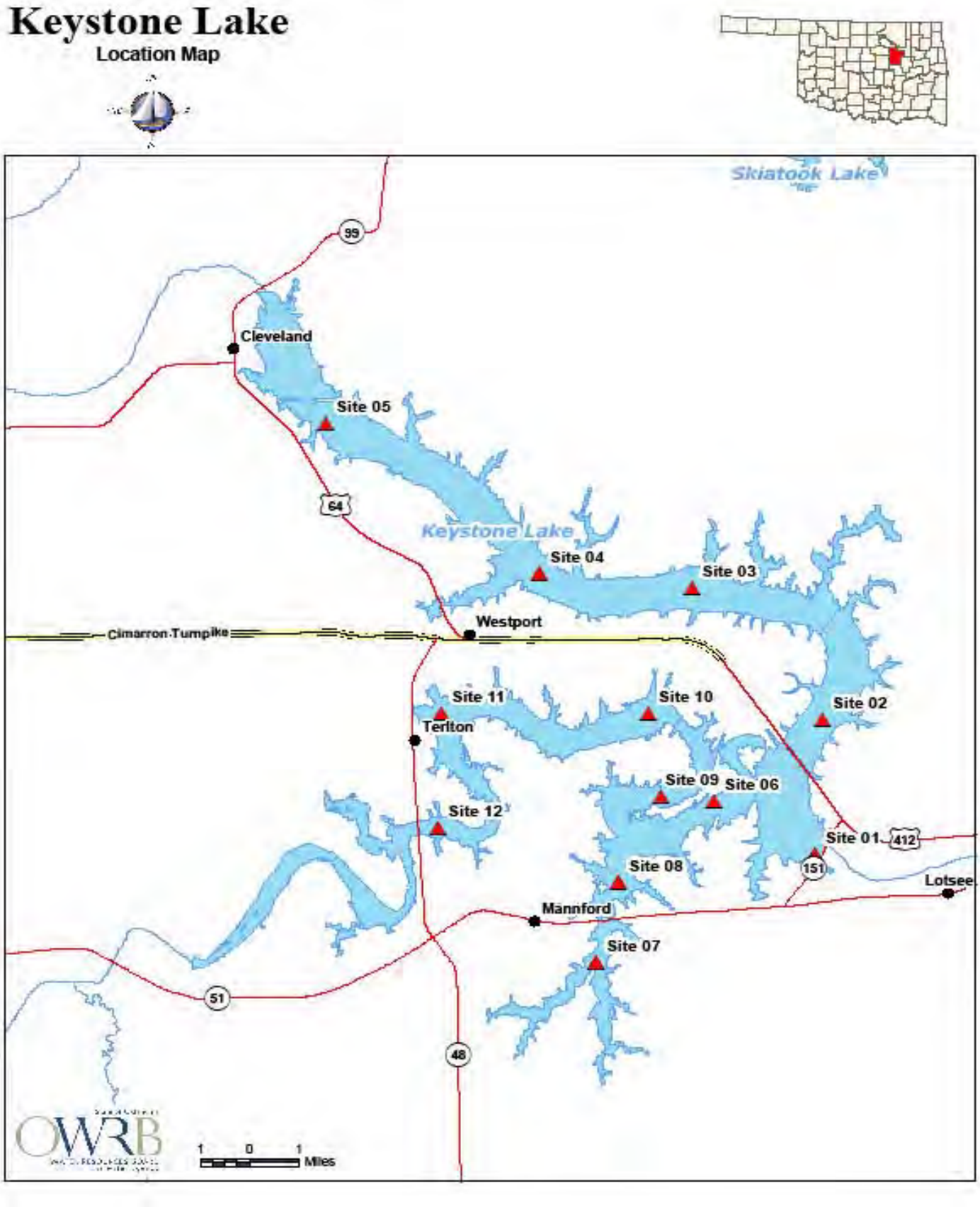


Figure 78. Keystone Lake Site Map

Konawa Reservoir

Konawa Reservoir was sampled for three seasons, from November 2004 through September 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 7 NTU (Plate 65), true color was 18 units, and secchi disk depth was 94 centimeters in sample year 2005. Based on these three parameters, Konawa Reservoir had good to excellent water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 53 (Plate 65), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. This is consistent with that of the previous evaluation in 2002 (TSI=54), indicating no change in productivity has occurred. The TSI values were fairly constant from season to season in the eutrophic range with only a small number of instances where the lake was classified in the upper end of mesotrophy. Seasonal turbidity values are displayed in Figure 79a. Of the twenty values collected only one was at the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Konawa Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it pertains to turbidity with only 5% of the values at the standard of 25 NTU. Seasonal true color values are displayed in Figure 79b. All of the true color values were below the numeric criteria of 70 units. Applying the same default protocol, the Aesthetic beneficial use is considered supported based on true color.

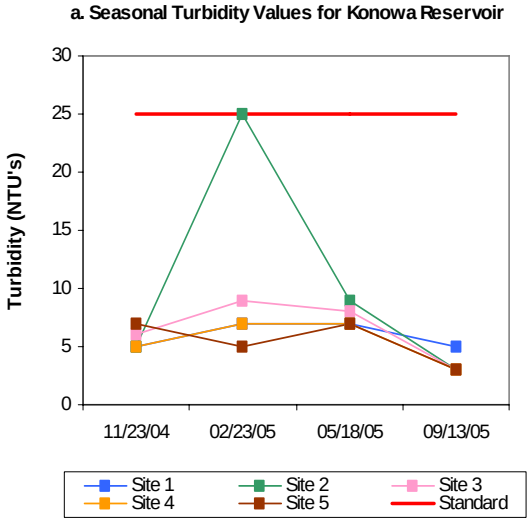
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.66 parts per thousand (ppt) to 0.74 ppt much higher than the range of values normally observed in Oklahoma reservoirs. Readings for specific conductivity were also elevated with values ranging from 1234 µS/cm to 1428 µS/cm, indicating the strong presence of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline, ranging from 7.29 to 8.7 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from –75 mV at the sediment-water interface in the summer to 435 mV also recorded in the summer. Redox readings indicated that reducing conditions were not present in the reservoir to any appreciable degree. The lake was not thermally stratified in the fall or winter and dissolved oxygen (D.O.) values were above 5.0 mg/L throughout the water column at all sites (see Figure 79c-79d). Thermal stratification and anoxic conditions were present in both spring and summer sampling intervals. Site 1 was the only site in the spring exhibit stratification with dissolved oxygen (D.O.) less than 2.0 mg/L from 9 meters to the lake bottom of 10.6 meters. In the summer, the lake exhibited weak thermal stratification at sites 1 and 3 with 33-36% of the water column less than 2.0 mg/L (see Figure 79f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70%

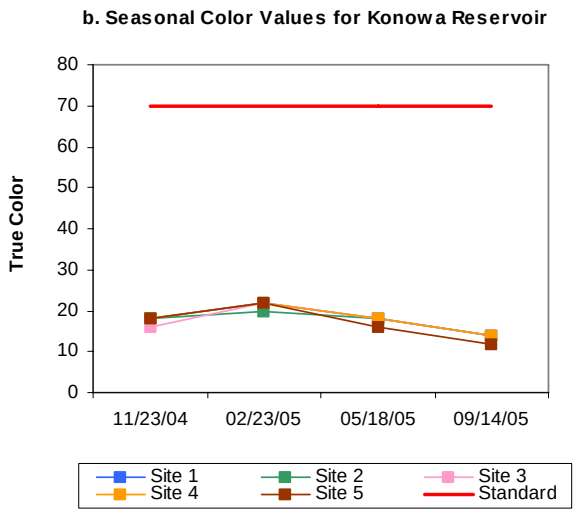
of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Konawa Reservoir, with 33 to 36% of the water column experiencing anoxic conditions in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

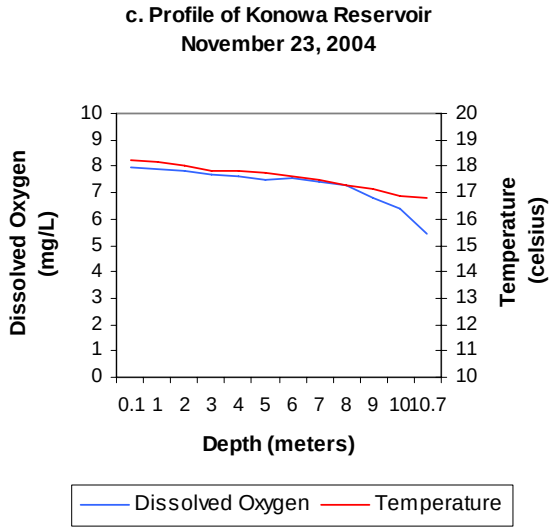
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

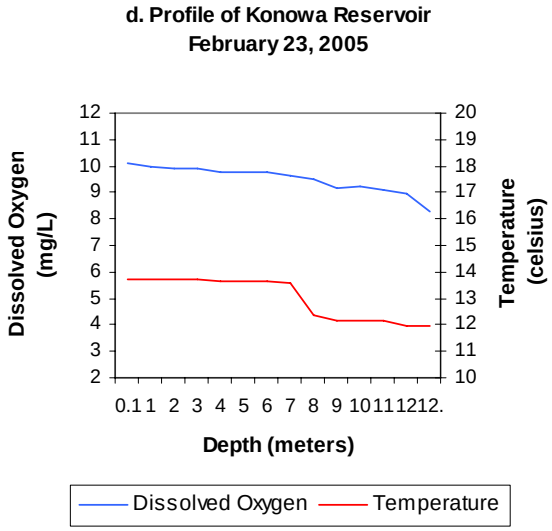
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.69 mg/L at the surface. Surface TN ranged from 0.38 mg/L to 0.96 mg/L, with the highest values reported in the summer and the lowest values in the winter quarter. The lake-wide total phosphorus (TP) average was 0.033 mg/L at the surface. Total phosphorus at the surface ranged from 0.021 mg/L to 0.044 mg/L. TP was highest in the spring and lowest in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 21:1 for sample year 2004-2005 This is higher with the 7:1 ratio characterizing the lake as phosphorus limited (Wetzel, 1983).

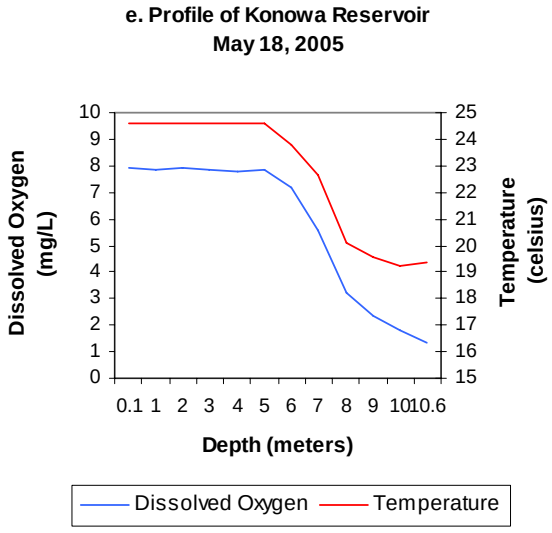
In summary, Konawa Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient levels in 2004-2005 (Plate 65). This is consistent with that of the previous evaluation in 2002 (TSI=54), indicating no change in productivity has occurred. Water clarity was good based on turbidity, true color and secchi disk depth. Konawa Reservoir was meeting its FWP beneficial use based on recorded pH, turbidity, and D.O. values. Konawa Reservoir was meeting its Aesthetics beneficial use based on trophic status and true color as all values reported during the study period were well below the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Konawa Reservoir was constructed in 1968 and is owned and operated by the Oklahoma Gas & Electric Company. Although it serves as a cooling reservoir it offers numerous recreational opportunities for the public.











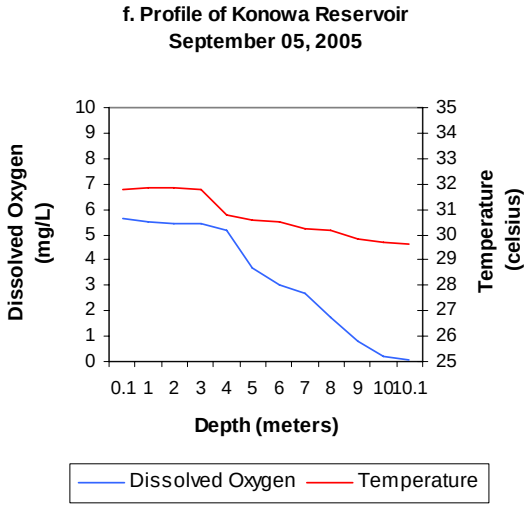
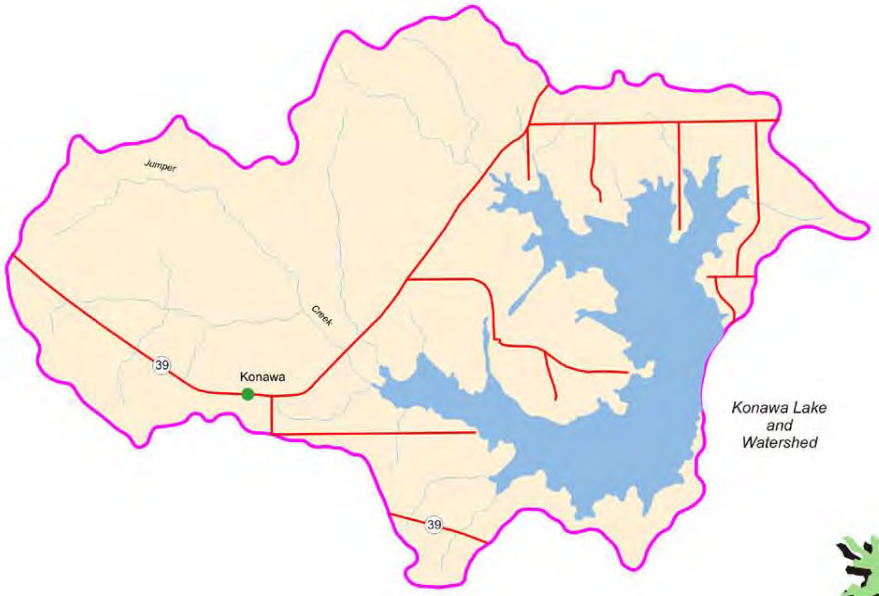
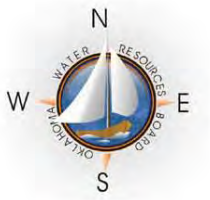


Figure 79a-79f. Graphical representation of data results for Konawa Reservoir.



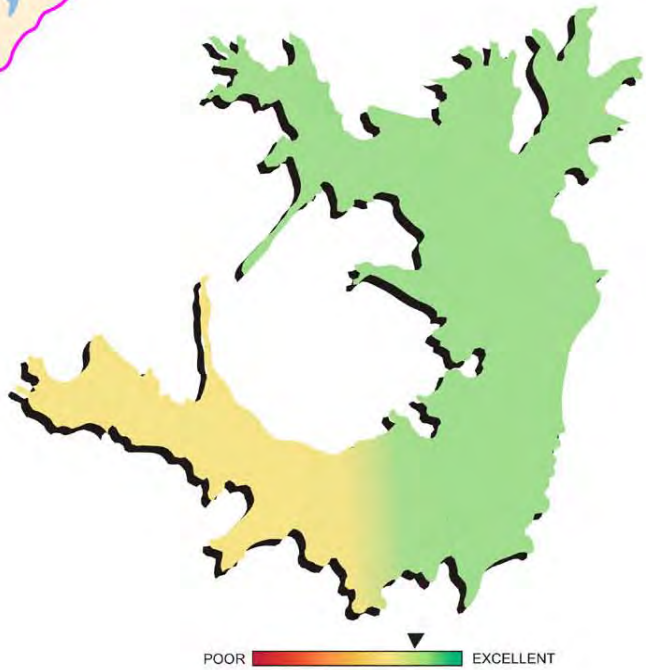
Konawa Lake and Watershed

Konawa Lake Location



Lake Data	
Owner	Oklahoma Gas & Electric Co.
County	Seminole
Constructed in	1968
Surface Area	1,350 acres
Volume	23,000 acre/feet
Shoreline Length	20 miles
Mean Depth	17.04 feet
Watershed Area	12 square miles

Trophic State 2005



Turbidity 2005

Plate 65 - Lake Water Quality for
Konawa Lake

LAKES MONITORING PROGRAM

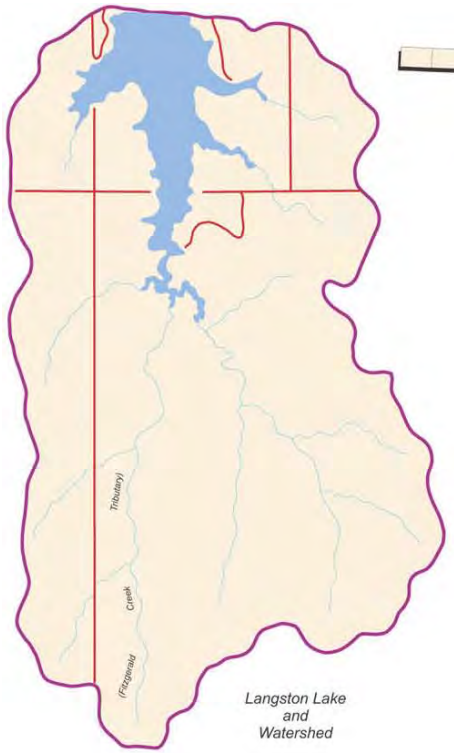
Langston Lake

Langston Lake, located in Logan County, was constructed in 1966 and is owned and operated by the City of Langston. The lake serves as a municipal water supply for the city and also serves as a flood control structure. The lake also offers many recreational opportunities for the public. The lake was scheduled for sampling during the 2005-2006 sample year however due to the drought conditions lake levels were too low for OWRB staff to launch a boat. The lake will be placed on the next sample rotation once water levels rise enough for staff to access the lake safely.

Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the lake. Samples were collected at all sites from the lake surface and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 11 NTU (Plate 66), true color was 12 units, and secchi disk depth was 103 centimeters. Based on these three parameters, Langston Lake had excellent water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 47 (Plate 66), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This finding is very similar to that of 2002 (TSI=44), indicating that no significant increase or decrease in productivity has occurred over time. The TSI values were consistently mesotrophic throughout all four quarters sampled 2003-2004. All turbidity values collected were less than the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 10% of the collected turbidity values exceeding the WQS, Langston Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. All of the true color values were below the numeric criteria of 70 units. Applying the same default protocol, the Aesthetics beneficial is considered fully supported.

Please refer to the "Beneficial Use Monitoring Report 2004 Draft Final Report" for the full discussion of monitoring results for this lake. The report may be access via the OWRB's web page at http://www. owrb.state.ok.us or you may contact the Water Resources for a copy of the 2004 BUMP Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the address below:

Oklahoma Water Resources Board
3800 N. Classen Blvd.
Oklahoma city, Oklahoma 73118
Attn: Nikki Cole



Langston Lake and Watershed

Langston Lake Location

Lake Data	
Owner	City of Langston
County	Logan
Constructed in	1966
Surface Area	304 acres
Volume	5,792 acre/feet
Shoreline Length	8 miles
Mean Depth	19.05 feet
Watershed Area	3798 acres

Turbidity 2004

Trophic State 2004

Plate 66 - Lake Water Quality for
Langston Lake

LAKES MONITORING PROGRAM

Lake Lawtonka

Lake Lawtonka was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as any major arms of the lake. Samples were collected from the lake surface with an additional sample taken at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 7 NTU (Plate 67), true color was 12 units, and secchi disk depth was 102 centimeters. Based on these three parameters, Lake Lawtonka had good water clarity in comparison to other Oklahoma reservoirs. Results were similar if not slightly better than that of the previous evaluation. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 58 (Plate 67), classifying the lake as eutrophic with high primary productivity and nutrient conditions. Results in 2002 were very similar (TSI=53), indicating no significant increase or decrease in productivity has occurred. The TSI values were primarily eutrophic to the lower end of hypereutrophy. Site 1 was the only site to have a mesotrophic value, which occurred in the spring quarter. The turbidity values for Lake Lawtonka were all less than the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 80a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Lawtonka is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity values. Seasonal true color values are displayed in Figure 80b. All of the true color values were well below the numeric criteria of 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the true color values.

Vertical profiles for dissolved oxygen; pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five (5) sample sites. Salinity values ranged from 0.19 parts per thousand (ppt) to 0.23 ppt and were within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductivity were also within the range of expected values for Oklahoma lakes, ranging from 386.5 cm/cm to 464.1 cm/cm, indicating moderate levels of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline, ranging from 7.29 in the summer to 8.55 units in the winter quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. None of the collected pH values were outside the acceptable range. Lake Lawtonka is fully supporting its FWP beneficial use based on pH values recorded during the study period. Oxidation-reduction potentials (redox) ranged from 171 mV to 529 mV. Redox readings indicated that reducing conditions were not present in the reservoir at any time in an appreciable way. The lake was not thermally stratified in the fall, winter, or spring quarters and dissolved oxygen (D.O.) values were generally above 5.0 mg/L throughout most of the water

column. (See Figure 80c-80e). In the summer, the lake was thermally stratified between 8 and 9 meters below the lake surface. D.O. readings below 9 meters were less than 2.0 mg/L extending all the way to the lake bottom at 16 meters at site 1 (see Figure 80f). Stratification and anoxic conditions were also present at sites 2 and 3. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Lake Lawtonka with 47% of the water column experiencing anoxic conditions at site 1 during the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

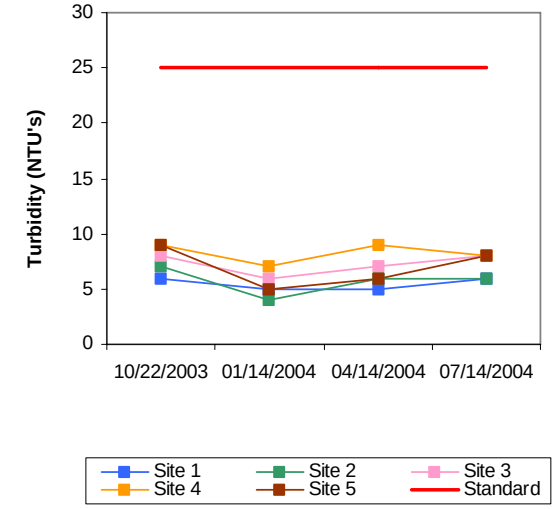
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected four (40%) exceeded the prescribed screening level of 61 cfu/ml for enterococci, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.61 mg/L at the lake surface and 0.61 mg/L at the lake bottom. The TN at the surface ranged from 0.25 mg/L in the spring quarter to 0.92 mg/L in the fall quarter. The lake-wide total phosphorus (TP) average was 0.028 mg/L at the lake surface and 0.055 at the lake bottom. The surface TP ranged from 0.022 mg/L in the spring quarter to 0.036 mg/L in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 22:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

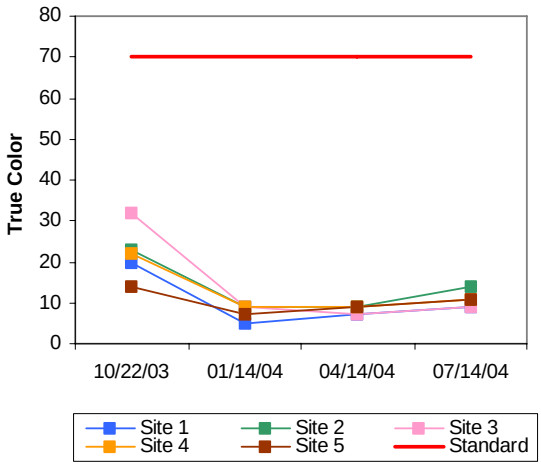
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1996 and 1997 as part of their Toxics Monitoring Program and detected no compounds at the FDA Action level, ODEQ warning level or ODEQ concern level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Lawtonka was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 67). Water clarity is good based on true color, turbidity and secchi disk depth. Lake Lawtonka was fully supporting the FWP beneficial use based on turbidity, pH and D.O. values recorded during the study period. The lake was also fully supporting its Aesthetics beneficial use based on true color values and its trophic status. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected four (40%) exceeded the prescribed screening level of 61 cfu/ml for enterococci, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Lake Lawtonka is the municipal water supply for the City of Lawton and is owned and operated by the city. The lake is also provides numerous recreational activities for the citizens of Oklahoma.

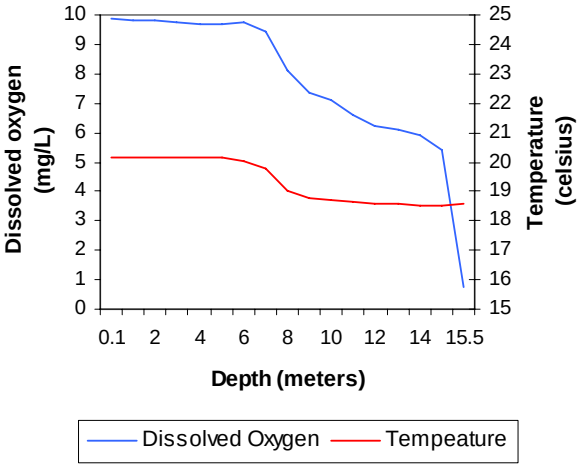
a. Seasonal Turbidity Values for Lake Lawtonka



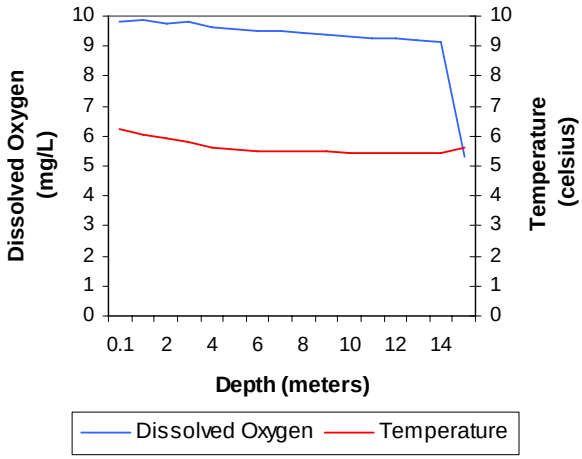
b. Seasonal Color Values for Lake Lawtonka



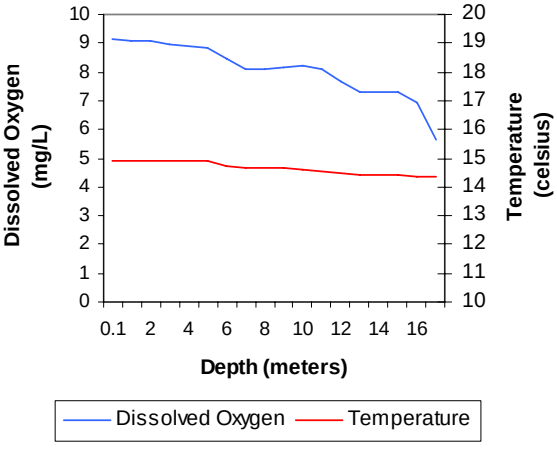
c. Profile of Lake Lawtonka
October 22, 2003



d. Profile of Lake Lawtonka
January 14, 2004



e. Profile of Lake Lawtonka
April 14, 2004



f. Profile of Lake Lawtonka
July 14, 2004

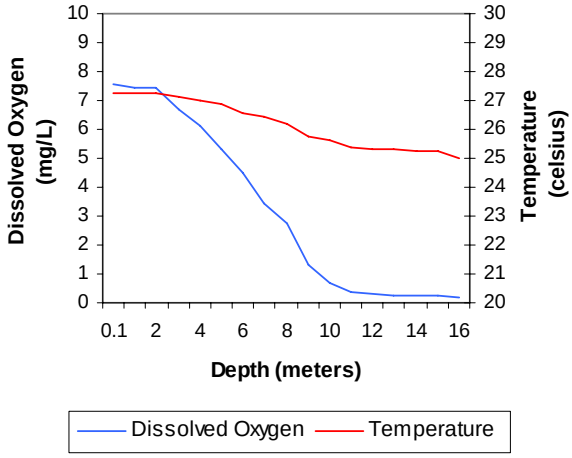
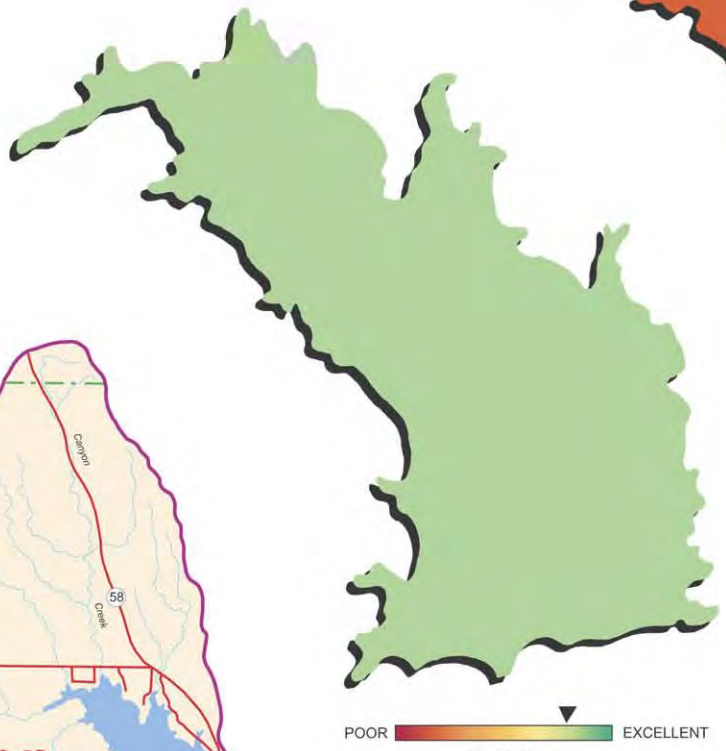


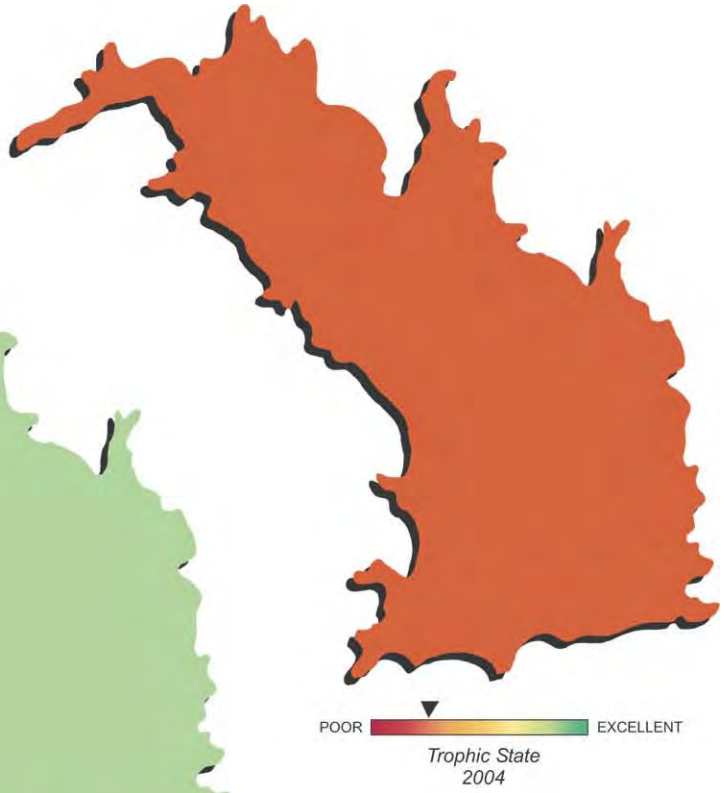
Figure 80a-80f. Graphical representation of data results for Lake Lawtonka.

Lake Lawtonka
Location

Lake Lawtonka
and
Watershed



Turbidity
2004



Trophic State
2004

Lake Data	
Owner	City of Lawton
County	Comanche
Constructed in	1905
Surface Area	2,398 acres
Volume	55,574 acre/feet
Shoreline Length	21 miles
Mean Depth	23.59 feet
Watershed Area	92 square miles

Plate 67 - Lake Water Quality for
Lake Lawtonka

LAKES MONITORING PROGRAM

Liberty Lake

Liberty Lake, located in Logan County, was constructed in 1948 and serves as a municipal water supply for the City of Guthrie. The lake is also used as a recreational outlet for the general public. Liberty Lake was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at three sites during the study period. The lake-wide annual turbidity value was 21 NTU (Plate 68), true color was 20 units, and secchi disk depth was 42 centimeters. Results were similar to that of the 2004 evaluation. Based on these three parameters, Liberty Lake had good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for all quarters (n=12). The average TSI was 67 (Plate 68), classifying the lake as hypereutrophic, indicative of excessive primary productivity and nutrient rich conditions. This value is higher than that of 2004 (TSI=56) and 2002 (TSI=55), indicating a significant increase in trophic status since previous data collection efforts were conducted. Although the current TSI is greater than 62, which normally triggers consideration to be included as an NLW, this is the first time since 1999 that this threshold had been crossed. It is hard to say if this increase is due to the lower lake levels brought on by the drought the state is experiencing or an actual change in productivity therefore the lake will not be recommended for inclusion during the next Oklahoma Water Quality Standards revision process, but will be monitored closely in the future. The TSI values were consistently in the hypereutrophic range for the entire sample year. The turbidity values for the lake were all below the Oklahoma Water Quality Standard (WQS) of 25 NTU except for two values recorded in spring and summer quarters for site 3 at the upper end of the lake (see Figure 81a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Liberty Lake is partially supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity concentrations in the lake as only 16.7% of the collected values exceeded the criteria. Seasonal true color values are displayed in Figure 81b. All of the true color values recorded were below the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is considered fully supported as it relates to true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.22 parts per thousand (ppt) to 0.30 ppt, which is higher than the expected range of values for Oklahoma lakes indicating above average salt content levels. Readings for specific conductivity ranged from 439.1 µS/cm to 580.5 µS/cm, indicating the presence of moderate levels of electrical current conducting compounds (salts) in the water column throughout the year. These values were also paralleled by the recorded salinity values. In general, pH values were neutral to slightly alkaline in nature, ranging from 7.94 units in the spring quarter to 8.48 units in the fall quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of

the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All pH values collected on Liberty Lake were within the allowable range therefore the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 404 mV in the fall to 544 mV recorded in the winter quarter. Redox readings indicated that reducing conditions were not present in the reservoir during the sample year. The lake was not thermally stratified in the fall, winter or spring quarters and the dissolved oxygen (D.O.) values were above 7.0 mg/L throughout the water column at all sites and times (see Figure 81c-81e). Profile data for the summer is not available for assessment due to equipment failure. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Liberty Lake with anoxic conditions absent during the first three sampling intervals. Without profile data available for the summer, an assessment of this quarter cannot be made. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

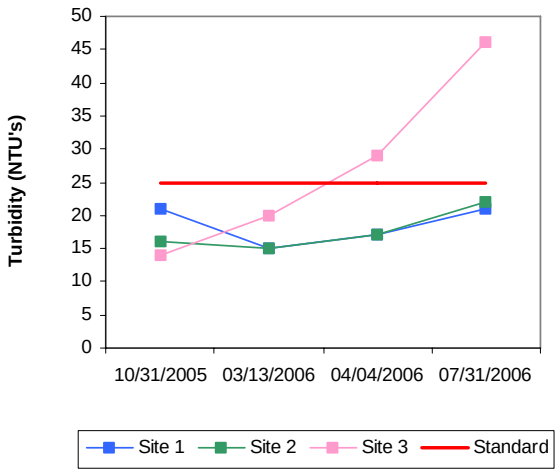
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.10 mg/L at the lake surface. The TN at the surface ranged from 0.82mg/L recorded in the spring quarter to 1.19 mg/L in the fall quarter. The lake-wide total phosphorus (TP) average was 0.071 mg/L at the lake surface. The surface TP ranged from 0.056 mg/L in the fall quarter to 0.110 mg/L recorded in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 16:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake was re-sampled in 2005, however the results are not available at this time and will be included as they become available. Liberty Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

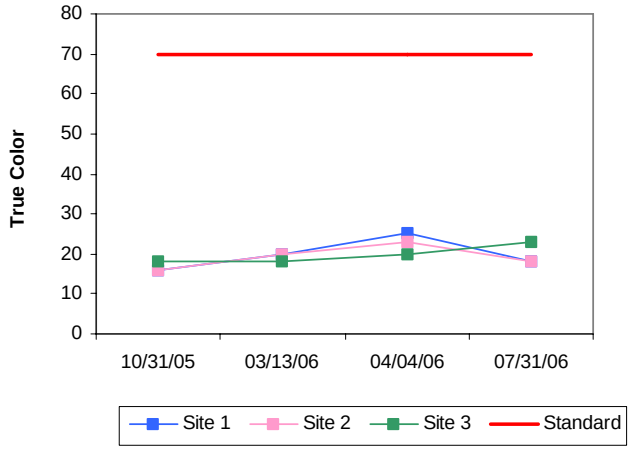
In summary, Liberty Lake was classified as hypereutrophic TSI=67), indicative of high primary productivity and nutrient levels (Plate 68). Although the current TSI is greater than 62, which normally triggers consideration to be included as an NLW, this is the first time since 1999 that this threshold had been crossed. It is hard to say if this increase is due to the lower lake levels brought on by the drought the state is experiencing or an actual change in productivity therefore the lake will not be recommended for inclusion during the next Oklahoma Water Quality Standards revision process, but will be monitored closely in the future. Based on true color,

turbidity and secchi disk depth, water clarity was good at Liberty Lake. The lake is meeting its FWP beneficial use for dissolved oxygen and pH, but partially supporting for turbidity, with 16.7% of the values exceeding the WQS of 25 NTU. Liberty Lake is also fully supporting its based on true color with 100% of the reported values below the WQS of 70 units. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

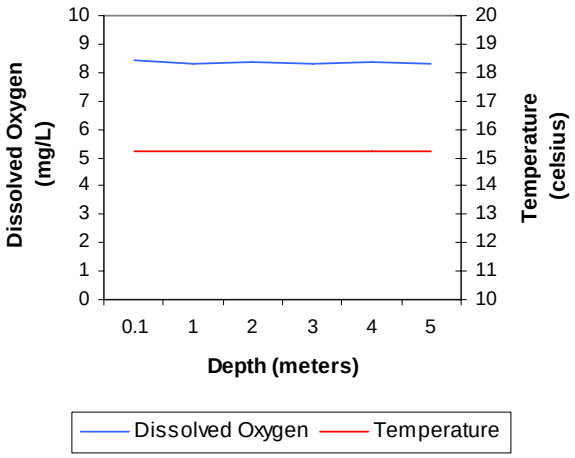
a. Seasonal Turbidity Values for Liberty Lake



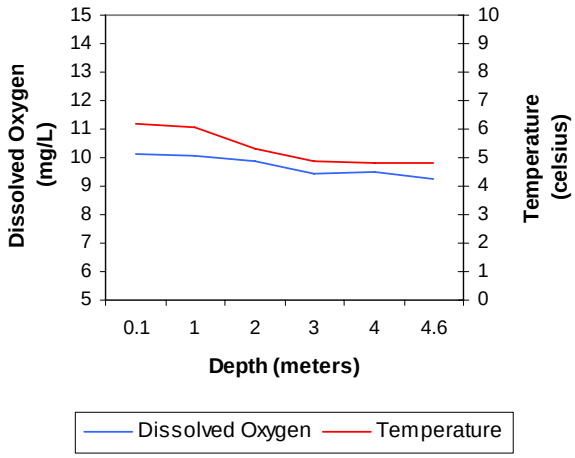
b. Seasonal Color Values for Liberty Lake



c. Profile of Liberty Lake
October 31, 2005



d. Profile of Liberty Lake
January 30, 2006



e. Profile of Liberty Lake
April 4, 2006

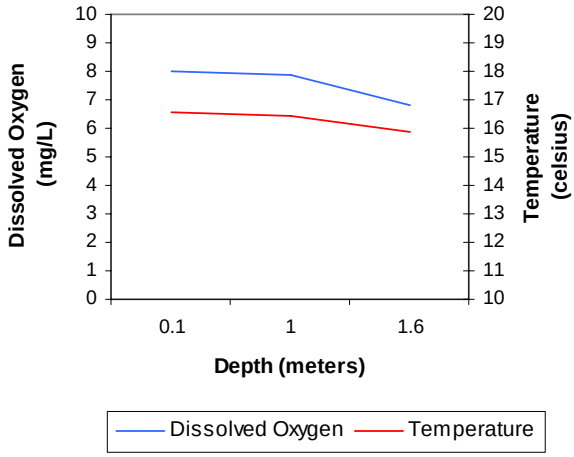


Figure 81a-81f. Graphical representation of data results for Liberty Lake.

Liberty Lake and Watershed

Liberty Lake Location

Lake Data	
Owner	City of Guthrie
County	Logan
Constructed in	1948
Surface Area	167 acres
Volume	2,740 acre/feet
Shoreline Length	5 miles
Mean Depth	16.41 feet
Watershed Area	11 square miles

Turbidity 2006

Trophic State 2006

Plate 68- Lake Water Quality for
Liberty Lake

Lloyd Church (Wilburton) Lake

Lloyd Church Lake, located in Latimer County, serves as the municipal water supply for the city of Wilburton. Lloyd Church Lake was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at three sites during the study period. The lake-wide annual turbidity value was 14 NTU, true color was 79 units, and secchi disk depth was 64 centimeters. Based on these three parameters, Lloyd Church Lake had fairly good water clarity in comparison to other Oklahoma reservoirs. Water clarity was similar to that reported in 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 45, classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is consistent with the one calculated in 2004 (TSI=44), indicating no significant change in productivity has occurred since previous data collection efforts were conducted on the lake. The TSI values were oligotrophic in the fall and winter quarters and mesotrophic in the spring and summer sampling intervals. Of the twelve turbidity values collected, three (25%) exceeded the Oklahoma Water Quality Standard (WQS) of 25 for sample year 2006 (Figure 82a). According to USAP (OAC 785:46-15-5), a beneficial use is considered not supported if ≥25% of the samples exceeds the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Lloyd Church Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use for turbidity. Seasonal true color values are displayed in Figure 82b. Values throughout the sample year were above the standard of 70 units, with the exception of the summer quarter. The Aesthetics beneficial use is considered not supported at Lloyd Church Lake with 75% of the values exceeding 70 units.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.01 ppt. Specific conductivity values were also very low, ranging from 25.4 µS/cm to 71.9 µS/cm. The values recorded for both salinity and specific conductivity are much lower than that typically seen in Oklahoma lakes and reservoirs and are indicative of extremely low concentrations of electrical current conducting ions (salts or other chlorides) in the lake system. Values for pH were slightly acidic to neutral, ranging from 5.9 in the hypolimnion in the spring to 7.51 in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 26% of the recorded values falling outside the acceptable range the FWP beneficial use is considered not supported based on pH concentrations. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of

soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Continued monitoring should be conducted to determine if impairment due to pH exists. Oxidation-reduction potentials (redox) ranged from 79 mV to 503 mV, indicating an absence of reducing conditions during the sample year. Low redox values in the hypolimnion are not uncommon when a lake is strongly thermally stratified and anoxic conditions are present as seen in the summer quarter. The lake was not thermally stratified in the fall or winter quarters and the dissolved oxygen (D.O.) values were above 7.0 mg/L throughout the water column at all sites (see Figure 82c-82d). During the spring the lake was thermally stratified between 8 and 9 meters, however dissolved oxygen (D.O.) never fell below 3.0 mg/L (Figure 82e). In the summer, the lake was strongly thermally stratified between 4 and 5 meters with anoxic conditions comprising approximately 62% of the water column at site 1 (see Figure 82f). Site 2 also exhibited stratification at the same point in the water column with D.O. values less than 2.0 mg/L from 4 meters to the lake bottom of 4.5 meters. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Lloyd Church Lake with approximately 62% of the water column less than 2.0 mg/L at site 1 in the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 fecal coliform samples collected only one exceeded the prescribed screening level or geometric mean The PBCR beneficial use is therefore considered fully supported.

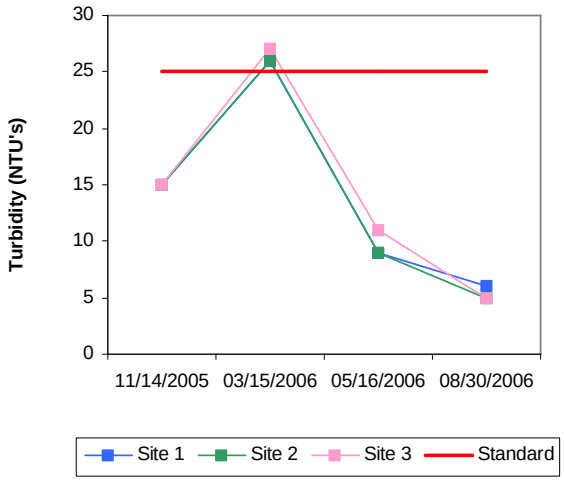
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.38 mg/L at the lake surface. The TN at the surface ranged from 0.15 mg/L recorded in the fall quarter to 0.57 mg/L in the spring quarter. The lake-wide total phosphorus (TP) average was 0.031 mg/L at the lake surface. The surface TP ranged from 0.020 mg/L in the summer quarter to 0.043 mg/L recorded in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 12:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lloyd Church Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

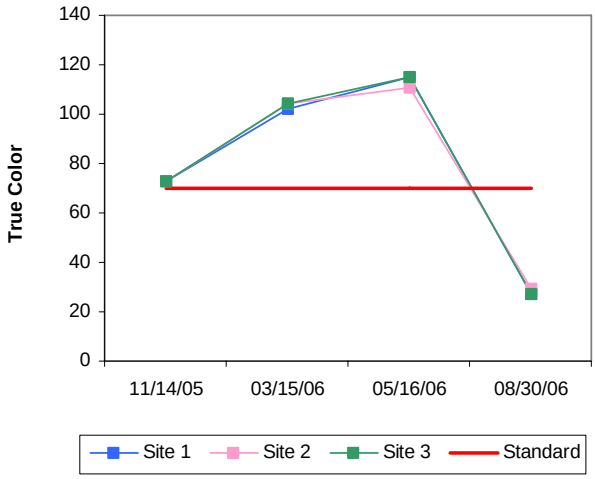
In summary Lloyd Church Lake was classified as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is consistent with the one calculated in 2004 (TSI=44), indicating no significant change in productivity has occurred since previous data collection efforts were conducted on the lake. Based on turbidity, true color and secchi disk depth Lloyd Church Lake had fairly good water clarity. The FWP beneficial use is considered partially supporting with approximately 62% of the water column experiencing anoxic conditions. Although 25% of the turbidity values exceeding the WQS of 25 NTU, available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm

events, and the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates turbidity.. With 26% of the recorded values falling outside the acceptable range, the FWP beneficial use is considered not supported based on pH concentrations. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Continued monitoring should be conducted to determine if impairment due to pH exists. The Aesthetics use is also considered supported based on trophic status however is not supporting with 75% of the reported true color values exceeding the standard of 70 units. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 fecal coliform samples collected only one exceeded the prescribed screening level or geometric mean The PBCR beneficial use is therefore considered fully supported.

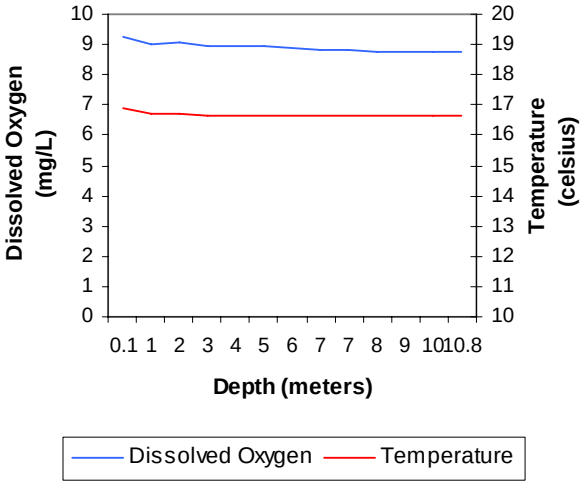
a. Seasonal Turbidity Values for Lloyd Church Lake



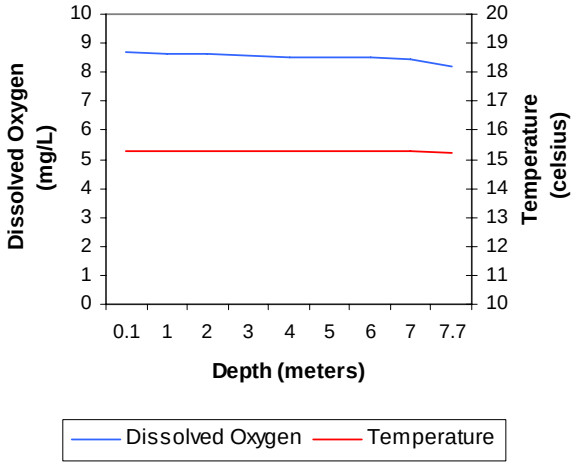
b. Seasonal Color Values for Lloyd Church Lake



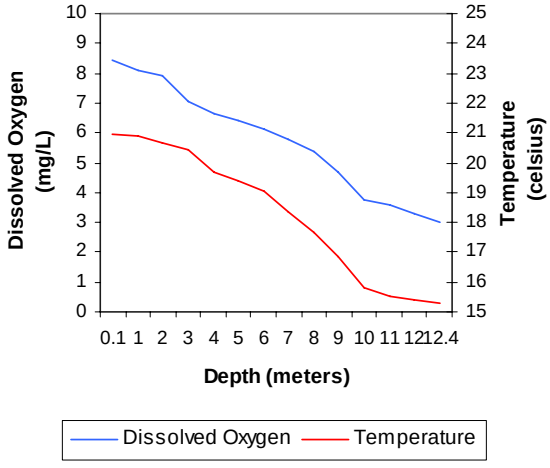
c. Profile of Lloyd Church Lake
November 14, 2005



d. Profile of Lloyd Church Lake
March 15, 2006



e. Profile of Lloyd Church Lake
May 16, 2006



f. Profile of Lloyd Church Lake
August 30, 2006

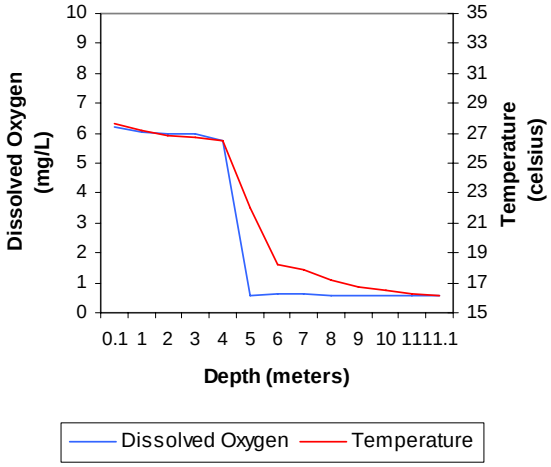
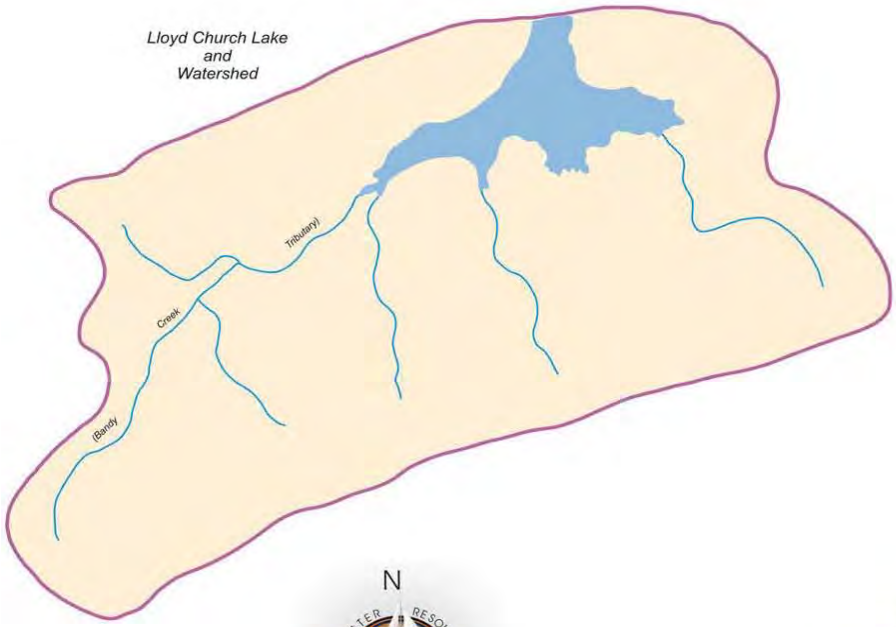
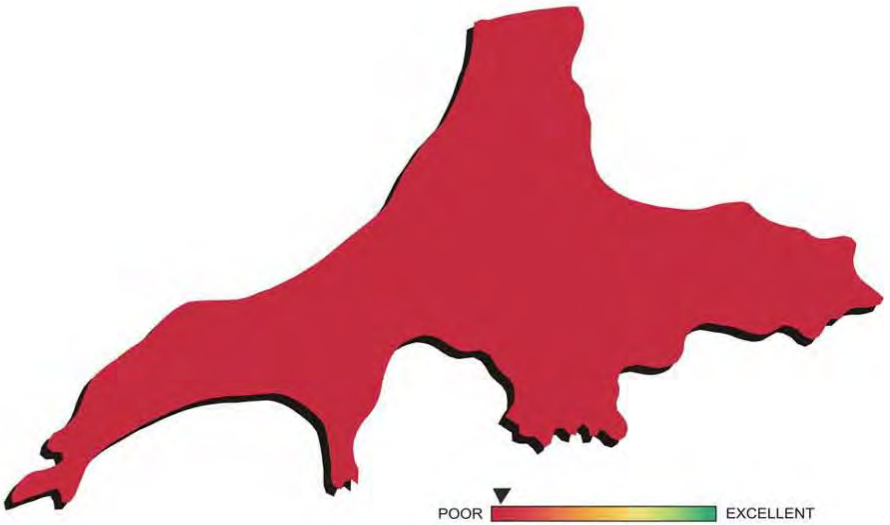


Figure 82a-82f. Graphical representation of data results for Lloyd Church Lake.

Lloyd Church Lake
Location





Trophic State
2006

Turbidity
2006

Lake Data	
Owner	City of Wilburton
County	Latimer
Constructed in	1964
Surface Area	160 acres
Volume	3,060 acre/feet
Shoreline Length	4 miles
Mean Depth	19.13 feet
Watershed Area	2,627 acres

Plate 69 - Lake Water Quality for
Lake Lloyd Church

Lone Chimney Lake

Lone Chimney Lake was sampled for four quarters, from October 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface with an additional sample taken at 0.5 meters from the lake bottom at site 1, near the dam. The lake-wide annual turbidity value was 18 NTU (Plate 70), true color was 41 units, and secchi disk depth was 63 centimeters. Based on these three parameters, Lone Chimney Lake had fair to good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for all quarters (n=20). The average TSI was 53 (Plate 70), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. The TSI values were consistent throughout all four quarters and ranged from the lower end of eutrophy to the upper end of eutrophy. The turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU with the exception of the spring quarter when all five sites were above the standard (see Figure 83a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Lone Chimney Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 83b. Of the true color values collected 20% were above the numeric criteria of 70 units. Similar to turbidity a peak in true color occurred in the spring quarter and is likely the result of seasonal storm events and therefore the Aesthetics beneficial will be considered supported at Lone Chimney Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.06 parts per thousand (ppt) to 0.17 ppt indicating low to moderate salt content and well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductivity were somewhat lower, ranging from 156.9 µS/cm to 312.5 µS/cm, indicating low to moderate electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline, ranging from 7.01 units near the lake bottom in the spring quarter to 8.31 units recorded in the winter quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all collected pH values falling well within the acceptable range of pH, Lone Chimney Lake was fully supporting its FWP beneficial use. Oxidation-reduction potentials (redox) ranged from 319 mV in the summer to 552 mV near the sediment-water interface in the winter quarter. Redox readings indicated that reducing conditions were not present in the reservoir. In the fall, weak thermal stratification was evident and anoxic conditions were present in approximately 23% of the water column (Figure 83c).

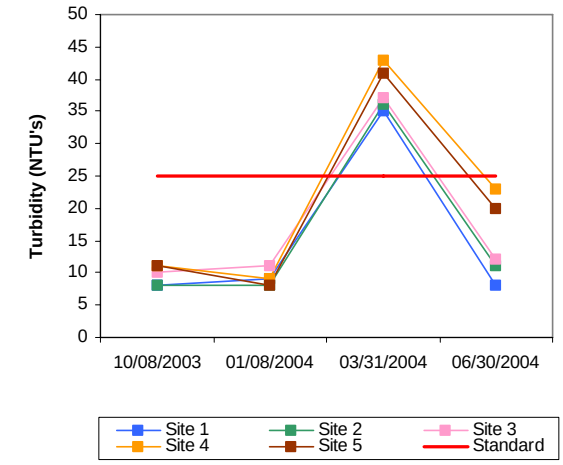
The lake was not thermally stratified in the winter or spring quarters and the dissolved oxygen (D.O.) values were above 5.0 mg/L throughout the water column except near the lake bottom (see Figure 83d-83e). In the summer, the lake was again strongly thermally stratified between 4 and 5 meters and below 4 meters from the surface the D.O. values were less than 1.0 mg/L to the lake bottom at sites 1 and 2 (see Figure 83f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Lone Chimney Lake because 23% of the water column was anoxic in the fall quarter and 44% of the water column during the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.77 mg/L at the lake surface. The TN at the surface ranged from 0.58 mg/L in the winter quarter to 1.05 mg/L recorded in the spring. The lake-wide total phosphorus (TP) average was 0.041 mg/L at the lake surface. The surface TP ranged from 0.021 mg/L in the winter to 0.083 mg/L in the spring. The nitrogen to phosphorus ratio (TN:TP) was approximately 19:1. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

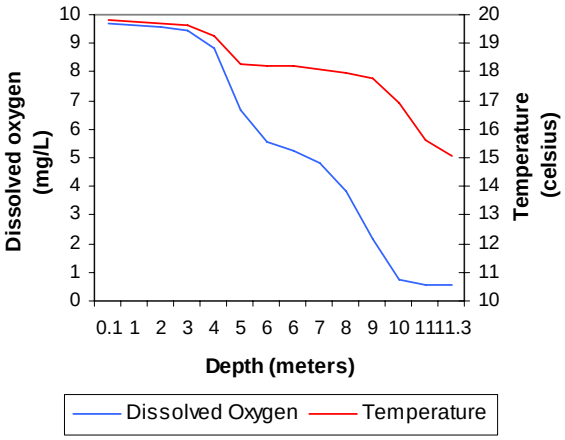
In summary, Lone Chimney Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 70). The lake was fully supporting its FWP beneficial use based on pH and dissolved oxygen values recorded during the study period. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Lone Chimney Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Lone Chimney was supporting its Aesthetics beneficial used based on its assessed trophic status. Similar to turbidity a peak in true color occurred in the spring quarter and is likely the result of seasonal storm events and therefore the Aesthetics beneficial will be considered supported at Lone Chimney Lake.. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Lone Chimney Lake was constructed in 1984 and is owned and operated by the Tri-county Development Authority. The lake serves as a municipal water supply and is also used for flood control and recreational purposes.

a. Seasonal Turbidity Values for Lone Chimney Lake

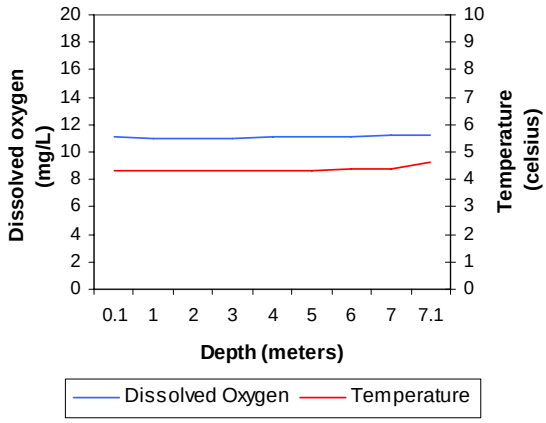


b. Seasonal Color Values for Lone Chimney Lake

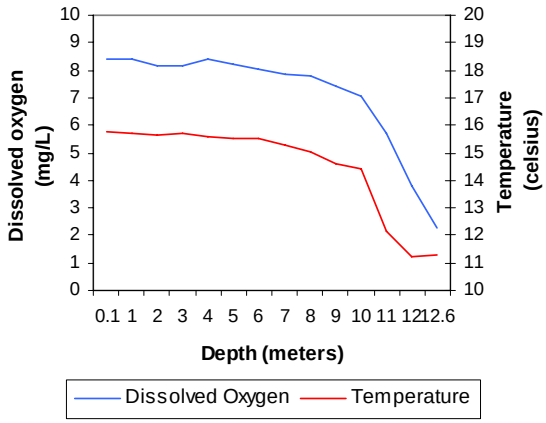
c. Profile of Lone Chimney Lake October 08, 2003



d. Profile of Lone Chimney Lake January 07, 2004



e. Profile of Lone Chimney Lake March 30, 2004



f. Profile of Lone Chimney Lake June 30, 2004

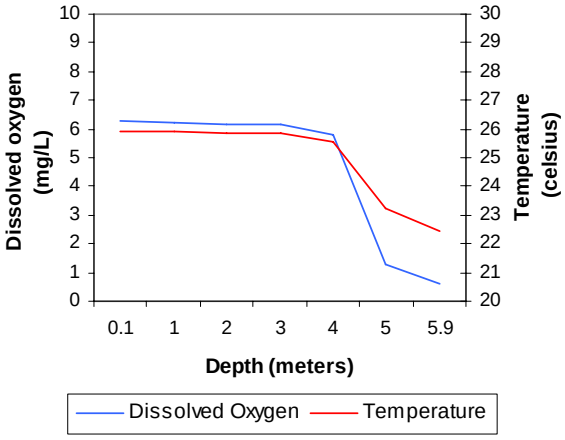
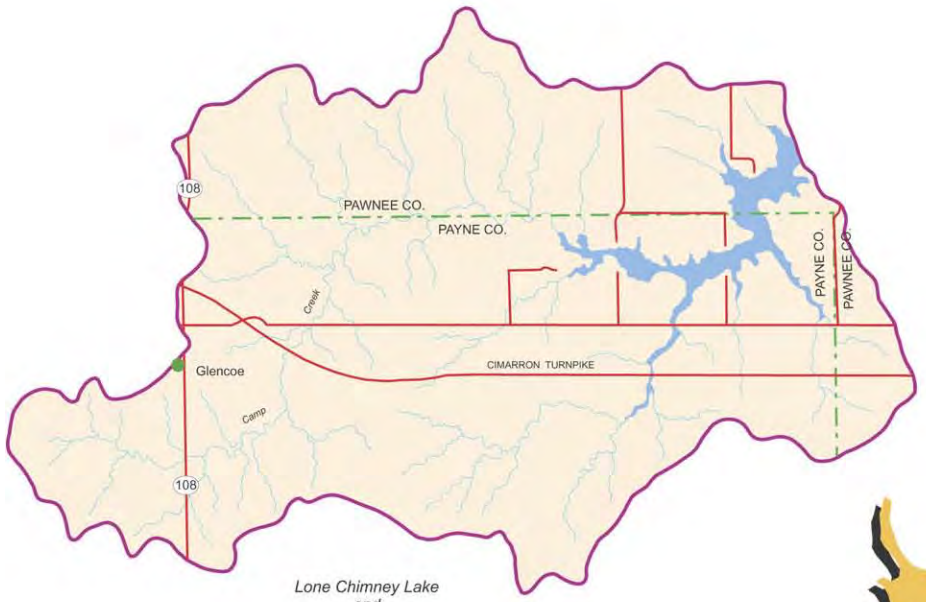
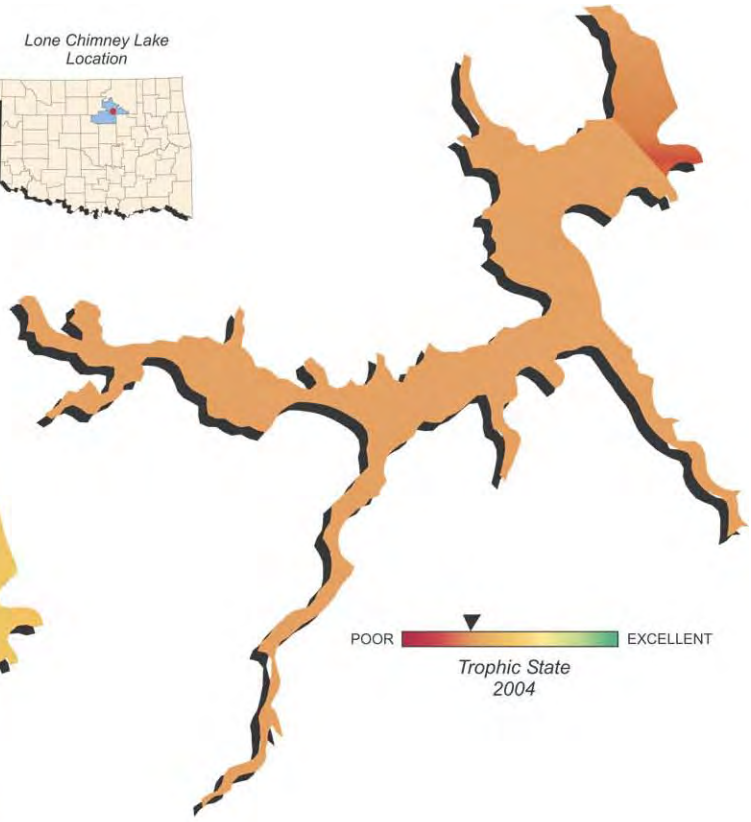


Figure 83a-83f. Graphical representation of data results for Lone Chimney Lake.



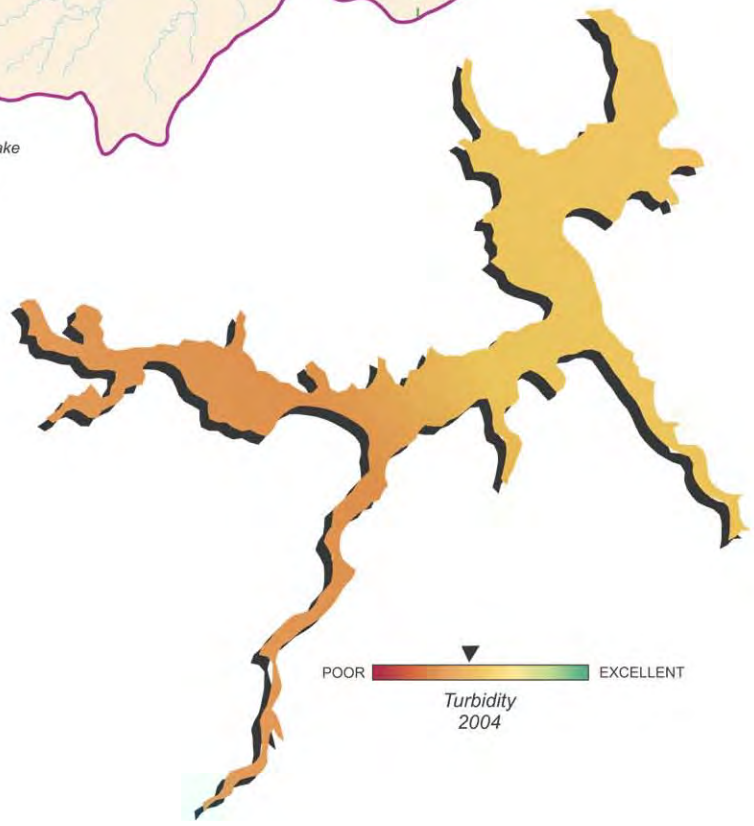
Lone Chimney Lake and Watershed

Lone Chimney Lake Location



POOR EXCELLENT

Trophic State 2004



POOR EXCELLENT

Turbidity 2004

Lake Data	
Owner	Tri-County Dev. Auth.
County	Pawnee
Constructed in	1984
Surface Area	550 acres
Volume	6,200 acre/feet
Shoreline Length	17 miles
Mean Depth	11.27 feet
Watershed Area	26 square miles

Plate 70 - Lake Water Quality for
Lone Chimney Lake

LAKES MONITORING PROGRAM

Lugert-Altus Reservoir

Lugert-Altus Reservoir was sampled for four quarters from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake wide turbidity was 23 NTU (Plate 71), true color was 18 units, and average secchi disk depth was 37 centimeters. Results are consistent with those observed in the 2003 evaluation. Based on these three parameters, Lugert-Altus Reservoir had fair water clarity. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=19). The result was a TSI of 59 (Plate 71), indicating the lake was eutrophic, bordering hypereutrophic, with high primary productivity and nutrient conditions in sample year 2005. The TSI values ranged from hypereutrophic in the fall and winter, eutrophic in the spring to mesotrophic in the summer. The steady increase in productivity over the last several years is likely the result of lower lake levels due to drought conditions. Seasonal turbidity values are displayed in Figure 84a. Turbidity values ranged from a low of 10 NTU to a maximum of 53 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. With 30% of the samples exceeding 25 NTU, the beneficial use of Fish and Wildlife propagation (FWP) should be considered not supported in regards to turbidity. Seasonal true color values are displayed in Figure 84b. All color values were well below the aesthetics WQS of 70 units. Applying the same default protocol, the Aesthetic beneficial use is considered supported based on reported true color values.

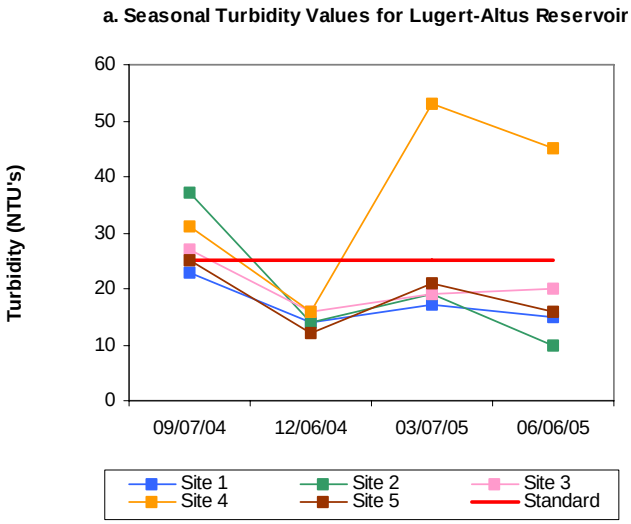
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites. The salinity values for Lugert-Altus Reservoir ranged from 1.01 parts per thousand (ppt) to 1.29 ppt for this sample year. Specific conductivity ranged from 1866 to 2397 µS/cm, which is higher than most Oklahoma reservoirs. These values indicate the presence high levels of electrical current conducting compounds (salts) in the lake, consistent with higher salinity concentrations. The pH values were neutral to slightly alkaline, ranging from 7.67 in the winter to 8.22 in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials ranged from 343 mV in the fall to 480 mV recorded in the hypolimnion during the fall, indicating reducing conditions were not present at the time of sampling. The water column was not stratified and was well mixed with dissolved oxygen (D.O.) remaining above 5.0 mg/L during the winter, spring and summer sampling intervals (see Figure 84c-84e). Due to equipment failure no Hydrolab readings were recorded and an assessment of conditions during the fall quarter cannot be made. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC

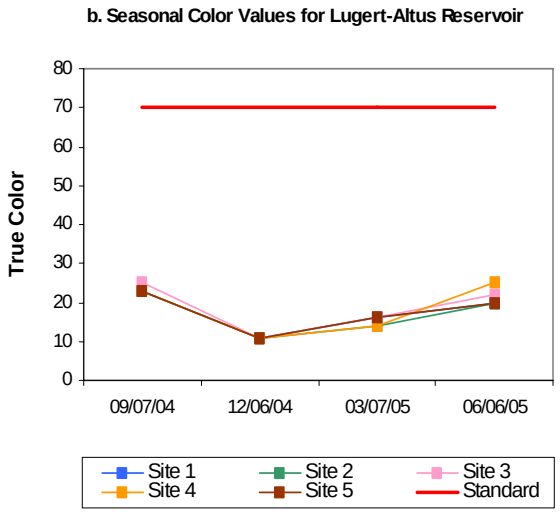
785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 100% of the collected values greater than 2.0 mg/L, the lake is fully supporting its FWP beneficial use based on dissolved oxygen. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

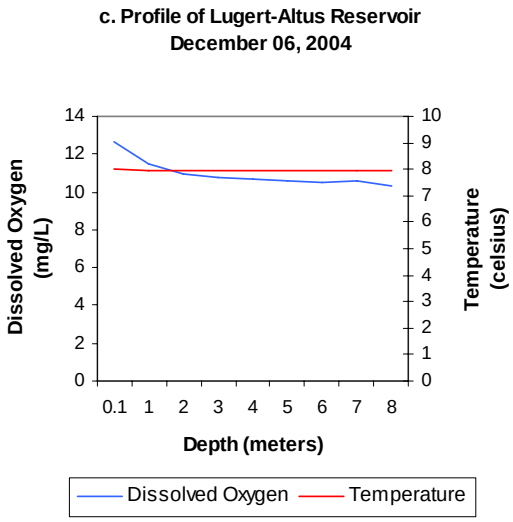
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

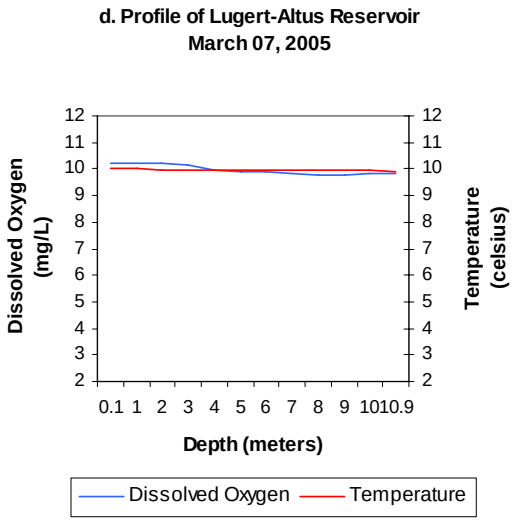
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.88 mg/L. The TN at the surface ranged from 0.69 mg/L to 1.17 mg/L in the upper reaches of the lake. Surface total nitrogen was highest in the winter and lowest in the summer. The lake-wide total phosphorus (TP) was 0.051 mg/L. The TP at the surface ranged from 0.031 mg/L to 0.084 mg/L. Similar to nitrogen, surface TP was highest in the winter and lowest in the summer. The nitrogen to phosphorus ratio (TN:TP) was 17:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lugert-Altus Reservoir was classified as eutrophic bordering hypereutrophic, with high primary productivity and nutrient conditions in sample year 2005. The steady increase in productivity over the last several years is likely the result of lower lake levels due to drought conditions. Water clarity was fair based on turbidity, true color, and secchi disk depth. The lake is supporting its FWP beneficial use based on dissolved oxygen values and on pH, however with 30% of the turbidity values exceeding the WQS of 25 NTU, the FWP beneficial use is not supported as it relates to turbidity. The lake is currently supporting the Aesthetics beneficial use based on true color as well as trophic status (TSI=59). Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lugert-Altus Reservoir is located in Greer County and is utilized for water supply, flood control, and irrigation purposes.









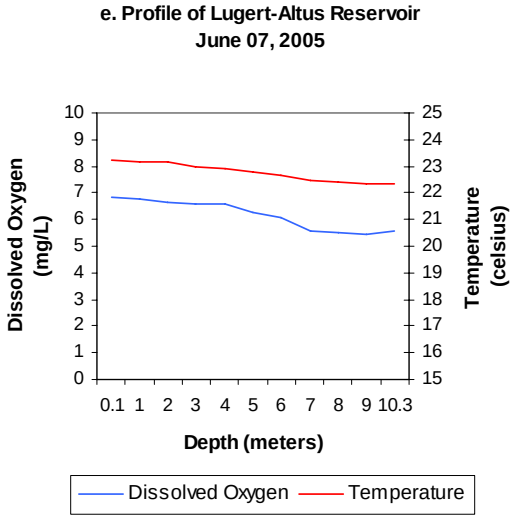
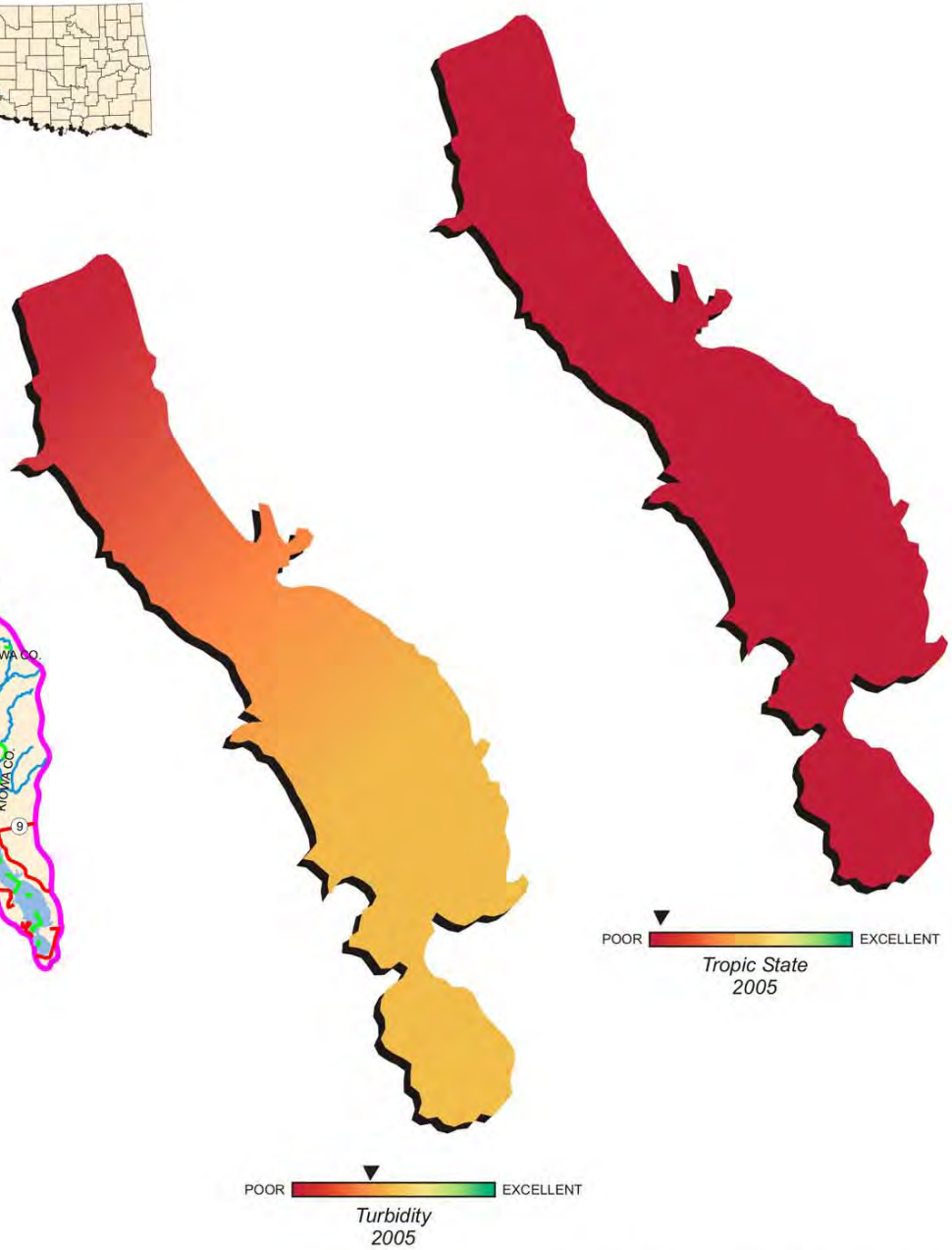


Figure 84a-84e. Graphical representation of data results for Lugert-Altus Reservoir.



Lake Data	
Constructed by	Bureau of Reclamation
County	Greer
Constructed in	1948
Surface Area	6,260 acres
Volume	132,830 acre/feet
Shoreline Length	49 miles
Mean Depth	21.22 feet
Watershed Area	2,515 acres

Plate 71 - Lake Water Quality for
Lugert-Altus Lake

LAKES MONITORING PROGRAM

Maysville (Wiley Post) Lake

Maysville Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 63 NTU (Plate 128), true color was 102 units, and secchi disk depth was 22 centimeters in 2004-2005. Based on these three parameters, Maysville Lake had poor water clarity in comparison to other Oklahoma reservoirs and was slightly worse than reported in 2002. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 57 (Plate 128), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. This value is the same as that calculated in 2002, indicating no significant increase or decrease in productivity has taken place. The TSI values were fairly consistent with values in the eutrophic category in the first three sampling intervals and hypereutrophic during the summer. Site 5 showed the most variability ranging from hypereutrophic in the fall to mesotrophic in the winter. The turbidity values collected on this lake consistently exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU (Figure 85a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the samples collected exceeding the turbidity criteria, the Fish and Wildlife Propagation (FWP) beneficial use is considered not supported Maysville Lake. Seasonal true color values are displayed in Figure 85b. Of the twenty true color values collected 50% were above the numeric criteria of 70 units. Applying the same default protocol, the Aesthetics beneficial use is also considered not supporting for true color.

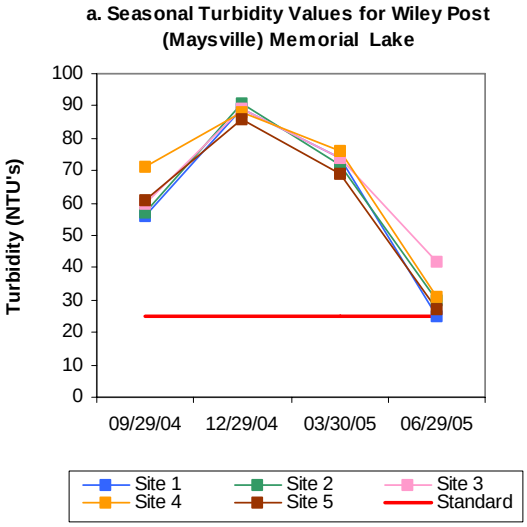
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.18 parts per thousand (ppt) to 0.27 ppt, which is within the expected range of salinity values, reported for most Oklahoma lakes. Readings for specific conductivity ranged from 324 cm/cm in the winter to 538.9 cm/cm in the summer, indicating the presence of moderate amounts of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline in nature, ranging from 7.46 units in the summer quarter to 8.29 units in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 275 mV at the sediment-water interface in the summer to 567 mV in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir at any point during the sample year. The lake was not thermally stratified in the fall, winter or

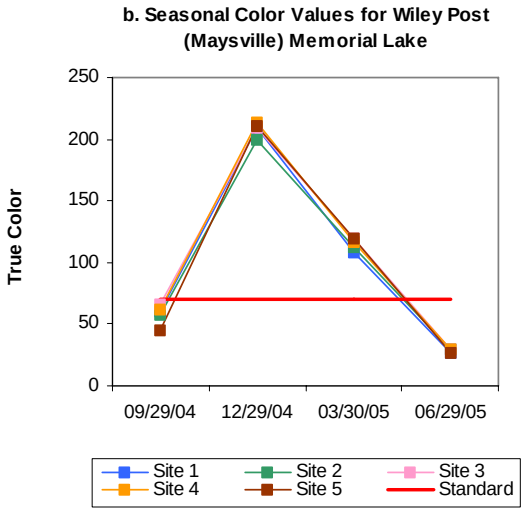
spring quarters and dissolved oxygen (D.O.) values were above 6.0 mg/L (see Figure 85c-85e). In the summer the lake was strongly thermally stratified between 2 and 3 meters and also between 3 and 4 meters. In a lake that was only 4 meters deep when sampled in the summer quarter this was an unexpected occurrence. The water column at site 1 had only one D.O. reading less than 2.0 mg/L from 3 meters to the lake bottom accounting for anoxic conditions in 25% of the water column (see Figure 85f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (USAP 785:46-15-5). If D.O. concentration is less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Maysville Lake although approximately 25% of the water column was anoxic at site 1 in the summer quarter. This is not a situation that is normally seen for such a shallow reservoir and can only be attributed to a long period of calm winds and/or a pattern where little rainfall occurred. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

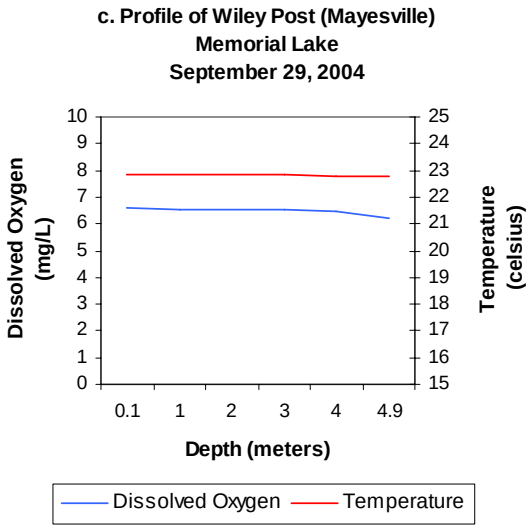
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

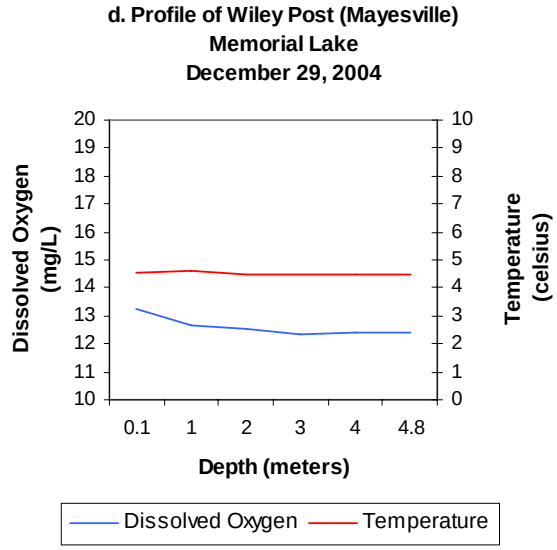
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.83 mg/L. The TN at the surface ranged from 0.48 mg/L in the spring to 1.26 mg/L in the summer quarter. The lake-wide total phosphorus (TP) average was 0.109 mg/L. The surface TP ranged from 0.064 mg/L in the summer quarter to 0.143 mg/L in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2004-2005. This value is slightly greater than 7:1, characterizing the lake as phosphorus-limited or co-limited (Wetzel, 1983).

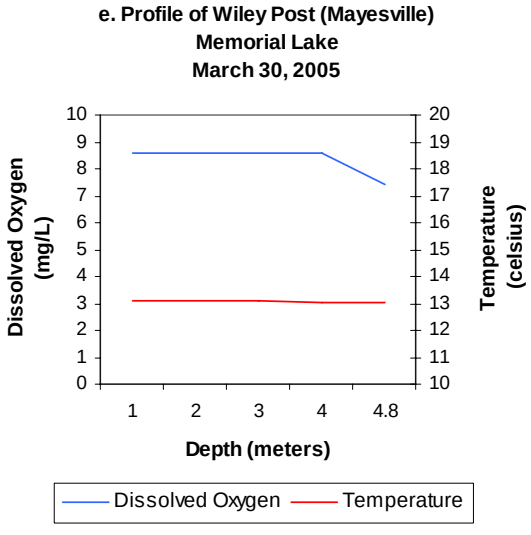
In summary, Maysville Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 128). This is identical to the 2002 evaluation, indicating no significant increase or decrease in productivity has taken place. Based on turbidity, true color, and secchi disk depth, Maysville Lake had poor water clarity in comparison to other Oklahoma reservoirs. With 100% of the turbidity values greatest than the WQS of 25 NTU, the FWP beneficial use is considered not supporting. The lake was fully supporting the FWP beneficial use based on pH and dissolved oxygen. The lake is fully supporting its Aesthetics beneficial use based on the lakes trophic status however the use is not supported in regards to true color, with half of the reported true color values exceeding the numerical criteria of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Maysville Lake was constructed in 1971 and is owned and operated by the City of Maysville and serves as a municipal water supply. The lake is also used for flood control and recreational purposes.











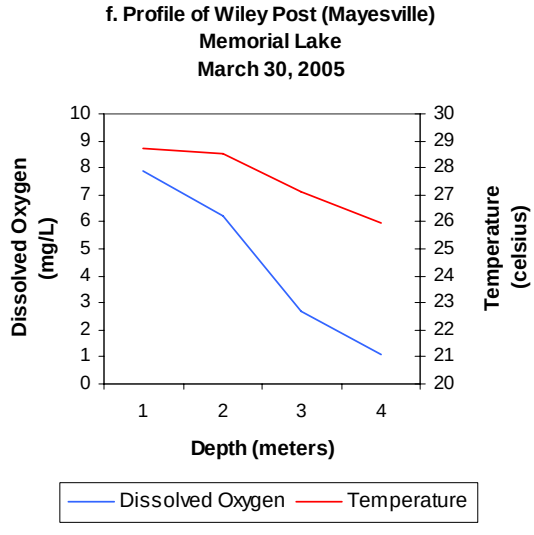
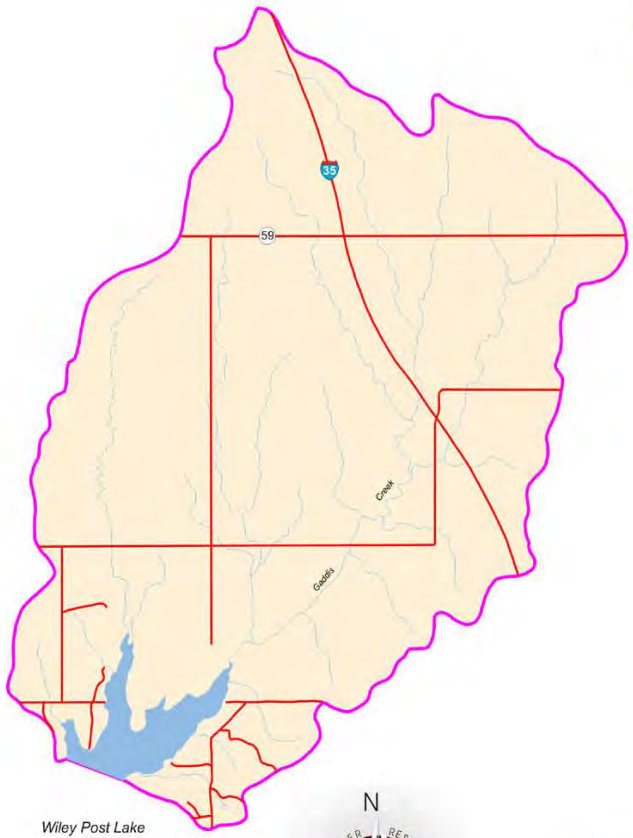
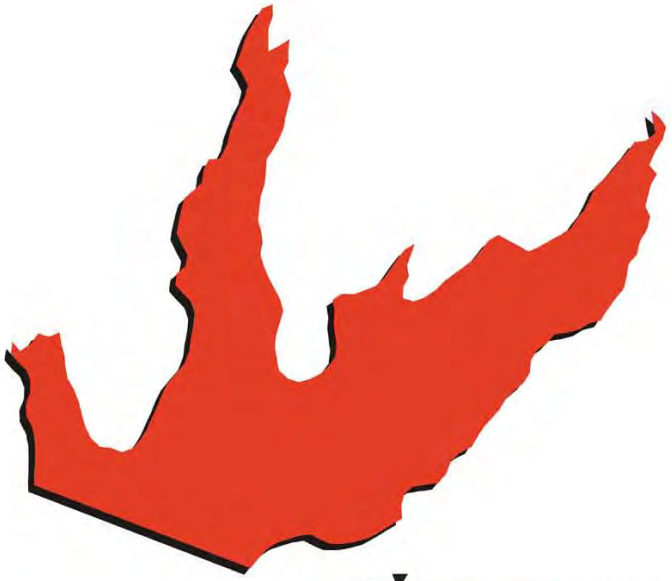


Figure 85a-85f. Graphical representation of data results for Maysville Lake.



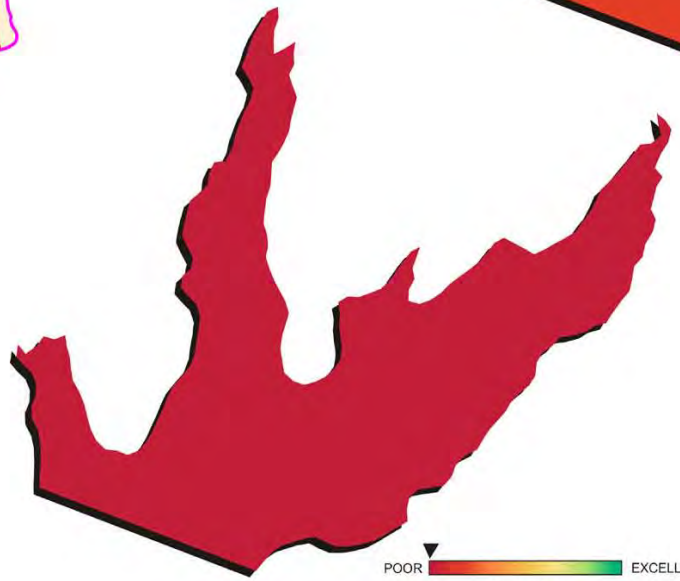
Wiley Post Lake and Watershed

Wiley Post Lake Location



POOR EXCELLENT

Trophic State 2005



POOR EXCELLENT

Turbidity 2005

Lake Data

Owner	City of Maysville
County	McClain
Constructed in	1971
Surface Area	302 acres
Volume	2,082 acre/feet
Shoreline Length	5 miles
Mean Depth	6.89 feet
Watershed Area	13 square miles

Plate 128 - Lake Water Quality for
Wiley Post (Maysville) Lake

LAKES MONITORING PROGRAM

Lake McAlester

Lake McAlester was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 107 NTU (Plate 72), true color was 250 units, and secchi disk depth was 17 centimeters in 2005. Based on these three parameters, Lake McAlester had poor water clarity. This is consistent with historical observations and is likely always poor based on the soil composition. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 42 (Plate 72), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is similar to the one calculated in 2003 (TSI=42), and in the same trophic category, indicating no significant change in productivity has occurred. The high turbidity and true color values are probably the reason for the trophic state determination, as inorganic turbidity is a limiting factor in lake productivity. The TSI varied by site and season with values in both oligotrophic and mesotrophic categories the majority of the year. Turbidity values ranged from a low of 71 NTU to a maximum of 152 NTU (see Figure 86a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Due to a post-processing error turbidity was not run for any of the summer samples. Although 100% of the samples collected in 2005 exceeded the WQS of 25 NTU and assessment of the, Fish and Wildlife Propagation (FWP) beneficial use cannot be made due to minimum data requirements not being met. Based upon current and historical data sets, it is likely that the use would not be supported. Seasonal true color is displayed in Figure 86b. The Aesthetics beneficial use is not supported with all samples having a reporting of value of 250 units, greatly exceeding the WQS of 70.

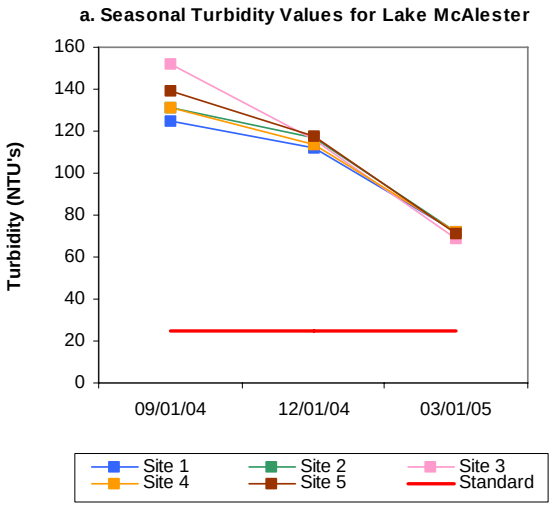
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sites. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.04 ppt. This is well within the average values reported for Oklahoma lakes. Specific conductivity ranged from 45 µS/cm to 100.5 µS/cm indicating that minimal concentrations of electrical current conducting compounds were present in the lake system. The pH values at Lake McAlester ranged from 6.32 in the summer to 8.28 in the hypolimnion in the spring, representing a slightly acidic to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only 7.7% of the collected values outside the acceptable range the lake is considered to be supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 407 mV in the summer to 578 mV in the winter. Reducing conditions were not present at this reservoir with all values being positive and above 100 mV throughout the study period. In the winter, and spring quarters, stratification was

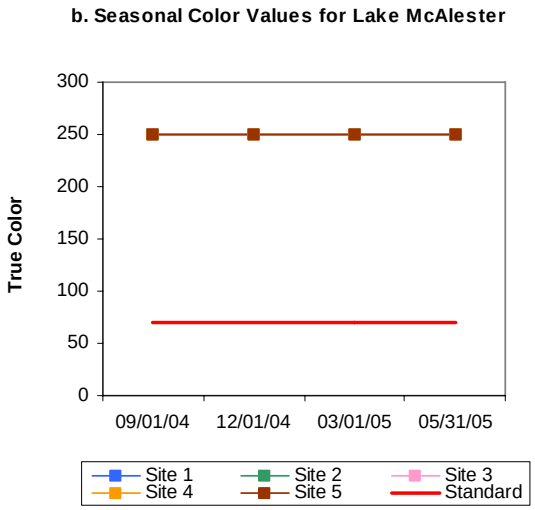
not present and the lake was well mixed with dissolved oxygen (D.O.) levels generally above 5.0 mg/L (Figure 86d-85e). During both fall and summer quarters, thermal stratification was evident, however dissolved oxygen remained above 2.0 mg/L. (Figure 86c, 86f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Lake McAlester based with all D.O. values above 2.0 mg/L. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

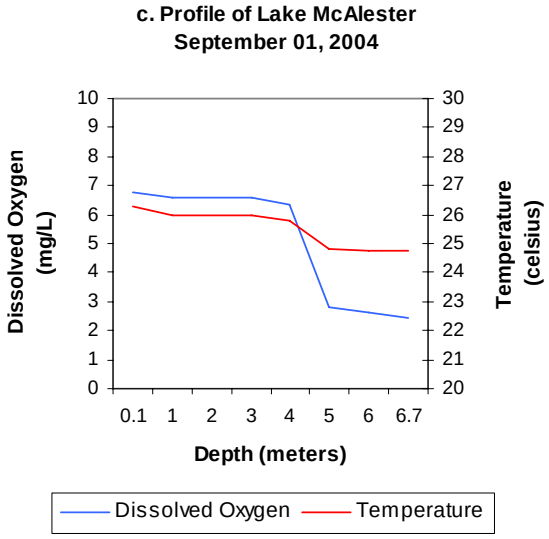
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

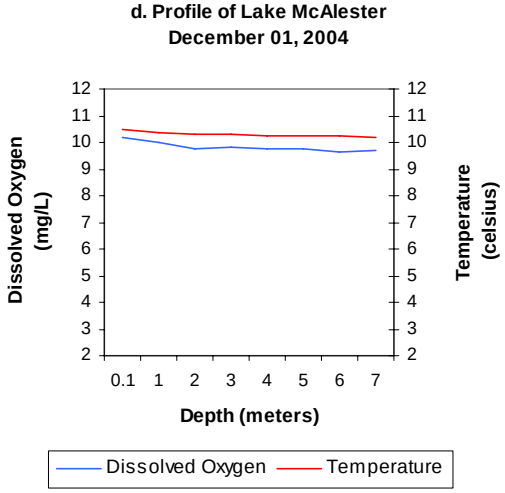
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.94 mg/L. Surface TN ranged from 0.72mg/L to 1.06 mg/L, with the highest values reported in the spring and the lowest values in the fall. The lake-wide total phosphorus (TP) average was 0.140 mg/L. Total phosphorus at the surface ranged from 0.095 mg/L to 0.202 mg/L. Surface TP was highest in the winter and lowest during the spring quarter. This is the same as the 7:1 ratio used to determine the limiting nutrient, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

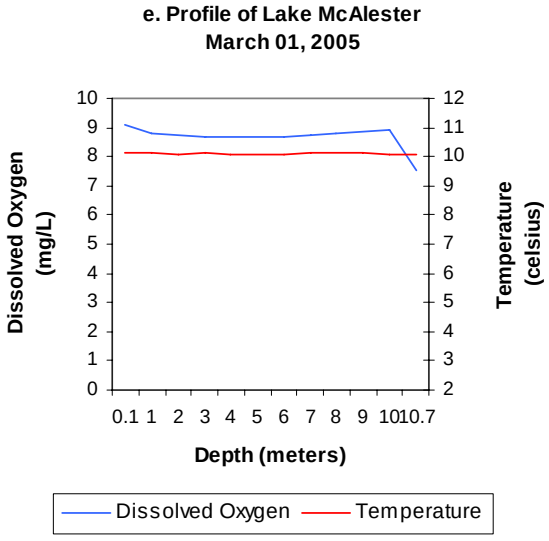
In summary, Lake McAlester was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions (Plate 72). Similar conditions were found during the 2003 evaluation, indicating that no significant increase or decrease in productivity has occurred. Water clarity was poor based on true color, turbidity and secchi disk depth and is likely to always be poor based on the soil composition of the area. The lake is supporting the FWP beneficial use based on pH and on dissolved oxygen values recorded during the study period, however an assessment based on turbidity could not be made due to minimum data requirements not being met. High inorganic turbidity is a limiting factor in lake productivity, keeping nutrients at bay. The Aesthetics beneficial use is supported based on its trophic status, however it is not supported for true color with 100% of the values exceeding the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake McAlester is located in Pittsburg County and was constructed in 1930 for water supply and recreational purposes.











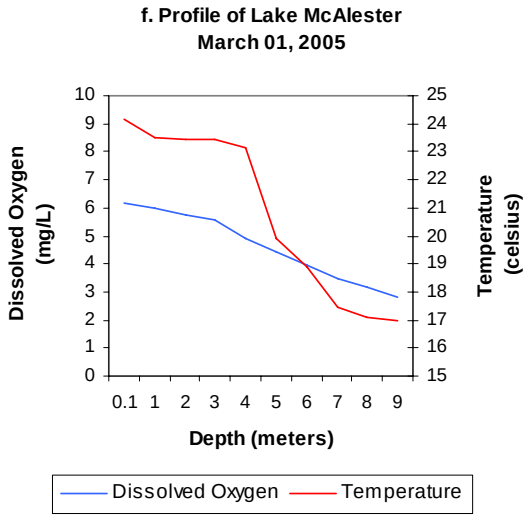
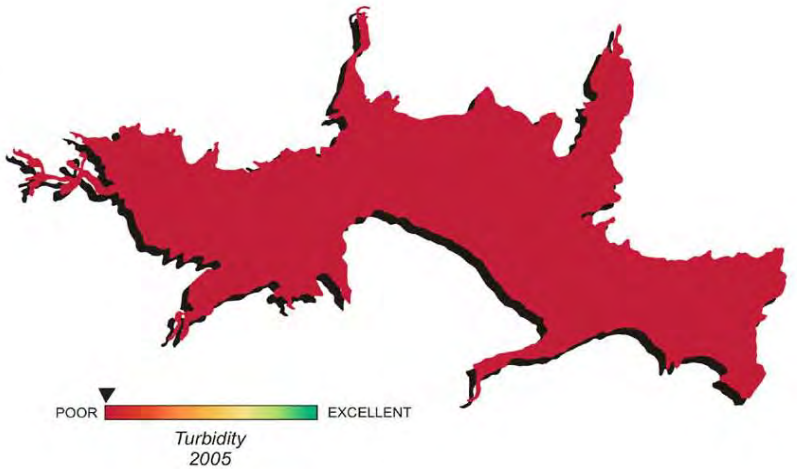


Figure 86a-86f. Graphical representation of data results for Lake McAlester.

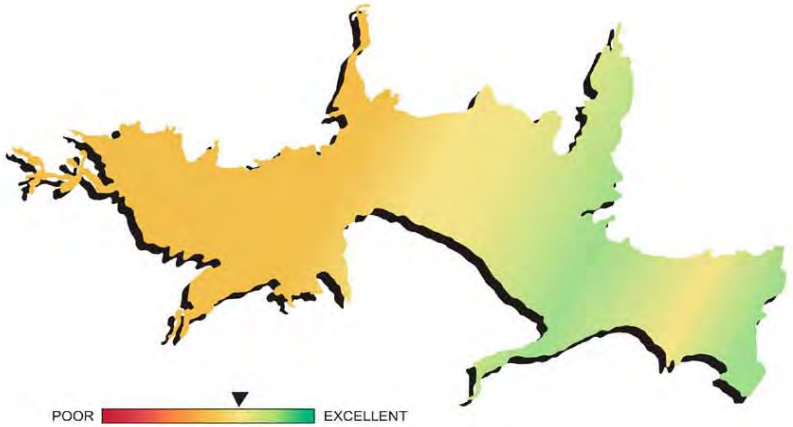
Lake McAlester Location

Lake McAlester and Watershed

Lake Data	
Owner	City of McAlester
County	Pittsburg
Constructed in	1930
Surface Area	1,521 acres
Volume	13,398 acre/feet
Shoreline Length	20 miles
Mean Depth	8.81 feet
Watershed Area	31 square miles



Turbidity 2005



Trophic State 2005

Plate 72 - Lake Water Quality for
Lake McAlester

LAKES MONITORING PROGRAM

McGee Creek Lake

McGee Creek Lake was sampled for four quarters, from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as major lake arms. Samples were collected from the lake surface at all sites with an additional sample taken at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 5 NTU (Plate 73), true color was 18 units, and secchi disk depth was 175 centimeters. Based on these three parameters, McGee Creek Lake had excellent water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for all four quarters (n=20). The average TSI was 39 (Plate 73), classifying the lake as oligotrophic bordering on mesotrophic, indicative of low to moderate levels of primary productivity and nutrients. The TSI values were consistent across all sample seasons varying from lower oligotrophic to upper oligotrophic at all sites in the winter, spring, and summer sampling intervals. The most productive quarter observed in the lake was actually in the fall, where four of the five sites were classified as mesotrophic. Site 4 was mesotrophic in nature or bordering mesotrophic conditions throughout all four quarters. All of the collected turbidity values were well below the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 87a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. McGee Creek Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it related to nephelometric turbidity. Seasonal true color values are displayed in Figure 87b. All of the true color values were below the numeric criteria of 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is fully supported based on the true color values.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.03ppt, well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductivity were also extremely low, ranging from 20.8 µS/cm to 83.2 µS/cm, indicating the presence of little to no electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were slightly acidic to neutral, ranging from 5.93 in the summer quarter to 7.24 units at site 3 in the fall quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 40% of the recorded values less than 6.5, McGee Creek Lake is not supporting the FWP beneficial use as it relates to turbidity. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state.

Oxidation-reduction potentials (redox) ranged from 285 mV at the sediment-water interface in the fall quarter to 550 mV in the spring. Redox readings indicated that reducing conditions were not present in the reservoir during any of the sampling intervals. The lake was thermally stratified and anoxic conditions were present in fall quarter between 9 and 10 meters below the lake surface at sites 1,2 and 5. Approximately 59% of the water column was experiencing dissolved oxygen (D.O.) concentrations below 1.0 mg/L at site 1 near the dam (see Figure 87c). McGee Creek was not thermally stratified in the winter quarter and D.O. values were above 7.0 mg/L throughout the water column (See Figure 87d). In the spring, the lake was strongly thermally stratified between 10 and 11 meters below the lake surface; however all D.O. concentrations remained above 5.0 mg/L throughout the water column at all sites (see Figure 87e). In the summer quarter, there was a metalimnetic oxygen deficit that occurred in the main body of the lake (site 1 and 5) between 5 and 9 meters below the surface (Figure 87f). Dissolved oxygen values were less than 2.0 mg/L within this layer and from 10 meters to the lake bottom of 32 meters D.O. ranged from 2.6 to 5.08 mg/L (see Figure 87f). It is not known at this time what caused this to occur and the lake should be studied further. At sites 2,3 and 4, thermal stratification occurred between 3 and 4 meters in depth with D.O. falling to below 2.0 mg/L and anoxic conditions present in 40 to 70% of the water column. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. In the spring quarter 59% of the water column at site 1, near the dam had dissolved oxygen readings of less than 2.0 mg/l. During the summer 40 to 70% of the water column was anoxic in the arms of the lake, McGee Creek Lake is partially supporting its FWP beneficial use based on low D.O. readings in the water column. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric means. The PBCR beneficial use is therefore considered supported.

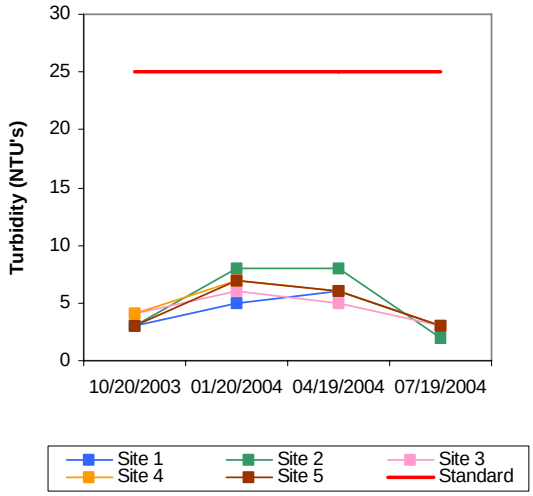
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.37 mg/L at the lake surface and 0.47 mg/L at the lake bottom. The TN at the surface ranged from 0.17 mg/L in the fall quarter to 0.66 mg/L in the winter. The lake-wide total phosphorus (TP) average was 0.012 mg/L at the lake surface and 0.018 mg/L at the lake bottom. The surface TP ranged from 0.006 mg/L in the fall to 0.0.18 mg/L also recorded in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 32:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 and 1999 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

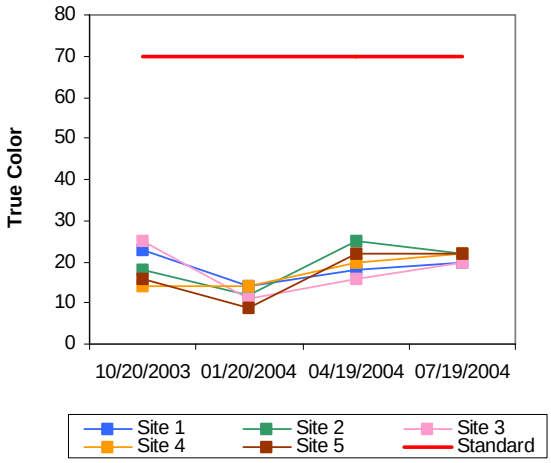
In summary, McGee Creek Lake was classified as oligotrophic bordering mesotrophic, indicative of low to moderate primary productivity and nutrient levels in 2003-2004 (Plate 73). Water clarity continues to be excellent at this reservoir based on turbidity, true color and secchi disk

depth. The lake was fully supporting its FWP based on turbidity readings, however is partially supported based on anoxic conditions present in both the fall and summer quarters. With 40% of the pH values recorded in the fall, spring and summer below 6.5 units the FWP beneficial is considered not supported. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial use is fully supported based trophic status and true color readings with 100% of the values being below the WQS of 70 units. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected none exceeded the prescribed screening level or geometric means. The PBCR beneficial use is therefore considered supported. McGee Creek Lake was constructed in 1988 and is owned and operated by the Bureau of Reclamation. The lake serves as a municipal water supply source, flood control, fish & wildlife habitat, and offers many recreational opportunities for the citizens of Oklahoma. The City of Oklahoma City can transfer water from McGee Creek Lake to Lake Atoka and then pump that water to Lake Stanley Draper where is can be used by the citizens of Oklahoma City and its suburbs. In 1997 the Oklahoma Legislature directed the OWRB to conduct a study on the impact of Confined Animal Feeding Operations (CAFO) in watersheds that supply potable water to municipalities with a population over 250,000. As part of this study a bathymetric survey was completed on Oklahoma City's water supply reservoirs. A bathymetric map (Figure 88) was generated to determine current storage capacity and identify areas of extreme sedimentation. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800.

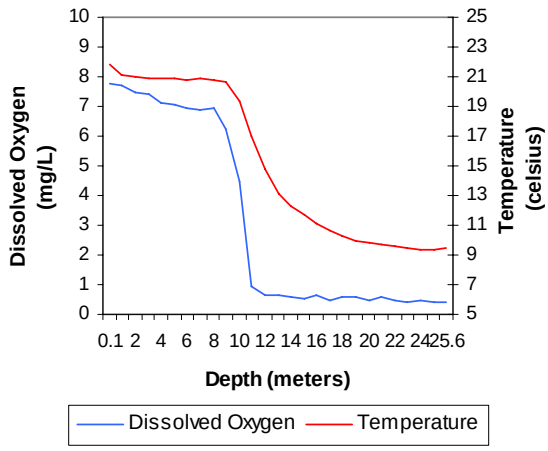
a. Seasonal Turbidity Values for McGee Creek Reservoir



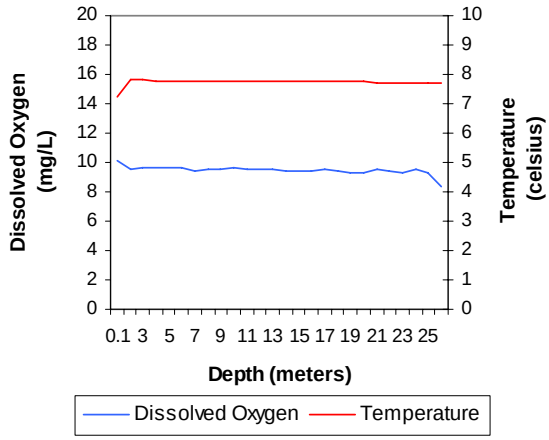
b. Seasonal Color Values for McGee Creek Reservoir



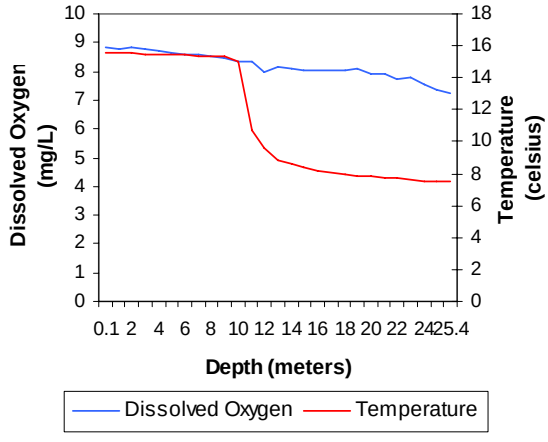
c. Profile of McGee Creek Reservoir October 20, 2003



d. Profile of McGee Creek Reservoir January 21, 2004



e. Profile of McGee Creek Reservoir April 13, 2004



f. Profile of McGee Creek Reservoir July 20, 2004

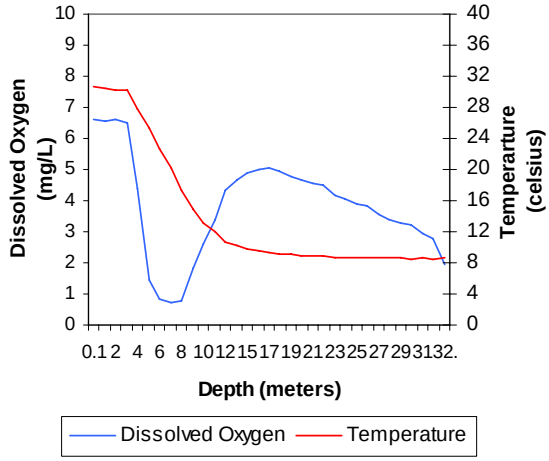
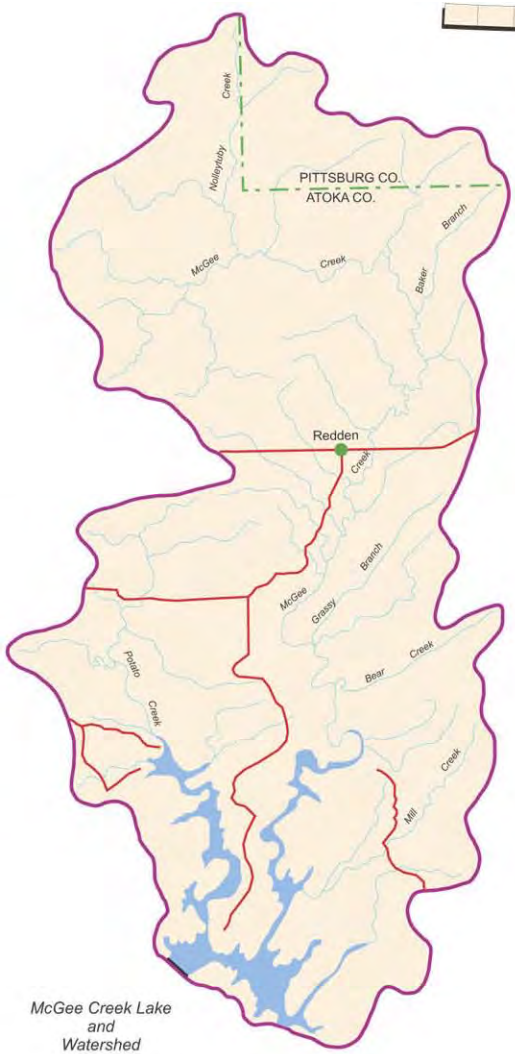
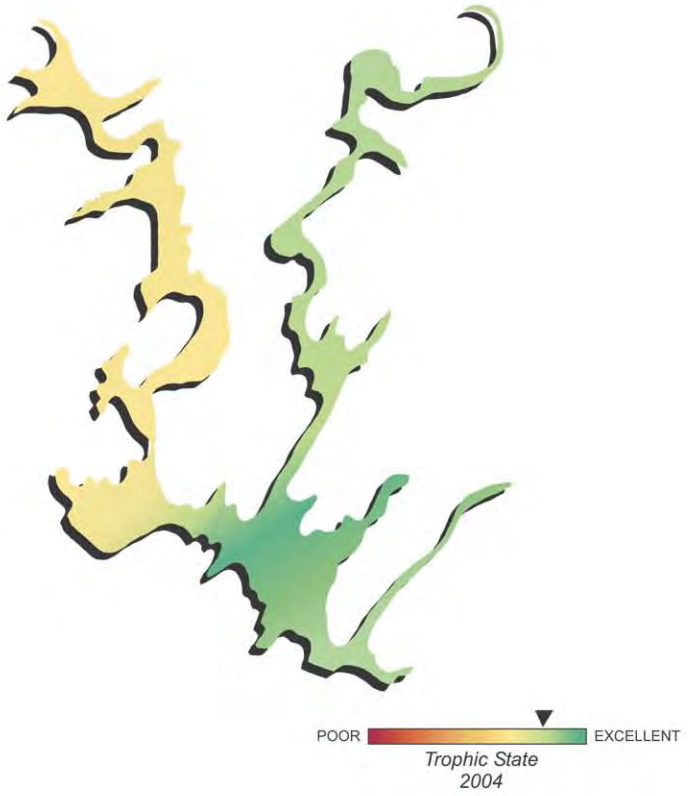


Figure 87a-87f. Graphical representation of data results for McGee Creek Lake.

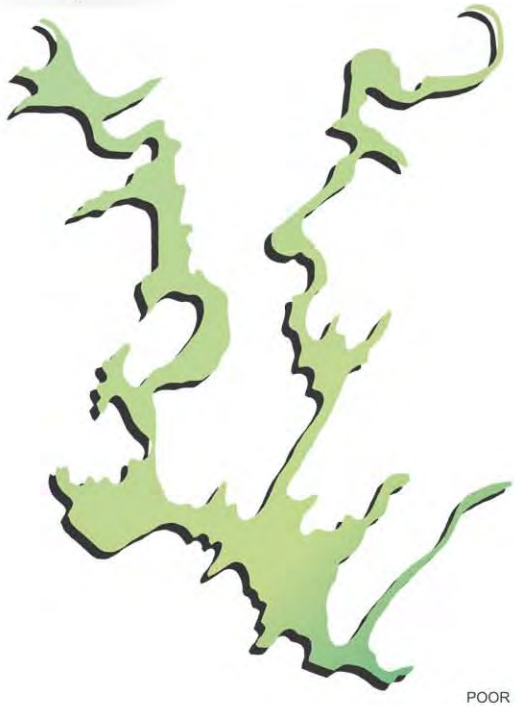


McGee Creek Lake and Watershed

McGee Creek Lake Location



Trophic State 2004



Turbidity 2004

Lake Data	
Constructed by	Bureau of Reclamation
County	Atoka
Constructed in	1987
Surface Area	3,709 acres
Volume	100,146 acre/feet
Shoreline Length	80 miles
Mean Depth	26.9 feet
Watershed Area	178 square miles

Plate 73 - Lake Water Quality for
McGee Creek Lake

LAKES MONITORING PROGRAM

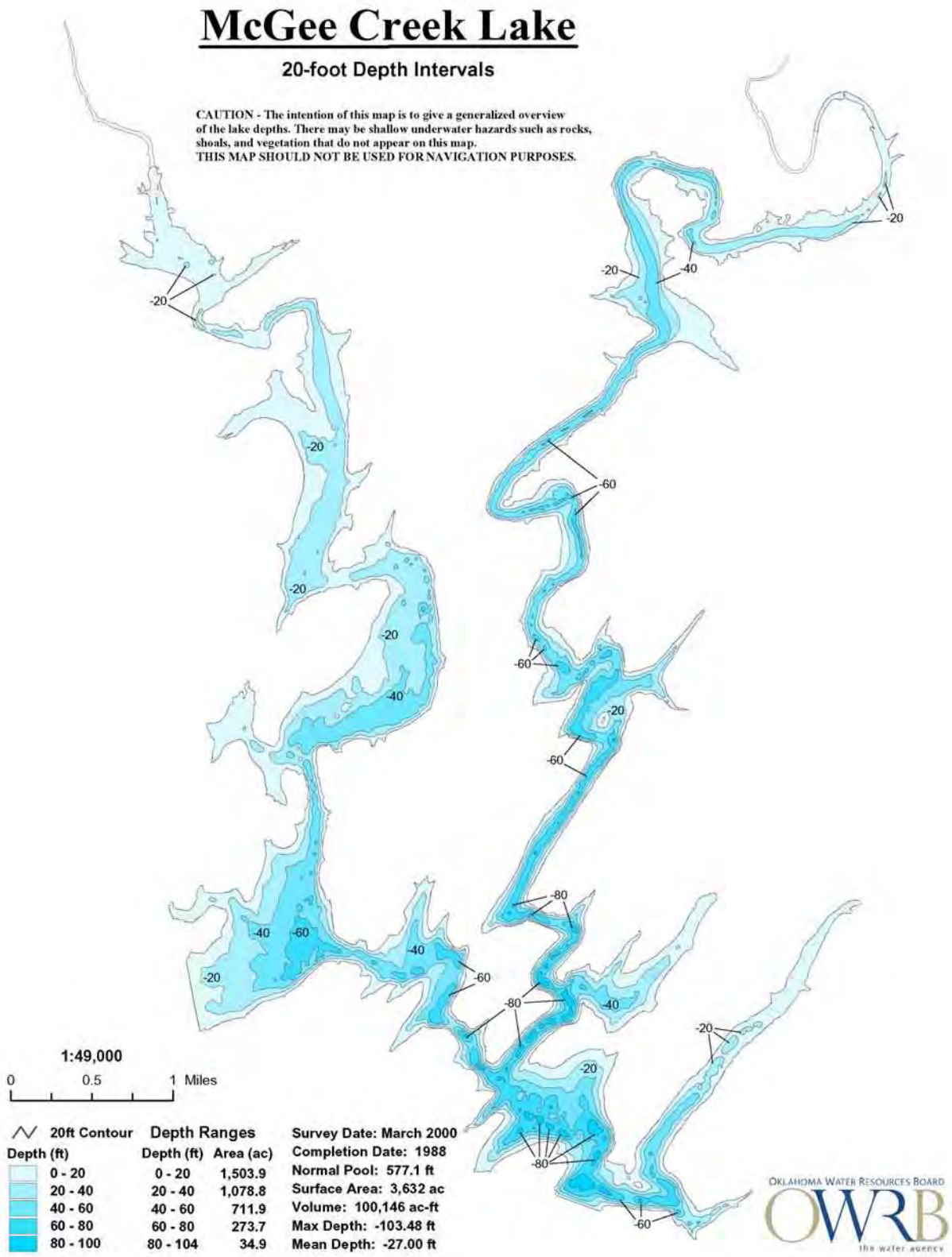


Figure 88. Bathymetric map of McGee Creek Reservoir.

Lake McMurtry

Lake McMurtry was sampled for four quarters from September 2004 through June 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major lake arms. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 17 NTU (Plate 74), true color was 17 units, and secchi disk depth was 73 centimeters in 2005. Based on these three parameters, Lake McMurtry had average water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 47 (Plate 74), classifying the lake at the upper end of mesotrophy, indicative of moderate levels of primary productivity and nutrients. The TSI values were primarily mesotrophic with eutrophic condition present during the fall quarter. The only exception to this was site 1, which had low chlorophyll-a values reported in both winter and spring quarters, placing the site in the oligotrophic category in two of the four sampling intervals. Seasonal turbidity values are displayed in Figure 89a. Of the twenty values collected, only two were greater than the Oklahoma Water Quality Standard (WQS) of 25 NTU. These values were collected at sites 3 and 5 at the upper end of the lake in the fall quarter (see Figure 89a). According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 20% of the samples collected above the standard the lake is partially fully supporting its Fish & Wildlife Propagation (FWP) use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 89b. All true color values well below the WQS of 70 units in sample year 2004-2005. Applying the same default protocol, the Aesthetics beneficial use is considered supported.

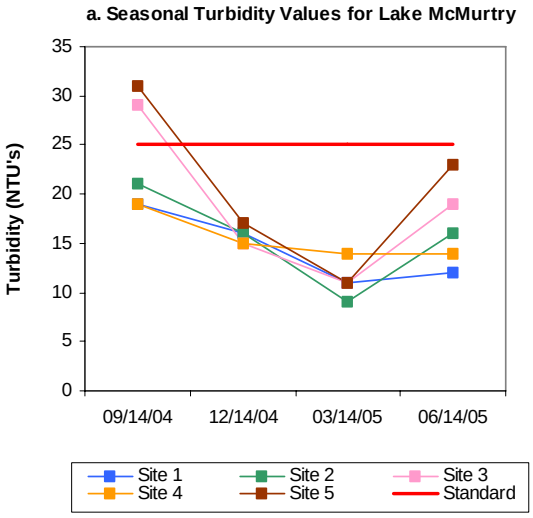
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.16 parts per thousand (ppt) to 0.23ppt, indicating low to moderate salt content. Collected values were well within the range of salinity values reported for most Oklahoma lakes. Readings for specific conductivity were also within the range of normally encountered values, ranging from 320.3 µS/cm in the fall to 449.2 µS/cm in the summer, indicating moderate presence of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline with values ranging from 7.43 to 8.39. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range, the FWP beneficial is considered supported based on pH. Oxidation-reduction potentials (redox) ranged from 126 mV in the fall to 430 mV in the winter quarter, indicating an absence of reducing conditions during the study period. Lake McMurtry was not thermally stratified in the winter or spring quarters and dissolved oxygen (D.O.) values were above 7.5 mg/L throughout the water column (see Figure 89d-89e). In the fall quarter the lake was only stratified near the lake bottom and only two D.O. values were below 2.0 mg/L (see Figure 89e). In the summer, the lake was thermally stratified between 5 to 6 meters in depth, however D.O. was only below 2.0 mg/L from 9 meters to the lake bottom of 10.5 meters (see Figure 89f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are

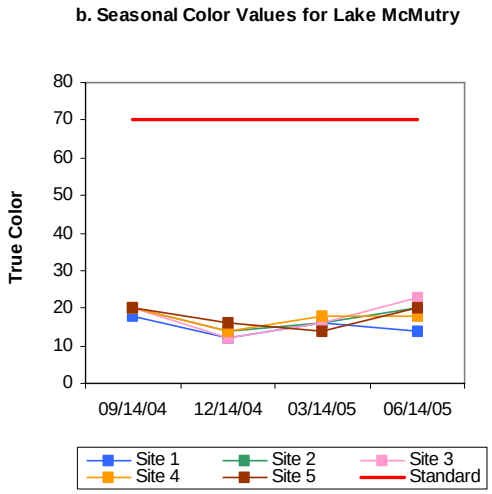
less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Lake McMurtry with 14% of the water column in the fall and 18% in the summer below 2.0 mg/L. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

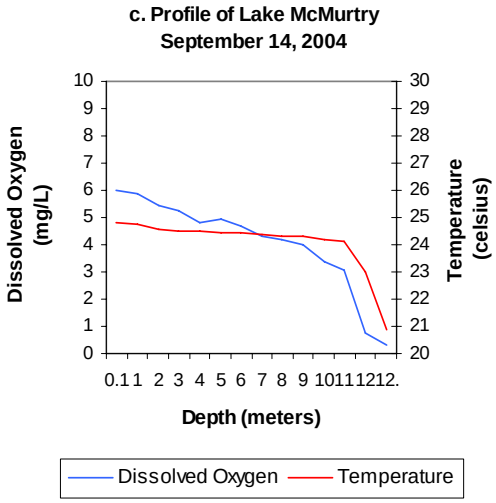
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

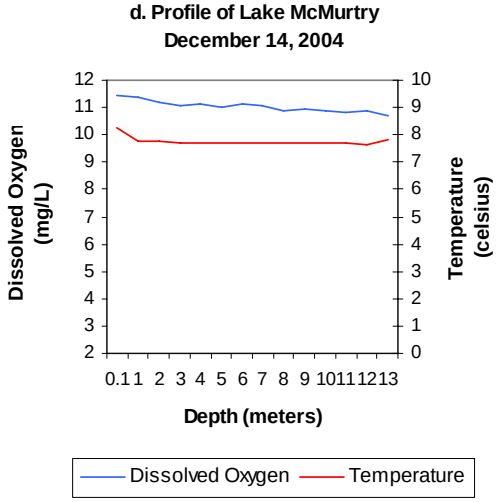
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.48 mg/L at the lake surface. The TN at the surface ranged from 0.34 mg/L to 0.81 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average was 0.023 mg/L at the lake surface. The surface TP ranged from 0.019 mg/L to 0.034 mg/L. The highest surface TP value was reported in the summer quarter and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 21:1 for sample year 2004-2005. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

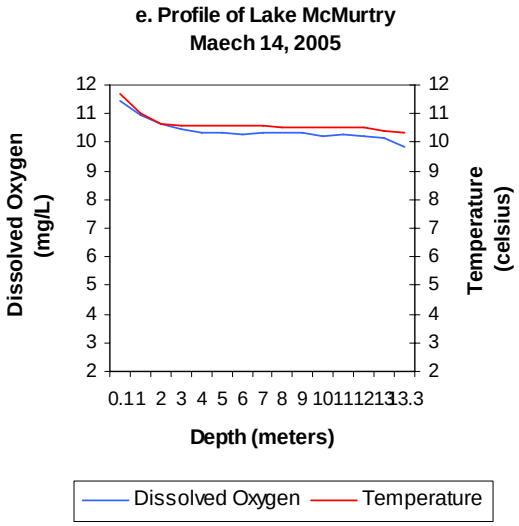
In summary, Lake McMurtry was classified as upper mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 74). Water clarity was average based on turbidity, true color and secchi disk depth. The lake was fully supporting its FWP beneficial use based on dissolved oxygen and pH and partially supporting the use based on turbidity with 20% of the values exceeding the WQS of 25 NTU. The lake was fully supporting its Aesthetics beneficial use based on true color and lake trophic status. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake McMurtry was constructed in 1971 and is owned and operated by the City of Stillwater. The lake is used as a municipal water supply and for flood control and recreational purposes.











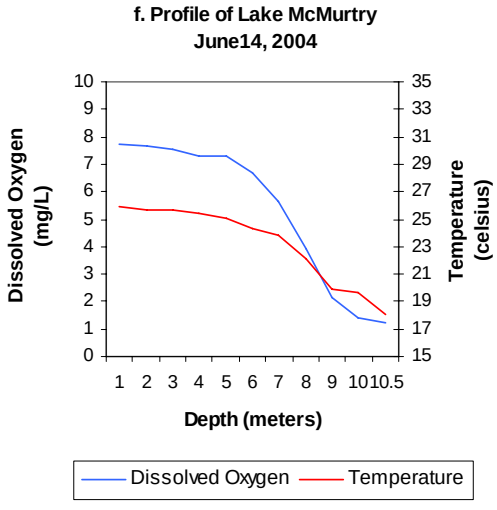


Figure 89a-89f. Graphical representation of data results for Lake McMurtry.

McMurtry Lake
and
Watershed

Lake Data	
Owner	City of Stillwater
County	Noble
Constructed	1971
Surface Area	950 acres
Volume	19,733 acre/feet
Shoreline Length	28 miles
Mean Depth	17.08 feet
Watershed Area	25 square miles

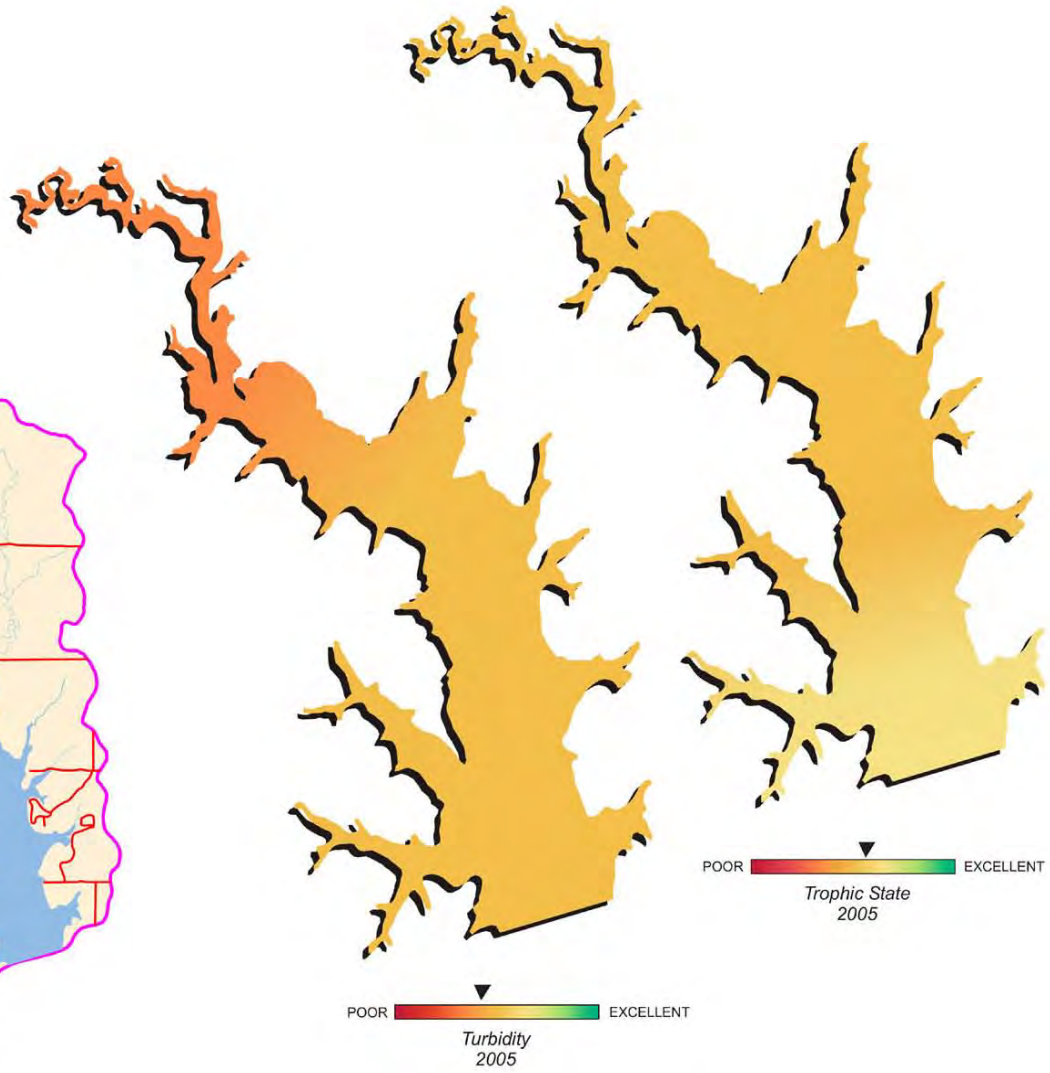


Plate 74 - Lake Water Quality for
Lake McMurtry

LAKES MONITORING PROGRAM

Meeker Lake

Meeker Lake, located in Lincoln County, was constructed in 1970 and is owned and operated by the City of Meeker. The lake is utilized as a municipal water supply, for flood control, and for recreational purposes. Meeker Lake was sampled for four quarters, from October 2005 through August 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 48 NTU (Plate 75), true color was 43 units, and secchi disk depth was 39 centimeters. Results are almost identical to that observed in 2004. Based on these three parameters, Meeker Lake had fair to poor water clarity when compared to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 50 (Plate 75), classifying the lake as mesotrophic bordering eutrophic, indicative of moderate to high levels of primary productivity and nutrients. The TSI values were fairly consistent with mesotrophic conditions in the fall and winter and eutrophic during the spring and summer quarters. Of the twelve values collected, nine of the turbidity values in 2005-2006 were above the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 90a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 75% of the collected turbidity values exceeding the criteria the lake is not meeting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 90b. Although all sites were near the standard in the fall, none of the true color values recorded exceeded the WQS of 70 units; therefore the Aesthetics beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values were 0.12 parts per thousand (ppt) to 0.36 ppt throughout the study period, indicating minimal salt content and within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductivity were also within the expected range of values reported for most Oklahoma lakes, ranging from 253.2 µS/cm to 705.4 µS/cm, indicating the presence of minimal concentrations of electrical current conducting compounds (salts) in the water column. In general, pH values were neutral to slightly alkaline with values ranging from 7.67 units in the summer to 8.72 in the spring quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 37 mV in the hypolimnion during the summer winter to 451 mV in the winter quarter, indicating an

absence of reducing conditions in the water column during any of the sampling events. Meeker Lake was not thermally stratified in the fall, winter, or spring quarters and dissolved oxygen (D.O.) values were above 6.0 mg/L throughout the water column in all three seasons (see Figure 90c-90e). In the summer the lake was thermally stratified between 2 and 3 meters with D.O. falling below 2.0 mg/L from 5 meters below the surface to the lake bottom of 6.4 meters (see Figure 90f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Meeker Lake with only 38% of the water column experiencing anoxic conditions in the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

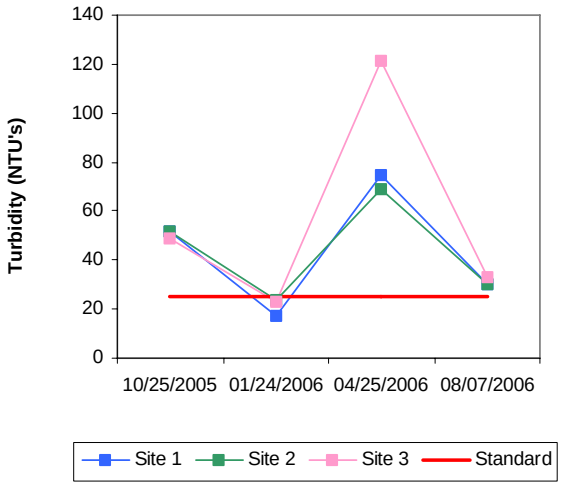
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) was 0.63 mg/L at the lake surface. The TN at the surface ranged from 0.50 mg/L to 0.89 mg/L. The highest surface TN value was reported in the fall quarter while lowest values were reported during the spring sampling interval. The lake-wide total phosphorus (TP) average was 0.047 mg/L at the lake surface. The surface TP ranged from 0.027 mg/L to 0.090 mg/L. The highest surface TP value was reported in the spring quarter and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 13:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

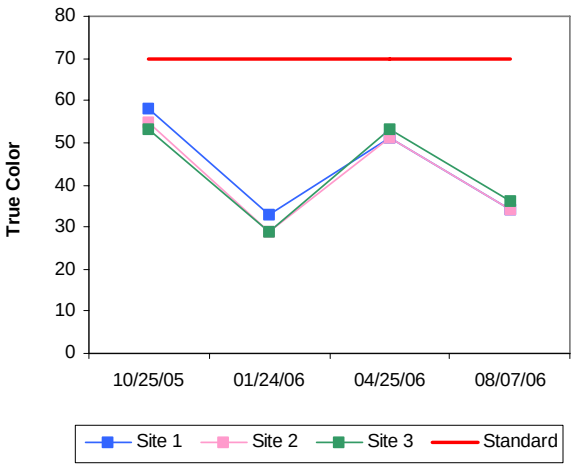
Meeker Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Meeker Lake was classified as mesotrophic (TSI=50) bordering eutrophic, indicative of moderate to high levels of primary productivity and nutrients (Plate 65). Water clarity is fair to poor based on turbidity, true color and Secchi disk depth. The lake is fully supporting its Aesthetics beneficial use based on its trophic state as well as true color with 100% of the values below the WQS of 70 units. The lake is fully supporting its FWP beneficial use based on pH and D.O. concentrations recorded in the water column, however it is not supporting the use based on high nephelometric turbidity concentrations in the lake. Meeker Lake is one of Oklahoma's more turbid reservoirs. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

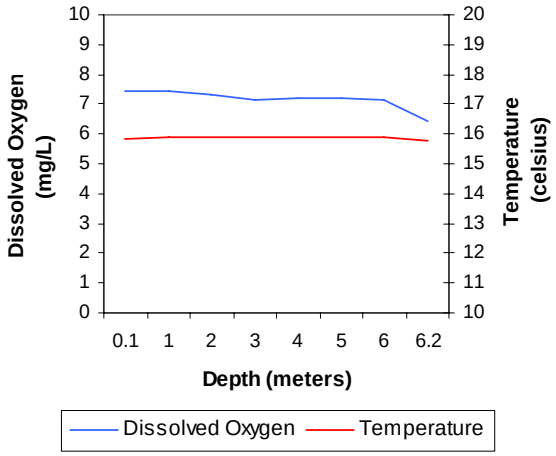
a. Seasonal Turbidity Values for Meeker Lake



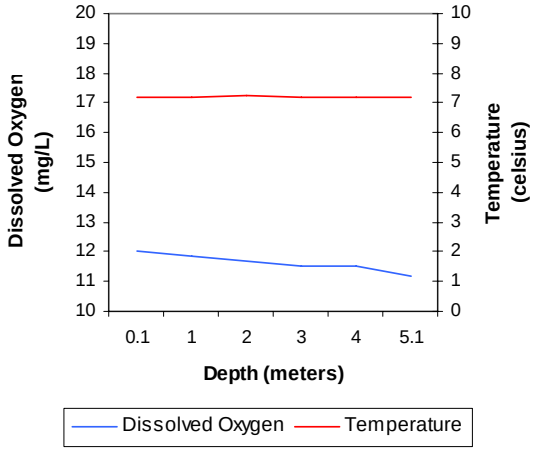
b. Seasonal Color Values for Meeker Lake



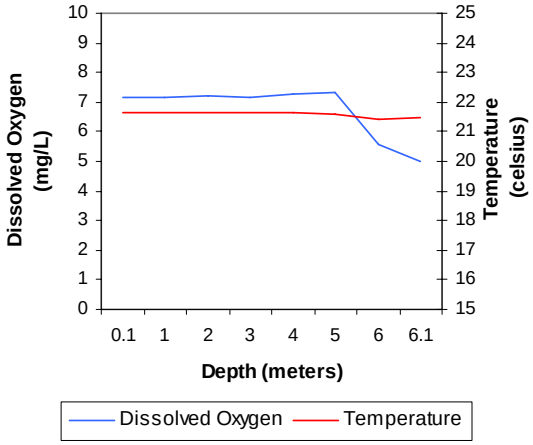
c. Profile of Meeker Lake
October 25, 2005



d. Profile of Meeker Lake
January 24, 2006



e. Profile of Meeker Lake
April 25, 2006



f. Profile of Meeker Lake
August 07, 2006

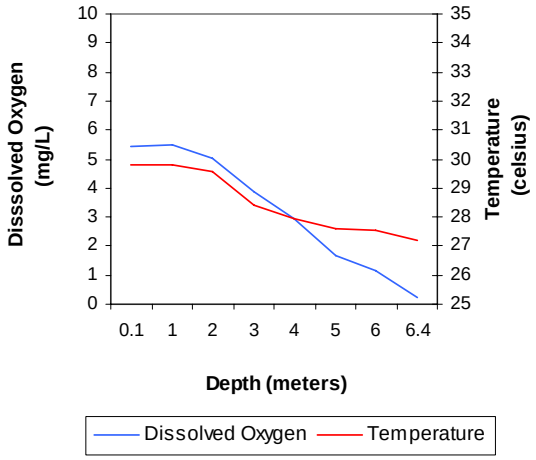
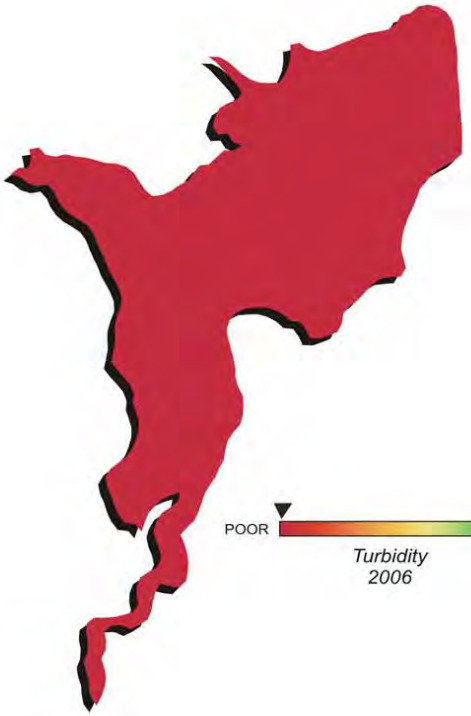


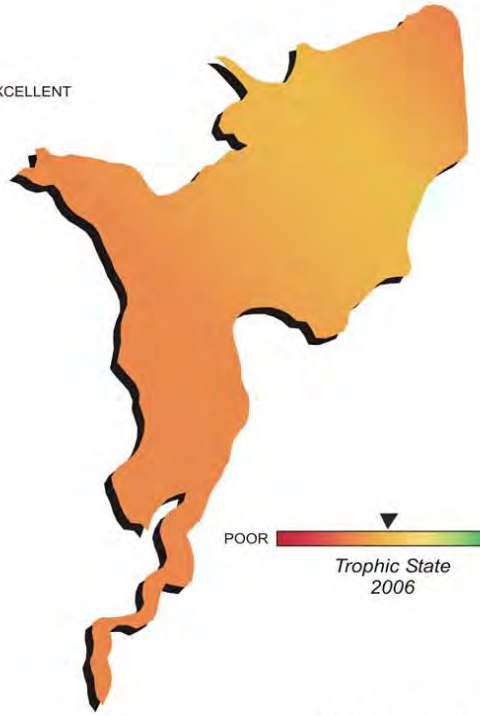
Figure 90a-90f. Graphical representation of data results for Meeker Lake.

Meeker Lake and Watershed



POOR — EXCELLENT

Turbidity 2006



POOR — EXCELLENT

Trophic State 2006

Meeker Lake Location

Lake Data	
Owner	City of Meeker
County	Lincoln
Constructed in	1970
Surface Area	250 acres
Volume	1,818 acre/feet
Shoreline Length	5 miles
Mean Depth	7.27 feet
Watershed Area	12 square miles

Plate 75 - Lake Water Quality for
Meeker Lake

LAKES MONITORING PROGRAM

Lake Murray

Lake Murray, located in Love County is owned by the State of Oklahoma and is utilized for recreational purposes. Lake Murray and the state park surrounding it are one of the state's nicer recreational get aways. Lake Murray was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones and major arms of the reservoir. Samples were collected from the lake surface at all sites during the sample year. The lake-wide annual turbidity value was 4 NTU (Plate 76), true color was 12 units, and secchi disk depth was 184 centimeters. Based on these three parameters, Lake Murray had excellent water clarity in sample year 2006. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 36 (Plate 76), classifying the lake as oligotrophic, indicative of low levels of productivity and nutrients. This value is consistent with the one calculated in 2004 (TSI=34) indicating no change in productivity since previous data collection efforts. The TSI values were consistently oligotrophic in all seasons, with the exception of site 5 in the summer, which was borderline mesotrophic. All turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU ranging from a low of 1 NTU to a maximum of 5 NTU (Figure 91a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the collected turbidity values well below the criteria, the lake is meeting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 91b. Similar to turbidity 100% of the true color values were below the WQS of 70 units. Applying the same default protocol, the Aesthetic beneficial use is considered fully supported at Lake Murray.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values were 0.11 parts per thousand (ppt) to 0.15 ppt. Readings indicate low to moderate salt content and are within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductivity were also within the expected range of values reported for most Oklahoma lakes, ranging from 230 µS/cm to 311.9 µS/cm, indicating the presence of low to moderate concentrations of electrical current conducting compounds (salts) in the water column. In general, pH values were neutral to slightly alkaline with values ranging from 7.16 units in the spring to 8.34 in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 147 mV

in the summer to 496 mV in the fall quarter, indicating an absence of reducing conditions during any of the sampling period. Lake Murray was not thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 7.0 mg/L throughout the water column (see Figure 91c-91d). Thermal stratification was gradual in the spring quarter between 9 and 10 meters in depth, with dissolved oxygen remaining well above 2.0 mg/L except at the very bottom at sites 1 and 4 (Figure 91e). In the summer the lake was thermally stratified at several 1-meter intervals and anoxic conditions were present in a large portion of the water column. Below the thermocline D.O. values were less than 2.0 mg/L, extending from 11 meters below the surface to the lake bottom of 28.7 meters at site 1, the dam (see Figure 91f). The same pattern was observed at site 2 with 48% of the water column less than 2.0 mg/L. Due to equipment failure the profile was unable to be completed at site 3-5. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 70% of the water column experiencing anoxic conditions in the summer quarter, Lake Murray is partially supporting the FWP beneficial use based on dissolved oxygen values. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) was 0.27 mg/L at the lake surface during the study period. The TN at the surface ranged from 0.20 mg/L to 0.36 mg/L. The highest TN value was reported in the winter quarter and lowest surface TN value was reported in the fall quarter. The lake-wide total phosphorus (TP) average was 0.017 mg/L at the lake surface. The surface TP ranged from 0.008 mg/L to 0.026 mg/L. Similar to TN, the highest a TP value was reported in the winter however the lowest occurred in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 16:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1998 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The ODEQ re-sampled the lake in 2004 and found Mercury residue in largemouth bass exceeding both the ODEQ detection limit and screening level, however no species was found to be exceeding the ODEQ advisory level. Lake Murray was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Lake Murray was classified as oligotrophic, with low primary productivity and nutrient conditions (Plate 76). This value is consistent with the one calculated in 2004 (TSI=34) indicating no change in productivity since previous data collection efforts. Water clarity continues to be excellent at this reservoir based on turbidity, true color and secchi disk depth. The FWP beneficial use is fully supported based on turbidity and pH, however the lake is

partially supporting the use with anoxic conditions present in 70% of the water column during the summer. The Aesthetic beneficial use is considered fully supported based on trophic status and low true color values reported during the study period. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported. In 2001, a bathymetric survey (Figure 92) was conducted to determine current storage capacity and volume as well as create a database for future determination of sedimentation and assesses shoreline exposure during lake level fluctuations. The data collected was also used to create a water usage plan for the reservoir. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800.

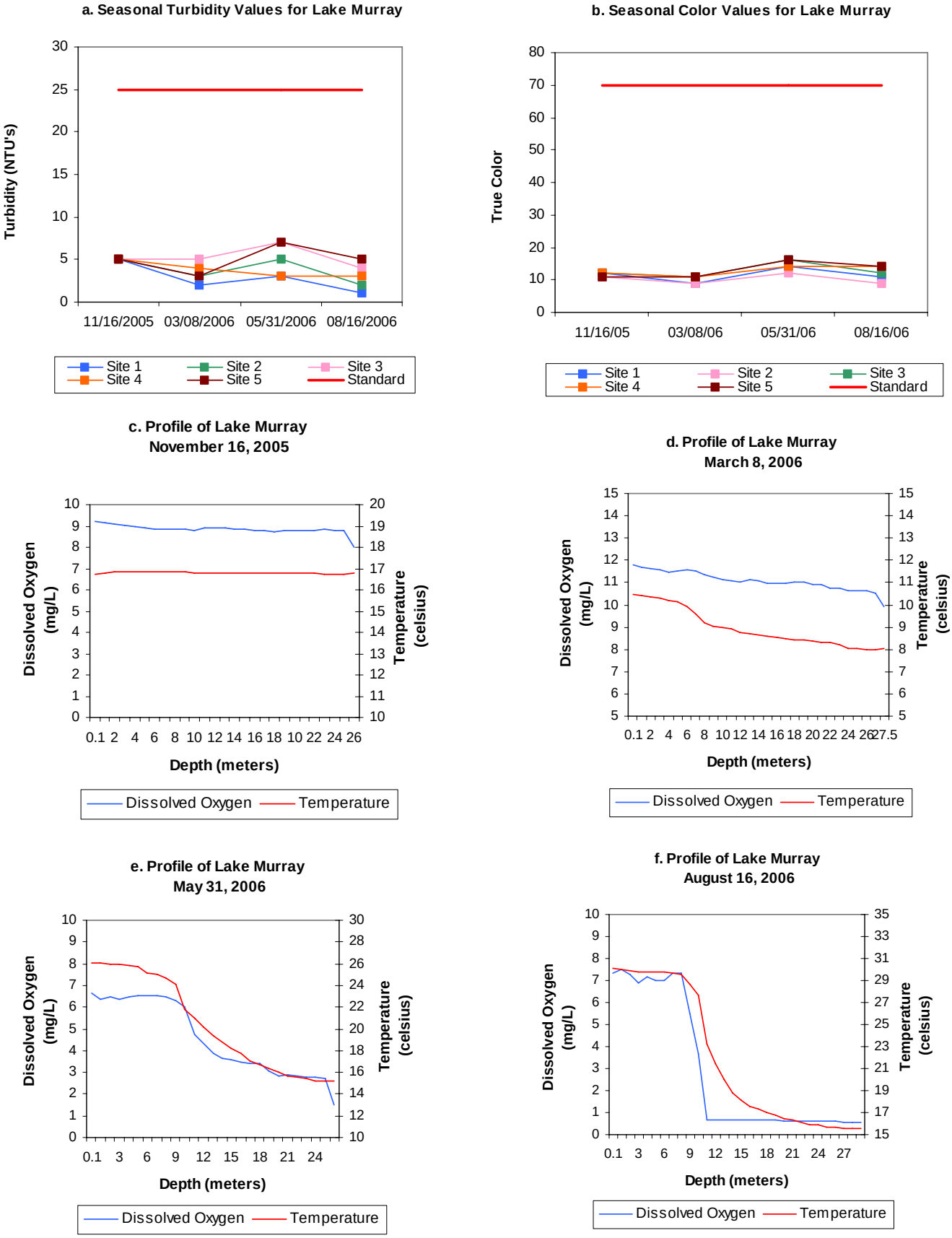
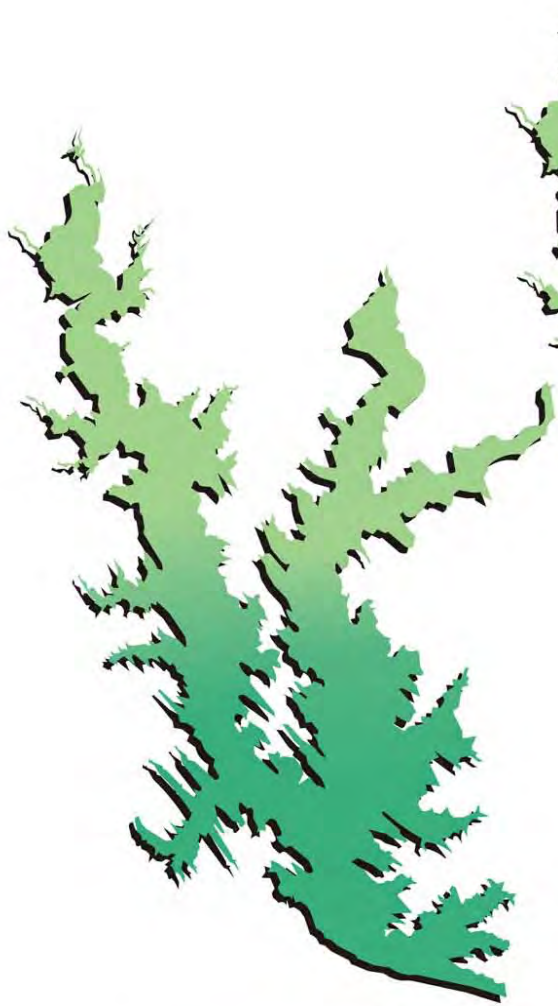


Figure 91a-91f. Graphical representation of data results for Lake Murray.

Lake Murray and Watershed

Lake Data	
Owner	State of Oklahoma
County	Love (Dam)
Constructed	1960
Surface Area	5,728 acres
Volume	153,250 acre/feet
Shoreline Length	67 miles
Mean Depth	26.75 feet
Watershed Area	55 square miles

Lake Murray Location



Turbidity 2006

Trophic State 2006

Plate 76- Lake Water Quality for
Lake Murray

LAKES MONITORING PROGRAM

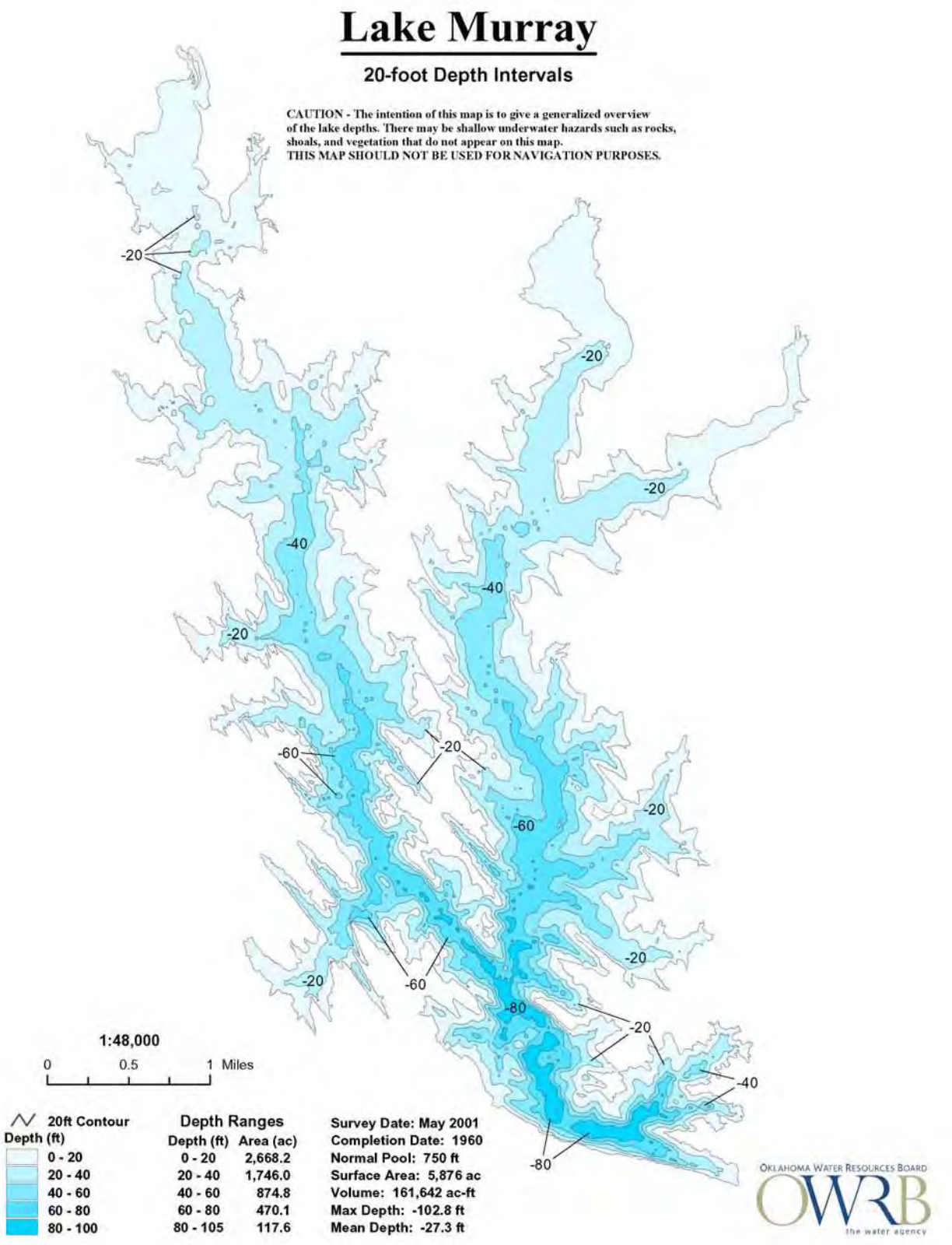


Figure 92. Bathymetric map of Lake Murray.

Lake Nanih Waiya

Lake Nanih Waiya was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected from three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 8 NTU (Plate 77), true color was 29 units, and average secchi disk depth was 143 centimeters. Based on these three parameters Lake Nanih Waiya had excellent water clarity in sample year 2004-2005, similar to that observed in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a) was calculated using values collected at all sites for four quarters (n=12). The TSI was 45 (Plate 77), classifying the lake as mesotrophic, indicative of moderate primary productivity and nutrient conditions. This is identical to the value calculated in 2003 (TSI=45), indicating no significant change in productivity has taken place. The TSI values were fairly consistent with all values in the mesotrophic category with the exception of site 3, in the spring, which dipped down to the oligotrophic category. Seasonal turbidity values are displayed in Figure 93a. Turbidity values ranged from a low 2 NTU to a maximum of 25 NTU, both recorded at site 3. According to the Use Support Assessment Protocols (USAP) specified in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 8.3% of the samples collected above the standard the lake is fully supporting its Fish & Wildlife Propagation (FWP) use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 93b. Applying the same default protocol, the Aesthetics beneficial use is considered fully supported with 100% of the collected values below the WQS of 70 units.

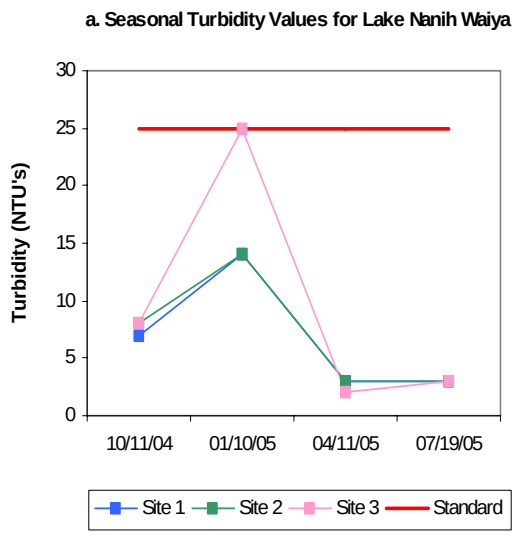
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.08 ppt. This is lower than the average range of values reported for Oklahoma lakes. Readings for specific conductivity ranged from 58 µS/cm to 178 µS/cm, indicating that low concentrations of electrical current conducting compounds (salts) were present in the lake system. Values for pH were slightly acidic to neutral, ranging from 6.57 in the hypolimnion in the summer to 7.48 near the surface in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only one of the recorded values less than 6.5, Lake Nanih Waiya is supporting the FWP beneficial use. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potential (ORP) ranged from 316 mV in the winter to 481 mV in the summer. In general, reducing conditions were not present at this reservoir with all values being positive and above 100 mV throughout the study period.

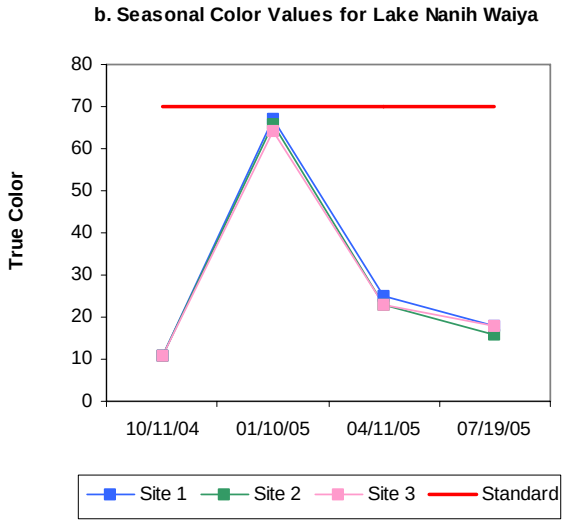
Stratification was not present during the fall, winter or spring and the lake was well mixed with dissolved oxygen (D.O.) levels generally above 6.0 mg/L (see Figure 93c-93e). Thermal stratification was evident in the summer and anoxic conditions were present. In the summer sampling quarter, stratification occurred between 2 and 3 meters at which point the D.O. fell below 2.0 mg/L to the lake bottom of 5.4 meters. This accounts for approximately 43% of the water column, at site 1 to be experiencing anoxic conditions. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Lake Nanih Waiya based on D.O. values in the summer quarter. This is not a situation that is normally seen in such a shallow reservoir and may be attributed to a long period of calm winds and/or a pattern where little rainfall occurred. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

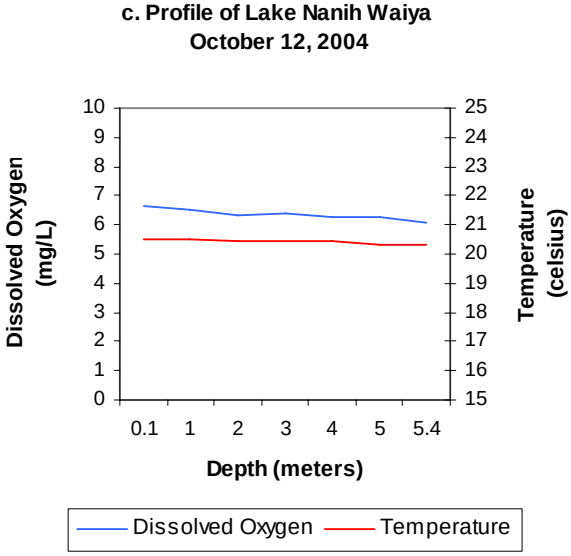
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

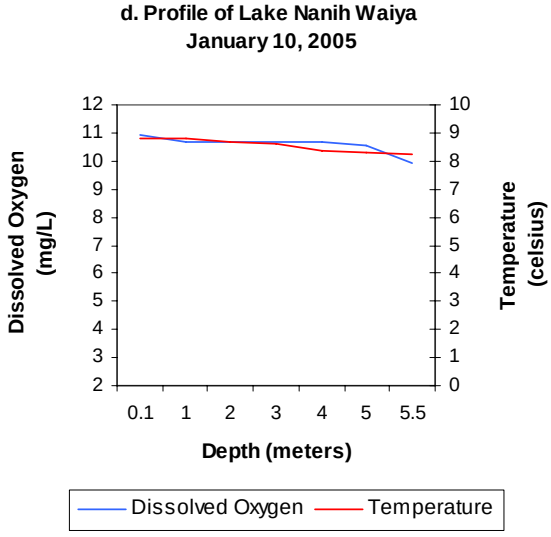
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.35 mg/L at the lake surface. The TN at the surface ranged from 0.19 mg/L to 0.63 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average was 0.020 mg/L at the lake surface. The surface TP ranged from 0.012 mg/L to 0.025mg/L. Similar to TN, the highest surface TP value was reported in the fall quarter, however the lowest was in the winter spring. The nitrogen to phosphorus ratio (TN:TP) was approximately 18:1 for sample year 2004-2005. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

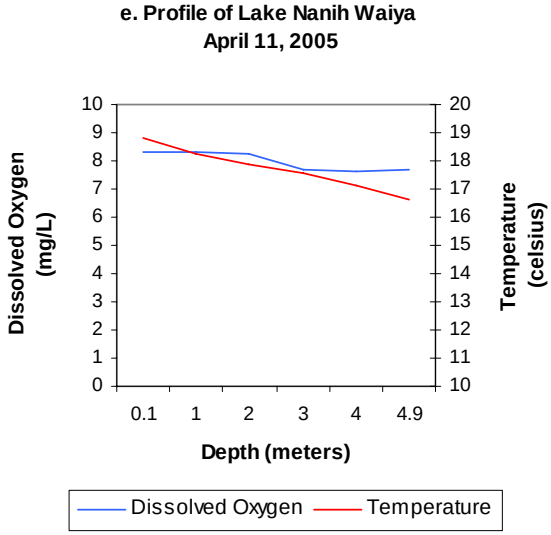
In summary, Lake Nanih Waiya was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions (Plate 77). This is identical to the value calculated in 2003 (TSI=45), indicating no significant change in productivity has taken place. Water clarity was excellent based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial used based on turbidity, pH values and D.O. values reported during the study period. The Aesthetics beneficial use is fully supported based on its trophic status and true color values. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake Nanih Waiya, located in Pushmataha County, is owned by the State of Oklahoma and is utilized for recreational purposes.











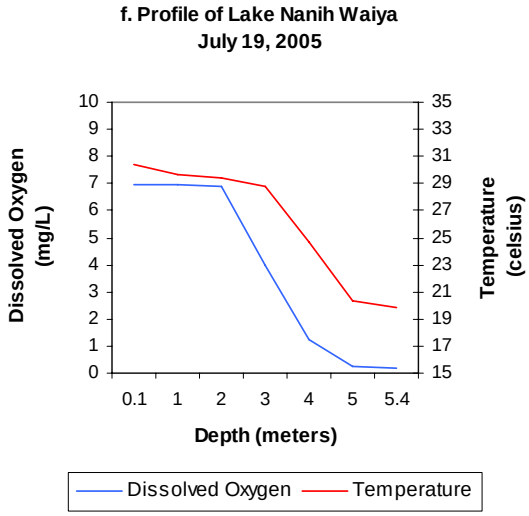
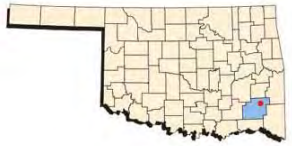
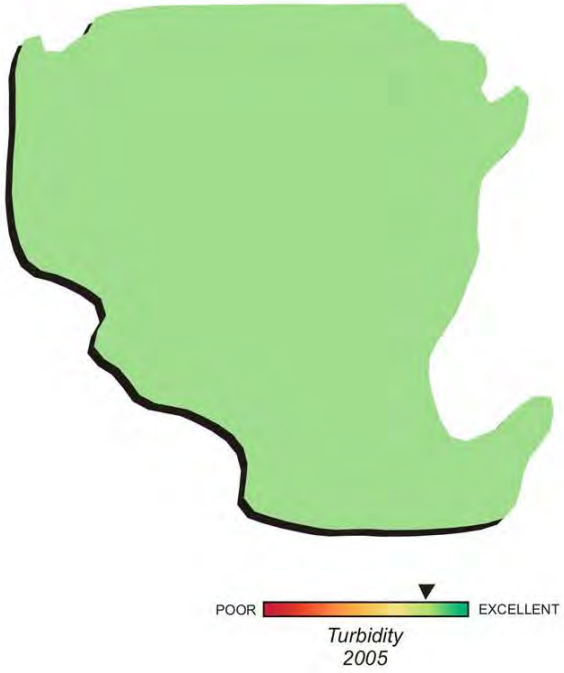


Figure 93a-93f. Graphical representation of data results for Lake Nanih Waiya.





Lake Data	
Owner	State of Oklahoma
County	Pushmataha
Constructed in	1958
Surface Area	131 acres
Volume	1,064 acre/feet
Shoreline Length	3 miles
Mean Depth	8.12 feet
Watershed Area	2,848 acres

Plate 77 - Lake Water Quality for
Lake Nanih Waiya

LAKES MONITORING PROGRAM

Okemah Lake

Okemah Lake was sampled for four quarters, from December 2004 through August 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 13 NTU (Plate 78), true color was 39 units, and secchi disk depth was 92 centimeters in 2004-2005. Based on these three parameters, Okemah Lake had good water clarity in comparison to other Oklahoma reservoirs. Results are similar to those observed in the previous evaluation in 2002. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 51 (Plate 78), indicating the lake was eutrophic, indicative of high primary productivity and nutrients levels. The TSI values were primarily mesotrophic throughout the year. The only exception to this occurred in the spring when site 2 was oligotrophic and site 4 peaked in the hypereutrophic category. Seasonal turbidity values are displayed in Figure 94a. In general turbidity values were all well below the turbidity standard of 25 NTU with the exception of one value reported at site 4 during the winter quarter. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Due to a post-processing error turbidity was not run for any of the summer samples. Although only 8.3% of the samples collected in 2005 exceeded the WQS of 25 NTU and assessment of the, Fish and Wildlife Propagation (FWP) beneficial use cannot be made due to minimum data requirements not being met. Seasonal true color values are displayed in Figure 94b. Of the twenty values collected, 10% exceeded the WQS of 70 units. Applying the same default protocol, the Aesthetic beneficial use is considered partially supported.

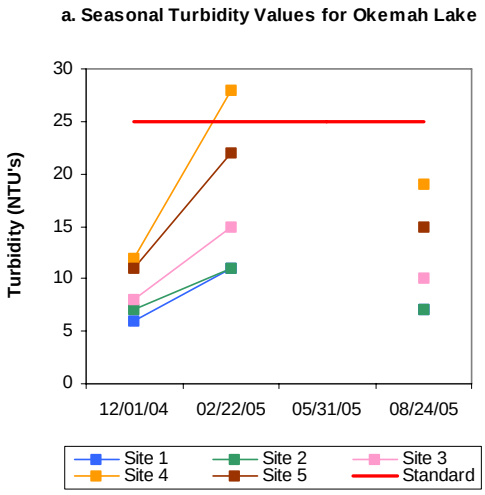
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.13 ppt, well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductivity were also low, ranging from 163.8 µS/cm to 246.1 µS/cm, indicating the minimal presence of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to alkaline in nature with values ranging from 6.79 units in the fall quarter to 8.13 in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range, Okemah Lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 142 mV to 446 mV, indicating an absence of any significant reducing conditions in the lake. Okemah Lake was not stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 5.0 mg/L throughout the water column in both seasons (see Figure 94c-94d). Thermal stratification and anoxic conditions were present in both spring and summer sampling intervals. In the spring the lake was stratified at several 1-meter intervals among site 1-4. At site 1, stratification first occurred between 4 and 5 meters in depth with D.O. remaining above 2.0 mg/L until 9 meters below the surface, accounting for 27% of the water to be anoxic (Figure 94e). In the summer quarter, the lake was again strongly thermally stratified between 4 and 5 meters and between 5 and 6 meters at site 1 (see Figure 94f). Anoxic conditions were present below the 5-meter depth

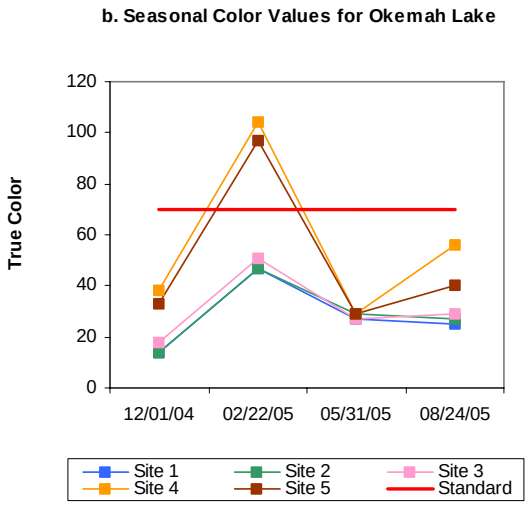
at site 1 and D.O. readings were below 1.0 mg/L from 6 meters to the lake bottom at 13 meters. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, with 27% in the spring and 57% of the water column at site 1 in the summer less than 2.0 mg/L, the FWP beneficial use is partially supported at Okemah Lake. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

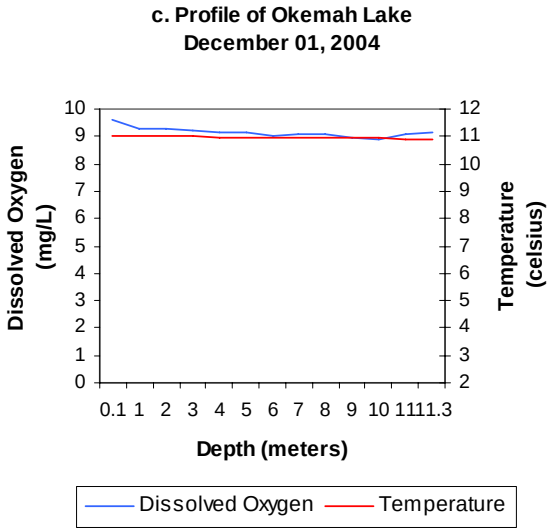
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

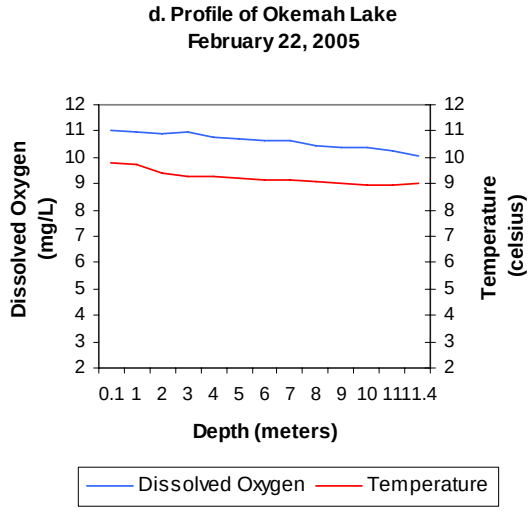
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.40 mg/L. The TN at the surface ranged from 0.17 mg/L to 1.00 mg/L. The highest surface TN value was reported in the winter quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average was 0.019 mg/L at the lake surface. The surface TP ranged from 0.012 mg/L to 0.039 mg/L. The highest surface TP value was reported in the winter quarter and the lowest was in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 21:1 for sample year 2004-2005. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

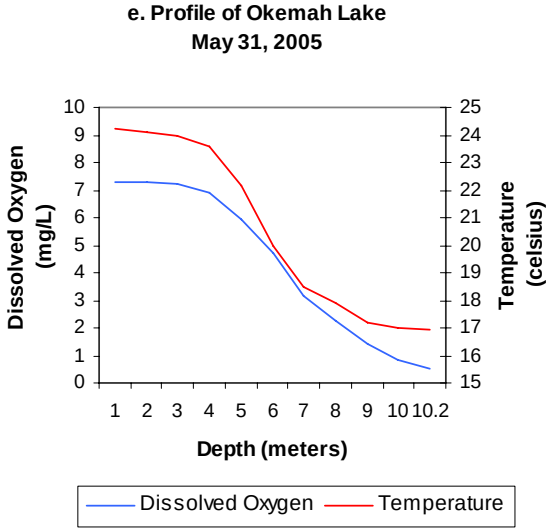
In summary, Okemah Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 78). Water clarity was good based on turbidity, true color and secchi disk depth. The lake was fully supporting its Aesthetics beneficial use based on its trophic status and partially supported based on true color with 10% of the values exceed the WQS of 70 units. Okemah Lake was fully supporting its FWP beneficial use based on pH, however due to minimum data requirements not being met an assessment for turbidity could not be made. The FWP beneficial use was partially supported based on anoxic condition present in both spring and summer sampling intervals. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Okemah Lake is owned and operated by the City of Okemah and serves as a municipal water supply and offers numerous recreational opportunities to the public. Okemah Lake is one of the nicer small municipal reservoirs in Oklahoma and should managed and preserved to ensure that its water quality is not degraded over time.











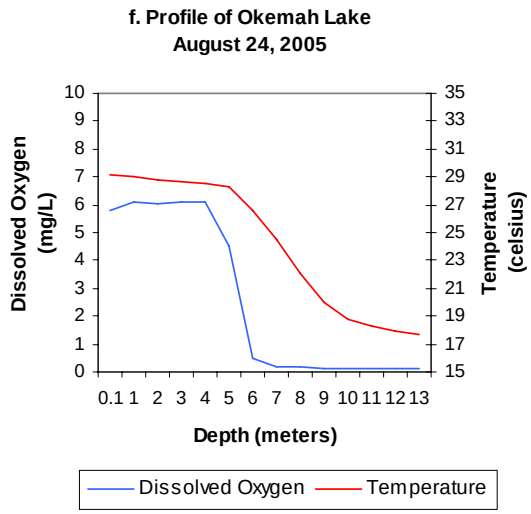
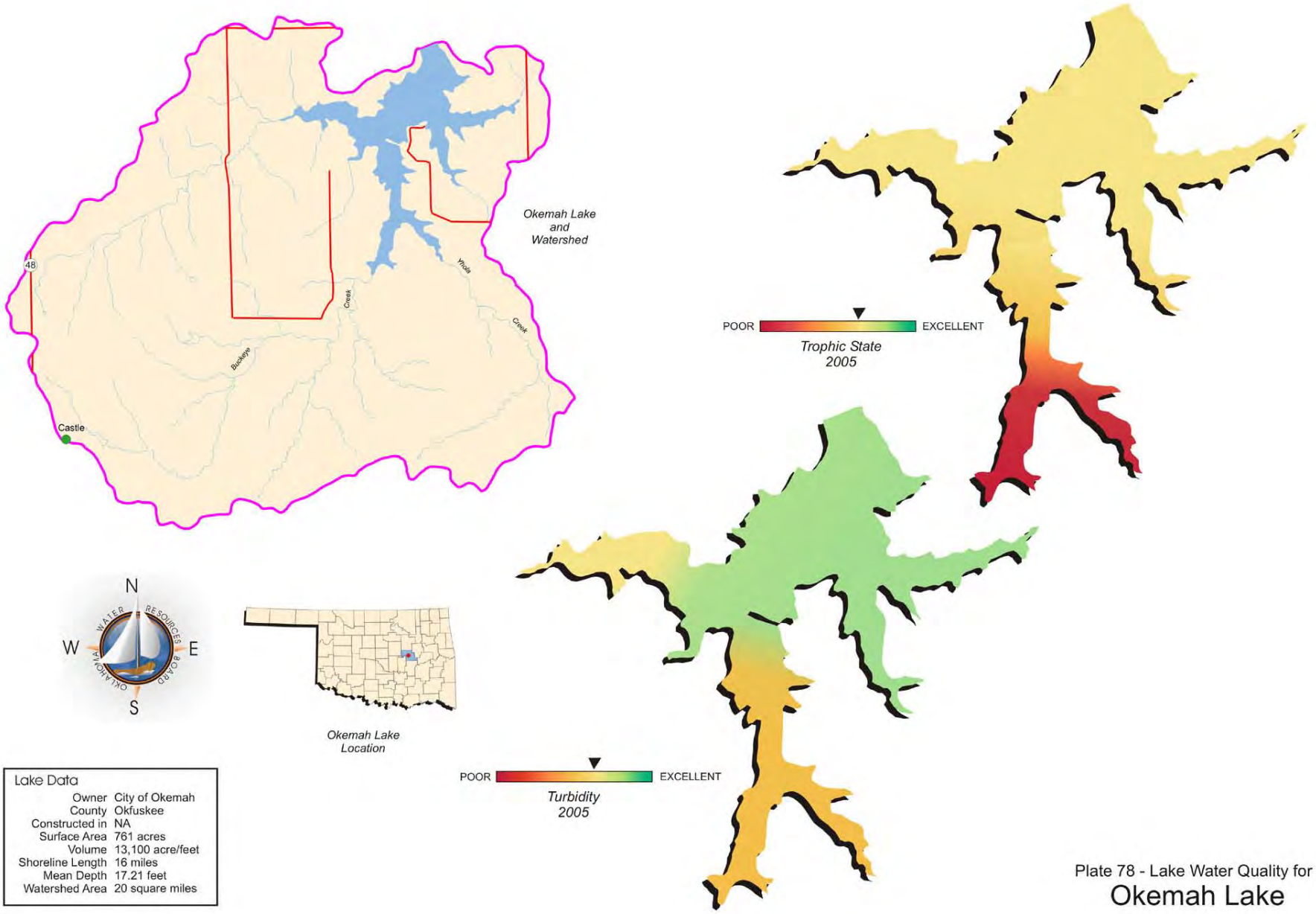


Figure 94a-94f. Graphical representation of data results for Okemah Lake.



Lake Data

Owner	City of Okemah
County	Okfuskee
Constructed in	NA
Surface Area	761 acres
Volume	13,100 acre/feet
Shoreline Length	16 miles
Mean Depth	17.21 feet
Watershed Area	20 square miles

Plate 78 - Lake Water Quality for
Okemah Lake

LAKES MONITORING PROGRAM

Okmulgee Lake

Okmulgee Lake was sampled for four quarters, from November 2004 through August 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 9 NTU (Plate 79), true color was 39 units, and secchi disk depth was 122 centimeters in 2004-2005. Based on these three parameters, Okmulgee Lake had good water clarity in comparison to other Oklahoma reservoirs. Results are similar to those observed in 2002 with the current secchi disk depth being slightly better. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 46 (Plate 79), indicating the lake was mesotrophic with moderate primary productivity and nutrient conditions. This is consistent with that of the 2002 evaluation (TSI=45), indicating no significant change in productivity has taken place. The TSI values were primarily mesotrophic during the sample year. The only exceptions to this were sites 2 and 4 in the spring and site 2 in the summer when low chlorophyll-a values were reported, placing these sites in the oligotrophic category. Seasonal turbidity are displayed in Figure 95a. Turbidity values ranged from a low 3 NTU to a maximum of 21 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the recorded turbidity values were below the criteria, so the Fish & Wildlife Propagation (FWP) beneficial use is fully supported as it relates to turbidity. Seasonal true color values are displayed in Figure 95b. True color values were below the WQS of 70 units in three of the four quarters. In the spring all sites were at our above the standard accounting for 25% of the total values to be exceeding 70 units. Applying the same default protocol, the lake is partially supporting the Aesthetics beneficial use.

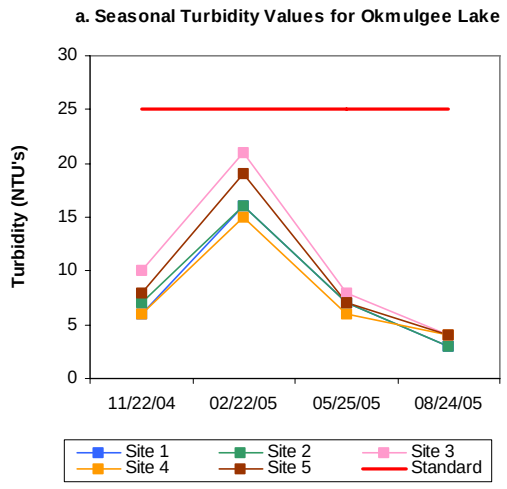
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.03 parts per thousand (ppt) to 0.04 ppt, indicating low salt content and all values were well within the expected range of salinity reported for most Oklahoma lakes. Readings for specific conductivity were very low, ranging from 79.1 µS/cm to 170 µS/cm, indicating the very minimal presence of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were slightly acidic to alkaline with values ranging from 6.4 units in the summer quarter to 8.06 in the fall at site 1 at the lake surface. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Okmulgee Lake had only 2% of its pH values falling outside the acceptable range and therefore it is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 137 mV in the summer to 482 mV in the spring quarter, indicating an absence of reducing conditions. The lake was not stratified during the fall and winter and the water column was well mixed (see Figure 95c-95d). During the spring sampling interval the lake was stratified at several 1-meter intervals among all the sites, with 23 to 46% of the water column exhibiting anoxic conditions (Figure 95e. In the summer the lake was also strongly thermally at several depths throughout the water column (see Figure 95f) and D.O. values below the 5-meter depth were all less than 2.0 mg/L and were generally less than 1.0 mg/L. Anoxic conditions were present in 33-62% of the water column

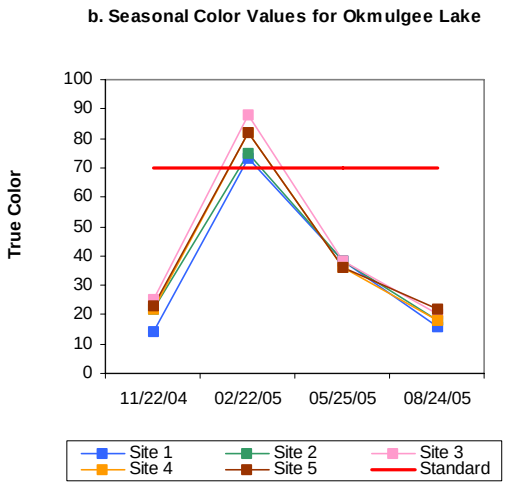
during this sampling interval. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is partially supported based on dissolved oxygen levels recorded during both spring and summer quarters. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

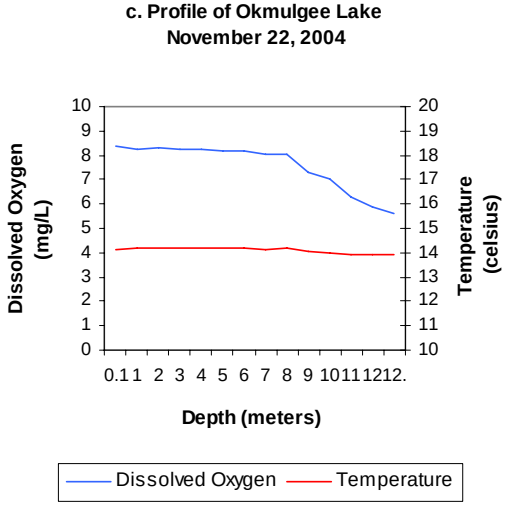
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

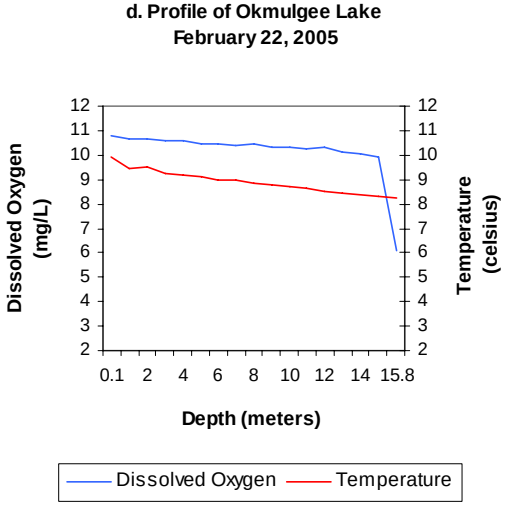
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.35 mg/L at the lake surface. The TN at the surface ranged from 0.17 mg/L to 0.59 mg/L. The highest surface TN value was reported in the winter and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average was 0.017 mg/L at the lake surface. The surface TP ranged from 0.010 mg/L to 0.026 mg/L. Similar to TN, the highest surface TP value was reported in the winter and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 21:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

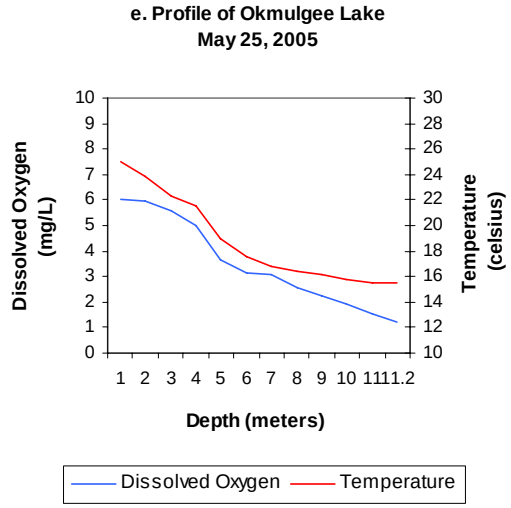
In summary, Okmulgee Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 79). This is consistent with that of the 2002 evaluation (TSI=45), indicating no significant change in productivity has taken place. Water clarity was good at Okmulgee Lake based on true color, turbidity, and secchi disk depth. The lake was fully supporting its FWP beneficial use based on turbidity and pH concentrations, however the lake was only partially supporting based on low D.O. readings in the water column in both spring and summer quarters. The lake was fully supporting its Aesthetics beneficial use based on trophic state; however the use is considered not supported for true color with 25% of the collected values exceeding the WQS if 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Okmulgee Lake, located in Okmulgee County, was constructed in 1928 and is owned and operated by the City of Okmulgee. The lake is the municipal water supply for the city and is also utilized for recreational purposes.











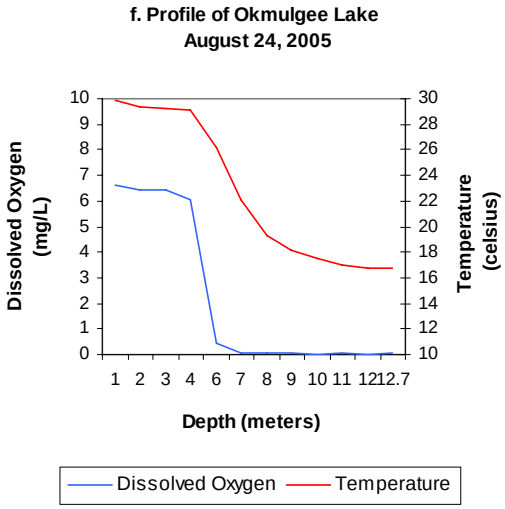


Figure 95a-95f. Graphical representation of data results for Okmulgee Lake.

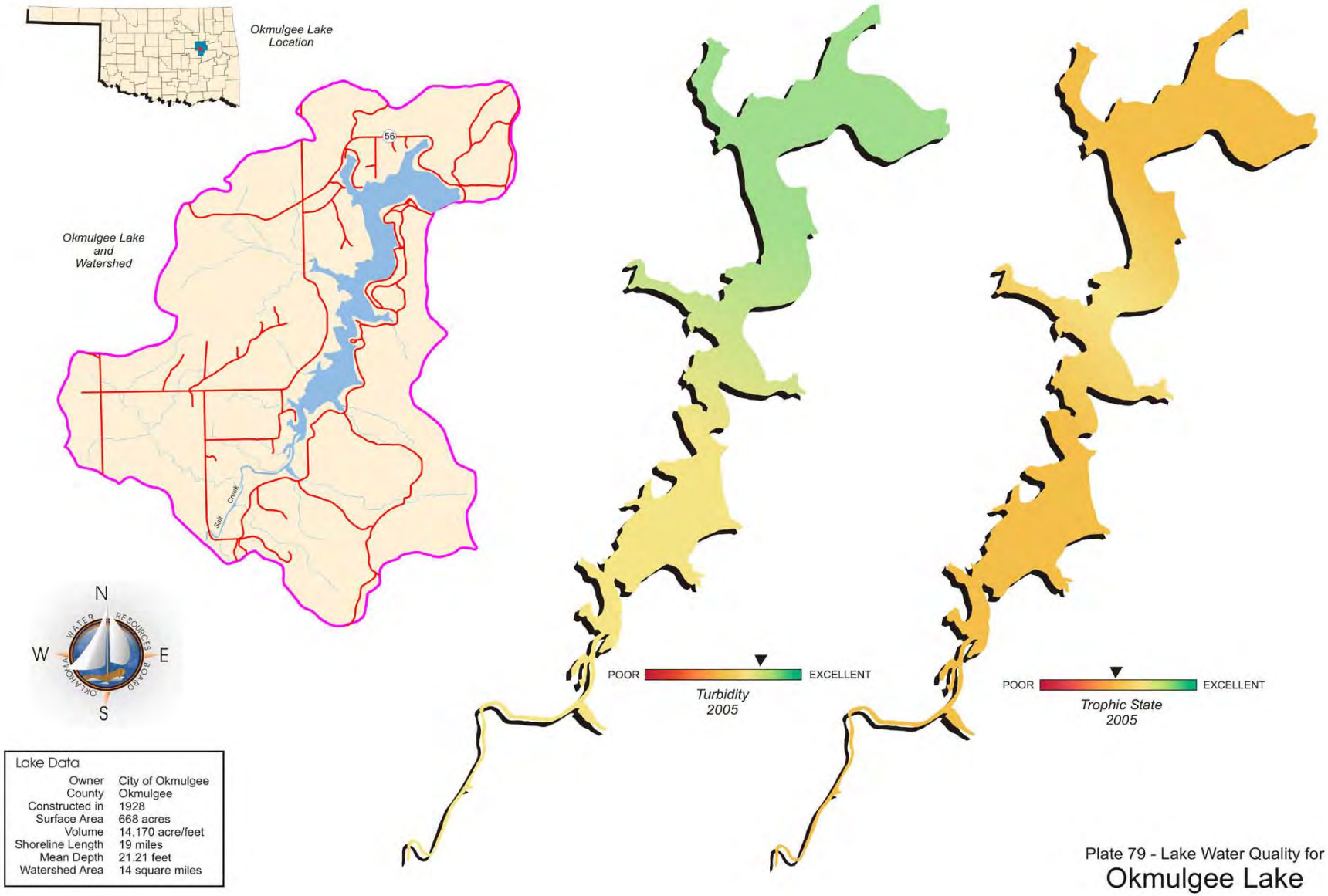


Plate 79 - Lake Water Quality for
Okmulgee Lake

Oologah Lake

Oologah Lake was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected at seven (7) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 26 NTU (Plate 80), true color was 44 units, and secchi disk depth was 56 centimeters in 2004-2005. Based on these three parameters, Oologah Lake had fair water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=28). The TSI was 46 (Plate 80), indicating the lake was mesotrophic with moderate primary productivity and nutrient conditions. This is similar to the value calculated in 2002 (TSI=48), no significant change in productivity has occurred since the last evaluation. The TSI values varied by site and season and ranged mesotrophic to eutrophic in the fall, spring and summer, with Oligotrophic conditions present during the winter interval. Site 1 had low chlorophyll - a reported in 3 of the 4 quarters. Seasonal turbidity values are displayed in Figure 96a. Turbidity ranged from a low of 6 NTU to a maximum of 100 NTU, with the highest values being recorded at sites 5-7 throughout sample year 2004-2005. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 28.5% of the recorded turbidity values above the standard the Fish and Wildlife Propagation (FWP) beneficial use is not supported based on turbidity. Seasonal true color values are displayed in Figure 96b. Like turbidity, true color values were highest at sites 5-7 and lowest at sites 1-4. Of the twenty values recorded three (10.7%) exceeded the WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is partially supported based on true color values.

In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sites. Salinity values at Oologah Lake ranged from 0.12 parts per thousand (ppt) to 0.22 ppt. This is within the average range of values reported for Oklahoma reservoirs. Specific conductivity ranged from 245 µS/cm to 437.7 µS/cm, indicating that low to moderate concentrations of electrical current conducting materials (salts) were present in the lake system. Values for pH ranged from 6.82 to 8.26 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all values within the acceptable range, Oolagah Lake is meeting the FWP use as it relates to pH. Oxidation-reduction potentials ranged from 69 mV in the fall to 499 mV in the summer. In general, reducing conditions were not present in 2005, with all recorded values positive and above 100 mV. The one value recorded at site 4 in the fall is the only instance where values fell below 100 and is likely the result of the Hydrolab probe resting on the lake

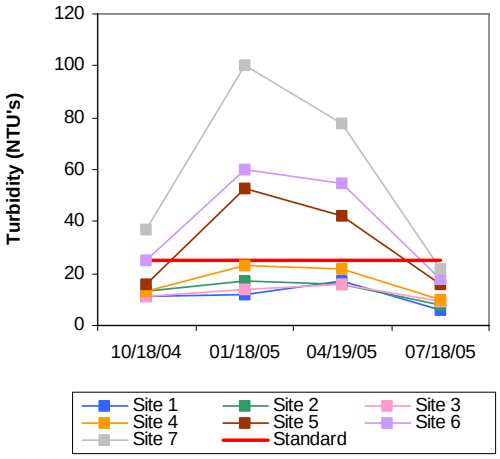
bottom. Thermal stratification was not present during the fall, winter, or spring sampling quarters, and the lake was well mixed with dissolved oxygen (D.O) levels remaining above 6.0 mg/L (see Figure 96c-96e). In the summer, stratification was evident and anoxic conditions were present at sites 1,2 and 4. Dissolved oxygen was less than 2.0 mg/L from 9 meters in depth to the lake bottom of 21.1 meters accounting for 10 to 59% of the water column to be experiencing anoxic conditions (see Figure 96f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, Oologah Lake is considered partially supporting the FWP beneficial based on dissolved oxygen, as 59% of the water column was anoxic at site 1, the dam. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

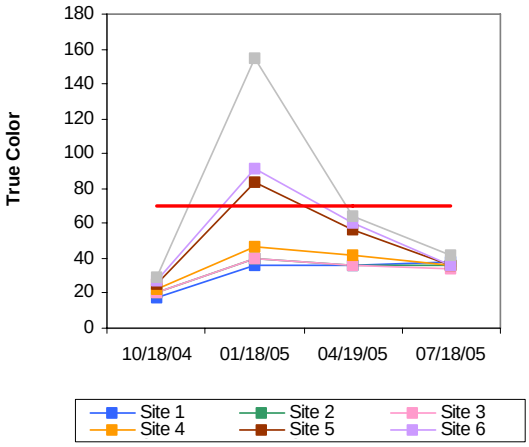
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.61 mg/L at the surface. Surface TN ranged from 0.26 mg/L to 1.01 mg/L, with the highest values reported in the winter and lowest values in the fall. The lake-wide total phosphorus (TP) average was 0.071 mg/L at the surface. Total phosphorus at the surface ranged from 0.033 mg/L to 0.178 mg/L. Similar to TN, surface TP was highest in the spring, however, the lowest values were recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 9:1 for sample year 2004-2005. This is slightly higher than 7:1, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Oologah Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions (Plate 80). This is similar to the value calculated in 2002 (TSI=48), no significant change in productivity has occurred since the last evaluation. Water clarity was fair based on turbidity, true color and secchi disk depth readings. The lake is supporting the FWP beneficial use based on pH, partially supporting based on dissolved oxygen, and not supporting the use based on turbidity. The Aesthetics beneficial use is supported based on both its trophic status and partially supported for true color with 10.7% of the values exceeding the standard values. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Oologah Lake, constructed by the United States Army Corps of Engineers (UASCE), serves a water supply for the City of Tulsa and is utilized for flood control and navigational purposes.

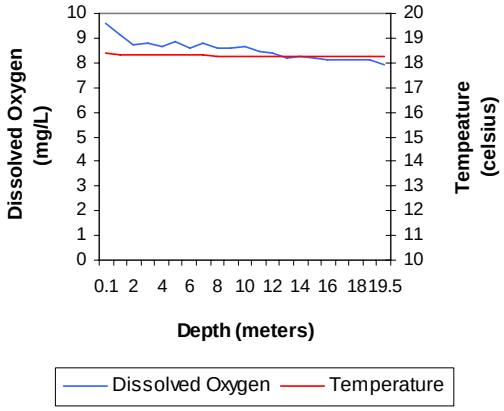
a. Seasonal Turbidity Values for Oologah Lake



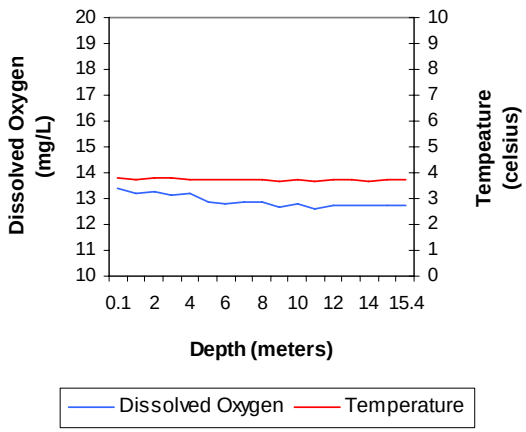
b. Seasonal Color Values for Oologah Lake



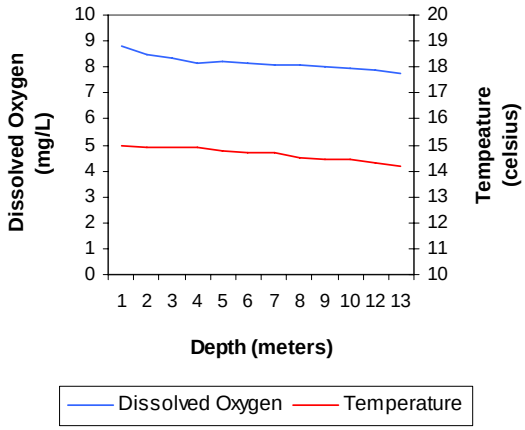
c. Profile of Oologah Lake
October 18, 2004



d. Profile of Oologah Lake
January 18, 2005



e. Profile of Oologah Lake
April 19, 2005



f. Profile of Oologah Lake
July 18, 2005

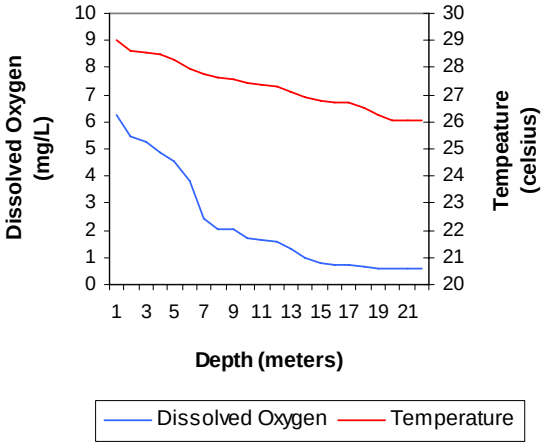
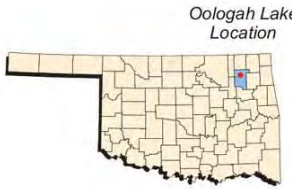


Figure 96a-96f. Graphical representation of data results for Oologah Lake.



Lake Data	
Constructed by	Corps of Engineers
County	Rogers
Constructed in	1974
Surface Area	29,460 acres
Volume	553,400 acre/feet
Shoreline Length	180 miles
Mean Depth	18.7 feet
Watershed Area	4,339 square miles

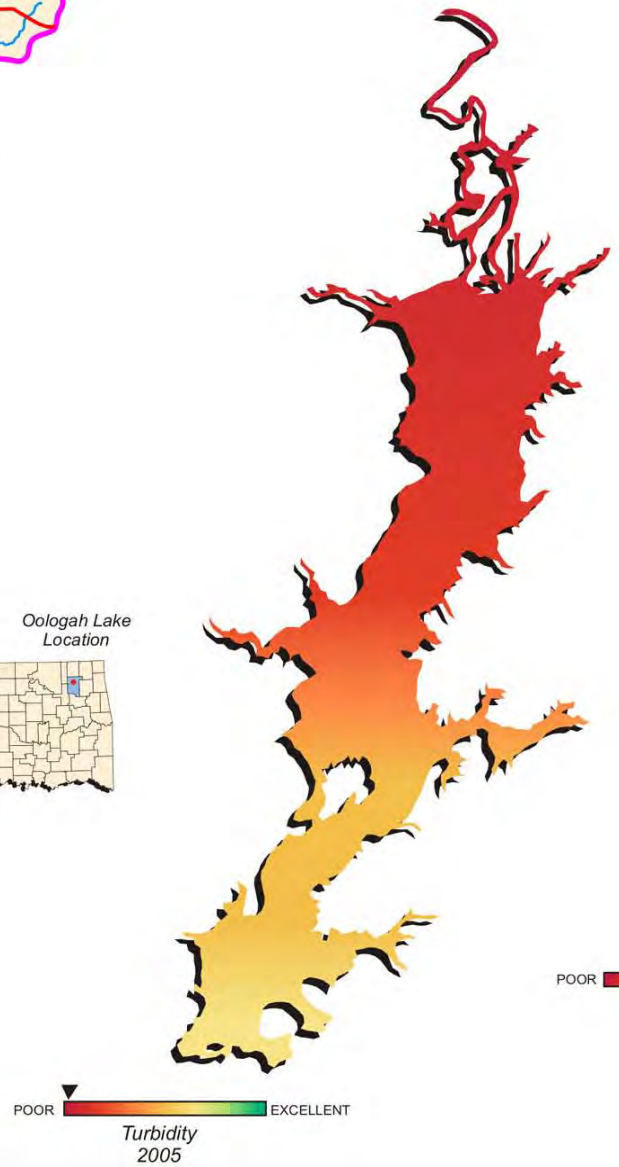


Plate 80 - Lake Water Quality for
Oologah Lake

LAKES MONITORING PROGRAM

Lake Overholser

Lake Overholser was constructed in 1919 and is owned and operated by Oklahoma City. It serves as a municipal water supply and offers recreational opportunities to the public. Lake Overholser was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at three sites during the sample year. The lake-wide annual turbidity value was 60 nephelometric turbidity units (NTU) (Plate 81), true color was 38 units, and secchi disk depth was 32 centimeters. Based on these three parameters, Lake Overholser had fair to poor water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was calculated at 67 (Plate 81), indicating the lake was hypereutrophic with excessive primary productivity and nutrient levels in sample year 2005-2006. This is consistent with the TSI calculated in 2004 (TSI=64) and 2002 (TSI=68), which also found the lake to be hypereutrophic. The TSI values were consistent ranging from eutrophic in the fall and winter quarters to hypereutrophic in the spring and summer sampling intervals. Based on the trophic classification, the lake is listed in the last Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Turbidity values were also elevated in the lake with 75% of the collected data exceeding the WQS of 25 NTU (see Figure 97a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Overholser is not supporting its Fish & Wildlife Propagation (FWP) beneficial use based on high nephelometric turbidity concentrations in the water column. Seasonal true color values are displayed in Figure 97b. All true color values were below the Aesthetics WQS of 70 units except sites 4 and 5, which were just above, during the fall sampling interval. With 90% of the values below than the standard, the Aesthetics beneficial use is considered partially supporting for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.04 parts per thousand (ppt) to 0.74 ppt, indicating moderate to high amounts of salts in the water column when compared to most Oklahoma lakes. Readings for specific conductivity were also very high, ranging from 102 µS/cm to 1399 µS/cm, indicating moderate to high amounts of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline with values ranging from 7.80 units in the winter quarter to 8.64 units in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall

outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All pH values were within the accepted range therefore supporting the FWP beneficial use as it relates to pH. Oxidation-reduction potentials (redox) ranged from 359 mV in the summer quarter to 431 mV in the winter quarter, indicating an absence of reducing conditions during the study period. Lake Overholser was not thermally stratified in any of the sampling quarters and dissolved oxygen (D.O.) values were above 6.0 mg/L throughout the water column in all four seasons (see Figure 97c-97f). This lake is very shallow (about 2.5 meters deep) and it is likely wind mixing precludes the onset of thermal stratification. If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the Fish & Wildlife Propagation (FWP) beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is fully supported at Lake Overholser. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

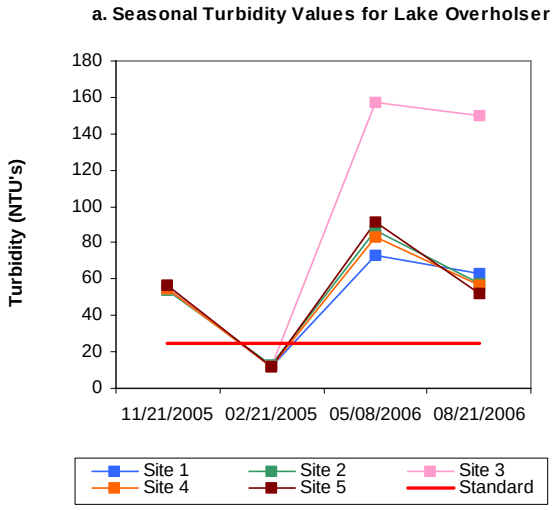
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected, six (60%) exceeded the prescribed screening level and geometric means. The PBCR beneficial use is therefore considered not supported.

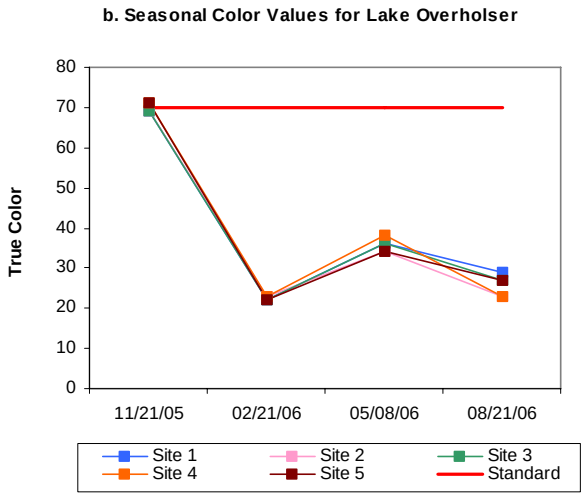
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.47 mg/L at the lake surface. The TN at the surface ranged from 0.88 mg/L to 2.38 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average was 0.211 mg/L at the lake surface. The surface TP ranged from 0.100 mg/L to 0.317 mg/L. Similar to total nitrogen, the highest surface TP value was reported in the summer quarter and the lowest was in the winter quarter. In general, nutrient concentrations in this lake were very high, probably due to its shallow nature and re-suspension of nutrient laden sediment into the water column. The nitrogen to phosphorus ratio (TN: TP) was approximately 7:1. This value is identical to 7:1, characterizing the lake possibly co-limited (Wetzel, 1983).

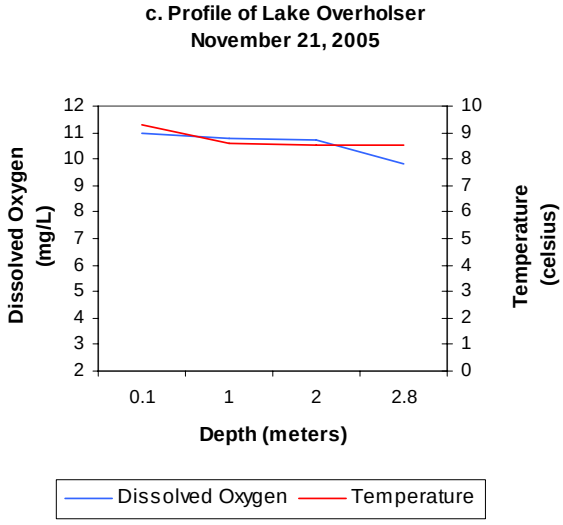
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2004 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. Lake Overholser was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

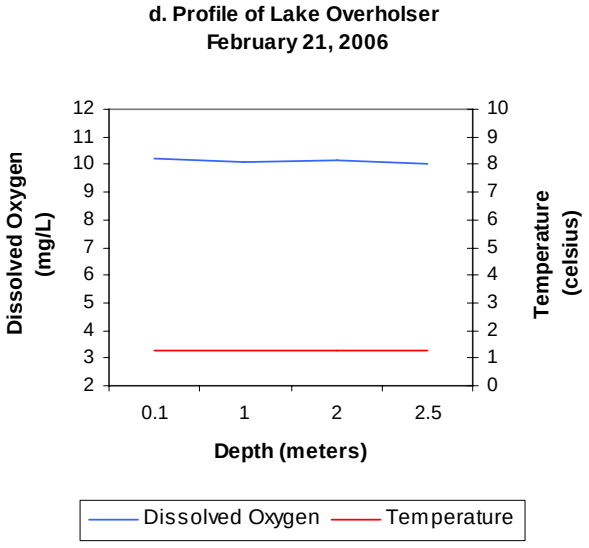
In summary, Lake Overholser was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels (Plate 81). Water clarity was fair to poor based on turbidity, true color and secchi depth. The lake was recommended for listing as a Nutrient Limited watershed (NLW) in the next WQS revision process and its Aesthetics beneficial use is considered nutrient threatened until studies can be conducted to confirm non-support status. The Aesthetics use is partially supported with 10% of the reported values exceeding 70 units. The lake is fully supporting its FWP beneficial use based on pH and dissolved oxygen, however, the lake is not supporting the use due to high nephelometric turbidity readings. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the

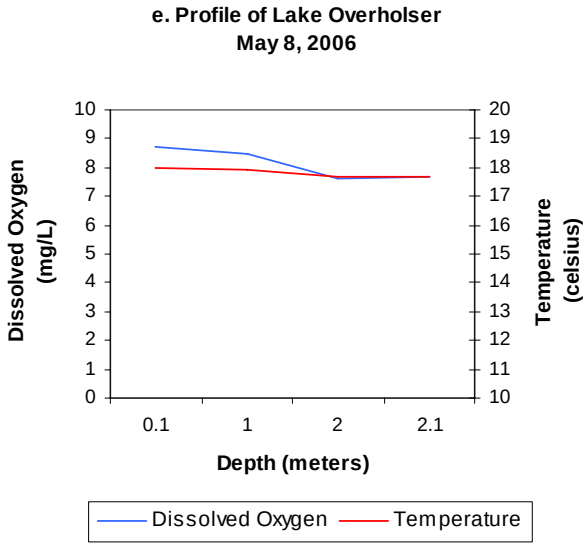
recreation season of May through September. Of the 10 enterococci samples collected, six (60%) exceeded the prescribed screening level and geometric means. The PBCR beneficial use is therefore considered not supported. In 1997 the Oklahoma Legislature directed the OWRB to conduct a study on the impact of Confined Animal Feeding Operations (CAFO) in watersheds that supply potable water to municipalities with a population over 250,000. As part of this study a bathymetric survey was completed on Oklahoma City's water supply reservoirs. A bathymetric map (Figure 98) was generated to determine current storage capacity and identify areas of extreme sedimentation. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800.











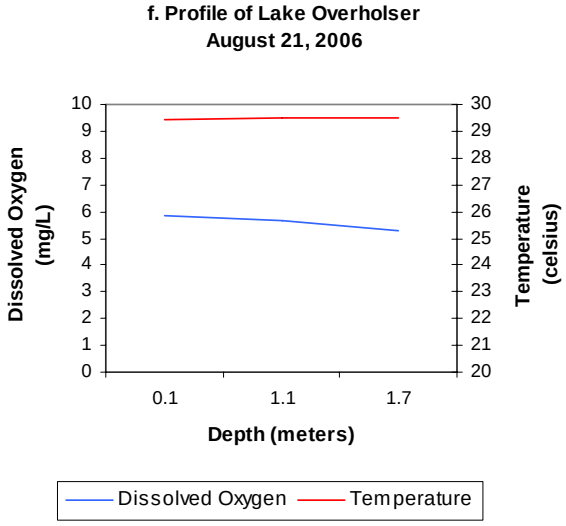


Figure 97a-97f. Graphical representation of data results for Lake Overholser.

Overholser Lake and Watershed

Overholser Lake Location

Lake Data	
Owner	City of Oklahoma City
County	Oklahoma
Constructed in	1919
Surface Area	1,591 acres
Volume	13,913 acre/feet
Shoreline Length	7.4 miles
Mean Depth	18.75 feet
Watershed Area	13,215 square miles

POOR — EXCELLENT

Trophic State 2006

POOR — EXCELLENT

Turbidity 2006

Plate 81 - Lake Water Quality for
Overholser Lake

LAKES MONITORING PROGRAM

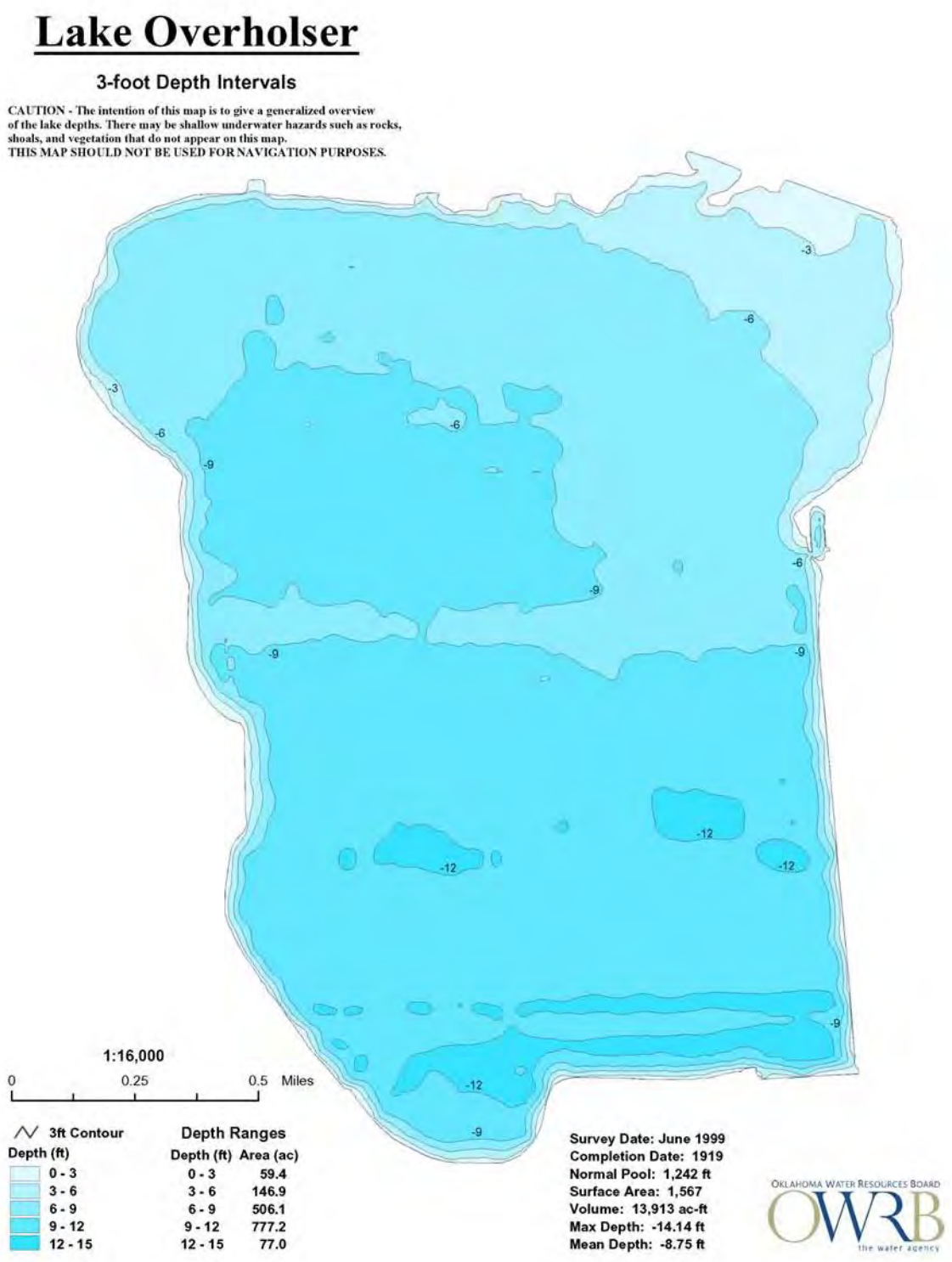


Figure 98. Bathymetric map of Lake Overholser.

Lake Ozzie Cobb

Lake Ozzie Cobb was sampled for four quarters, from November 2004 through August 2005. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 16 NTU (Plate 82), true color was 58 units, and secchi disk depth was 66 centimeters. Based on these three parameters, Lake Ozzie Cobb had fair to average water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was calculated at 55 (Plate 82), indicating the lake was eutrophic with high primary productivity and nutrient levels in sample year 2004-2005. This is similar to the value calculated in 2003, (TSI=54), indicating no significant increase or decrease in productivity has occurred. Lake Ozzie Cobb is listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. The TSI values varied seasonally and were generally eutrophic in the fall and summer and mesotrophic in the winter and spring quarters. Seasonal turbidity values are displayed in Figure 99a. Turbidity values ranged from a low of 8 NTU to a maximum of 35 NTU with the highest values reported in the winter quarter. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. With 16.6% of the samples exceeding 25 NTU, the beneficial use of Fish and Wildlife propagation (FWP) is considered not supporting in regards to turbidity. Seasonal true color values are displayed in Figure 99b. Applying the same default protocols, the Aesthetics beneficial use is considered not supported with 25% of the reported values exceeding the WQS of 70 units.

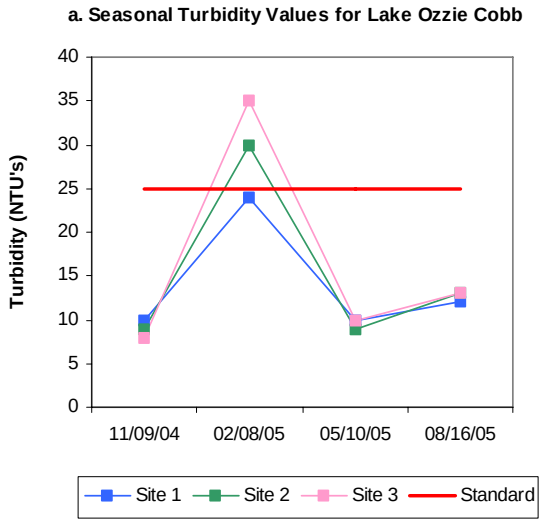
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. The salinity values for Lake Ozzie Cobb ranged from 0.01 parts per thousand (ppt) to 0.04 ppt for this sample year. Specific conductivity ranged from 20.3 to 162.7 µS/cm, which is much lower than most Oklahoma reservoirs. These values indicate the low to minimal presence of electrical current conducting compounds (salts) in the lake, consistent with low salinity concentrations. The pH values at Lake Ozzie Cobb were slightly acidic to neutral, ranging from 6.05 to 7.05. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 33.9% of the values recorded being less than 6.5 the lake should be listed as not supporting the FWP beneficial use based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials

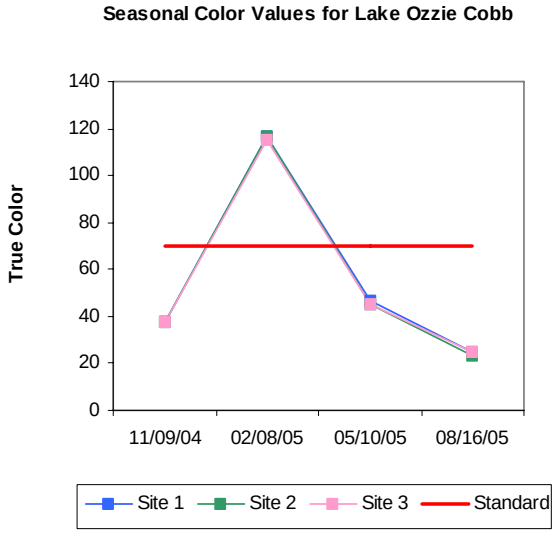
ranged from 266 mV to 487 mV. Reducing conditions were not present at this reservoir in the 2004-2005-sample year. During the fall and winter quarters stratification was not present and dissolved oxygen (D.O.) values were generally above 7 mg/L (see Figure 99c-99d). Thermal stratification was evident in both spring and summer quarters. In the spring, the lake was stratified between 1 and 2 meters however D.O. remained above 2.0 mg/L (Figure 99e). In the summer stratification also occurred between 1 and 2 meters with dissolved oxygen below 2.0 mg/L to the lake bottom of 4 meters, accounting for 40% of the water column experiencing anoxic conditions (Figure 99f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the lake is supporting its FWP beneficial use based on dissolved oxygen values. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

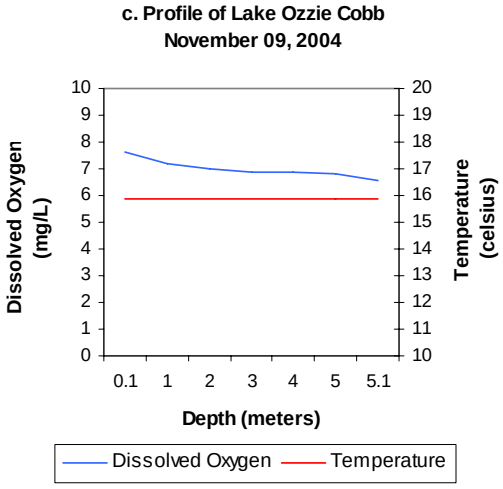
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

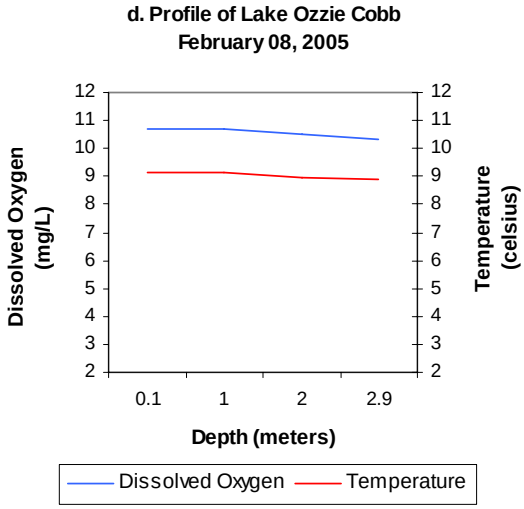
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.50 mg/L at the surface. Surface TN ranged from 0.23 mg/L to 0.84 mg/L, with the highest values reported in the summer and lowest values in the winter. The lake-wide total phosphorus (TP) average was 0.036 mg/L at the surface. Total phosphorus at the surface ranged from 0.028 mg/L to 0.048 mg/L. Similar to TN, surface TP was highest in the summer, however the lowest values were recorded during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 9:1 for sample year 2004-2005. This is slightly higher than 7:1, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

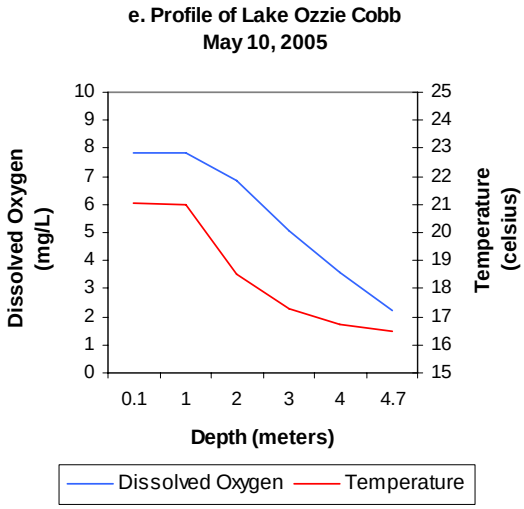
In summary, Lake Ozzie Cobb was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2004-2005. This is similar to the value calculated in 2003, (TSI=54), indicating no significant increase or decrease in productivity has occurred. Lake Ozzie Cobb is listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Water clarity was fair to average based on true color, turbidity and secchi disk depth. The lake is supporting the FWP beneficial use and dissolved oxygen, partially supporting for turbidity, but not supporting due to low pH values reported throughout the year. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial use is considered not supported based on true color with 25% of the recorded values exceeding the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake Ozzie Cobb is owned by the State of Oklahoma and is utilized for recreation.











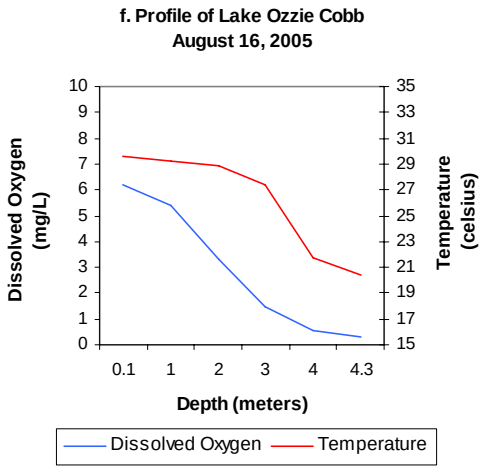
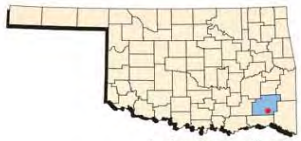


Figure 99a-99f. Graphical representation of data results for Lake Ozzie Cobb.



Lake Data	
Owner	State of Oklahoma
County	Pushmataha
Constructed in	1958
Surface Area	116 acres
Volume	833 acre/feet
Shoreline Length	4 miles
Mean Depth	7.18 feet
Watershed Area	4,378 acres

Plate 82 - Lake Water Quality for
Lake Ozzie Cobb

LAKES MONITORING PROGRAM

Pauls Valley City Lake

Pauls Valley City Lake was sampled for four quarters, from October 2004 through August 2005. Water quality samples were collected at five (5) to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 29 NTU (Plate 83), true color was 58 units, and secchi disk depth was 54 centimeters. Based on these three parameters, Pauls Valley City Lake had average water clarity in sample year 2004-2005. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 49 (Plate 83), indicating the lake was mesotrophic with moderate primary productivity and nutrient conditions. The TSI values throughout the sample year were fairly consistent with values ranging from upper mesotrophic to lower eutrophic at all sites throughout the year. Seasonal turbidity values are displayed in Figure 100a. Turbidity values in the winter, spring and summer seasons were below the turbidity standard of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 50% of the collected values exceeding 25 NTU, the FWP use is considered not supported for turbidity. Seasonal true color values are displayed in Figure 100b. True color values followed the same pattern as turbidity with higher values observed in the winter and spring sampling quarters. Applying the same default protocol, the Aesthetics beneficial use is considered not supported with 50% of samples above the 70-unit standard.

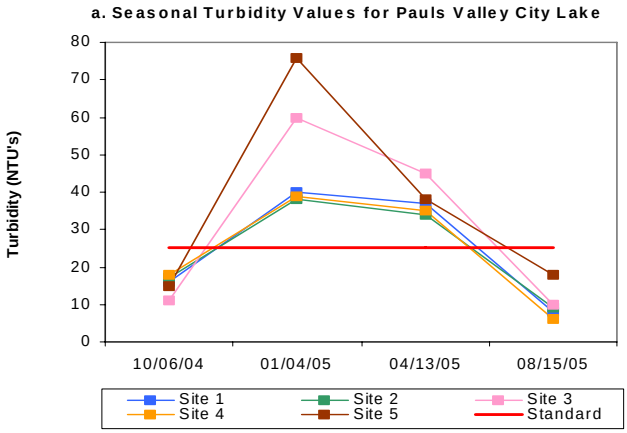
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation- reduction potential, and salinity were recorded at all sample sites. Salinity values for Pauls Valley City Lake ranged from 0.09 parts per thousand (ppt) to 0.15 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductivity ranged from 200.1 to 314.1 cm/cm, indicating the minimal presence of electrical current conducting compounds (salts) in the lake, consistent with salinity concentrations. In general pH values were neutral to slightly alkaline with values ranging from 7.28 to 8.33 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 191 mV to 427 mV, indicating an absence of reducing conditions. During the fall, winter and spring quarters, stratification was not present and lake was well mixed (see Figure 100c-98e). In the spring, the lake was weakly stratified between 4 and 5 meters, however dissolved oxygen (D.O.) remained above 2.0mg/L. In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline (see Figure 100f). In the summer stratification occurred at between 5 and 6 meters with D.O. falling below 2.0 mg/L from 6 meters to the lake bottom of 8 meters, accounting for

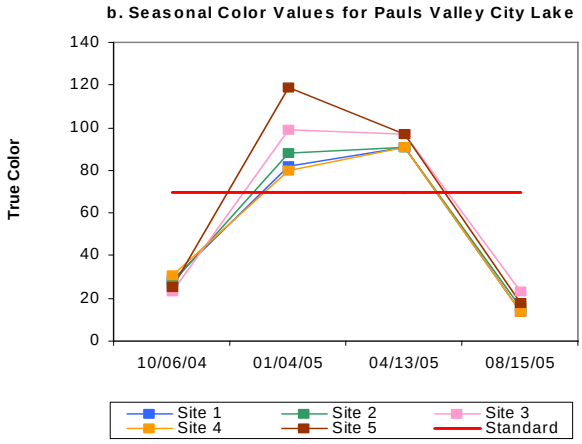
approximately 33% of the water column experiencing anoxic conditions. Sites 2 and 4 were also stratified between 5 and 6 meters with 25% of the water column at both sites below 2.0 mg/L. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Pauls Valley City Lake is supporting its FWP beneficial use based on dissolved oxygen values recorded during the summer sampling interval. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

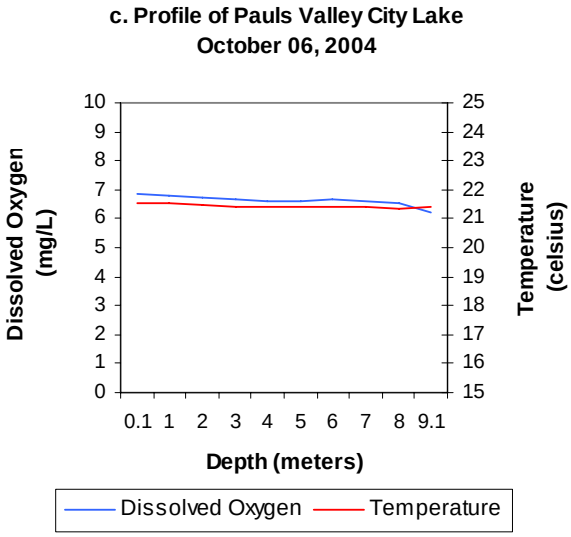
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

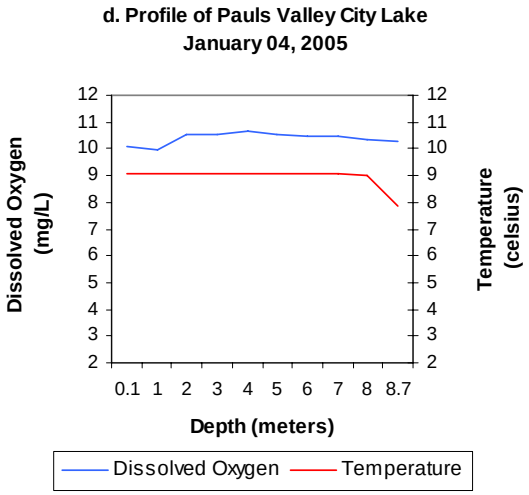
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.57 mg/L at the surface. Surface TN ranged from 0.40 mg/L to 0.85 mg/L, with the highest values reported in the summer and lowest values in the fall. The lake-wide total phosphorus (TP) average was 0.038 mg/L at the surface. Total phosphorus at the surface ranged from 0.022mg/L to 0.073 mg/L. Surface TP was highest in the winter, with the lowest values recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 15:1 for sample year 2004-2005. This is slightly higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

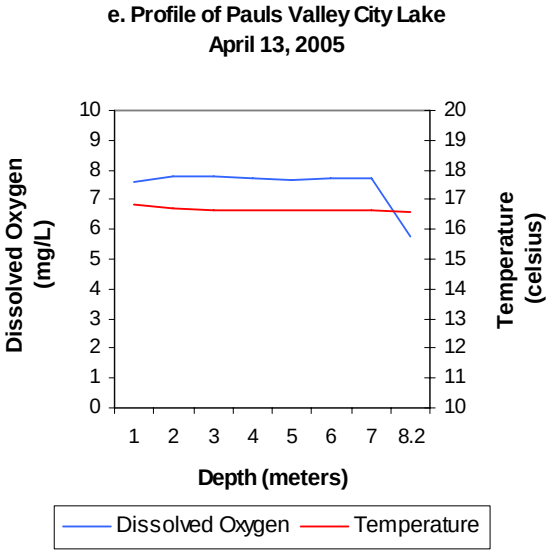
In summary, Pauls Valley City Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions. Water clarity was average based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on pH and dissolved oxygen values but is not supporting the use as it relates to turbidity. The Aesthetic beneficial use is supported based on its trophic status, however the use is not supporting for true color as 50% of the values exceeded the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season, therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Pauls Valley City Lake is located in Garvin County and serves as a water supply and recreational reservoir for the city.











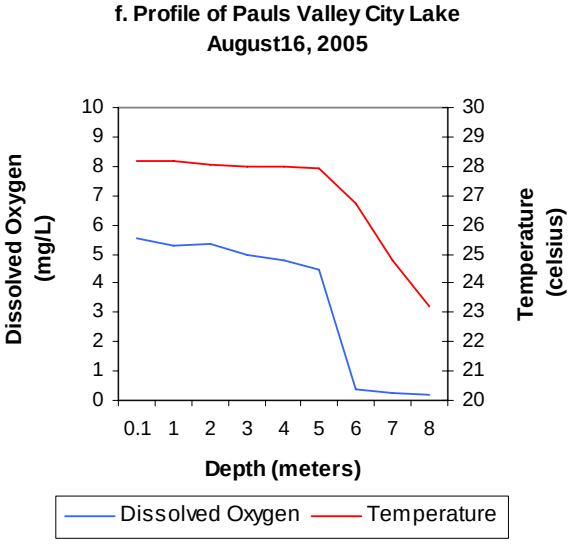


Figure 100a-98f. Graphical representation of data results for Pauls Valley City Lake.

Plate 83 - Lake Water Quality for
Pauls Valley Lake

Pauls Valley Lake and Watershed

Pauls Valley Lake Location

Lake Data	
Owner	City of Pauls Valley
County	Garvin
Constructed	1954
Surface Area	750 acres
Volume	8,730 acre/feet
Shoreline Length	8 miles
Mean Depth	11.64 feet
Watershed Area	21 square miles

Lake Pawhuska

Lake Pawhuska was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 2 NTU (Plate 84), true color was 10 units, and secchi disk depth was 274 centimeters. Based on these three parameters, Lake Pawhuska had excellent water clarity in sample year 2004-2005, consistent with data reported in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 39 (Plate 84), indicating the lake was oligotrophic with low primary productivity and nutrient levels in sample year 2005 (Plate 73). The TSI values throughout the sample year were fairly consistent with values ranging from mesotrophic at all sites in the fall and winter to oligotrophic in the spring and summer. Seasonal turbidity values per site are displayed in Figure 101a. Turbidity values throughout the year were all well below the turbidity standard of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is considered supported based on turbidity. Seasonal true color values are displayed in Figure 101b. True color values followed the same pattern as turbidity with all reported values well below the standard of 70 units, therefore the Aesthetics beneficial use is considered fully supported based on true color.

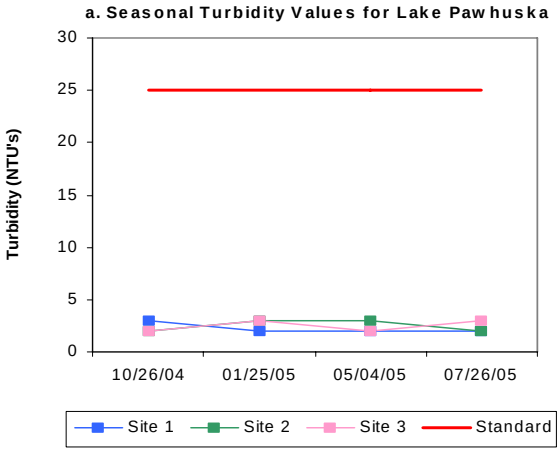
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.17 parts per thousand (ppt) to 0.22 ppt, which is within the average range of values reported in most Oklahoma reservoirs. Specific conductivity ranged from 338.4 µS/cm to 441.4 µS/cm, indicating the moderate presence of electrical current conducting compounds (salts) in the lake, consistent with salinity concentrations. The pH values were neutral to slightly alkaline with values ranging from 7.09 to 8.24 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. The ORP ranged from 125 mV to 440 mV, indicating an absence of reducing conditions during the study period. During the fall, and spring winter quarters, stratification was not present and lake was well mixed (see Figure 101c-99e). In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline. In the summer stratification occurred at several 1-meter intervals with D.O. falling below 2.0 mg/L from 7 meters to the lake bottom of 10.9 meters, accounting for approximately 27.3% of the water column at sites 1 and 2 to be experiencing anoxic conditions (Figure 101f). If

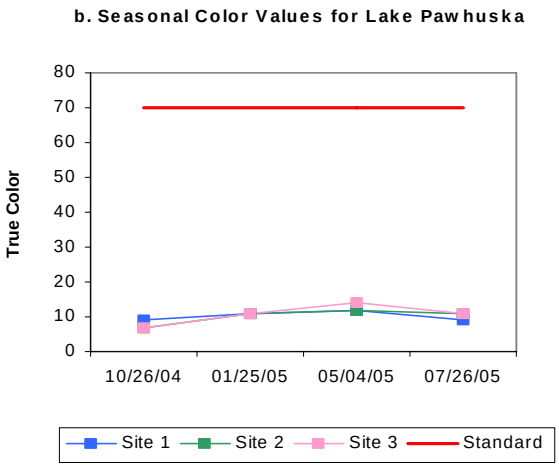
D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 27.3% of the water column below 2.0 mg/L the FWP beneficial use is considered partially supported based on dissolved oxygen values. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

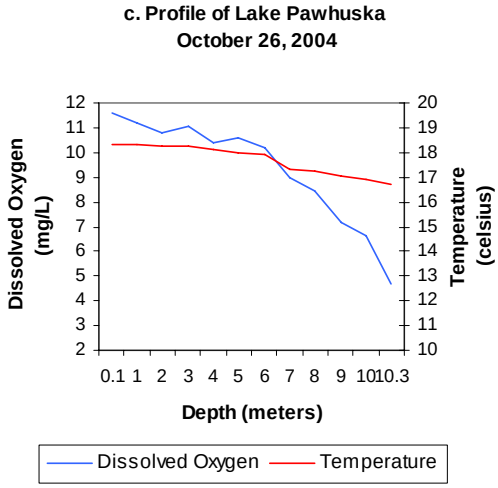
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

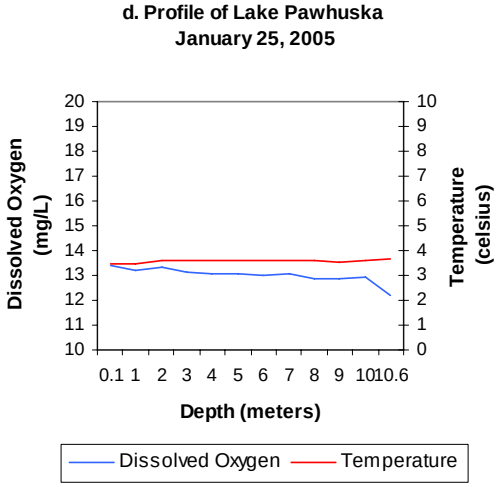
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.22 mg/L at the surface. Surface TN ranged from 0.13 mg/L to 0.51 mg/L, with the highest values reported in the summer and lowest values in the winter quarter. The lake-wide total phosphorus (TP) average was 0.013 mg/L at the surface. Total phosphorus at the surface ranged from 0.011mg/L to 0.017 mg/L. Surface TP was highest in the winter, and the lowest values were recorded during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 17:1 for sample year 2004-2005. This is slightly higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

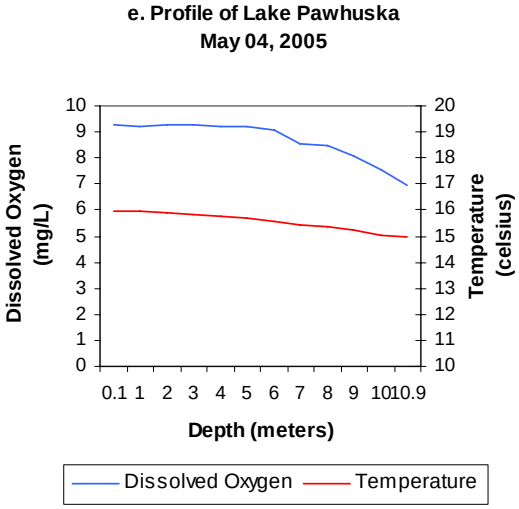
In summary, Lake Pawhuska was classified as oligotrophic, indicative of low primary productivity and nutrient conditions (Plate 84). Water clarity continues to be excellent based on true color, turbidity and the high secchi disk depths. The lake is supporting the FWP beneficial use based on turbidity and pH values collected during the study period. Although 27.3% of the water column was anoxic during the summer, the FWP beneficial use is considered supported based on low D.O. values in the summer. The Aesthetics beneficial use is fully supported as it relates to trophic status and true color. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake Pawhuska was constructed in 1936 and for the purpose of water supply and recreation. The lake is located in Osage County and is one of the nicer small lakes in the state.











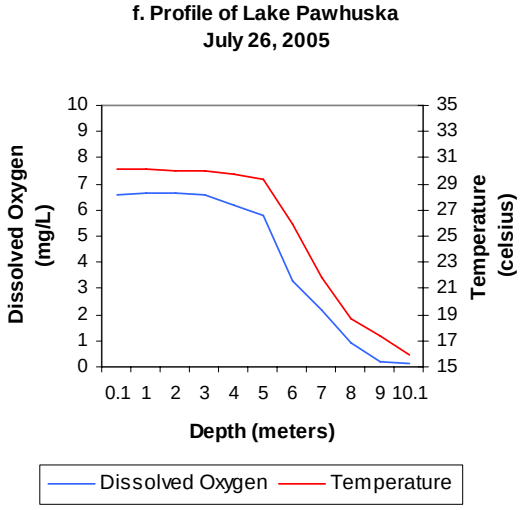
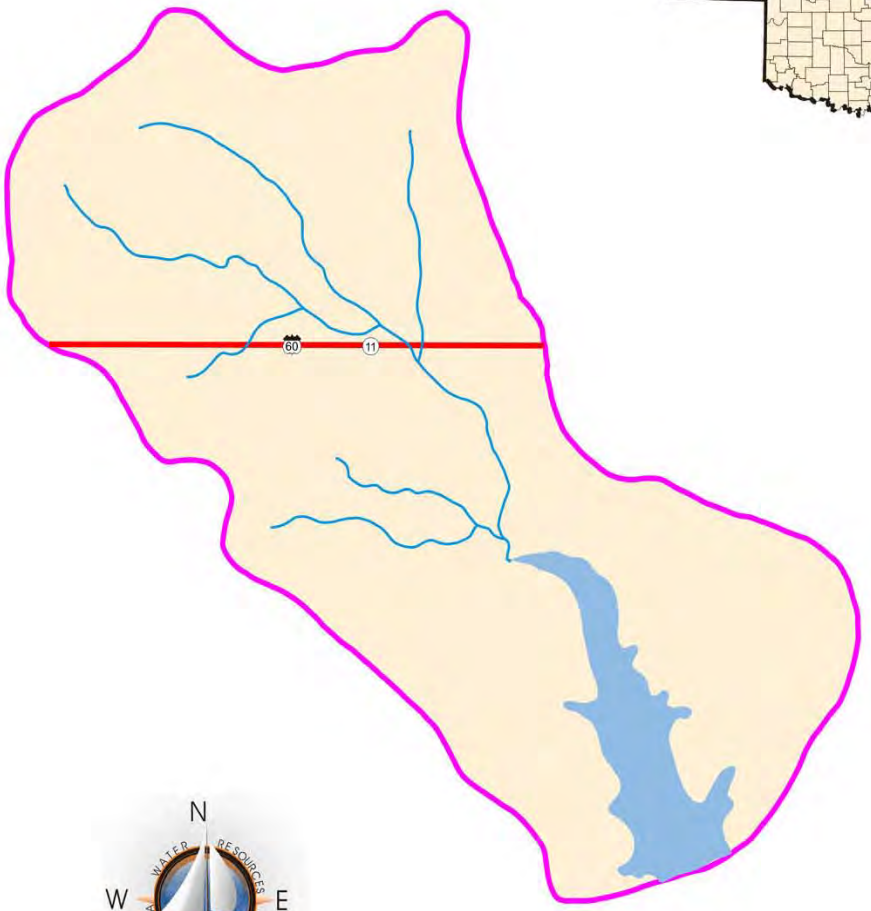
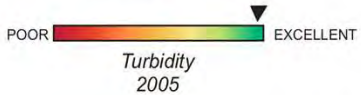


Figure 101a-101f. Graphical representation of data results for Lake Pawhuska.



Lake Pawhuska
and
Watershed

Trophic State
2005



Turbidity
2005

Lake Data	
Owner	City of Pawhuska
County	Osage
Constructed in	1936
Surface Area	96 acres
Volume	3,600 acre/feet
Shoreline Length	3 miles
Mean Depth	37.50 feet
Watershed Area	1754 acres

Plate 84 - Lake Water Quality for
Lake Pawhuska

LAKES MONITORING PROGRAM

Pawnee Lake

Pawnee Lake was sampled for four quarters, from October 2003 through June 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites with an additional sample taken at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 20 NTU (Plate 85), true color was 35 units, and secchi disk depth was 73 centimeters. Based on these three parameters, Pawnee Lake had average water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=19). The TSI was 51 (Plate 85), indicating the lake was eutrophic with high levels of primary productivity and nutrients. This is close to the value calculated in 2002 (TSI=55) indicating no significant increase or decrease in productivity occurred over time. The TSI values throughout the sample year varied seasonally from eutrophic in the fall quarter, to mesotrophic in the winter quarter and to upper eutrophy in summer quarter. In the spring quarter sites 1 and 5 were mesotrophic while the other three sites were in the oligotrophic category. Turbidity readings ranged from a low of 8 NTU to a high of 56 NTU (see Figure 102a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Pawnee Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 102b. True color values were generally below the aesthetics WQS of 70 units at all times with the exception of the spring quarter (see Figure 102b). Similar to turbidity a peak in true color occurred in the spring quarter and is likely the result of seasonal storm events and therefore the Aesthetics beneficial will be considered supported at Pawnee Lake.

In 2003-2004, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.10 parts per thousand (ppt) to 0.17 ppt, indicating moderate salt content in the lake system. Values were slightly higher than the expected range of salinity readings reported for most Oklahoma lakes. Readings for specific conductivity were also within the range of expected values, ranging from 212.7 µS/cm to 337.5 µS/cm, also indicative of moderate amounts of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly alkaline with values ranging from 6.97 units in the fall quarter to 8.33 units in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all values within the acceptable range the lake is fully supporting its FWP beneficial use as it relates to pH. Oxidation-reduction potentials (redox) ranged from 338 mV in the summer quarter to 674 mV in the fall quarter, indicating an absence of reducing

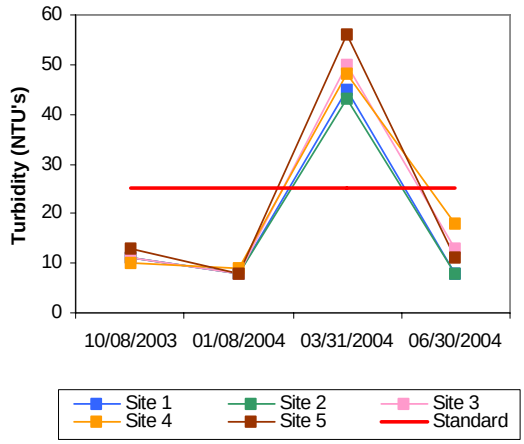
conditions in the lake at the time it was sampled. Pawnee Lake was not thermally stratified in the fall or winter or spring quarters and dissolved oxygen (D.O.) values were above 6.0 mg/L throughout the water column in all three seasons (see Figure 102c-100). In the summer, the lake was weakly thermally stratified, and anoxic conditions were also present at site 1(see Figure 102f). Although this lake is fairly shallow (about 7 meters deep), about 44% of the water column was anoxic. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Pawnee Lake with only 44% of the water column less than 2.0 mg/L in the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected two (20%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

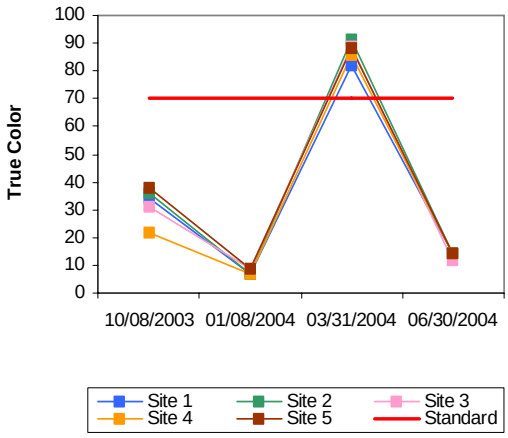
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.73 mg/L at the lake surface. The TN at the surface ranged from 0.55 mg/L to 1.06 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average was 0.040 mg/L at the lake surface. The surface TP ranged from 0.020 mg/L to 0.092 mg/L. Similar to total nitrogen, the highest surface TP value was reported in the spring quarter and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 18:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Pawnee Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 85). This is similar to the value calculated in 2002 (TSI=55) indicating no significant increase or decrease in productivity occurred over time. Water clarity is average based on true color, turbidity and secchi disk depth. The lake was fully supporting its Aesthetics beneficial use based on trophic status. Although 25% of the true color values were exceeding the WQS of 70 units, the peak in the spring quarter is likely the result of seasonal storm events, therefore the Aesthetics beneficial will be considered supported at Pawnee Lake. Pawnee was fully supporting its FWP beneficial use based on pH, and D.O. readings recorded during the study period. Available flow and rainfall data suggest that the peak in turbidity, which occurred in March is likely due to seasonal storm events, therefore Pawnee Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected two (20%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Pawnee Lake was constructed in 1932 and is owned and operated by the City of Pawnee. The lake is managed as a municipal water supply and offers numerous recreational opportunities to the public.

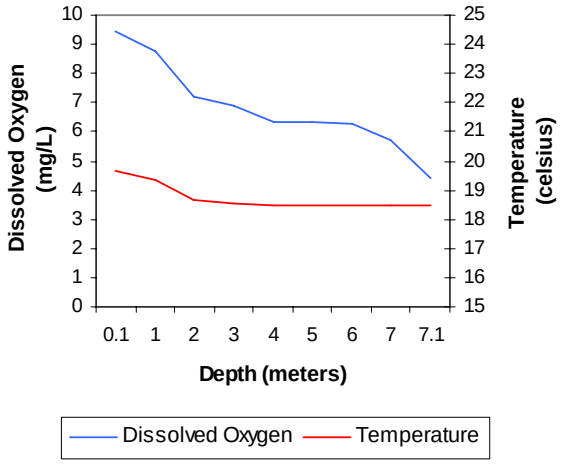
a. Seasonal Turbidity Values for Pawnee Lake



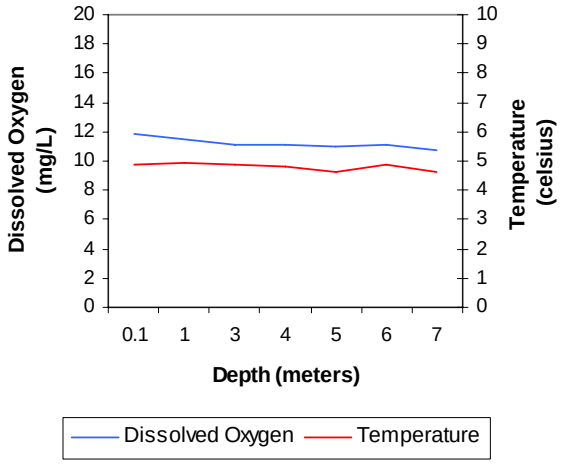
b. Seasonal Color Values for Pawnee Lake



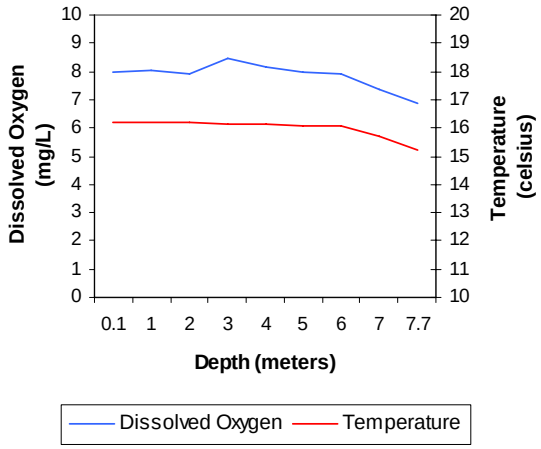
c. Profile of Pawnee Lake
October 08, 2003



d. Profile of Pawnee Lake
January 07, 2004



e. Profile of Pawnee Lake
March 30, 2004



f. Profile of Pawnee Lake
June 30, 2004

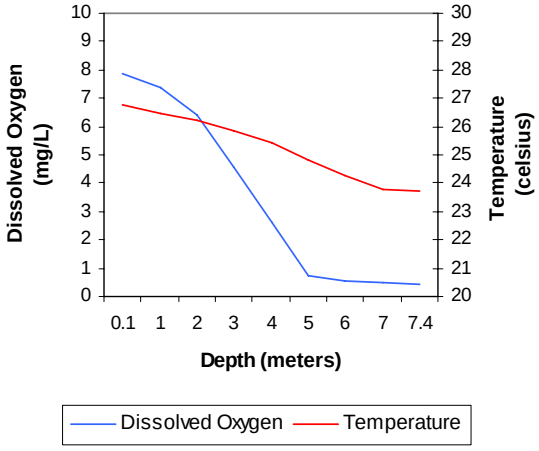


Figure 102a-102f. Graphical representation of data results for Pawnee Lake.

Pawnee Lake and Watershed

Pawnee Lake Location

Lake Data	
Owner	City of Pawnee
County	Pawnee
Constructed in	1932
Surface Area	257 acres
Volume	3,855 acre/feet
Shoreline Length	4 miles
Mean Depth	15.00 feet
Watershed Area	13 square miles

Turbidity 2004

Trophic State 2004

Plate 85 - Lake Water Quality for
Pawnee Lake

LAKES MONITORING PROGRAM

Perry Lake

Perry Lake was sampled for four quarters, from November 2004 through August 2005. Water quality samples were collected from five (5) sites to represent the riverine, transition and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 50 NTU (Plate 86), true color was 107 units, and average secchi disk depth was 35 centimeters. Based on these three parameters, Perry Lake had poor water clarity. These results are similar to those in 2003 indicating no significant change has occurred over time. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 44 (Plate 86) indicating the lake was mesotrophic in sample year 2004-2005 with moderate levels of primary productivity and nutrient levels. This value is similar to the TSI calculated in 2003 (TSI=42), and is in the same trophic category, indicating no significant change in productivity has occurred since the last time sampled. The TSI values throughout the sample year were fairly consistent ranging from oligotrophic in the fall and winter to mesotrophic in the spring and summer. The only exception to this was site 5, which had a low chlorophyll-a value reported in the spring place placing the site in the oligotrophic category. Seasonal turbidity values are displayed in Figure 103a. Turbidity ranged from a low of 24 NTU to a maximum of 107 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. The average lake-wide turbidity of 70 NTU seems representative of conditions at Perry Lake and is consistent with historical findings for this lake. With 95% of the collected values exceeding the standard of 25 NTU, the Fish and Wildlife Propagation (FWP) beneficial use is considered not supported. Seasonal true color values are displayed in Figure 103b. Of the 20 values collected, 15 (75%) were greater than the WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered not supported.

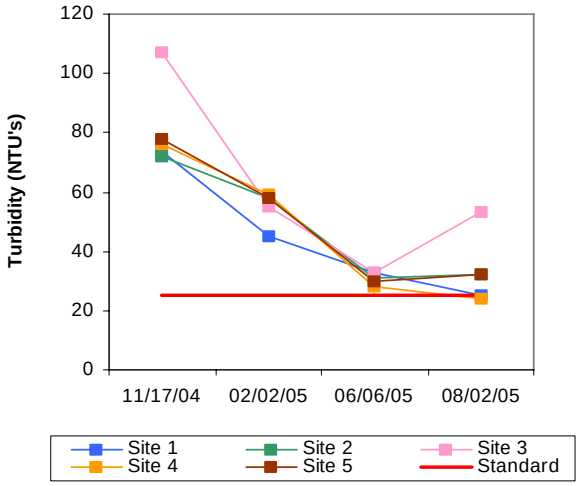
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at sample sites during the study period. The salinity values ranged from 0.15 parts per thousand (ppt) to 0.21 ppt, which is within the average range of values for most Oklahoma reservoirs. Specific conductivity ranged from 304.4 µS/cm to 421.2 µS/cm indicating low to moderate concentrations of electrical current conducting materials (salts & chlorides) were present in the lake. These values are also within the range commonly seen in Oklahoma reservoirs and are consistent with recorded salinity values. The pH values were neutral to slightly alkaline ranging from 7.12 to 8.09. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the recorded values with the acceptable range, the FWP use is supported based on pH. Oxidation-reduction potentials (ORP) ranged

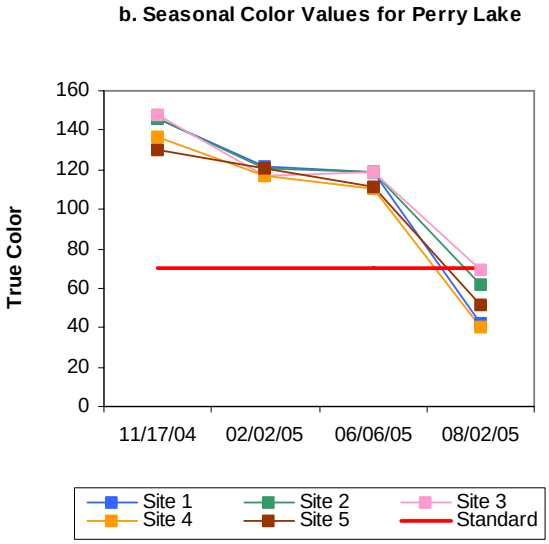
from 256 mV in the winter to 485 mV in the summer, indicating reducing conditions were not present in sample year 2004-2005. Stratification was not evident in any of the first two sampling intervals and the lake was well mixed with dissolved oxygen (D.O.) remaining above 7.0 mg/L (Figure 103c-103d). In both spring and summer quarters, the lake exhibited weak thermal stratification; however anoxic conditions were not present below the thermocline (see Figure 103e-101f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP is considered supported as it relates to dissolved oxygen with D.O. remaining above 2.0 mg/L during the study period. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

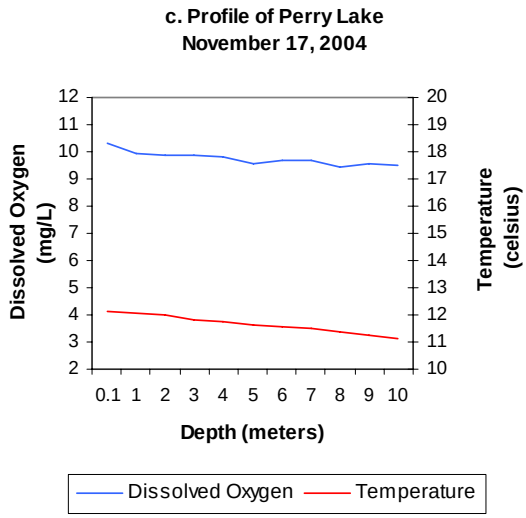
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

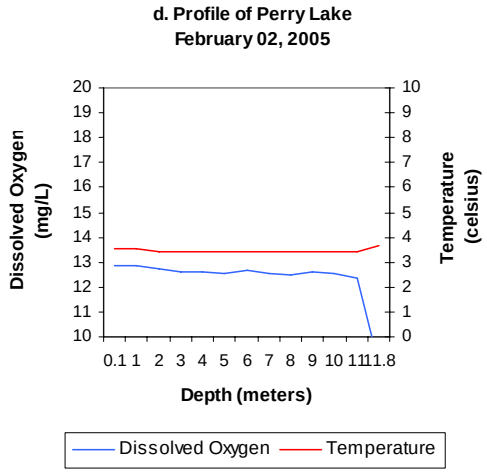
Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical WQS for these parameters. The lake-wide total nitrogen (TN) average was 0.65 mg/L at the surface. Surface TN ranged from 0.41 mg/L to 0.87 mg/L, with the highest values reported in the winter and lowest values in the summer quarter. The lake-wide total phosphorus (TP) average was 0.072 mg/L at the surface. Total phosphorus at the surface ranged from 0.041mg/L to 0.097 mg/L. Surface TP was highest in the fall, and the lowest values were recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 9:1 for sample year 2004-2005. This is slightly higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

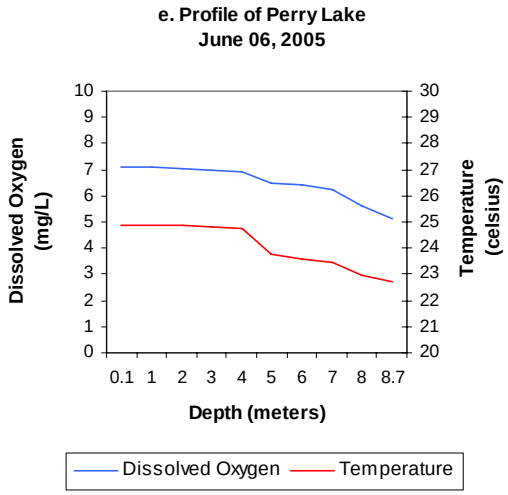
In summary, Perry Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions (Plate 86). The current trophic status is the same as that calculated in 2003, indicating little or no change in productivity has occurred. Water clarity is poor based on true color, turbidity and secchi depth and is likely to always be poor based on soil composition of the area. The FWP beneficial use is supported based on pH and dissolved oxygen and not supported based on high turbidity values. The Aesthetics beneficial use is supported based on trophic status, however the use not supported based on true color with 75% of the values exceeding the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Perry Lake, located in Noble County, was constructed for the purpose of flood control, water supply, and recreation.











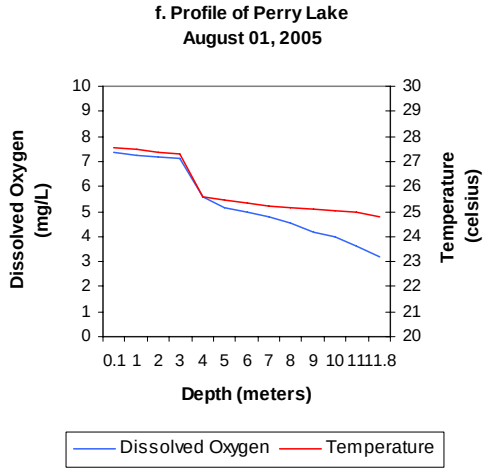
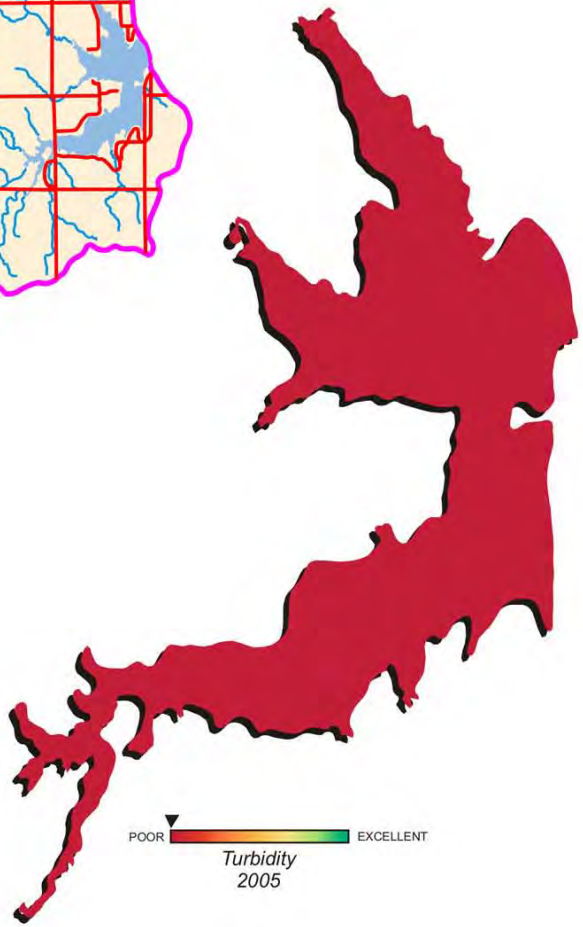


Figure 103a-103f. Graphical representation of data results for Perry Lake.



Lake Data	
Owner	City of Perry
County	Noble
Constructed in	1937
Surface Area	614 acres
Volume	6,892 acre/feet
Shoreline Length	11 miles
Mean Depth	11.22 feet
Watershed Area	16 square miles

Plate 86 - Lake Water Quality for
Perry Lake

LAKES MONITORING PROGRAM

Pine Creek Lake

Pine Creek Lake was sampled for four quarters from October 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as major lake arms and tributaries. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at site 1,near the dam. The lake-wide annual turbidity value was 13 NTU (Plate 87), true color was 26 units, and secchi disk depth was 89 centimeters. Results for true color and secchi disk depth were better than that observed in 2001-2002. Based on these three parameters, Pine Creek Lake had good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 54 (Plate 87), indicating the lake was eutrophic in nature with high levels of primary productivity and nutrients. This is identical to the value calculated in 2002 (TSI=54), indicating no significant increase or decrease in productivity has occurred. The TSI values throughout the sample year were predominantly eutrophic with only the winter quarter experiencing mesotrophic and oligotrophic conditions. This same pattern occurred in the 2001-2002 evaluation. Turbidity values in the fall, spring and summer seasons were below the Oklahoma Water Quality Standard (WQS) for turbidity of 25 NTU (see Figure 104a). There was a spike in turbidity in the winter quarter, possibly due to seasonal rain events, at which point values were at or above the standard at sites 3,4 and 5. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 10% of the collected values exceeding the criteria, the lake is partially supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 104b. True color values varied seasonally and with 100% of the sample values below the WQS of 70 units the lake is fully supporting its Aesthetics beneficial use for true color (see Figure 104b).

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.0 parts per thousand (ppt) to 0.02 ppt, well within the expected range of salinity values if not less than reported values for most Oklahoma lakes. Readings for specific conductivity were also lower than the expected range for most Oklahoma lakes, ranging from 0.0 µS/cm to 66.5 µS/cm, indicating the presence of little or no electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to slightly acidic with values ranging from 5.73 units in the summer quarter to 7.56 also in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 56% of the values recorded as less than 6.5 units Pine Creek Lake is not supporting the FWP as it relates to pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of

soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (redox) ranged from 323 mV in the summer quarter to 524 mV recorded at the lake surface in the winter quarter. Reducing conditions were not present during the study period. Pine Creek Lake was not thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) readings were above 3.0 mg/L (see Figure 104c-104d). The lake was weakly thermally stratified in the spring quarter between 12 and 13 meters below the lake surface at site 1; however, D.O. readings remained above 2.0 mg/L until very near the lake bottom at 17.1 meters (see Figure 104e). In the summer, the lake was strongly thermally stratified at several 1-meter intervals among all five sites with the first occurring between 2 and 3 meters below the surface. Dissolved oxygen was below 2.0 mg/L from 4 meters in depth to the lake bottom at 14 meters at site 1, the dam (see Figure 104f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. In the summer quarter 73% of the water column at site 1 was experiencing anoxic conditions, which is cause for classifying the lake as not supporting its FWP beneficial use based on D.O. concentrations in the water column. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling found the Agriculture beneficial use to be fully supported based on criteria in OAC 785:45 – Appendix F.

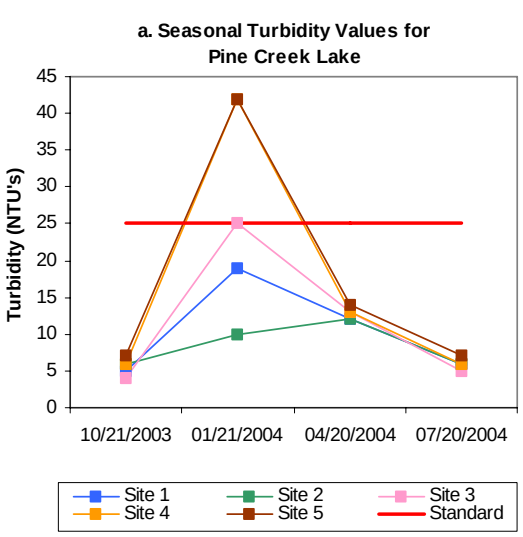
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml for enterococci, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

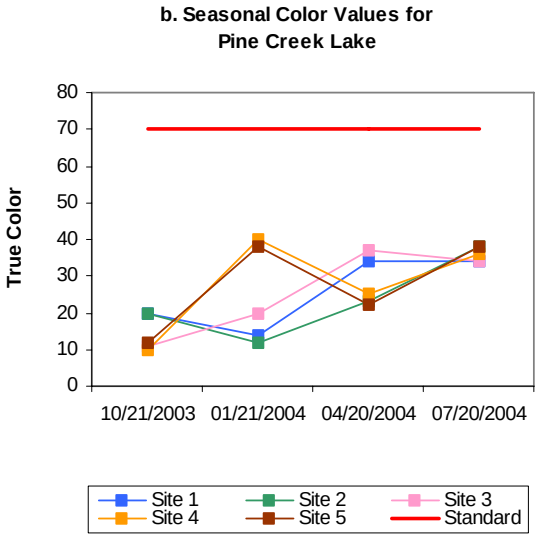
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.61 mg/L at the lake surface. The TN at the surface ranged from 0.10 mg/L to 2.16 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.025 mg/L at the lake surface. The surface TP ranged from 0.015 mg/L to 0.38 mg/L. The highest surface TP value was reported in the winter quarter and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 25:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

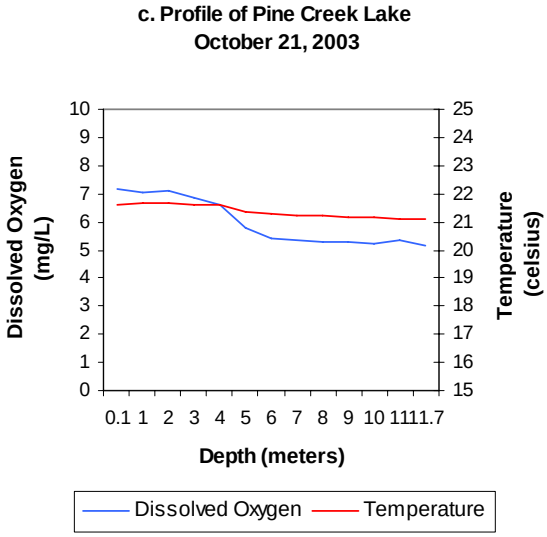
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2000 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

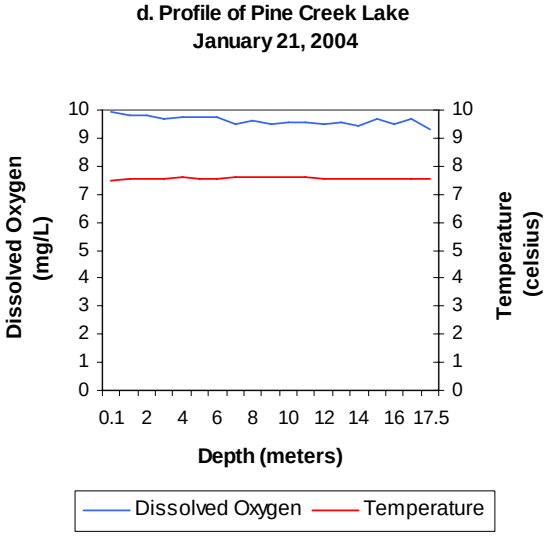
In summary, Pine Creek Lake was classified as eutrophic, indicating high primary productivity and nutrient levels (Plate 87). This is similar to the value calculated in 2002 (TSI=54), indicating no significant increase or decrease in productivity has occurred. Based on true color, turbidity and secchi disk depth, Pine Creek Lake had good water clarity in 2003-2004. The lake is fully supporting its Aesthetics beneficial use based on its trophic status and true color values recorded during the study period. The lake was partially supporting its FWP beneficial use based on nephelometric turbidity and not supporting for D.O. due to anoxic conditions present in 73% of the water column in the summer. With 56% of the pH values less than 6.5 the FWP

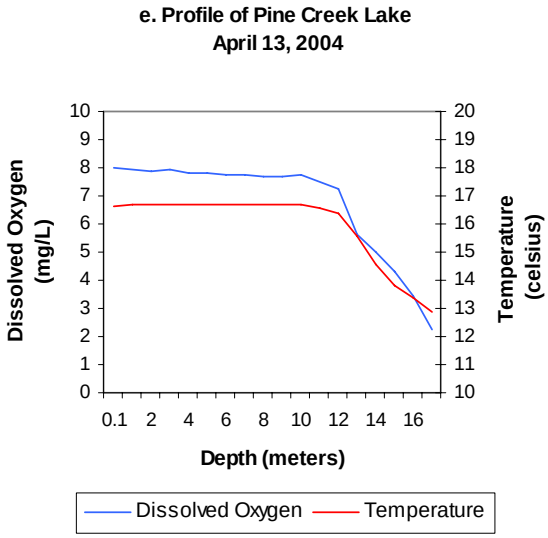
beneficial use is not supported based on collected pH values. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected one (10%) exceeded the prescribed screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Pine Creek Lake, was constructed in 1969 by the United States Army Corps of Engineers for multiple purposes including, flood control, municipal water supply, fish & wildlife, and general recreation.











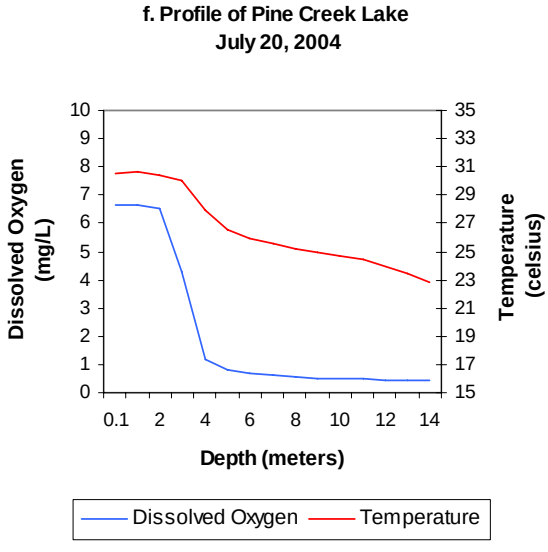


Figure 104a-104f. Graphical representation of data results for Pine Creek Lake.

Pine Creek Lake and Watershed

Pine Creek Lake Location

Lake Data	
Constructed by	Corps of Engineers
County	McCurtain
Constructed in	1969
Surface Area	3,750 acres
Volume	53,750 acre/feet
Shoreline Length	74 miles
Mean Depth	14.2 feet
Watershed Area	635 square miles

POOR — EXCELLENT

Turbidity 2004

POOR — EXCELLENT

Trophic State 2004

Plate 87 - Lake Water Quality for
Pine Creek Lake

LAKES MONITORING PROGRAM

Lake Ponca

Lake Ponca was sampled for four quarters, from November 2004 through August 2005. Water quality samples were collected from five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 10 NTU (Plate 88), true color was 21 units and average secchi disk depth was 90 centimeters. Based on these three parameters, Lake Ponca had good water clarity. These values are similar to if not better than those reported in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 52 (Plate 88), indicating the lake was eutrophic with high levels of primary productivity and nutrient levels. This value is similar to that from 2003 (TSI=54), indicating no significant change in productivity has occurred since the last evaluation. Seasonal TSI values varied by site and season and spanned three trophic categories in sample year 2005. In the fall, spring, and summer sampling quarters values were generally eutrophic. In the fall, values ranged from oligotrophic at site 4 to mesotrophic at sites 1 and 2, and eutrophic at sites 3 and 5. Seasonal turbidity values per site are displayed in Figure 105a. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. All turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU, therefore meeting the Fish and Wildlife (FWP) beneficial use. Seasonal true color values are displayed in Figure 105b. True color values ranged from a low of 12 to a maximum of 34 during the sample year. Applying the same default protocol, the Aesthetics beneficial use is considered fully supported with 100% of the reported values well below the WQS of 70 units.

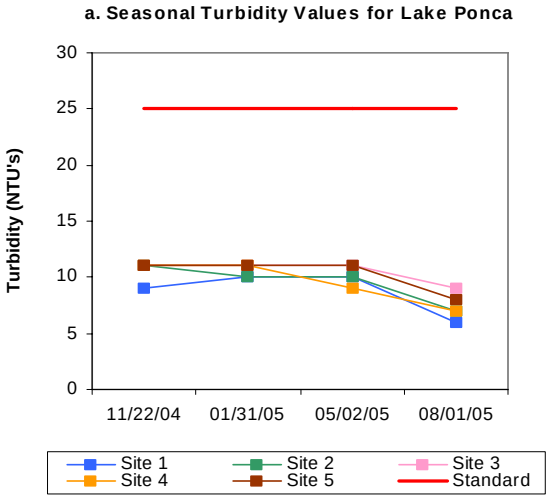
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.15 parts per thousand (ppt) to 0.21 ppt, which is within the average range of values, reported in most Oklahoma reservoirs. Specific conductivity ranged from 291 to 414.8 µS/cm, indicating low to moderate concentrations of electrical current conducting compounds (salts & chlorides) in the lake, consistent with salinity concentrations. The pH values were neutral to slightly alkaline with values ranging from 7.07 in the summer to 8.31 also recorded in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 54 mV in the hypolimnion in the summer to 414 mV in the spring. Reducing conditions were present during the summer interval when anoxic conditions were present in a large portion of the water column. During the fall or winter stratification was not present and lake was well mixed with dissolved oxygen generally above 7.0 mg/L (see Figure 105c-105d). Although the lake exhibited weak thermal stratification in the

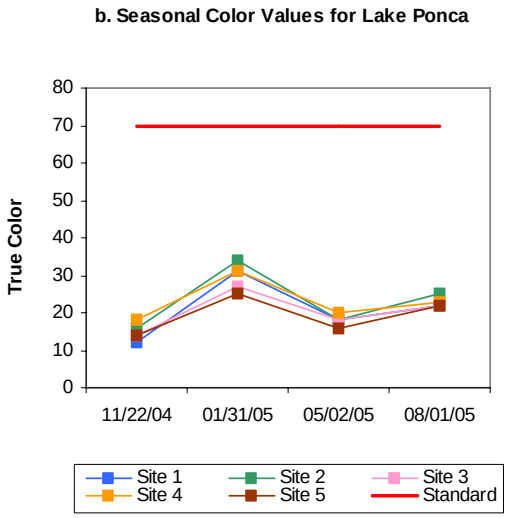
spring, the dissolved oxygen was generally above 4.0 mg/L throughout the water column (Figure 105e). In the summer stratification occurred at several 1-meter intervals with dissolved oxygen (D.O.) falling below 2.0 mg/L between 4 and 5 meters throughout the lake, accounting for 55 to 65% of the water column to be experiencing anoxic conditions. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported based anoxic conditions present at 4 of the 5 sites within the lake. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

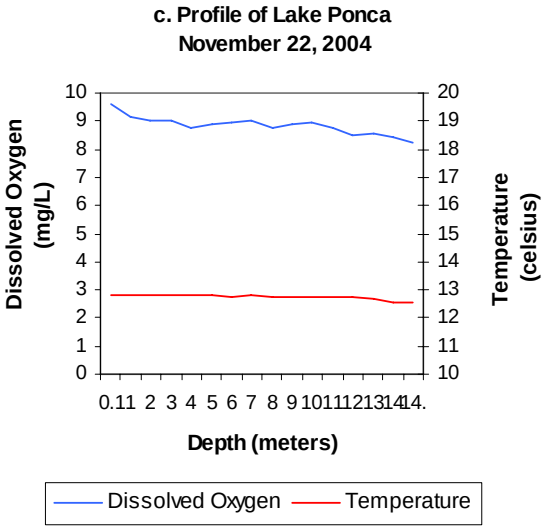
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

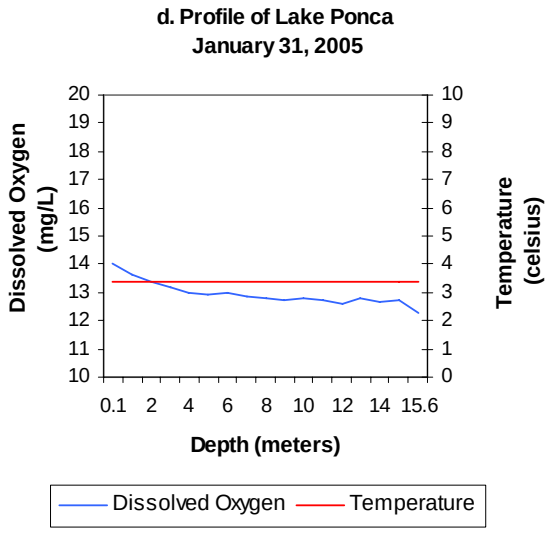
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.72 mg/L at the surface. Surface TN ranged from 0.13 mg/L to 1.24 mg/L, with the highest values reported in the summer and lowest values in the spring quarter. The lake-wide total phosphorus (TP) average was 0.034 mg/L at the surface. Total phosphorus at the surface ranged from 0.025mg/L to 0.052 mg/L. Surface TP was highest in the winter, and the lowest values were recorded during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 21:1 for sample year 2004-2005. This is slightly higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

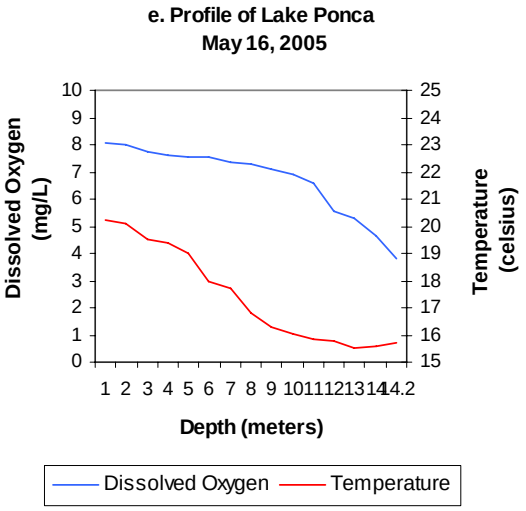
In summary, Lake Ponca was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2004-2005. This is consistent with the 2003 evaluation indicating no significant change in productivity has occurred. Based on true color, turbidity, and secchi disk depth, Lake Ponca had good water clarity in comparison to other Oklahoma lakes. The lake is supporting the FWP beneficial use based on turbidity and pH, and partially supporting based on low dissolved oxygen and anoxic conditions present in the summer quarter. The Aesthetics beneficial use is supported based on its trophic status and low true color values reported during the sample year. All color values were well below the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season, therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake Ponca is a water supply and recreational reservoir for the city of Ponca City.











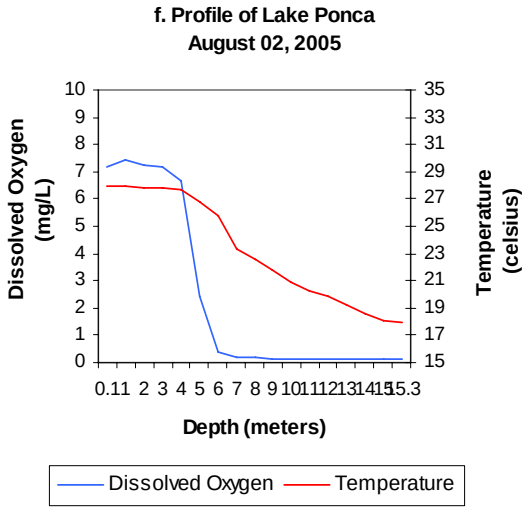
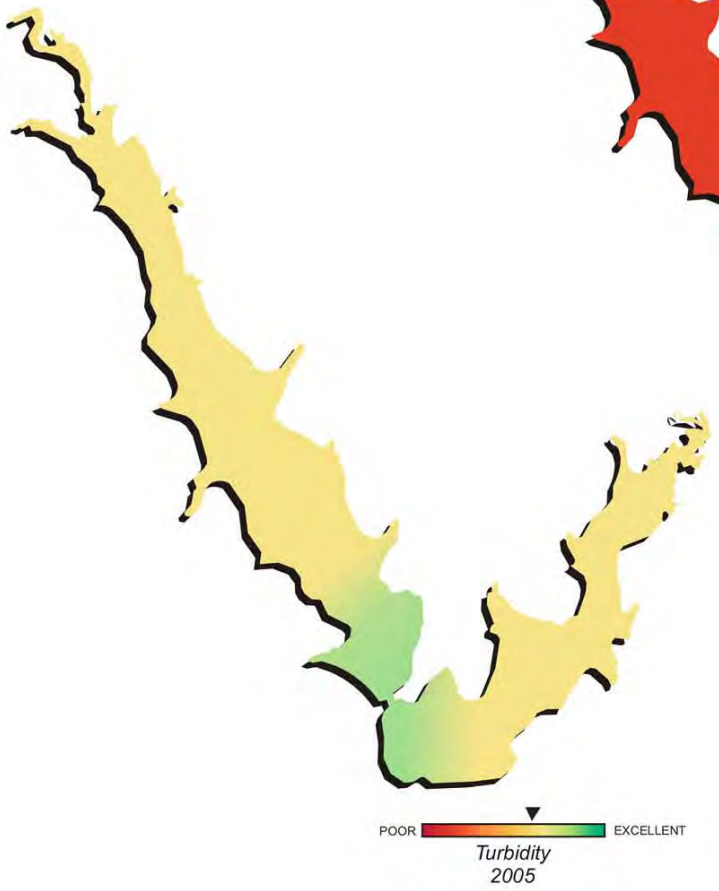


Figure 105a-105f. Graphical representation of data results for Lake Ponca.

Lake Ponca
and
Watershed

Lake Data	
Owner	City of Ponca City
County	Kay
Constructed in	1935
Surface Area	805 acres
Volume	14,440 acre/feet
Shoreline Length	16 miles
Mean Depth	17.94 feet
Watershed Area	28 square miles

Trophic State
2005



Turbidity
2005

Plate 88 - Lake Water Quality for
Lake Ponca

LAKES MONITORING PROGRAM

Prague City Lake

Prague City Lake was sampled for four quarters, from November 2004 through August 2005. Water quality samples were collected from three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 7 NTU (Plate 89), true color was 20 units and average secchi disk depth was 92 centimeters. Based on these three parameters, Prague City Lake had good water clarity in 2005. These values are similar to those in 2003, indicating no significant change in clarity has occurred over time. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 45 (Plate 89), indicating the lake was mesotrophic indicative of moderate levels of primary productivity and nutrient levels. This value is similar to that from 2003 (TSI=43), indicating no significant change in productivity has occurred since the last evaluation. Seasonal TSI values were fairly consistent with oligotrophic conditions in the spring and mesotrophic conditions in the fall, winter and summer sampling intervals. Seasonal turbidity values per site are displayed in Figure 106a. Turbidity ranged from a low of 4 NTU to a maximum of 16 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the turbidity values below the Oklahoma Water Quality Standard (WQS) of 25 NTU, the lake is meeting the Fish and Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 106b. Similar to turbidity, 100% of the collected values were well below the WQS of 70 units; therefore the lake is considered supporting the Aesthetics beneficial use.

In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.18 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductivity ranged from 227.8 to 359.4 µS/cm, indicating low concentrations of electrical current conducting compounds (salts) in the lake, consistent with salinity concentrations. The pH values were neutral to slightly alkaline with values ranging from 7.49 to 8.46 According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 211 mV in the hypolimnion in the fall to 537 mV in the winter, indicating the absence of reducing conditions. In the fall quarter the lake was weakly stratified with dissolved oxygen (D.O.) less than 2.0 mg/L from 6 meters to the lake bottom of 7.4 meters, accounting for approximately 22% of the water column at site 1 to be anoxic (see Figure 106c). The lake was not thermally stratified in the winter or spring quarters with dissolved oxygen (D.O) above 8.0 mg/L (Figure 106d-106e). During the summer sampling interval, thermal stratification was evident and

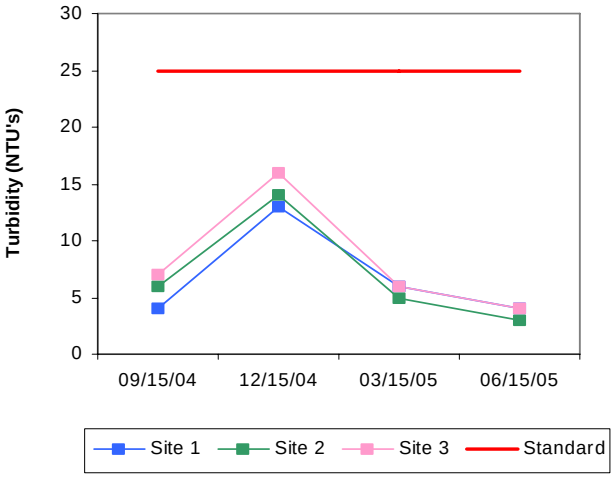
anoxic conditions present. Stratification occurred between 2 and 3 meters with dissolved oxygen falling below 2.0 mg/L to the lake bottom of 7.3 meters. This accounted for approximately 44% of the water column at site 1 being anoxic (Figure 106f). If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered supported at Prague City Lake with anoxic conditions present in 44% water column during summer sampling. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.42mg/L at the surface. Surface TN ranged from 0.33 mg/L to 0.54 mg/L, with the highest values reported in the fall and lowest values in the summer quarter. The lake-wide total phosphorus (TP) average was 0.019 mg/L at the surface. Total phosphorus at the surface ranged from 0.014mg/L to 0.024 mg/L. Surface TP was highest in the winter, and the lowest values were recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 22:1 for sample year 2004-2005. This is slightly higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

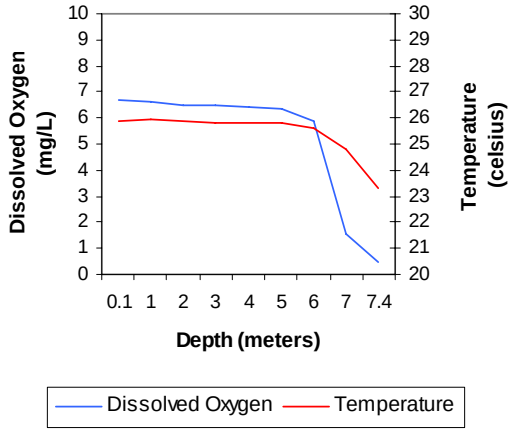
In summary, Prague City Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in 2004-2005. This is consistent with the 2000 evaluation (TSI=43), indicating no significant increase or decrease in productivity has occurred. Water clarity was good based on turbidity, true color, and secchi disk depth. The lake is supporting the FWP beneficial use based on turbidity, pH, and dissolved oxygen values recorded during the study period. The Aesthetics beneficial use is supported by both trophic status and true color. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Prague City Lake was constructed in 1984 for the purpose of flood control, water supply and recreation.

a. Seasonal Turbidity Values for Prague City Lake

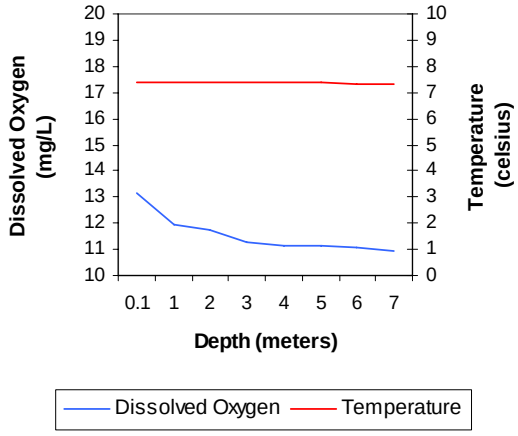


b. Seasonal Color Values for Prague City Lake

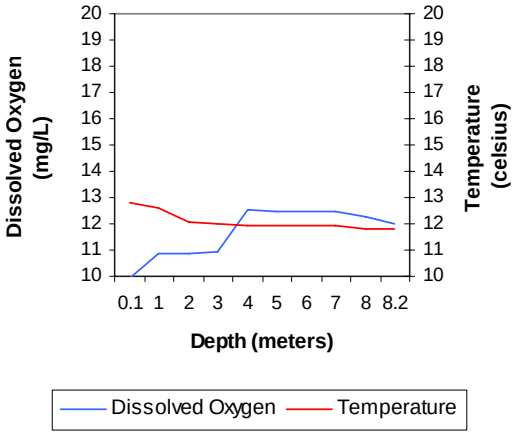
c. Profile of Prague City Lake
September 15, 2004



d. Profile of Prague City Lake
December 15, 2004



e. Profile of Prague City Lake
March 14, 2005



f. Profile of Prague City Lake
June 15, 2005

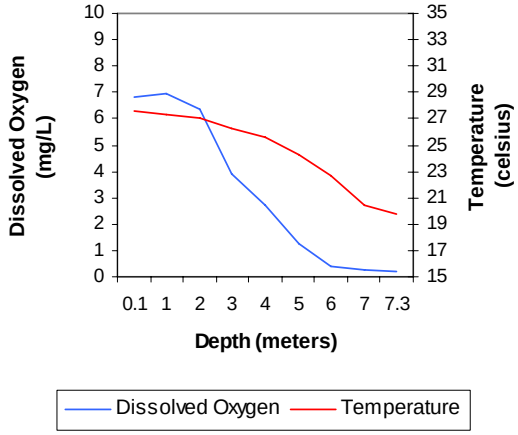
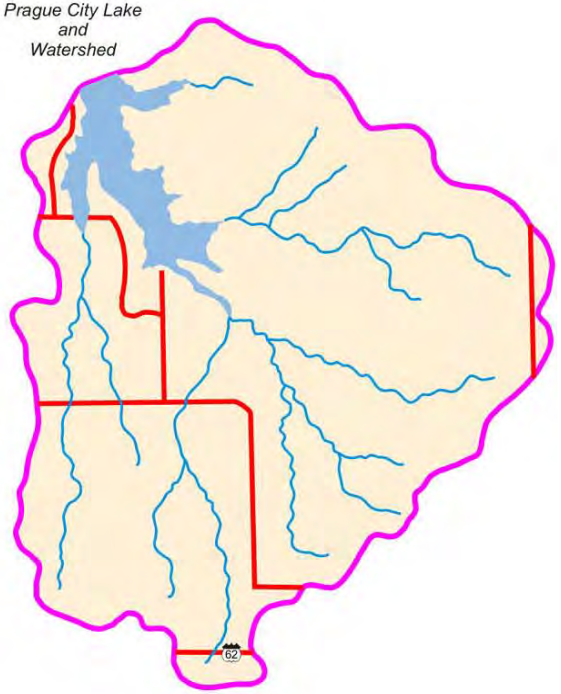


Figure 106a-106f. Graphical representation of data results for Prague City Lake.

Prague City Lake Location

Prague City Lake and Watershed



Lake Data	
Owner	City of Prague
County	Lincoln
Constructed in	1984
Surface Area	225 acres
Volume	2,415 acre/feet
Shoreline Length	6 miles
Mean Depth	10.73 feet
Watershed Area	4,322 acres

Turbidity
2005

Trophic State
2005

Plate 89 - Lake Water Quality for
Prague City Lake

LAKES MONITORING PROGRAM

Purcell Lake

Purcell Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 14 NTU (Plate 90), true color was 20 units, and secchi disk depth was 66 centimeters in 2004-2005. Based on turbidity, true color and secchi disk depth water clarity was average in comparison to other Oklahoma lakes. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 50 (Plate 90), indicating the lake was mesotrophic bordering eutrophic, with moderate to high levels of productivity and nutrient conditions. The TSI values ranged from eutrophic in the fall and summer quarters to mesotrophic in the winter and spring quarters. Seasonal turbidity by site is displayed in Figure 107a. Only two of the values collected were greater than the WQS of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Purcell Lake is partially supporting its Fish & Wildlife Propagation (FWP) beneficial use with 16.6% of the values exceeding the prescribed standard for nephelometric turbidity. Seasonal true color values are displayed in Figure 107b. All true color values were below the Aesthetics WQS of 70 units therefore Purcell Lake is fully supporting its Aesthetics beneficial use as it relates to true color.

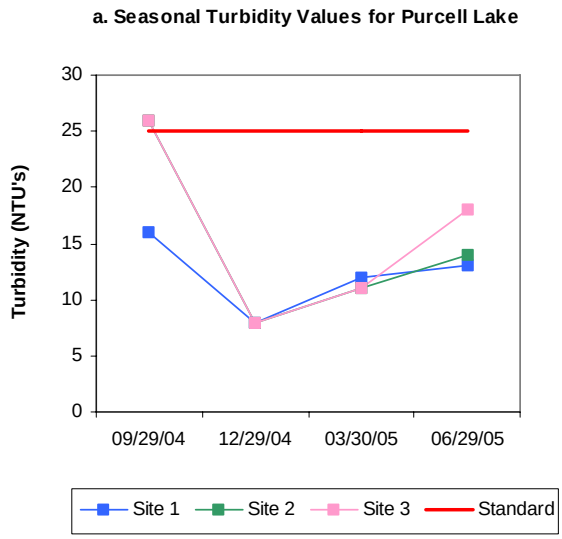
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites in 2004-2005. Salinity ranged from 0.17 parts per thousand (ppt) in the fall to 0.24 ppt in the summer, which is within the expected range of salinity values reported for most Oklahoma lakes. Specific conductivity ranged from 347.3 µS/cm in the fall quarter to 480.3 µS/cm in the summer quarter indicating that moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral to slightly alkaline, with values ranging from 7.21 units in the summer to 8.31 units in the fall quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All collected values were within the acceptable range; therefore the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 49 mV near the sediment-water interface in the summer to 463 mV in the fall. In general reducing conditions were not present during the study period. The lake was not thermally stratified in the fall, winter or spring quarters and was well mixed with dissolved oxygen (D.O.) concentrations above 6.0 mg/L throughout the water column (see Figure 107c-107e). In the summer the lake was thermally stratified between 3 and 4 meters below the surface at which point D.O. was below 2.0 mg/L to the lake bottom (5.1 meters), making about 33% of the water column anoxic (see Figure 107f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the

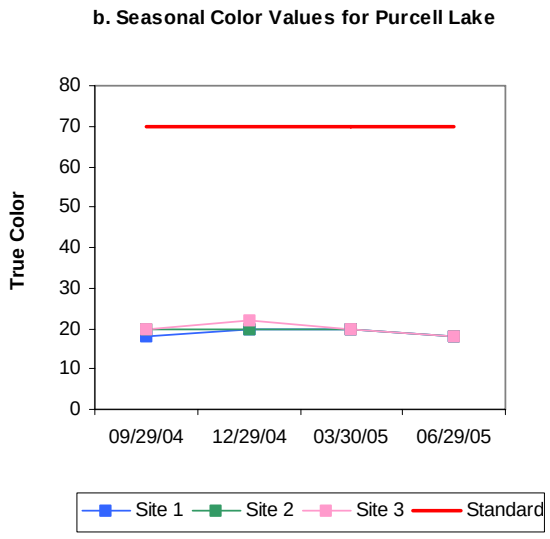
FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Purcell Lake based on dissolved oxygen concentration. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

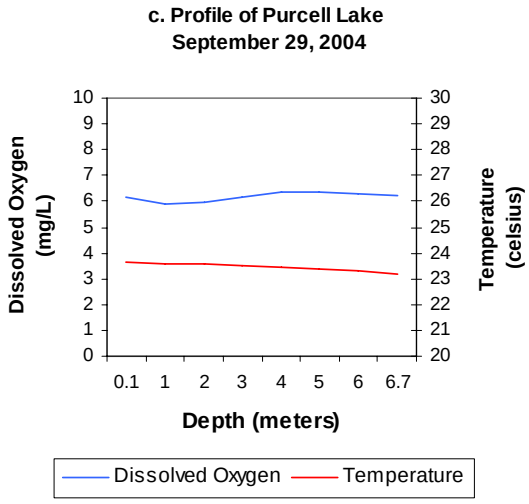
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

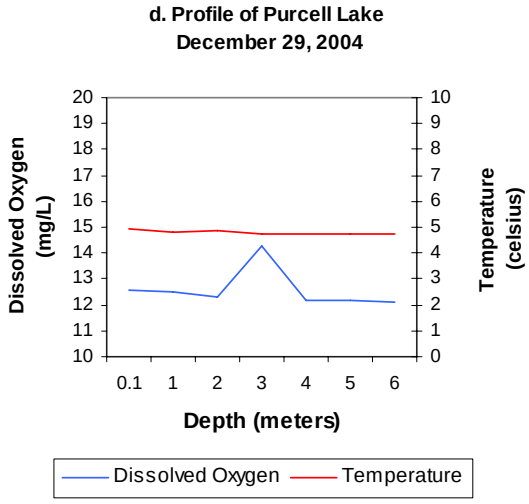
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.63 mg/L at the surface. Surface TN ranged from 0.40 mg/L to 0.88 mg/L, with the highest values reported in the fall and lowest values in the spring quarter. The lake-wide total phosphorus (TP) average was 0.032 mg/L at the surface. Total phosphorus at the surface ranged from 0.022mg/L to 0.044 mg/L. Both the high and low TP values were reported during the winter sampling interval. The nitrogen to phosphorus ratio (TN:TP) was approximately 20:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

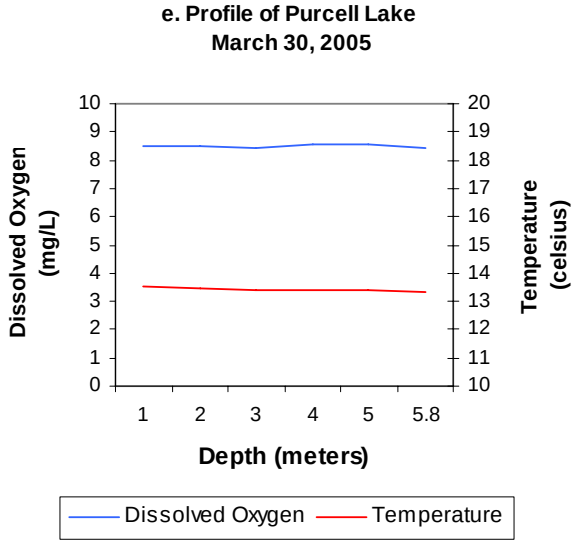
In summary, Purcell Lake was classified as mesotrophic bordering eutrophic, indicating moderate to high primary productivity and nutrient conditions (Plate 90). Water clarity was average based on turbidity, true color and secchi disk depth. The lake was fully supporting its Aesthetics beneficial use based on trophic status and true color readings as all color values were well below the WQS of 70 units. The lake was fully supporting its FWP beneficial use based on nephelometric turbidity, pH, and water column D.O. readings. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Purcell Lake was constructed in 1930 and is owned and operated by the City of Purcell. The lake is managed as a municipal water supply and is also utilized for recreational purposes.











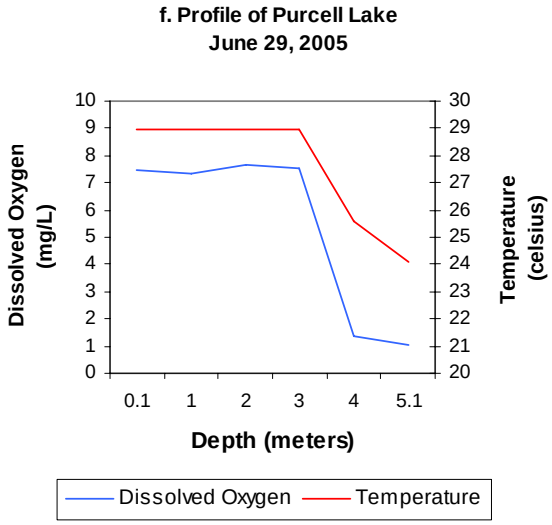
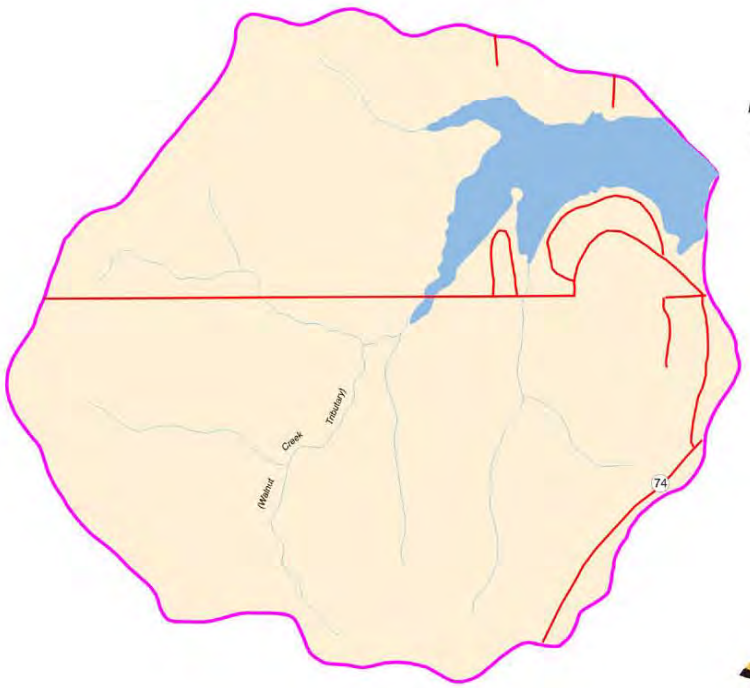
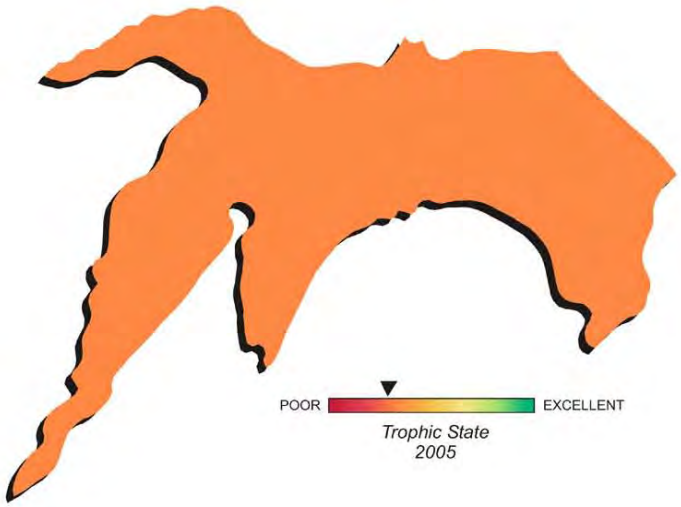


Figure 107a-107f. Graphical representation of data results for Purcell Lake.

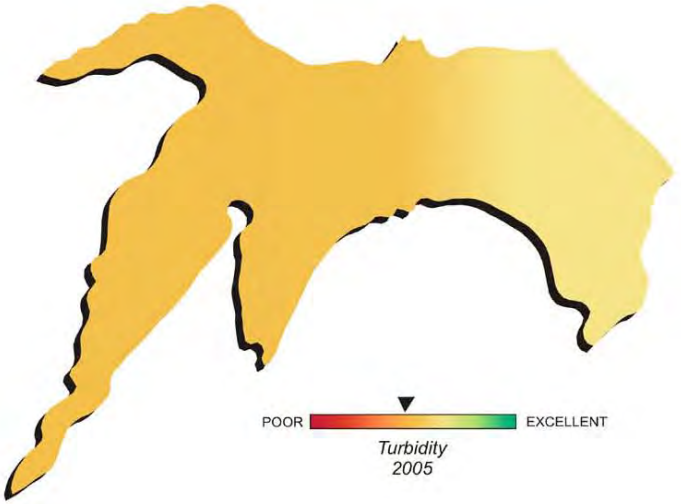


Purcell Lake and Watershed



Trophic State 2005

Purcell Lake Location



Turbidity 2005

Lake Data	
Owner	City of Purcell
County	McClain
Constructed in	1930
Surface Area	150 acres
Volume	2,600 acre/feet
Shoreline Length	4 miles
Mean Depth	17.33 feet
Watershed Area	2,432 acres

Plate 90 - Lake Water Quality for
Purcell Lake

LAKES MONITORING PROGRAM

Lake Raymond Gary

Lake Raymond Gary was sampled for four quarters, from November 2004 through August 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 14 NTU (Plate 91), true color was 48 units, and secchi disk depth was 71 centimeters. Based on these parameters water clarity was average in 2005. Results for these parameters were similar to the results found in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 50 (Plate 91), indicating the lake was mesotrophic bordering eutrophic, with moderate to high levels of productivity and nutrient conditions. The TSI values were primarily eutrophic in 2005, with the exception of the winter quarter. During the winter sites 2 and 4 were mesotrophic and site 3 dipped down into the oligotrophic category. Seasonal turbidity values are displayed in Figure 108a. Turbidity ranged from a low of 4 NTU to a maximum of 32 NTU, with higher values reported for all sites in the spring sampling quarter. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 2 (10%) of the values above the Oklahoma Water Quality Standard (WQS) of 25 NTU the Fish and Wildlife Propagation (FWP) beneficial use is partially supported in regards to turbidity. Seasonal true color values are displayed in Figure 108b. Applying the same default protocol, the Aesthetics beneficial use is considered partially supported with 15% of the reported values exceeding the WQS 70 units.

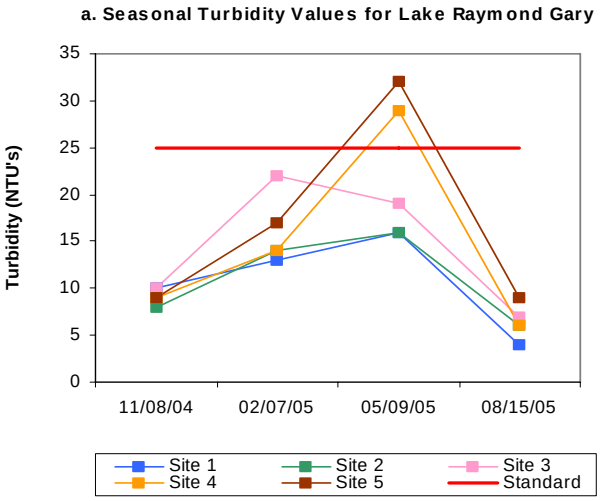
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were performed at all sample sites during the sample year. Salinity values ranged from 0.01 parts per thousand (ppt) in the winter to 0.78 ppt in the summer. Readings for specific conductivity ranged from 47 µS/cm in the winter to 1465 µS/cm in the summer, indicating that concentrations of chlorides or salts in the lake varied seasonally from very low to the very high in the summer. The higher readings were only recorded at sites 1, 2 and 4, both near the dam. The heavier saline waters have settled here, as these sites are located in the deepest part of the lake. The pH values at Lake Raymond Gary were slightly acidic, ranging from 6.21 in the winter to 7.48 in the summer. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 9.5 % of the values recorded being less than 6.5 the lake will be listed as supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials ranged from 221 mV in the hypolimnion in the fall to 449

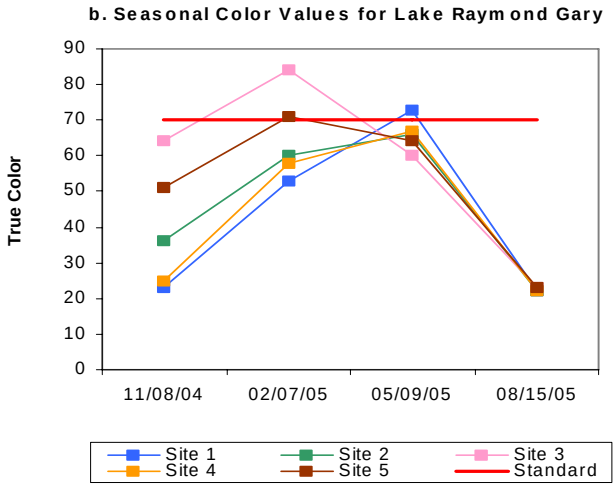
mV in the spring, indicating the absence of reducing conditions. The lake was not thermally stratified during the fall or winter and the lake was well mixed with dissolved oxygen (D.O.) values above 6.0 mg/L throughout the water column (Figure 108c-108d). In the spring, sites 1, 2 and 4 were the only sites to stratify however D.O. did not fall below 3.0 mg/L (Figure 108e). The lake exhibited strong thermal stratification in the summer and dissolved oxygen values were below 2.0 mg/L for 25 to 50% of the water column at sites 1, 2, and 4 (Figure 108f). This is not a situation that is normally seen in such a shallow reservoir and may be attributed to a long period of calm winds and/or a pattern where little rainfall occurred. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Lake Raymond Gary is considered partially supporting the FWP beneficial use based on dissolved oxygen values reported in the summer quarter. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

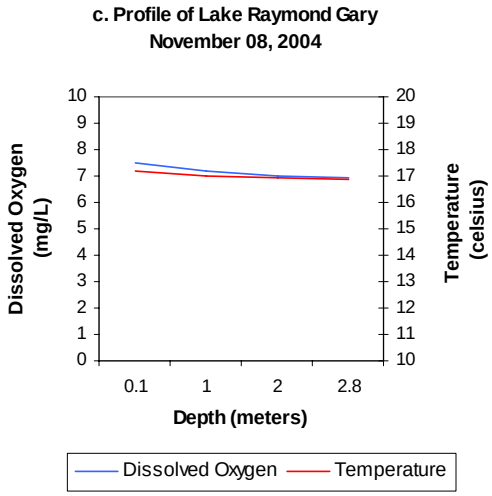
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

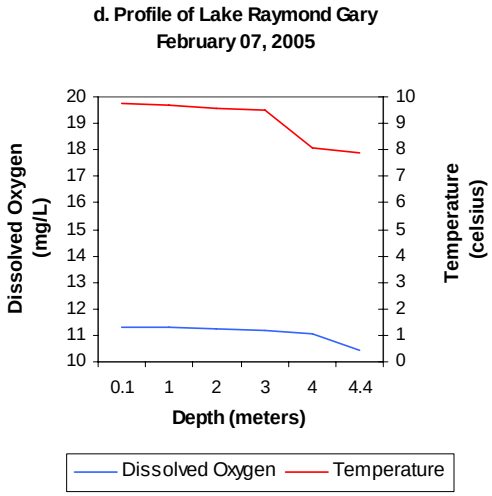
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.43 mg/L at the surface. Surface TN ranged from 0.16 mg/L to 1.87 mg/L, with the highest values reported in the fall and lowest values in the summer quarter. The lake-wide total phosphorus (TP) average was 0.054 mg/L at the surface. Total phosphorus at the surface ranged from 0.027mg/L to 0.045 mg/L. Surface TP was highest in the winter, and the lowest values were recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2004-2005. This is the very near the 7:1 ratio used to determine the limiting nutrient, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

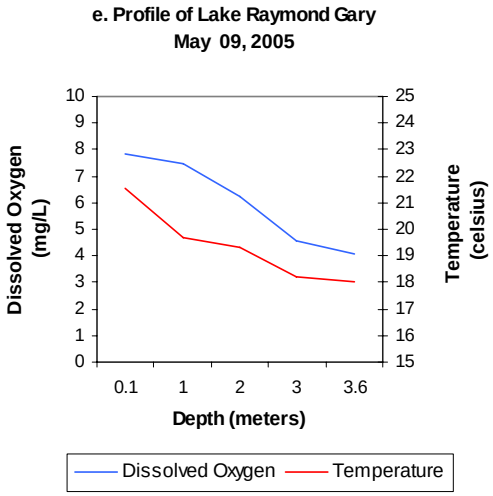
In summary, Lake Raymond Gary was classified as mesotrophic bordering eutrophic, indicative of moderate to high primary productivity and nutrient conditions. Water clarity was good in sample year 2004-2005, based on turbidity, true color, and secchi disk depth. The lake is partially supporting the FWP beneficial use based on turbidity and low dissolved oxygen levels in the summer quarter. With 9.5% of the recorded pH values less the 6.5 units the lake is also supporting the FWP beneficial use. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes, therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial is supported based on its trophic status, and partially supported for true color as 15% of the reported values were exceeding the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake Raymond Gary, near Fort Towson, is a recreational reservoir owned by the State of Oklahoma.











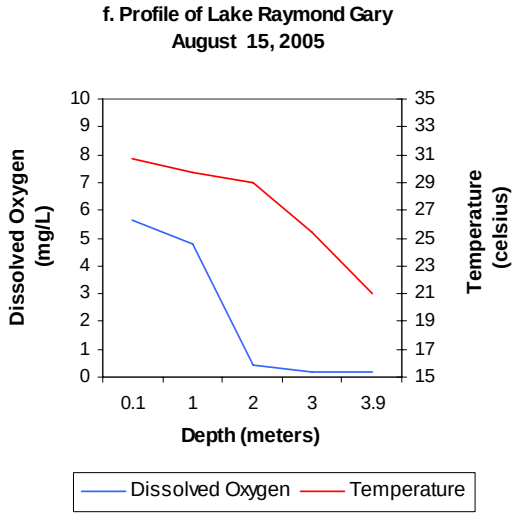
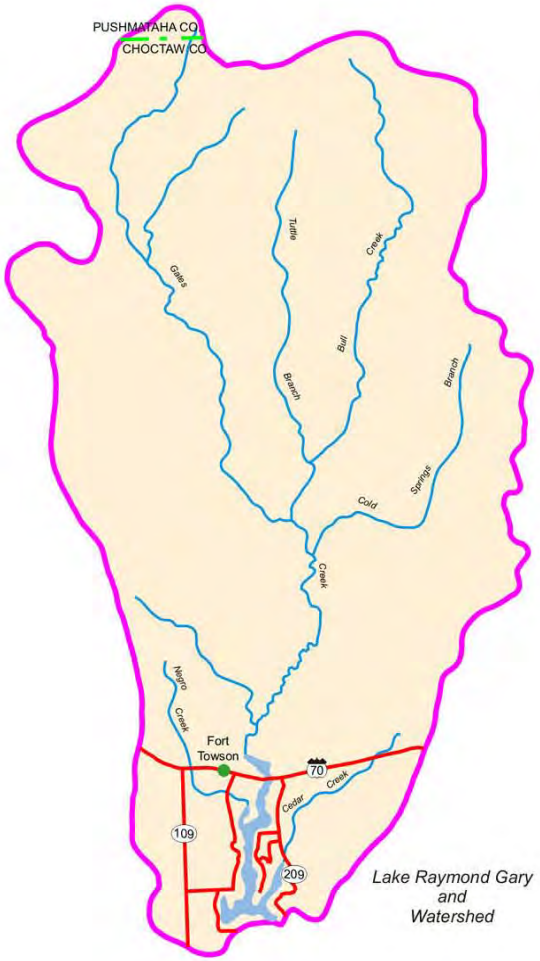


Figure 108a-108f. Graphical representation of data results for Lake Raymond Gary.



Lake Raymond Gary and Watershed

Lake Raymond Gary Location

Lake Data	
Owner	State of Oklahoma
County	Choctaw
Constructed in	1956
Surface Area	263 acres
Volume	1,681 acre/feet
Shoreline Length	10 miles
Mean Depth	6.39 feet
Watershed Area	56 square miles

Turbidity 2005

Trophic State 2005

Plate 91 - Lake Water Quality for
Lake Raymond Gary

LAKES MONITORING PROGRAM

R.C. Longmire Lake

R.C. Longmire Lake was sampled for four quarters, from October 2004 through August 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity value was 15 NTU (Plate 92), true color was 25 units, and secchi disk depth was 63 centimeters. Water clarity was good based on secchi disk depth, turbidity, and true color values. Results for these parameters are similar to the results found in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 56 (Plate 92), indicating the lake was eutrophic, with high levels of productivity and nutrient conditions. This value is higher than the TSI in 2003 (TSI=47). The TSI values were fairly consistent and generally eutrophic with hypereutrophic conditions occurring in the winter. The exception to this occurred at site 1 and 5, which were mesotrophic in the spring and summer. Seasonal turbidity values are displayed in Figure 109a. Only one turbidity value exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (70 units for color). If 10 to 25% of the values exceed the numeric criteria, the lake should be listed as partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is considered supported with 95% of the turbidity values below the standard. True color values varied seasonally and were below the aesthetics WQS of 70 units (Figure 109b). Applying the same default protocol, the Aesthetic beneficial use is considered supported based on true color values reported during the study period.

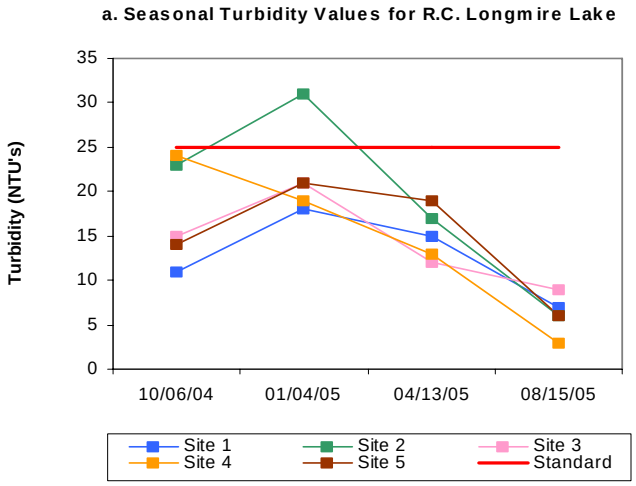
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values for R.C. Longmire Lake ranged from 0.08 parts per thousand (ppt) to 0.29 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductivity ranged from 175.8 to 572.3 µS/cm, indicating a low to moderate presence of electrical current conducting compounds (salts) in the lake, consistent with salinity concentrations. In general pH values were neutral to slightly alkaline with values ranging from 7.05 in the summer to 8.44 in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 155 mV in the summer to 519 mV also in the summer, indicating reducing conditions were not present at the time of sampling. Thermal stratification was not present during the fall, winter, or spring quarters and lake was well mixed (see Figure 109c-107e). In the summer the lake was strongly stratified between 4 and 5 meters in depth, at site 1, with dissolved oxygen (D.O.) falling below 2.0 mg/L to the lake bottom of 11.1 meters, accounting for 62% of the water column to be anoxic (Figure 109f). Site 4 also had D.O. levels of less than 2.0 mg/L for

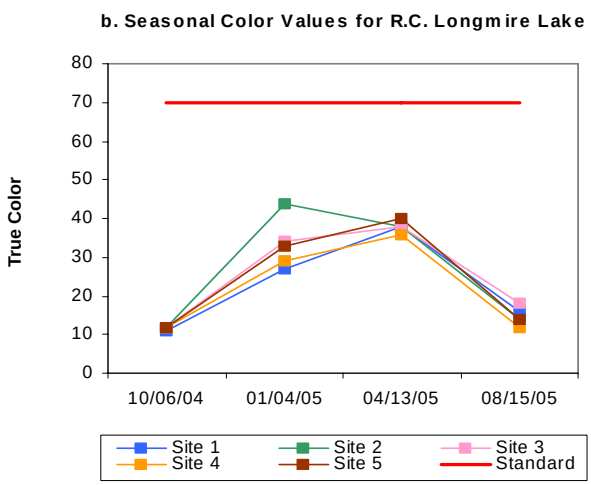
approximately 40% of the water column. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. R.C. Longmire Lake is partially supporting its FWP beneficial use with 40 to 62% of the water column experiencing anoxic conditions in the summer quarter. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

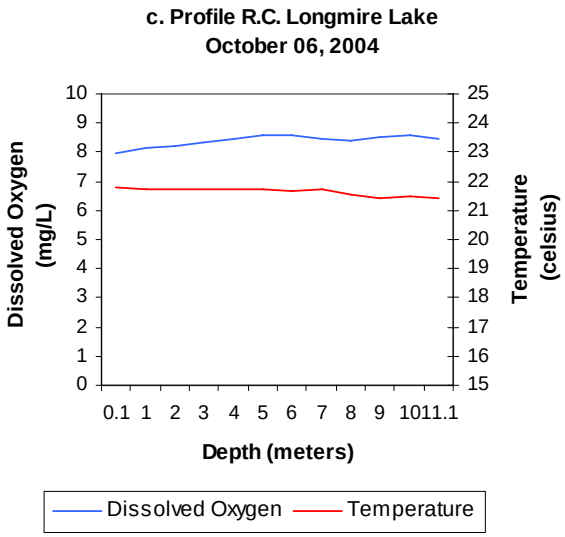
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

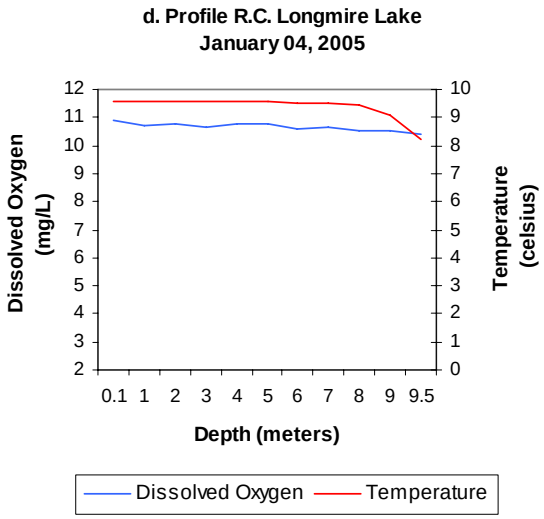
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.71 mg/L at the surface. The TN at the surface ranged from 0.62 mg/L to 0.84 mg/L. The highest surface total nitrogen was reported at site 5 in the winter. The lake-wide total phosphorus (TP) average was 0.039 mg/L at the lake surface. The surface TP ranged from 0.026 mg/L to 0.059 mg/L. The highest surface TP was reported in the winter and the lowest value seen during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 18:1 for sample year 2002-2003. This is higher than the 7:1 ratio used to determine the limiting nutrient, characterizing the lake as phosphorus limited (Wetzel, 1983).

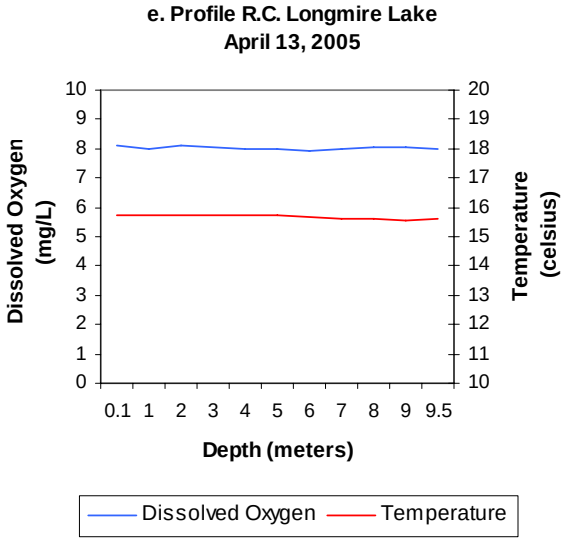
In summary, R.C. Longmire Lake was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2004-2005. Water clarity is good based on turbidity, true color and secchi disk depth, similar to the 2003 evaluation. The lake is supporting the Fish and Wildlife Propagation (FWP) beneficial use based on turbidity and pH, but is partially supporting based on anoxic conditions present in the summer. The lake is supporting the Aesthetics based on its trophic status, and true color with 100% of the color values well below the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. R.C. Longmire Lake is located in Garvin County and is a popular fishing lake.











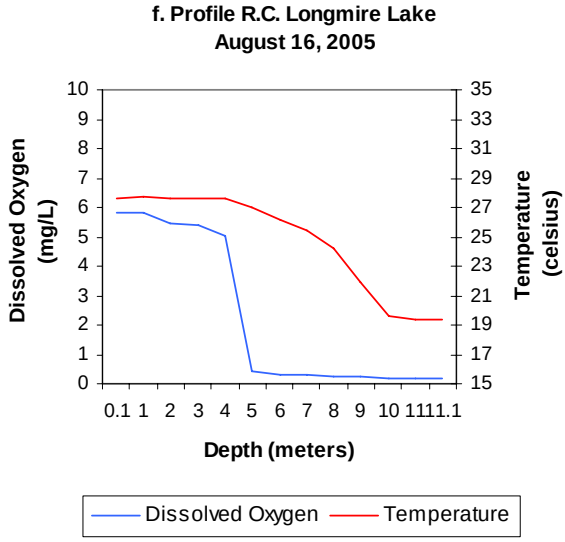


Figure 109a-109f. Graphical representation of data results for R.C. Longmire Lake.

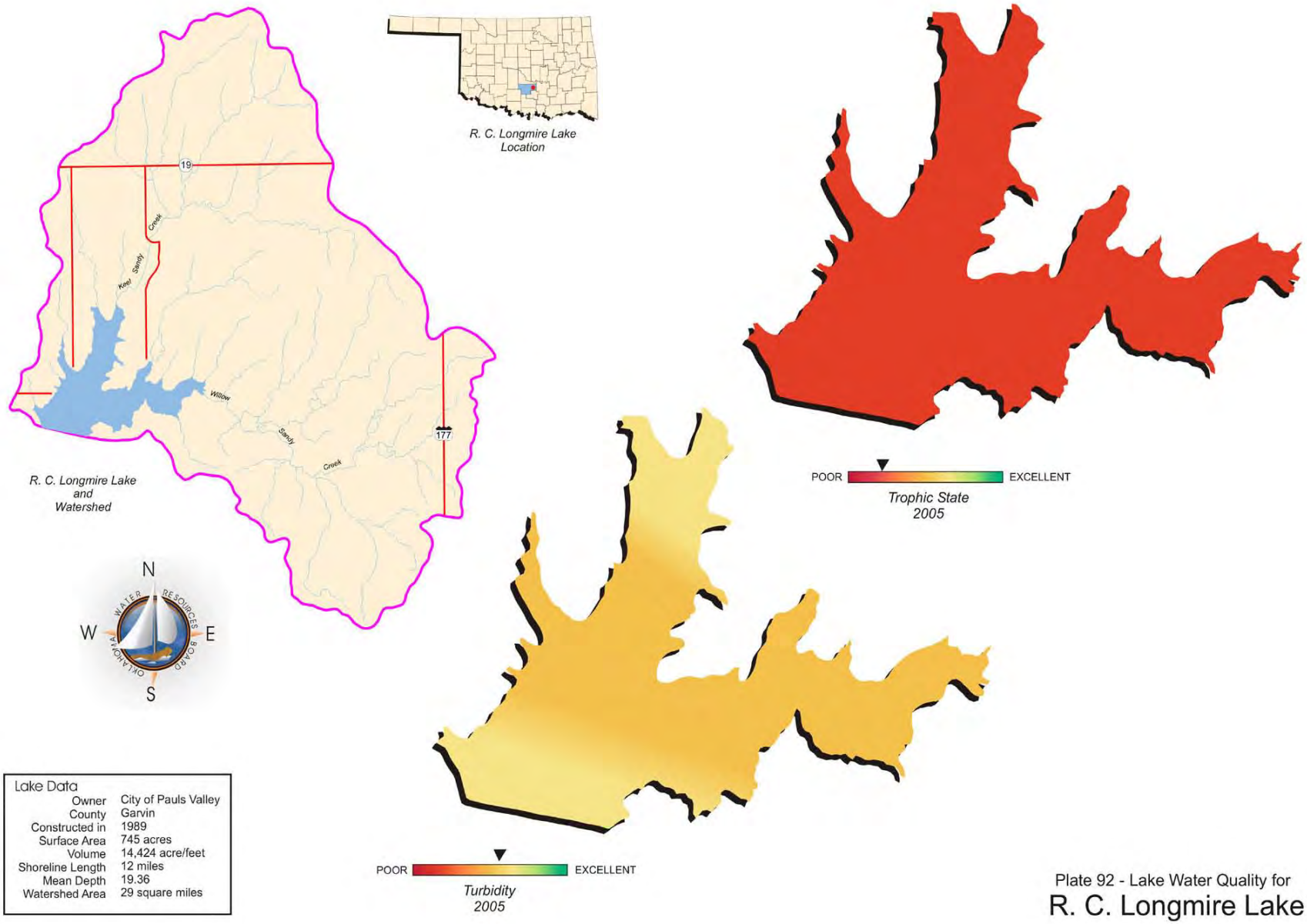


Plate 92 - Lake Water Quality for
R. C. Longmire Lake

LAKES MONITORING PROGRAM

OKLAHOMA'S BENEFICIAL USE MONITORING PROGRAM – LAKES SAMPLING, 2005-2006 DRAFT REPORT
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Robert S. Kerr Reservoir

Robert S. Kerr Reservoir was sampled for four quarters, from November 2004 through August 2005. Water quality samples were collected from six (6) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 33 NTU (Plate 95), true color was 44 units and average secchi disk depth was 39 centimeters. Based on these three parameters, water clarity at R.S. Kerr Reservoir was fairly poor. Results are similar to those reported in 2003, indicating little change has occurred over time. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=24). The average TSI was 58 (Plate 95), indicating the lake was eutrophic, with high levels of primary productivity and nutrient conditions. This value is similar to the one calculated in 2003 (TSI=55), indicating the no significant increase or decrease in productivity has occurred since the previous evaluation. The TSI values varied by site and season throughout the year from mesotrophic (sites 1 and 2) in the fall and winter to upper eutrophic and even hypereutrophic (sites 3 – 6) in the spring and summer. Seasonal turbidity values are displayed in Figure 110a. Turbidity values were fairly consistent with values ranging from 16 to 62 NTU with lower values occurring during the summer. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 75% of the samples collected in 2003 exceeding the standard, the lake is not supporting the Fish and Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed (Figure 110b). Like turbidity the lowest color values were recorded in the summer quarter. Applying the same default protocol, the Aesthetics beneficial use is considered supported with 100% of the values below the WQS of 70-units for true color.

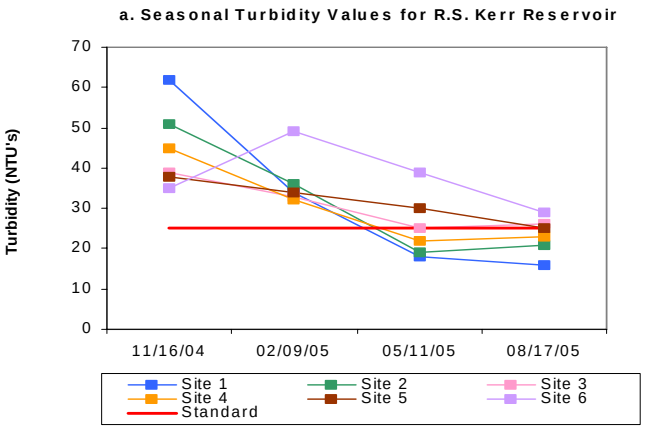
In 2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.17 parts per thousand (ppt) in the fall to 0.46 ppt in the winter. This is slightly higher than the average range of values reported for most Oklahoma reservoirs, however R.S. Kerr reservoir main tributary is the Arkansas River. Specific conductivity ranged from 340 to 877.4 µS/cm, indicating moderate to high concentrations of electrical current conducting compounds (salts) within the lake, consistent with the elevated salinity readings. In general, pH values were neutral to slightly alkaline with values ranging from 7.35 to 8.47 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 335 mV in the spring to 540 mV in the fall, indicating reducing conditions were not present during the study period. The lake did not exhibit

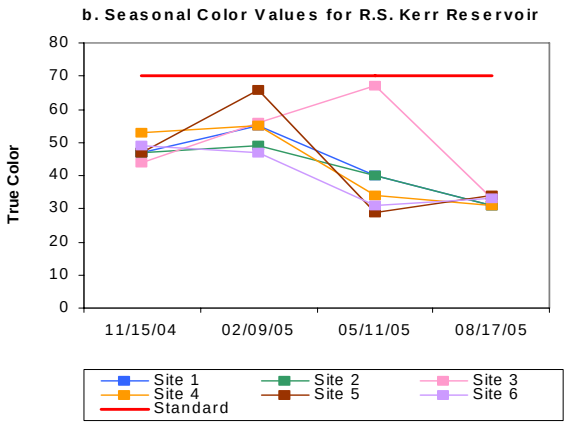
stratification during any of the sampling intervals and was well mixed with dissolved oxygen (D.O.) generally above 5.0 mg/L (Figure 110c-110f). The riverine nature of this reservoir aids in keeping it well oxygenated. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at R.S. Kerr Reservoir, with only 33 to 36% of the water column experiencing anoxic conditions in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

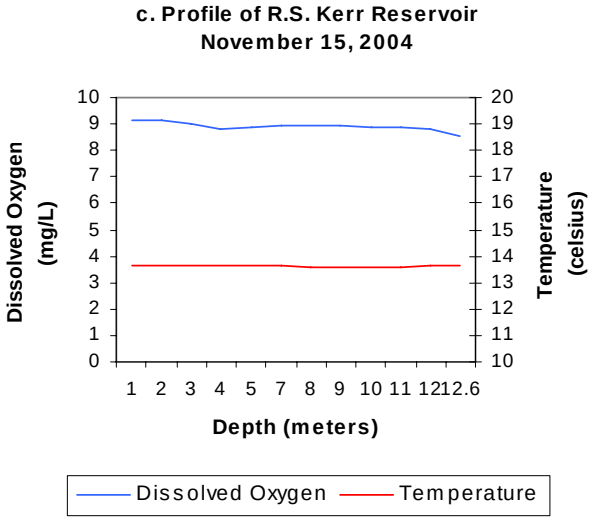
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

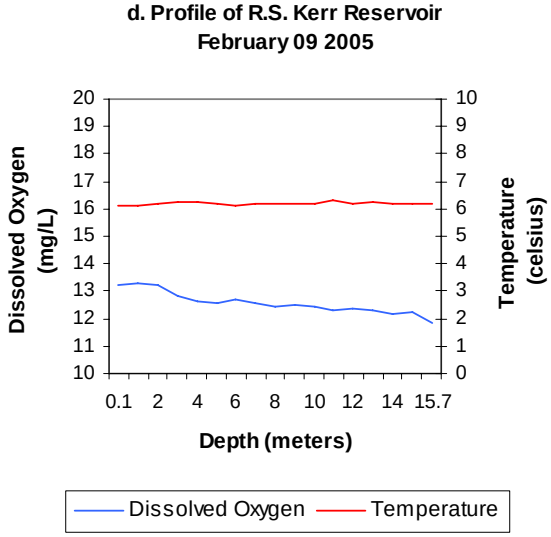
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.91 mg/L at the surface. The TN at the surface ranged from 0.61 mg/L to 1.48 mg/L. The highest surface total nitrogen was reported in the winter and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.123 mg/L at the lake surface. The surface TP ranged from 0.048 mg/L to 0.178 mg/L. The highest surface TP was reported in the summer and the lowest values were seen during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 7:1 for sample year 2002-2003. This is the same as the 7:1 ratio used to determine the limiting nutrient, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

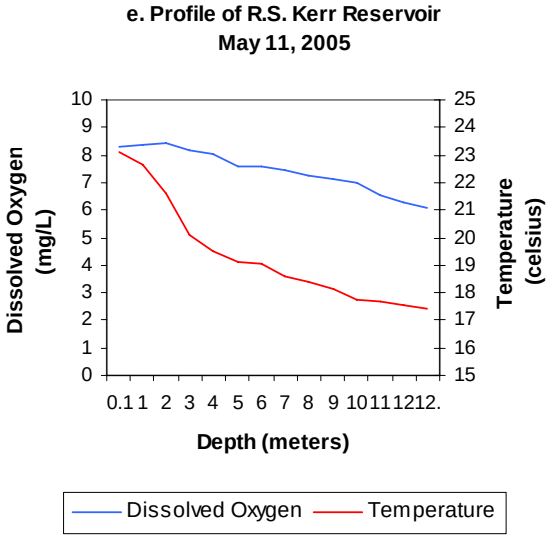
In summary, Robert S. Kerr Reservoir was classified as eutrophic with high primary productivity and nutrient conditions (Plate 95). This is similar to the value calculated in 2003(TSI=55), indicating no significant increase or decrease in productivity has occurred since the last evaluation. Water clarity was poor based on turbidity, true color, and secchi disk depth. The lake is supporting the FWP beneficial use based on dissolved oxygen and pH values, but not supporting for turbidity with 75% of the values above the WQS of 25 NTU. The Aesthetics beneficial use is supported based on its trophic status as well as supporting based on true color values reported during the sample year. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. The United States Army Corps of Engineers (USACE) constructed Robert S. Kerr Reservoir in 1971 for navigation, hydro-electrical and recreation purposes. The lake is located in both Sequoyah and LeFlore Counties approximately 8 miles south of Sallisaw.











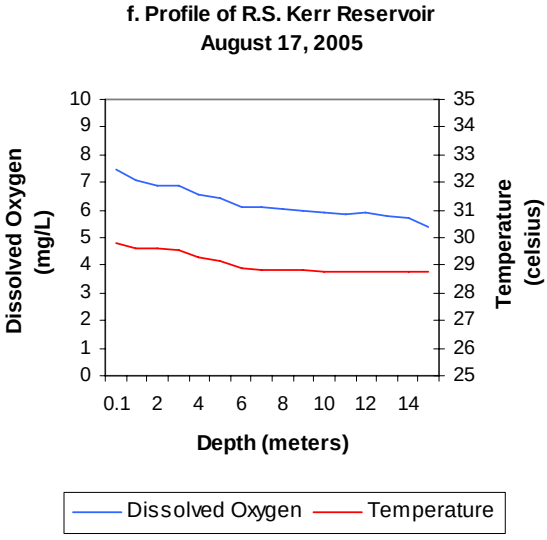
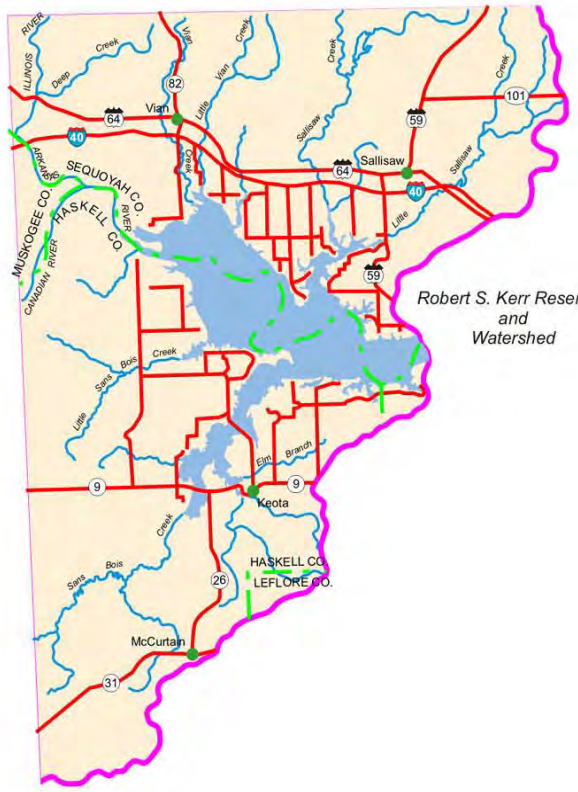
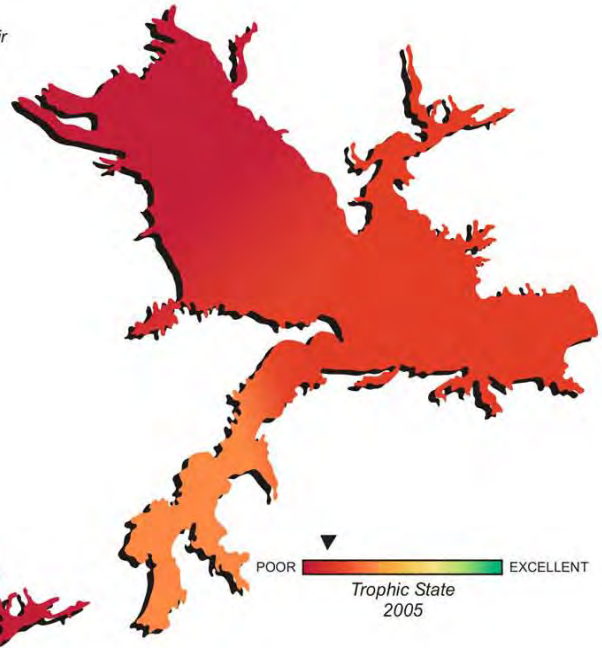


Figure 110a-110f. Graphical representation of data results for R.S. Kerr Reservoir.

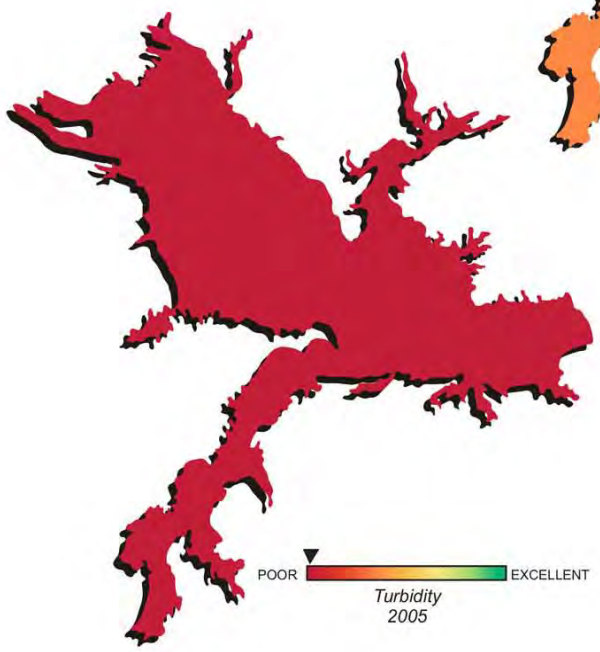


Robert S. Kerr Reservoir
and
Watershed

Robert S. Kerr Reservoir
Location



Trophic State
2005



Turbidity
2005

Lake Data	
Constructed by	Corps of Engineers
County	Sequoyah/LeFlore
Constructed in	1971
Surface Area	43,800 acres
Volume	525,700 acre/feet
Shoreline Length	250 miles
Mean Depth	11.75 feet
Watershed Area	147,756 square miles

Plate 95 - Lake Water Quality for

Robert S. Kerr Reservoir

LAKES MONITORING PROGRAM

Rock Creek Reservoir

Rock Creek Reservoir was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual average turbidity value was 16 NTU (Plate 93), true color was 29 units, and secchi disk depth was 67 centimeters. Based on these three parameters, Rock Creek Reservoir had average water clarity in 2005. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 48 (Plate 93), indicating the lake was mesotrophic, with moderate levels of productivity and nutrient conditions. This value is similar to the TSI in 2003 (TSI=50), and in the same trophic category, indicating no significant increase or decrease over time. The TSI values primarily mesotrophic with eutrophic conditions observed in the summer. Seasonal turbidity values are displayed in Figure 111a. All turbidity values, with the exception of site 2, which had a value of 31 NTU reported in the spring quarter, were below the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With only 1 (8.3%) of the samples above the standard, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported for sample year 2005. True color values were below the aesthetics WQS of 70 units at all sites throughout the year (Figure 111b). Applying the same default protocol, the lake is supporting the Aesthetics beneficial use.

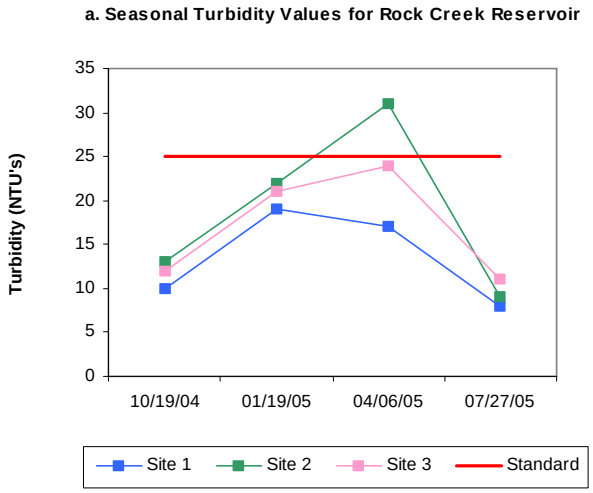
In 2005 vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.16 ppt, which is within the average range of values, reported for most Oklahoma reservoirs. Specific conductivity values ranged from 232.2 to 319.9 µS/cm, indicating low to moderate concentrations of electrical current conducting compounds (salts) were present in the lake. This is consistent with the reported salinity readings. In general pH values were neutral to slightly alkaline with values ranging from 7.07 to 8.19 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 275 mV in the winter to 432 mV in the spring, indicating reducing conditions were not present during the study period. The lake was not stratified during the fall, winter and spring quarters and the lake was well mixed with dissolved oxygen values generally above 7.0 mg/L (Figure 111c-111e). The lake was thermally stratified and anoxic conditions were present in the summer quarter. During the summer the thermocline occurred high in the water column (between 3 and 4 meters), falling below 2.0 mg/L from 4

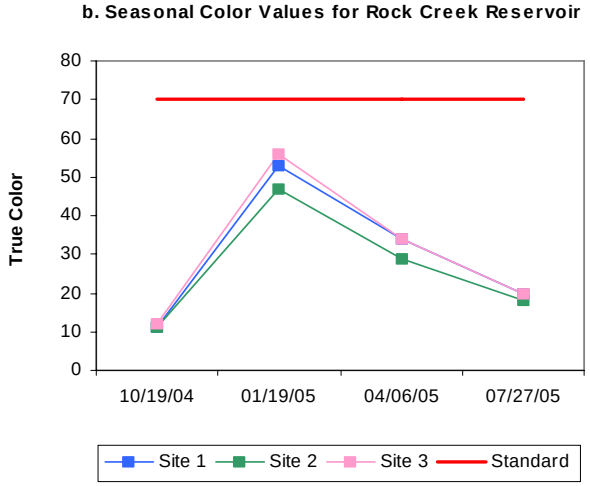
meters to the lake bottom of 8.8 meters at site 1 (Figure 111f). Anoxic conditions were also present at site 2 comprising approximately 25% of the water column. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Rock Creek Reservoir is partially supporting its FWP beneficial use with 25-50% of the D.O. values in the summer falling below 2.0 mg/L. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

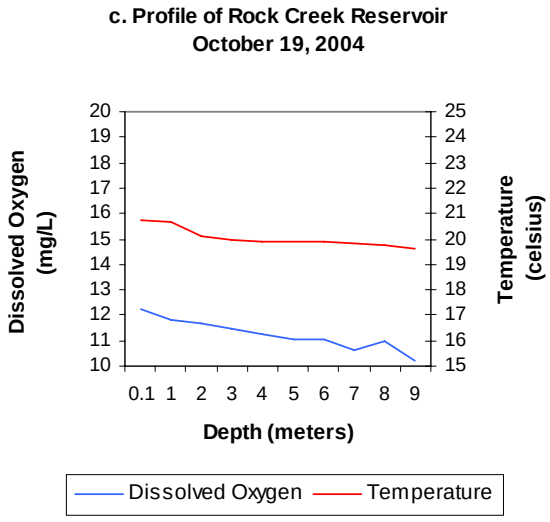
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

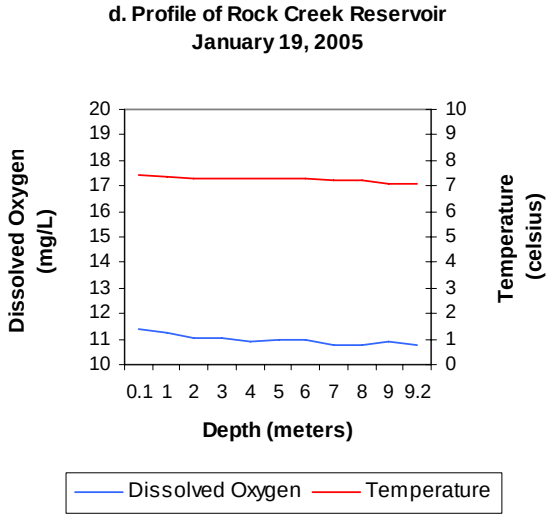
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.65 mg/L at the surface. Surface TN ranged from 0.30 mg/L to 0.83 mg/L, with the highest values reported in the spring and lowest values in the fall quarter. The lake-wide total phosphorus (TP) average was 0.028 mg/L at the surface. Total phosphorus at the surface ranged from 0.019mg/L to 0.028 mg/L. Similar to TN, surface TP was highest in the spring, and the lowest values were recorded during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 23:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

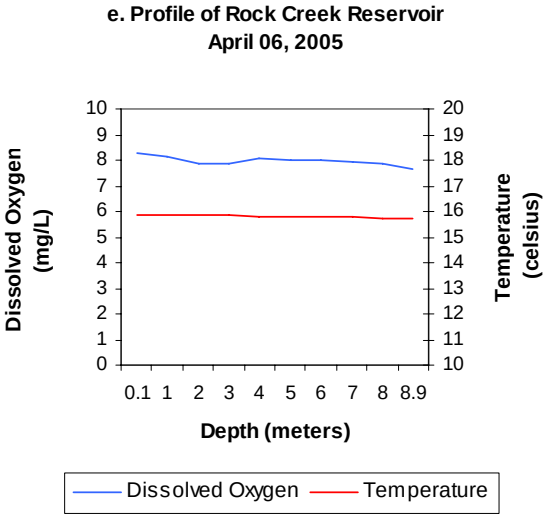
In summary, Rock Creek Reservoir was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in 2004-2005. This is consistent with the 2003 evaluation, indicating no significant change in productivity has occurred over time. Water clarity was average based on true color, secchi disk depth and turbidity. The lake is supporting the FWP beneficial use based on turbidity and pH, but only partially supporting the use due to anoxic conditions in 25-50% of the water column during the summer quarter. The Aesthetic beneficial use is fully supported by both trophic status and collected true color values with 100% of the values well below the WQS of 70 units for color. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Rock Creek Reservoir is located in Carter County and serves as a recreational reservoir for the City of Ardmore.











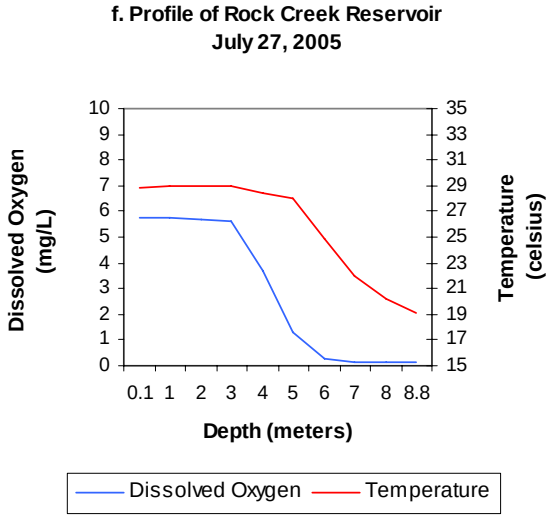
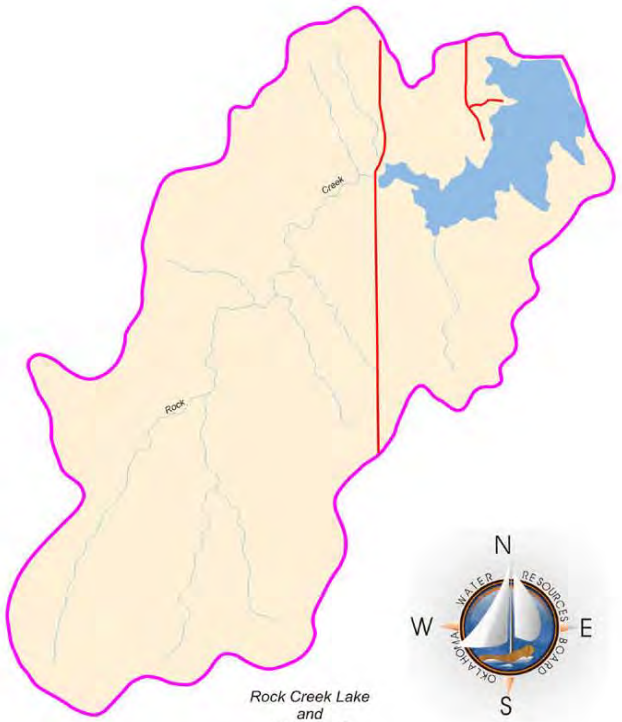


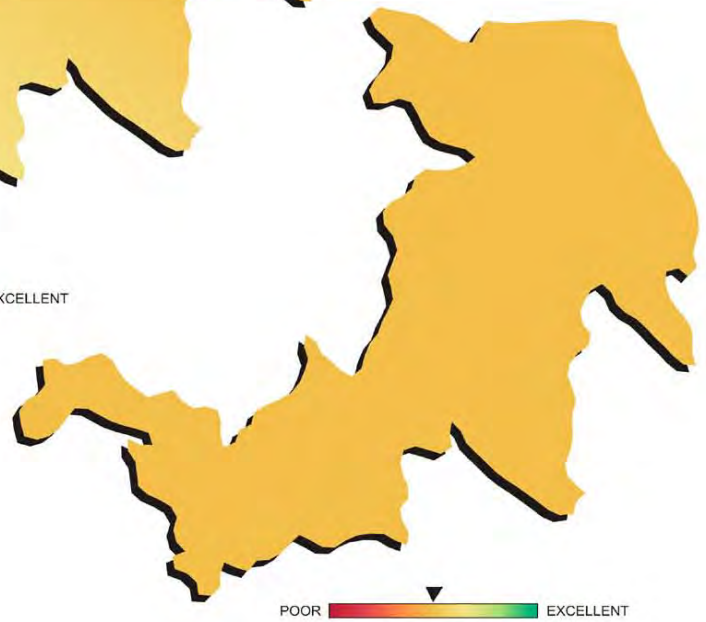
Figure 111a-111f. Graphical representation of data results for Rock Creek Reservoir.

Rock Creek Lake
Location



Rock Creek Lake
and
Watershed

Turbidity
2005



Trophic State
2003

Lake Data	
Owner	City of Ardmore
County	Carter
Constructed in	1979
Surface Area	248 acres
Volume	3,588 acre/feet
Shoreline Length	6 miles
Mean Depth	14.47 feet
Watershed Area	3,545 acres

Plate 93 - Lake Water Quality for
Rock Creek Reservoir

LAKES MONITORING PROGRAM

Rocky (Hobart) Lake

Rocky Lake was sampled for four quarters, from November 2003 through July 2004. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 40 NTU (Plate 94), true color was 29 units, and secchi disk depth was 31 centimeters. Based on these three parameters, Rocky Lake had poor water clarity in comparison to other Oklahoma reservoirs. Water clarity was similar in 2001; with true color improving slightly. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 68 (Plate 94), classifying the lake as hypereutrophic, indicative of excessive levels of productivity and nutrients. This value is very similar to the one calculated in 2001 (TSI=66) indicating little or no change in trophic status over time. The TSI values were hypereutrophic at all sites during the sample year. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. All turbidity values, except for four sites in the spring, were above the Oklahoma Water Quality Standard (WQS) of 25 NTU (Figure 112a). According to the Use Support Assessment Protocols (USAP) outlined in OAC 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 80% of the turbidity values exceeding the WQS of 25NTU, the Fish and Wildlife Propagation (FWP) beneficial us is considered not supported. Seasonal true color values are displayed in Figure 112b. Of the twenty true color values collected, only one (5%) was above the numeric criteria of 70 units in the fall quarter. Applying the same protocol for determining the short-term average for true color, the Aesthetics beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were performed at all sample sites and yielded the following results. Salinity readings ranged from 0.21 parts per thousand (ppt) to 0.35ppt, slightly higher than most values recorded in Oklahoma reservoirs. Readings for specific conductivity were also slightly higher than values normally seen in most Oklahoma reservoirs. Specific Conductivity ranged from 420.8 µS/cm in the spring quarter to 680.4 cm/cm in the winter quarter, indicating moderate to slightly elevated concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 353 mV to 455 mV, indicating reducing conditions were not present during any sampling events. Recorded pH values were neutral to slightly alkaline, ranging from 7.13 to 8.66 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Rocky Lake was fully supporting its FWP beneficial use based on pH values collected during the study period. Due to equipment failure, profile data is not available for the fall quarter, although it is likely that thermal stratification did not occur. The lake was not thermally stratified during winter, spring or summer quarters (see Figure 112c-112e). The water column was evenly mixed and oxygenated during the entire study period, which may be attributed to the shallow nature of the lake (mean depth of 2.9 meters). Dissolved oxygen (D.O.) concentrations never fell below 2.0 mg/L at any point in the water column during the sample year. If D.O. values are less than 2.0 mg/L for greater than 70% of

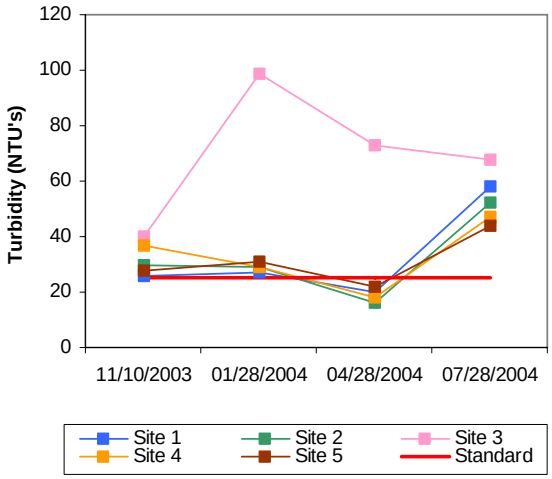
the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered supported based on dissolved oxygen concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci analysis during the recreation season of May through September. Of the 10 enterococci samples collected seven (70%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (74.3 cfu/ml) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

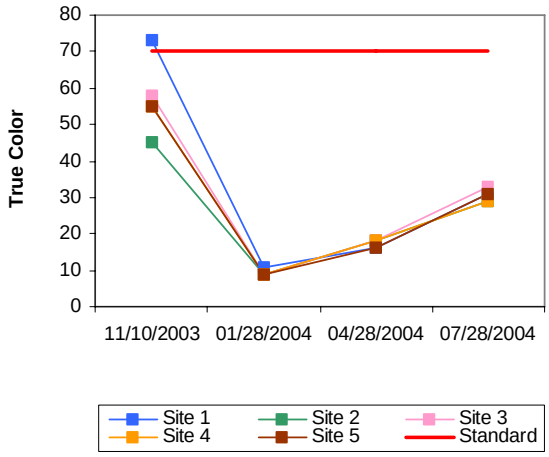
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.39 mg/L at the lake surface. The TN at the surface ranged from 0.92 mg/L to 2.12 mg/L. The highest surface TN value was reported in the winter quarter and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average was 0.130 mg/L at the lake surface. The TP ranged from 0.092 mg/L to 0.155 mg/L at the lake surface. Both the highest and lowest surface TP values were reported in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 11:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Rocky Lake was as hypereutrophic, indicative of excessive primary productivity and nutrient rich conditions (Plate 94). This is consistent with historical data collection efforts in 2001 (TSI=66), indicating no significant increase or decrease in productivity has occurred over time. Based on its trophic status the lake will be recommended for listing as a Nutrient Limited watershed (NLW) in the next WQS revision process and its Aesthetics beneficial use is considered nutrient threatened until studies can be conducted to confirm non-support status. With only 5% of the collected values greater than the WQS of 70 units, Rocky Lake is fully supporting its Aesthetics beneficial use based on true color readings. Water clarity continues to be poor at this lake based on true color secchi disk depth and high turbidity values. The FWP beneficial use is fully supporting based on pH and D.O., and is not supported for turbidity. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 enterococci samples collected seven (70%) exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (74.3) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported. Rocky Lake was constructed in 1933 and is owned and operated by the City of Hobart. The lake is utilized by the city for water supply and recreational purposes.

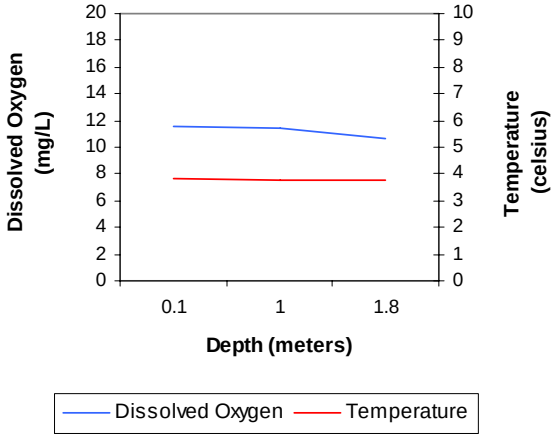
a. Seasonal Turbidity Values for Rocky Lake



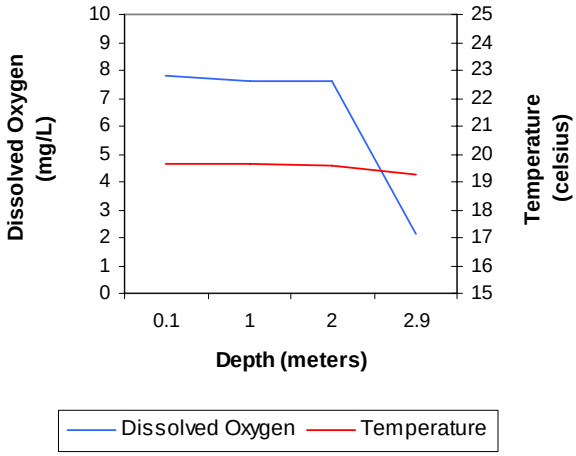
b. Seasonal Color Values for Rocky Lake



c. Profile of Rocky Lake
January 28, 2004



d. Profile of Rocky Lake
March 28, 2004



e. Profile of Rocky Lake
July 28, 2004

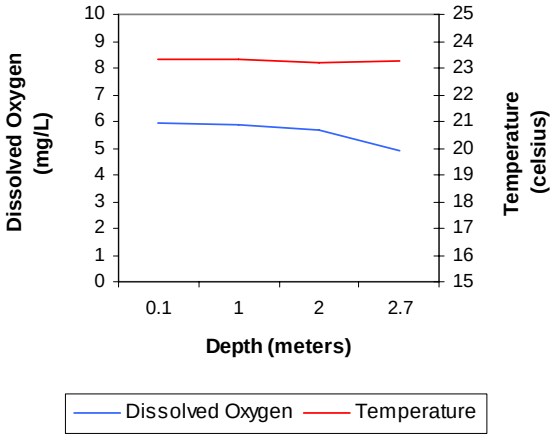
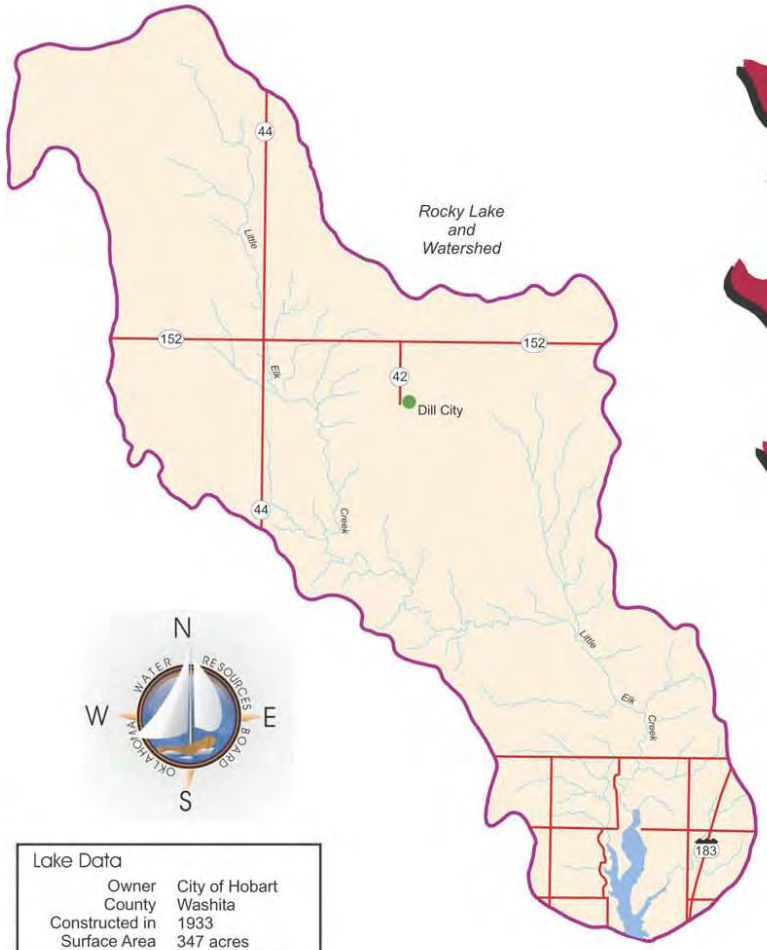


Figure 112a-112e. Graphical representation of data results for Rocky Lake.



Lake Data	
Owner	City of Hobart
County	Washita
Constructed in	1933
Surface Area	347 acres
Volume	4,210 acre/feet
Shoreline Length	8 miles
Mean Depth	11.64 feet
Watershed Area	58 square miles

Turbidity
2004

Trophic State
2004

Plate 94 - Lake Water Quality for
Rocky (Hobart) Lake

Lake Sahoma

Lake Sahoma, was constructed in 1947 and is owned and operated by the City of Sapulpa. The lake is managed as a municipal water supply and offers numerous recreational opportunities to the public. Lake Sahoma was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 9 NTU (Plate 96), true color was 30 units, and secchi disk depth was 73 centimeters. Water clarity was fair based on secchi disk depth, turbidity, and true color values collected in sample year 2006. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 51 (Plate 96), indicating the lake was eutrophic, with high levels of productivity and nutrient rich conditions. This is identical to the TSI calculated in 2004, indicating no significant increase or decrease in productivity has occurred. The TSI values varied seasonally ranging from oligotrophic in the winter to mesotrophic in the fall and eutrophic in both the spring and summer quarters. Turbidity values were all below the Oklahoma Water Quality Standard (WQS) of 25 NTU ranging from a low of 6 NTU to a maximum of 18 NTU (see Figure 113a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the collected turbidity values below the criteria, Lake Sahoma is supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 113b. Similar to turbidity 100% of the true color values were below the Aesthetics WQS of 70 units. Applying the same default protocol, the lake is considered supporting its Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity ranged from 0.08 parts per thousand (ppt) in the spring to 0.09 ppt in the fall and winter quarter, indicating low salt content and lower than the expected range of salinity values reported for most Oklahoma lakes. Specific conductivity ranged from 184.1 µS/cm to 203.1 µS/cm in the spring quarter, indicating that very low levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral with values ranging from 7.02 units to 7.8 units in the spring quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All collected pH values were within the acceptable range, therefore Lake Sahoma is fully supporting its FWP beneficial as it relates to pH. Oxidation-reduction potentials (redox) ranged from 125 mV to 451 mV, indicating reducing conditions were not present during the sampling events. In the fall and winter quarters the lake was well mixed and dissolved oxygen (D.O.) concentrations were above

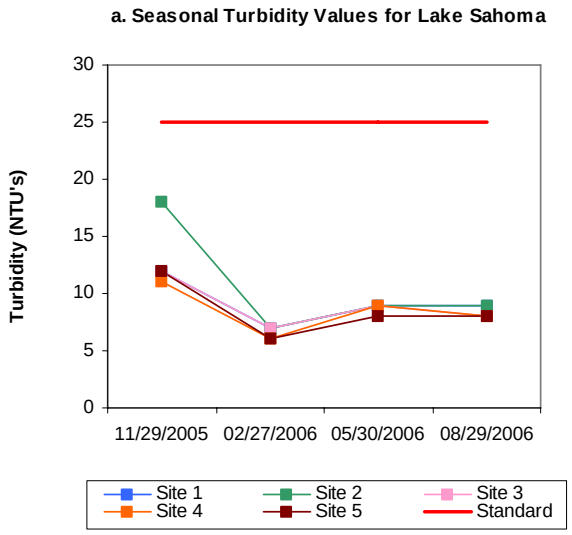
7.0 mg/L throughout the water column. Thermal stratification was evident and anoxic conditions present to some degree at all sites in the spring quarter. Stratification occurred between 3 and 4 meters below the surface at site 1 with anoxic conditions present in approximately 69% of the water column (Figure 113e). Sites 2-5 were all stratified at the same point and anoxic conditions were present in 20-56% of the water column among the various sites. Due to equipment malfunction profile data is not available for assessment for the summer sampling interval. It is likely that stratification and anoxic conditions would be present with the lake stratifying so strongly in the spring. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Lake Sahoma with approximately 69% of the water column anoxic during the spring. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported.

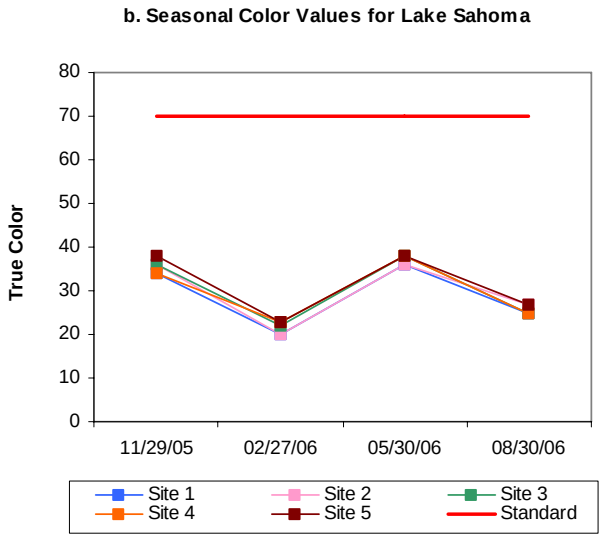
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

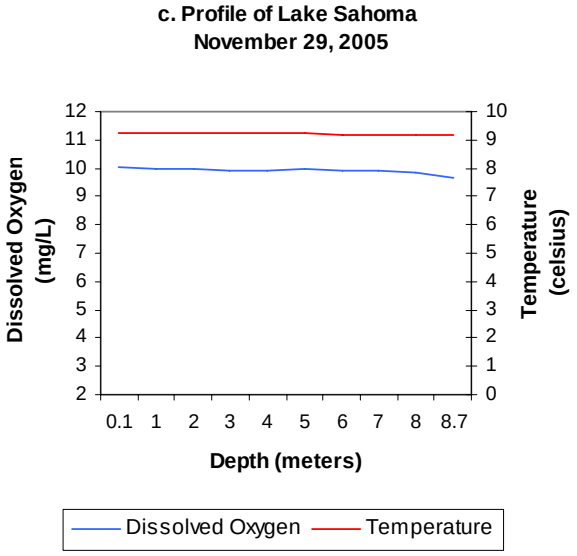
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.66 mg/L at the lake surface during the study period. The TN at the surface ranged from 0.58 mg/L to 0.74 mg/L. The highest surface TN values were reported in the spring and summer quarter and the lowest occurred in the fall and winter quarters. The lake-wide total phosphorus (TP) average was 0.031 mg/L at the lake surface. The surface TP ranged from 0.023 mg/L to 0.039 mg/L. The highest surface TP value was reported in the spring quarter and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 22:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

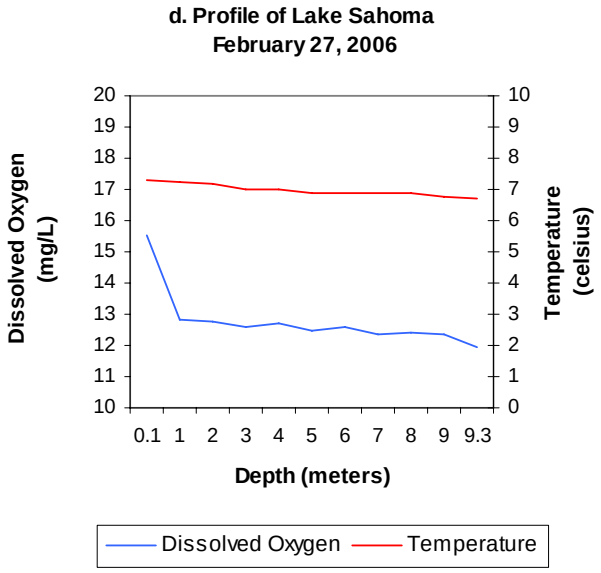
Lake Sahoma was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Lake Sahoma was classified as eutrophic (TSI=51), indicating high primary productivity and nutrient rich conditions (Plate 96). This is identical to the TSI calculated in 2004, indicating no significant increase or decrease in productivity has occurred. Water clarity was fair based on secchi disk depth, turbidity, and true color values. The lake was fully supporting its Aesthetics beneficial use based on its trophic status (for nutrients) as well as for true color as 100% of the recorded values were below the WQS of 70 units. Sahoma was fully supporting its FWP beneficial use based on pH and nephelometric turbidity however is partially supporting based on anoxic conditions present during the spring sampling interval. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.









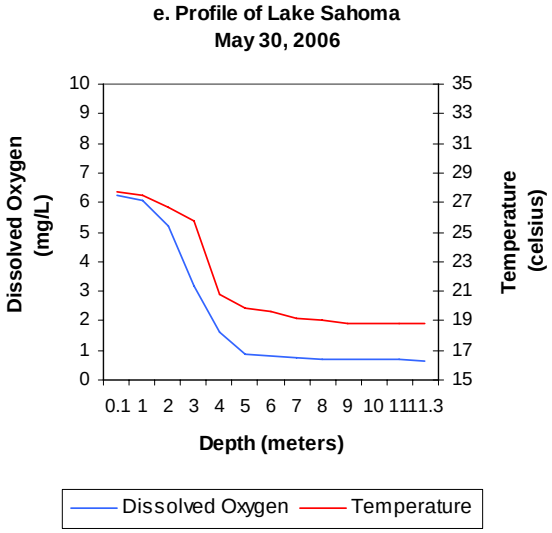
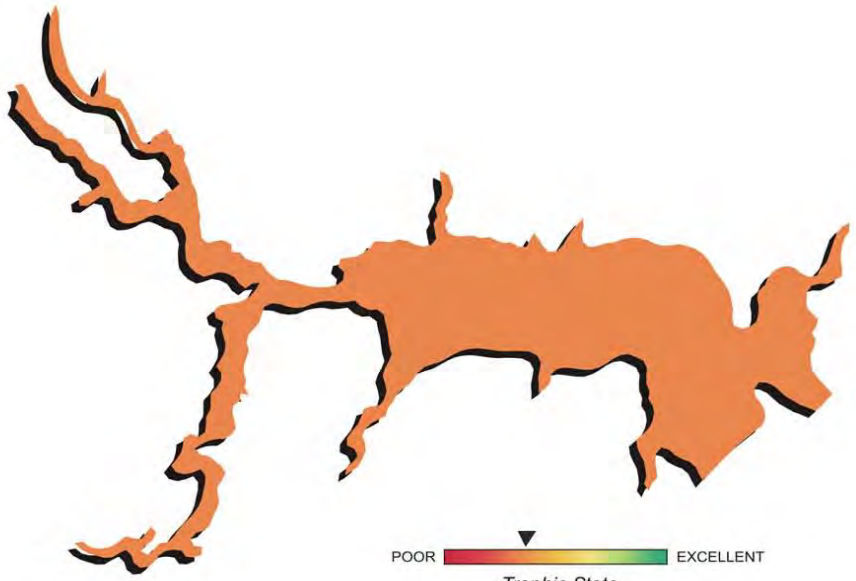


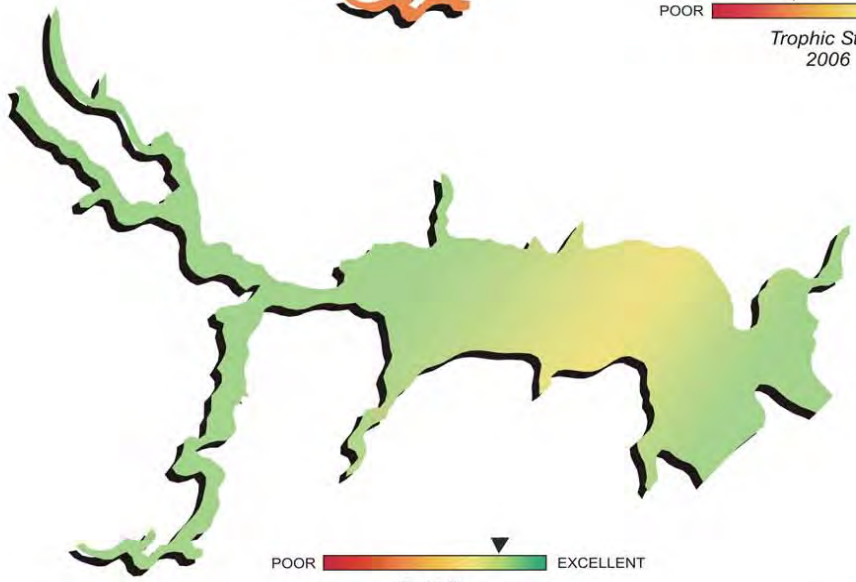
Figure 113a-113e Graphical representation of data results for Lake Sahoma.

Sahoma Lake and Watershed



Trophic State 2006

Sahoma Lake Location



Turbidity 2006

Lake Data	
Owner	City of Sapulpa
County	Creek
Constructed in	1947
Surface Area	312 acres
Volume	4,850 acre/feet
Shoreline Length	11 miles
Mean Depth	15.54 feet
Watershed Area	40 square miles

Plate 96 - Lake Water Quality for
Sahoma Lake

LAKES MONITORING PROGRAM

Sardis Lake

Sardis Lake was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 20 NTU (Plate 97), true color was 65 units, and average secchi disk depth was 74 centimeters. Based on these three parameters, Sardis Lake had average water clarity, in comparison to other Oklahoma reservoirs. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a) was calculated using values at all sites for four quarters (n=20). The TSI was 50 (Plate 97), classifying the lake as mesotrophic bordering eutrophic, with moderate to high primary productivity and nutrient conditions. This is very similar to the value calculated in 2003 (TSI=45), indicating no significant change in productivity has occurred. The TSI values were primarily upper mesotrophic throughout the year with eutrophic values in the winter quarter. The only exception to this was site 2, which remained in the mesotrophic category at the time of winter sampling. Seasonal turbidity values are displayed in Figure 114a. Turbidity varied throughout the year with the lowest values recorded in the fall and summer and the highest recorded in both winter and spring quarters. Available rainfall data suggest the peak in turbidity is likely due to seasonal storm events; however when this data is excluded 10% of the remaining values are still greater than 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Sardis Lake will be listed as partially supporting the FWP use. Seasonal true color values are displayed in Figure 114b. True color followed the same pattern as turbidity with elevated values reported in the spring sampling interval. Applying the same default protocol, the Aesthetics beneficial use is also partially supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites in 2004-2005. Salinity values ranged from 0.00 parts per thousand (ppt) to 0.02 ppt throughout the study period. This is much lower than the average range of values reported for most Oklahoma reservoirs. Specific conductivity ranged from 37.5 to 63.2 µS/cm, indicating extremely low concentrations of electrical current conducting compounds (salts) were present in the lake, consistent with the salinity readings. The pH values at were slightly acidic, ranging from 6.12 in the summer to 7.65 in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 7.5 % of the values recorded being less than 6.5 the lake will be listed as supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to

natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (ORP) ranged from 315 mV to 474 mV, indicating the absence of reducing conditions during the sample year. The lake was not stratified during the winter or spring sampling quarters and the lake was well mixed (Figure 114d-114e). Thermal stratification and anoxic conditions were present during the summer. In the summer the lake was stratified between 5 and 6 meters at which point dissolved oxygen (D.O.) fell below 2.0 mg/L for 60% of the water column (Figure 114f). Due to equipment failure no Hydrolab readings were recorded and an assessment of conditions during the fall quarter cannot be made. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Sardis Lake is partially supporting its FWP beneficial use due to anoxic conditions in the summer. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

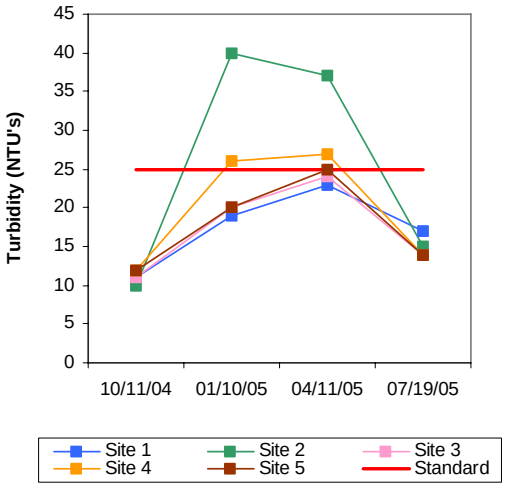
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.46 mg/L at the surface. Surface TN ranged from 0.22 mg/L to 1.01 mg/L, with the highest values reported in the spring and lowest values in the winter quarter. The lake-wide total phosphorus (TP) average was 0.030 mg/L at the surface. Total phosphorus at the surface ranged from 0.021mg/L to 0.054 mg/L. Similar to TN, surface TP was highest in the spring, however lower values were recorded during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 15:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

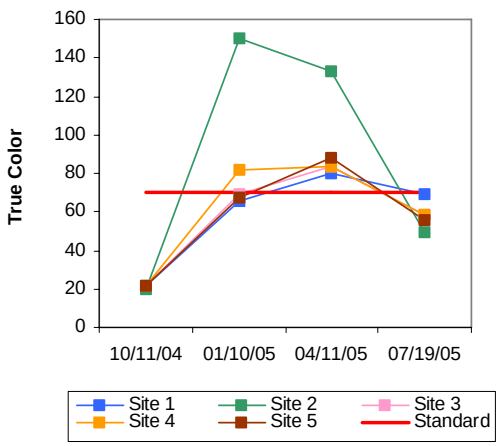
In summary, Sardis Lake was classified as mesotrophic with moderate primary productivity and nutrient conditions in 2005, consistent with results from the 2003 evaluation. Water clarity was average based on true color, turbidity, and secchi disk depth. The FWP beneficial use is partially supported by both turbidity as well as D.O. with anoxic conditions present in 60% of the water column during the summer. With 7.5% of the recorded pH values less the 6.5 units the lake is also supporting the FWP beneficial use. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The lake is supporting the Aesthetics beneficial use based on its trophic status and partially supporting the use for true color values. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. In 1999, a bathymetric survey was conducted at Sardis Lake (Figure 115) as part of the Kiamichi River Development Project. The purpose of the survey was to generate a 3-D simulation of water level changes within the reservoir in response to concerns local citizens had regarding the potential transfer of water to other areas of the state and /or the north Texas area. Specific concerns included fluctuating lake levels and the subsequent impacts on fish/wildlife, recreation, tourism and economic development in the area. For further information about this study or bathymetric

mapping visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800. Sardis Lake, located in Pushmataha County, was constructed by the United States Army Corps of Engineers (USACE) for flood control, water supply, and fish and wildlife purposes.

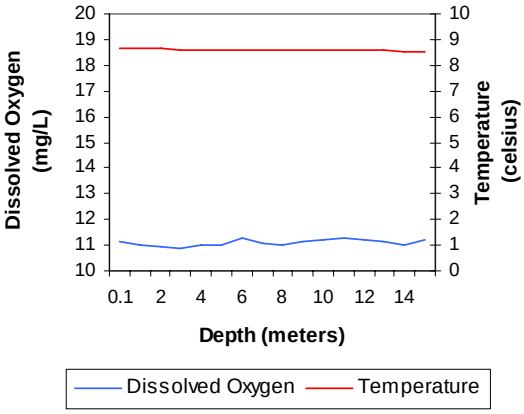
a. Seasonal Turbidity Values for Sardis Lake



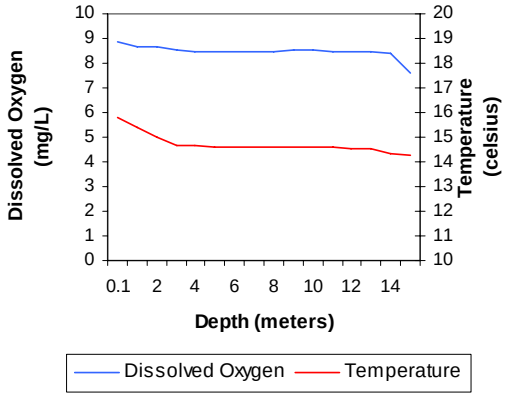
b. Seasonal Color Values for Sardis Lake



c. Profile of Sardis Lake
January 10, 2005



d. Profile of Sardis Lake
April 11, 2005



e. Profile of Sardis Lake
July 19, 2005

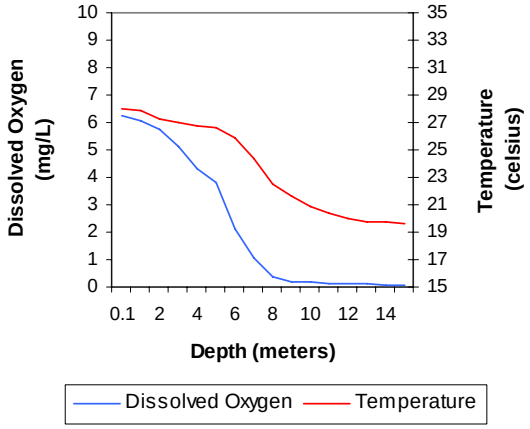
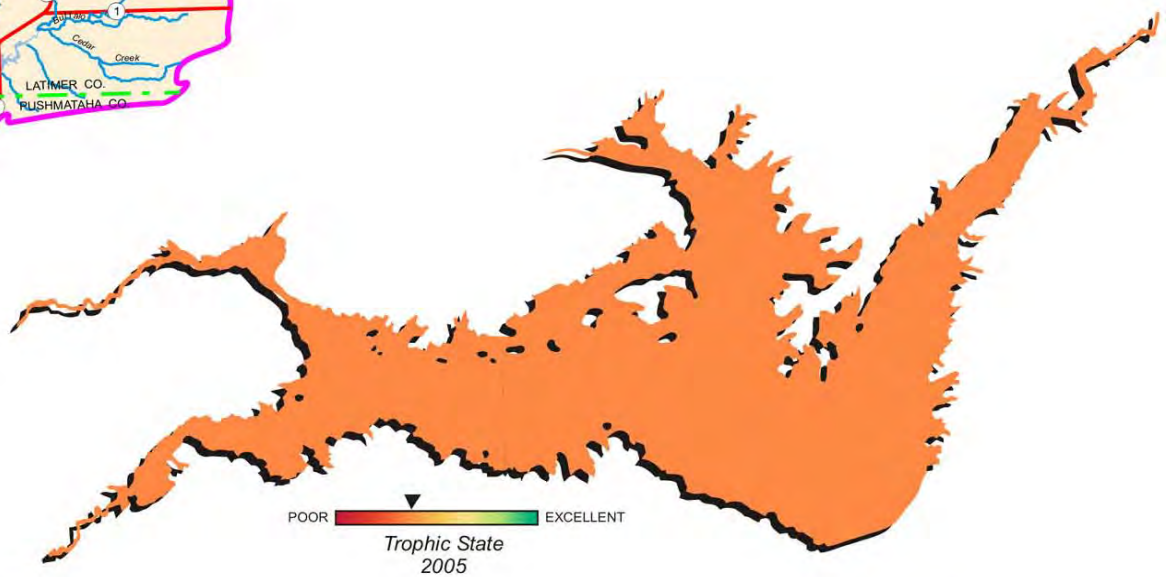
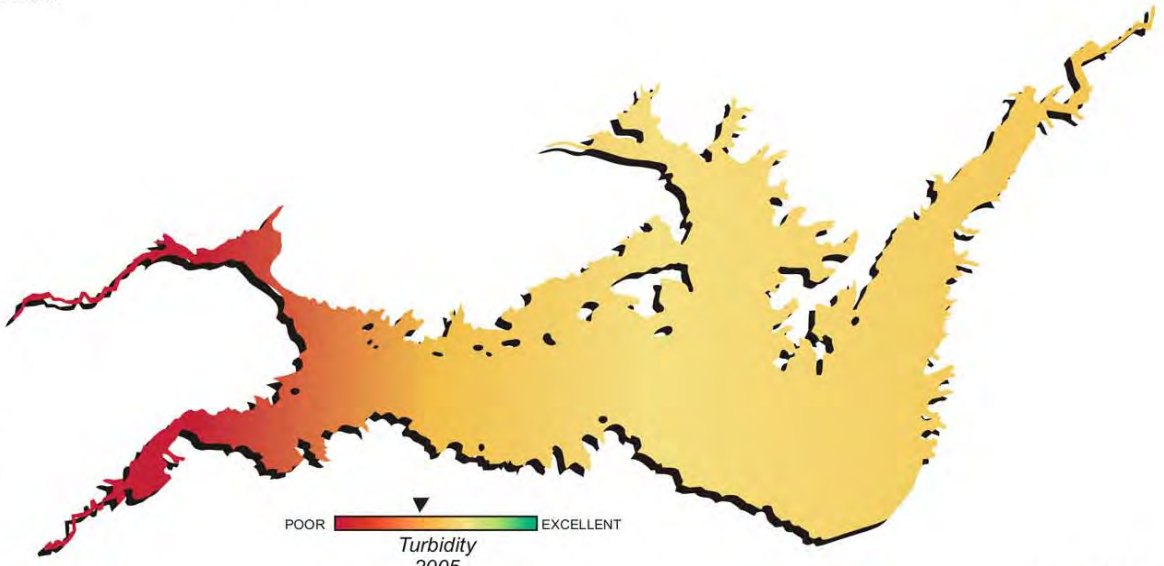


Figure 114a-114f. Graphical representation of data results for Sardis Lake.

Sardis Lake
Location



Trophic State
2005



Turbidity
2005

Lake Data	
Constructed by	Corps of Engineers
County	Pushmataha
Constructed in	1983
Surface Area	13,589 acres
Volume	233,053 acre/feet
Shoreline Length	92.5 miles
Mean Depth	16.47 feet
Watershed Area	275 square miles

Plate 97 - Lake Water Quality for
Sardis Lake

LAKES MONITORING PROGRAM

Figure 115. Bathymetric Map of Sardis Lake.

Shawnee Twin Lake # 1

Shawnee Twin Lake # 1 was constructed in 1935 and is owned and operated by the City of Shawnee. The lake is utilized as a municipal water supply and affords numerous recreational opportunities to the public. Shawnee Twin Lake # 1 was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major arms. Samples were collected from the lake surface at all five sites during the study period. Due to low lake levels OWRB staff were unable to access the lake in both the winter and summer sampling intervals. Lake levels were so low that the City of Shawnee closed both Twin Lakes and the canal joining the two lakes was completely dry. The following data discussion is based on the data collected in November 2005, February 2006 and was aggregated with past historical data collected since the beginning of the BUMP program in 1998. The lake-wide average turbidity value was 15 NTU (Plate 98), true color was 29 units, and secchi disk depth was 67 centimeters. Based on these three parameters, Shawnee Twin Lake # 1 had good water clarity. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites (n=73). The average TSI was 41 (Plate 98), indicating the lake was mesotrophic, bordering oligotrophic, with low to moderate levels of primary productivity and nutrient conditions. Turbidity values were generally well below the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Of the seventy-three samples collected, only 7 (9%) of the values were above the criteria therefore the lake is considered supporting its Fish & Wildlife Propagation (FWP) beneficial use. True color followed a similar pattern with values generally below the aesthetics WQS of 70 units at all sites throughout the sample period. With only 7% of the collected samples below the numerical criteria for true color, the lake is fully supporting its Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites throughout the period of record. Salinity ranged from 0.08 parts per thousand (ppt) to 0.22 ppt, which is within the range of salinity concentrations reported for most Oklahoma lakes. Specific conductivity ranged from 82 μS/cm to 433.5 μS/cm, indicating that low to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral with values ranging from 7.08 units to 9.85 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only 0.34% of the recorded values outside the allowable range, the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 43 mV to 523 mV indicating that reducing conditions were not present during any of the sampling events.

Lower redox values are not uncommon when a large portion of the water column is experiencing anoxic conditions as was the case in the summer of 1998 and 1999. Upon reviewing the profile data from 1998 to the present, the lake is generally well mixed in the fall, winter and spring sampling intervals with dissolved oxygen (D.O.) levels remaining above 2.0mg/L. Thermal stratification and anoxic conditions are evident during the warmer summer months with up to 67% (in 1999) of the water at site 1 having D.O. levels below 2.0 mg/L. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Shawnee Twin Lake # 1 due to anoxic conditions present during the summer months. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average for the period of record is 0.42 mg/L at the lake surface. The TN at the surface ranged from 0.06 mg/L to 2.33 mg/L. The lake-wide total phosphorus (TP) average is 0.019 mg/L at the lake surface. The surface TP ranged from 0.003 mg/L to 0.078 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 22:1. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

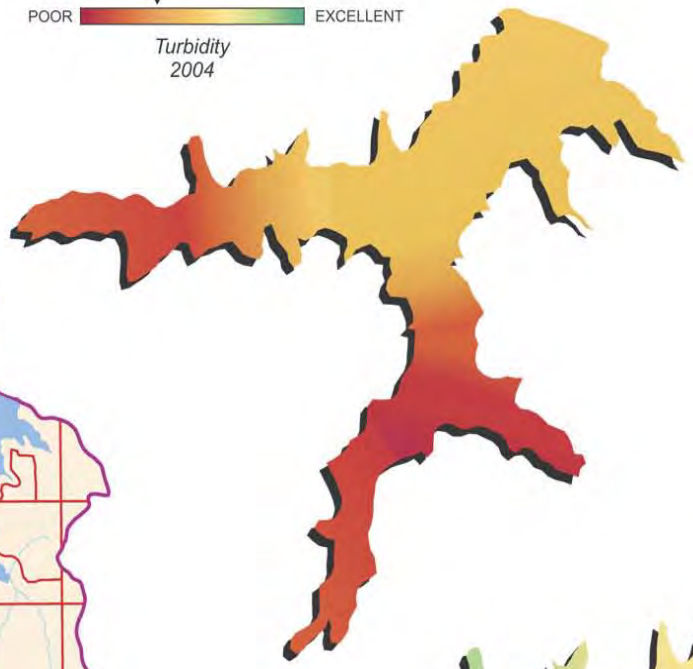
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1999 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Shawnee Twin Lake # 1 was classified as mesotrophic bordering oligotrophic, indicating low to moderate primary productivity and nutrient conditions (Plate 98). Water clarity is good based on turbidity, true color and Secchi disk depth. The lake is currently fully supporting its Aesthetics beneficial use based on the trophic status (nutrients) and true color. In reviewing profile data for the period of record the lake was fully supporting its FWP beneficial for pH and partially supporting the use as it relates to dissolved oxygen. With only 9% of the values exceeding the criteria of 25 NTU, the lake is considered supporting its Fish & Wildlife Propagation (FWP) beneficial use.

Shawnee Twin Lake No. 1 Location

Shawnee Twin Lake No. 1 and Watershed

Turbidity 2004



Trophic State 2004

Lake Data	
Owner	City of Shawnee
County	Pottawatomie
Constructed	1935
Surface Area	1,336 acres
Volume	22,600 acre/feet
Shoreline Length	16 miles
Mean Depth	16.92 feet
Watershed Area	21 square miles

Plate 98 - Lake Water Quality for

Shawnee Twin Lake No. 1

LAKES MONITORING PROGRAM

Shawnee Twin Lake # 2

Shawnee Twin Lake # 2, located in Pottawatomie County, was constructed in 1960 and is owned and operated by the City of Shawnee. The lake is utilized as a municipal water supply and affords numerous recreational opportunities to the public. The lake was scheduled for sampling during the 2005-2006 sample year however due to the drought conditions lake levels were too low for OWRB staff to launch a boat. The lake will be placed on the next sample rotation once water levels rise enough for staff to access the lake safely.

Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as any major lake arms Water quality samples were collected from the lake surface at five sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 25 NTU (Plate 99), true color was 34 units, and secchi disk depth was 47 centimeters in 2003-2004. Based on these three parameters, Shawnee Twin Lake # 2 had good water clarity in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for all four quarters (n=20). The average TSI was 42 (Plate 99), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. This value is exactly the same as that calculated in 2002, indicating that no significant change in trophic status has occurred. Seasonal TSI values were mesotrophic throughout the year except for site 3 in the winter quarter, which dipped down into the oligotrophic category in the winter quarter. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 25% of the values were above the criteria, available flow data suggests the peak in turbidity that occurred in May is likely due to seasonal storm events and the lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Of the twenty true color values collected, three (15%) were above the WQS of 70 units, corresponding with the elevated turbidity readings. The Aesthetics beneficial use is considered supported as the high true color readings are likely due to seasonal rain events.

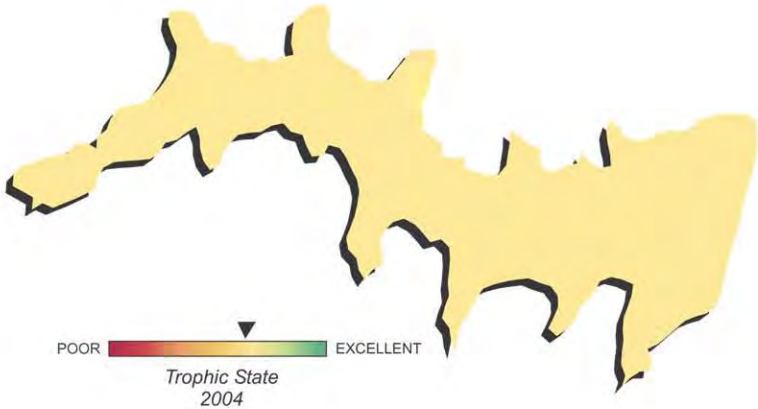
Please refer to the "Beneficial Use Monitoring Report 2004 Draft Final Report" for the full discussion of monitoring results for this lake. The report may be access via the OWRB's web page at http://www. owrb.state.ok.us or you may contact the Water Resources for a copy of the 2004 BUMP Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the address below:

Oklahoma Water Resources Board
3800 N. Classen Blvd.
Oklahoma city, Oklahoma 73118
Attn: Nikki Cole

Shawnee Twin Lake No. 2
Location

Shawnee Twin Lake No. 2
and
Watershed

Turbidity
2004



Trophic State
2004

Lake Data	
Owner	City of Shawnee
County	Pottawatomie
Constructed	1960
Surface Area	1,100 acres
Volume	11,400 acre/feet
Shoreline Length	9 miles
Mean Depth	10.36 feet
Watershed Area	11 square miles

Plate 99 - Lake Water Quality for
Shawnee Twin Lake No. 2

LAKES MONITORING PROGRAM

Shell Lake

Shell Lake, located in Osage County, was constructed in 1922 and is owned and operated by the City of Sand Springs. The lake is maintained as a municipal water supply offers numerous recreational opportunities to the public. Shell Lake was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones as well as any major arms of the reservoir. Samples were collected at the lake surface at all sample sites during the study period. The lake-wide annual turbidity value was 9 NTU (Plate 100), true color was 21 units, and secchi disk depth was 83 centimeters in 2005-2006. Based on these three parameters water clarity at Shell Lake was excellent at the time of sampling. This is consistent with the previous data collection efforts of 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 53 (Plate 100), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions. This value is similar to that calculated in 2004 (TSI=52) and 2002 (TSI=51), indicating no significant change in productivity has occurred over time. The TSI values varied seasonally from mesotrophic in the fall and winter quarters, to lower eutrophy in the spring, to upper eutrophy in the summer quarter All turbidity values were well below the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 116a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With a lake-wide annual turbidity average of 11 NTU Shell Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 116b. All of the true color values were below the numeric criteria of 70 units in 2005-2006. Applying the same default protocol; Shell Lake is supporting the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.08 parts per thousand (ppt) to 0.20 ppt, indicating low salt content and were well within the expected range of salinity values reported for most Oklahoma lakes and reservoirs. Specific conductivity ranged from 172.2 µS/cm to 280.5 µS/cm, indicating very low levels of electrical conducting compounds (salts) were present in the lake system, corresponding with the recorded salinity values. In general, pH values were neutral to slightly alkaline, ranging from 6.74 units to 8.52 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the collected pH values within the acceptable range; Shell Lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 327 mV at the sediment-water interface in the spring to 496 mV also in the spring quarter. Redox readings indicated that reducing conditions were not present in the reservoir during the study period. The lake was not

thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 7.0 mg/L throughout the water column (see Figure 116c-116d). In the spring the lake was strongly thermally stratified between 3 and 4 meters in depth with dissolved oxygen (D.O.) concentrations below 2.0 mg/L from 5 meters to the lake bottom of 13.9 meters. Approximately 67% of the water column at site 1, the dam, was experiencing anoxic conditions at the time of sampling (Figure 116e). Sites 2,3 and 5 were all stratified at the same point and anoxic conditions were present in 33-38% of the water column among the various sites. Due to equipment malfunction profile data is not available for assessment for the summer sampling interval. It is likely that stratification and anoxic conditions would be present with the lake stratifying so strongly in the spring. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Shell Lake with approximately 67% of the water column anoxic during the spring. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average for sample year 2005-2006 was 0.76 mg/L at the lake surface. The TN at the surface ranged from 0.55 mg/L to 0.96 mg/L. The highest surface TN value was reported in the winter quarter and the lowest was in the spring. The lake-wide total phosphorus (TP) average was 0.022 mg/L at the lake surface. The surface TP ranged from 0.019 mg/L to 0.027 mg/L. The highest surface TP value was reported in the fall and the lowest was in the spring quarter. The values for both parameters are very similar to those of the previous evaluation in 2004. The nitrogen to phosphorus ratio (TN: TP) was approximately 35:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Shell Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Shell Lake was eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate). The current TSI is similar to that calculated in 2004 (TSI=52) and 2002 (TSI=51), indicating no significant change in productivity has occurred over time. Based on turbidity, true color and secchi disk depth water clarity at Shell Lake was excellent at the time of sampling. This is also consistent with the previous data collection efforts of 2004. Shell Lake is fully supporting its Aesthetics beneficial use based on nutrients and true color for sample year 2005-2006. The FWP beneficial use was fully supported for turbidity and pH, but was partially supported for D.O. with 33-67% of the water column being anoxic during the spring sampling interval. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample

results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

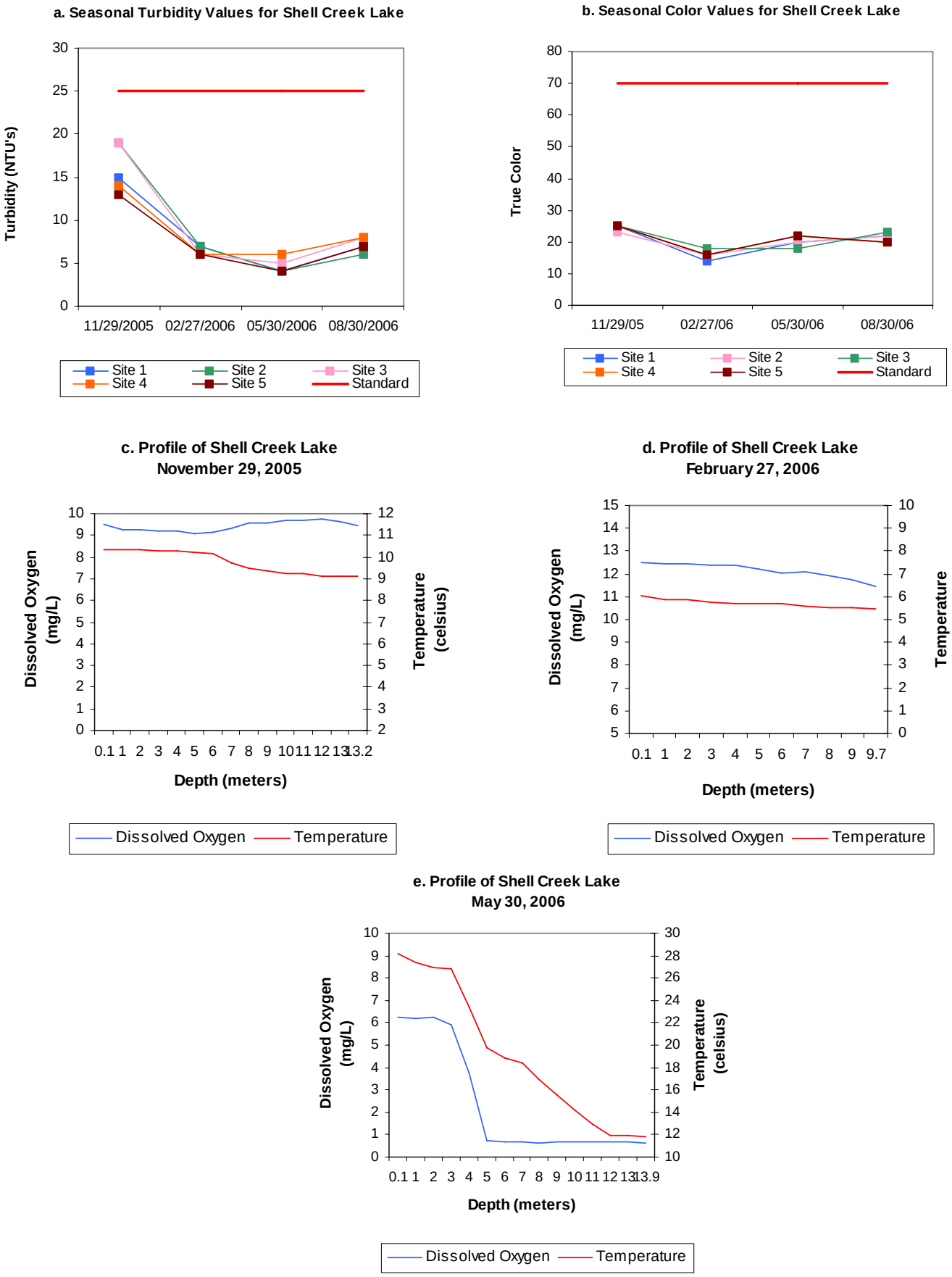
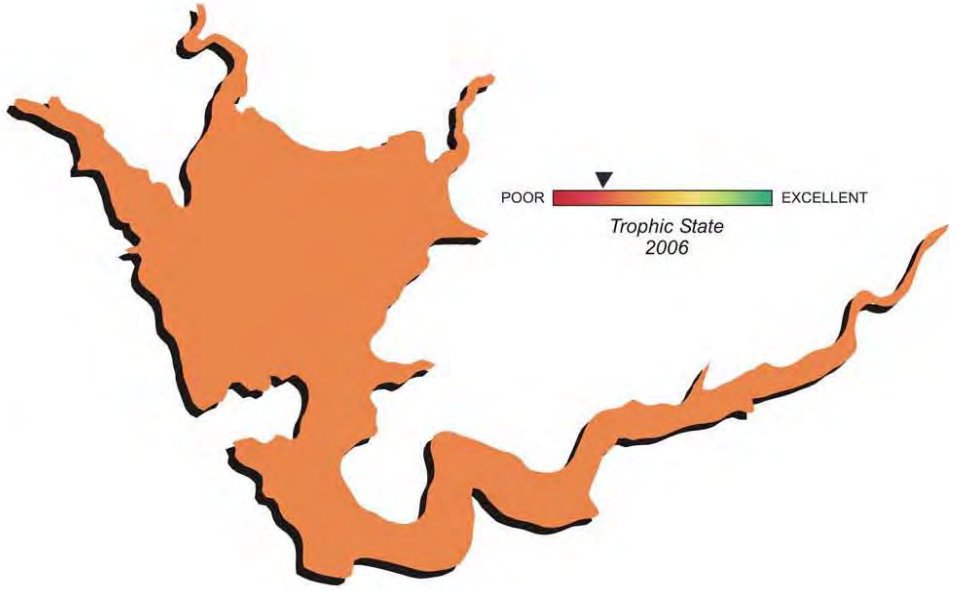
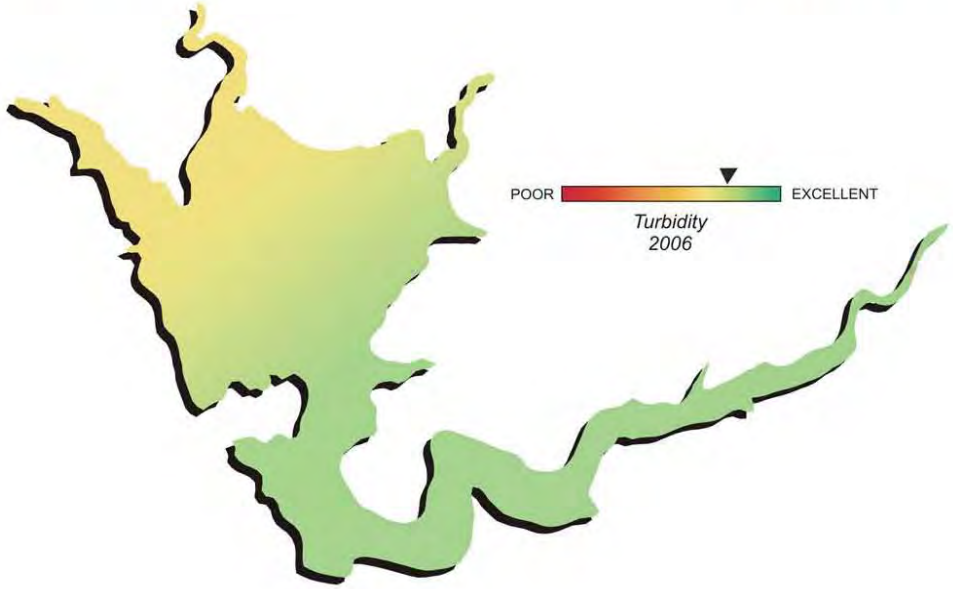


Figure 116a-116e. Graphical representation of data results for Shell Lake.

Shell Lake
and
Watershed



Trophic State
2006



Turbidity
2006

Lake Data

Owner	City of Sand Springs
County	Osage
Constructed in	1922
Surface Area	573 acres
Volume	9,500 acre/feet
Shoreline Length	13 miles
Mean Depth	16.58 feet
Watershed Area	15 square miles

Plate 100 - Lake Water Quality for
Shell Lake

LAKES MONITORING PROGRAM

Skiatook Lake

Skiatook Lake was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected at seven (7) sites to represent the riverine, transitional, and lacustrine zones and major arms of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The average lake-wide annual turbidity value was 13 NTU (Plate 101), true color was 27 units, and average secchi disk depth was 85 centimeters. Based on these three parameters Skiatook Lake had good water clarity in 2004-2005, similar to that reported in sample year 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=28). The average TSI was 43 (Plate 101), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions. This value is similar to the TSI calculated in 2003 (TSI=45), and in the same trophic category, indicating no significant change in productivity has occurred since the previous evaluation. The TSI values varied by site and season throughout the sample year with values primarily in the mesotrophic category. In the winter values were primarily mesotrophic with sites 1, 2 and 7 falling in the oligotrophic category. In the summer quarters TSI values were split with half of the values being oligotrophic and the other half mesotrophic. Seasonal turbidity values are displayed in Figure 117a. Turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU throughout the year, except sites 4 (Hominy Creek arm) and 5 (Bull Creek arm) in the spring. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 7.1% of the samples exceeding the standard, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported for sample year 2005. Seasonal true color values are displayed in Figure 117b. True color followed the same pattern as turbidity with all values below the WQS of 70, except for sites 4 and 5, which had a values of 121 and 113 units, respectively reported in the spring quarter. Applying the same default protocol, the Aesthetics beneficial use is fully supported.

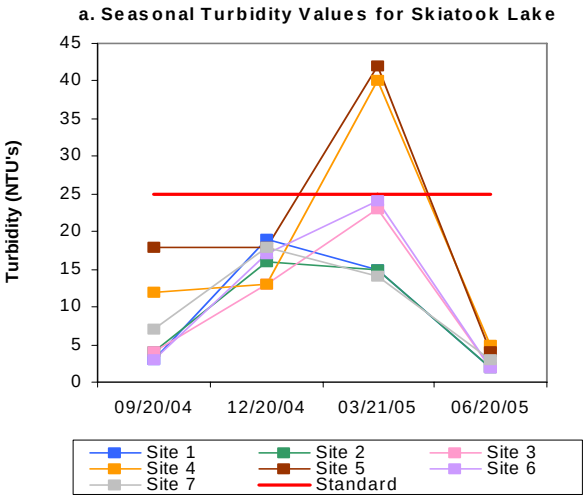
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites in 2004-2005. Salinity values ranged from 0.10 parts per thousand (ppt) to 0.19 ppt during the study period. This is within the average range of values reported for most Oklahoma reservoirs. Specific conductivity ranged from 206.6 to 388.5 µS/cm, indicating the presence of minimal concentrations of electrical current conducting compounds (salts) were present in the lake, consistent with the salinity readings. In general, pH values were neutral to slightly alkaline with values ranging from 6.7 to 8.35 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the recorded values within the acceptable range the lake is considered supporting

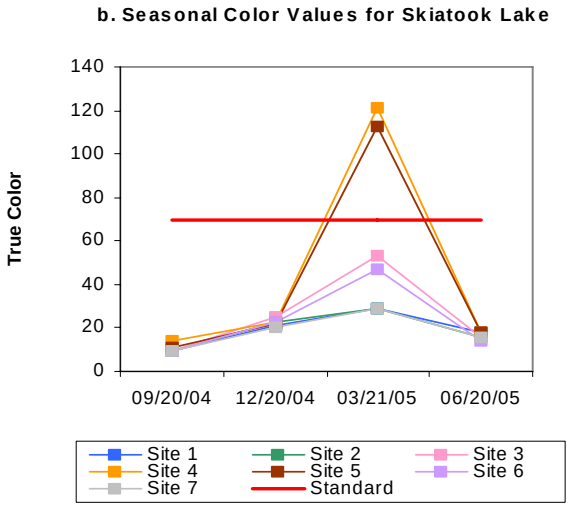
the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 45 mV in the hypolimnion during fall to 490 mV in the summer quarter. In general reducing conditions were not present at the time of sampling, although near reducing conditions were present in the fall when a large portion of the water column was anoxic. The lake was not stratified in the winter or spring sampling quarters and the water column was well mixed with dissolved oxygen (D.O.) concentrations generally above 7.0 mg/L (Figure 117d-115e). Thermal stratification was evident and anoxic conditions were present in both the fall and summer quarters. In the fall, the lake was stratified between 10 and 11 meters at sites 1-3 and 5-7 at which point D.O. fell below 2.0 mg/L for the rest of the water column (Figure 117c). Anoxic conditions were present in 14 (site 5) to 61% (site1) of the water column during the fall sampling interval. During the summer, stratification occurred at several 1-meter intervals throughout the entire waterbody with anoxic conditions constituting 25 to 65% of the water column. Site 3 (Osage Park) had the largest portion of the water column less than 2.0 mg/L during this time period. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Skiatook Lake is partially supporting its FWP beneficial use due to anoxic conditions in both fall and summer sampling quarters. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

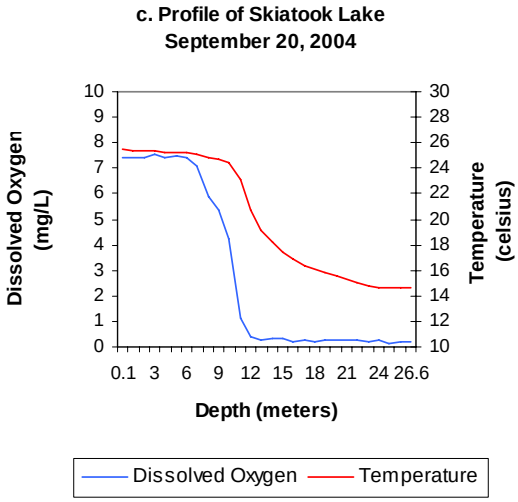
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

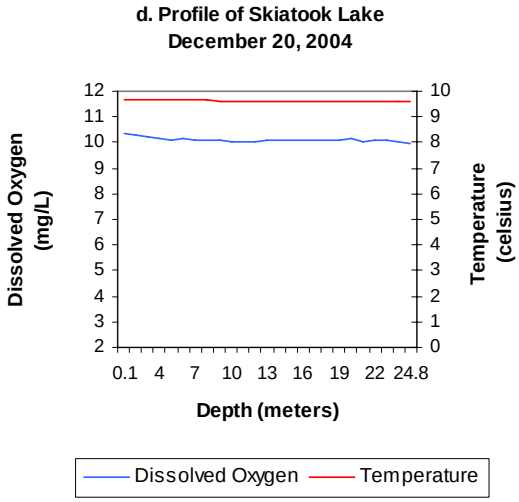
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.35 mg/L at the surface. Surface TN ranged from 0.10 mg/L to 0.51 mg/L, with the highest values reported in the spring and lowest values in the summer quarter. The lake-wide total phosphorus (TP) average was 0.017 mg/L at the surface. Total phosphorus at the surface ranged from 0.010mg/L to 0.045 mg/L. Surface TP was highest in the spring, and the lowest values were recorded during both fall and summer quarters. The nitrogen to phosphorus ratio (TN:TP) was approximately 20:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

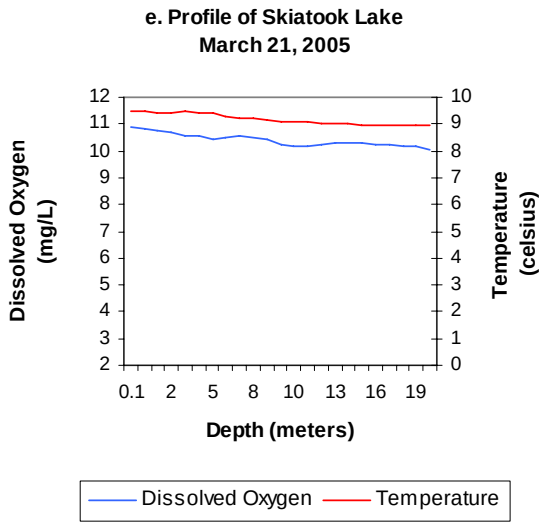
In summary, Skiatook Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions (Plate 101). These results are similar to those reported in 2003, indicating no significant increase or decrease in productivity has occurred. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on turbidity and pH, but only partially supporting due to anoxic condition in both fall and summer quarters. With anoxic conditions present for such a large portion of the water column the lake should be monitored closely in the future. The Aesthetics beneficial use is fully supported by both its trophic status and true color values. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Skiatook Lake was constructed by the United States Army Corps of Engineers (USACE) for flood control, water supply and quality control, recreation, fish and wildlife purposes. The lake is located in Osage County approximately five miles west of the City of Skiatook.











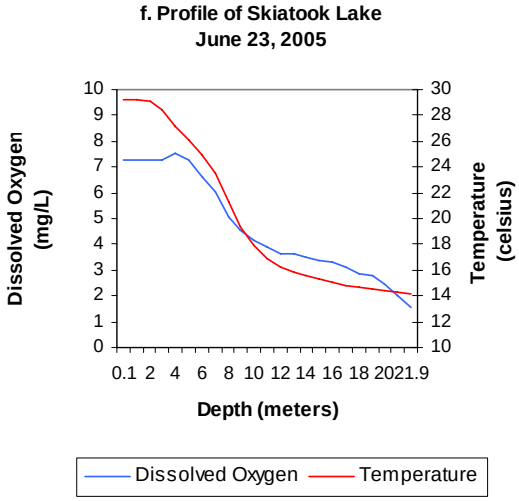
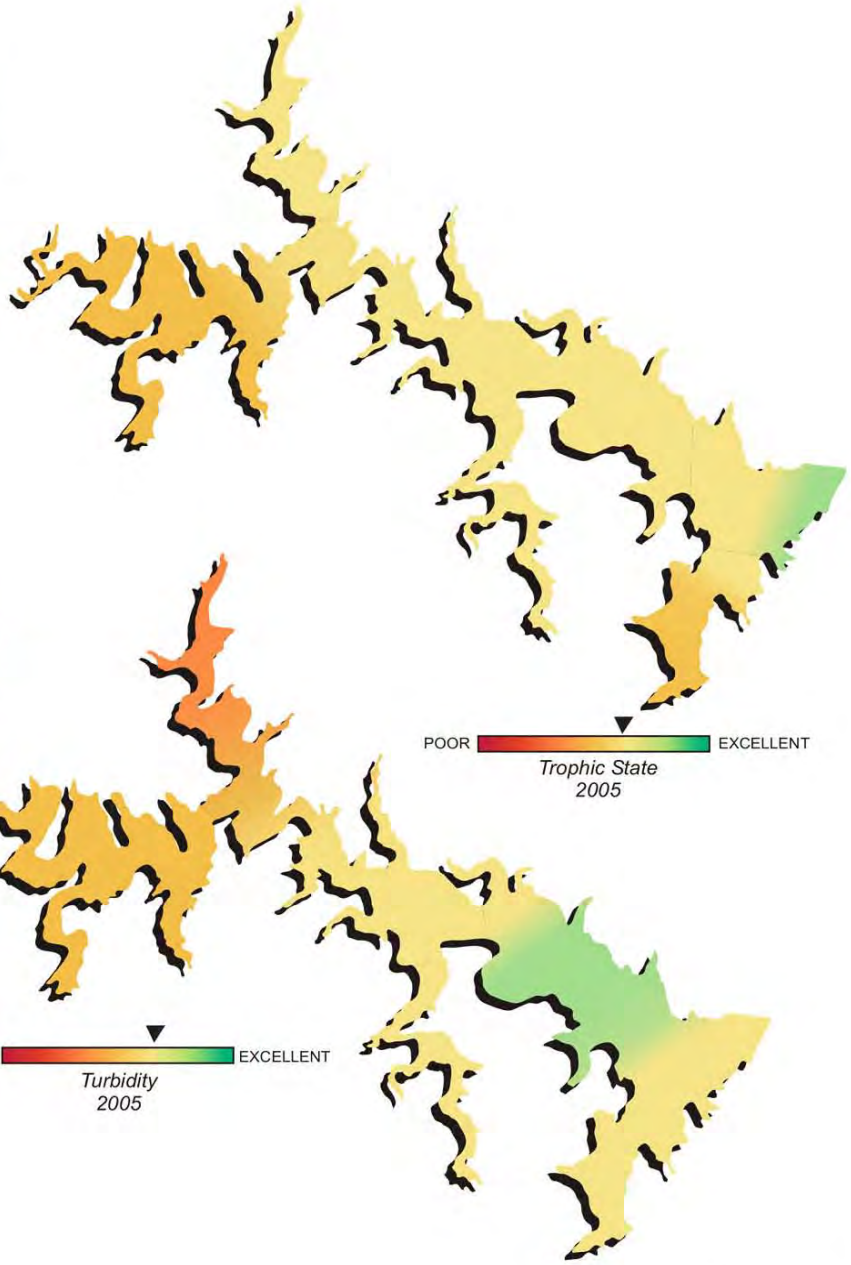


Figure 117a-117f. Graphical representation of data results for Skiatook Lake.

Skiatook Lake and Watershed

Skiatook Lake Location



Lake Data	
Constructed by	Corps of Engineers
County	Osage
Constructed in	1984
Surface Area	10,190 acres
Volume	322,700 acre/feet
Shoreline Length	160 miles
Mean Depth	31.42 feet
Watershed Area	354 square miles

Plate 101 - Lake Water Quality for

Skiatook Lake

LAKES MONITORING PROGRAM

Sooner Reservoir

Sooner Reservoir was sampled for four quarters, from November 2004 through August 2005. Water quality samples were collected at five (5) to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The average lake-wide turbidity value was 7 NTU (Plate 102), true color was 14 units, and average secchi disk depth was 114 centimeters. Based on these three parameters, Sooner Reservoir had excellent water clarity during the study period. These results are similar to those in 2003, indicating no change has occurred in clarity over time. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 48 (Plate 102), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions. This value is the same as the TSI calculated in 2003 (TSI=48), indicating no change in productivity has occurred since the last evaluation. The TSI values were primarily mesotrophic throughout the year. The exception to this occurred at sites 2, 3, and 5 in the fall and site 2 in the summer, when conditions at these sites were eutrophic. Seasonal turbidity per site is displayed in Figure 118a. All turbidity values were below the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the samples below the standard, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported for sample year 2005. Seasonal true color values are displayed in Figure 118b. All of the true color values were below the numeric criteria of 70 units, with values ranging from a low of 7 to a maximum of 20 units. Applying the same default protocol, the Aesthetic beneficial use is considered supported.

In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.75 parts per thousand (ppt) to 1.02 ppt during the study period. This is much higher than the average range of values reported for most Oklahoma reservoirs. Specific conductivity ranged from 1417 in the spring to 1914 µS/cm in the summer, indicating high concentrations of electrical current conducting compounds (salts) were present in the lake, consistent with the elevated salinity readings. In general pH values were neutral to slightly alkaline with values ranging from 7.11 to 8.44 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the recorded values within the acceptable range the Sooner Reservoir is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 99 mV near the sediment-water interface in the spring to 458 mV in the fall, indicating the absence of reducing conditions. During the fall and winter quarters the lake was well mixed with dissolved oxygen generally above 7.0 mg/L (Figure 118c-118d). In

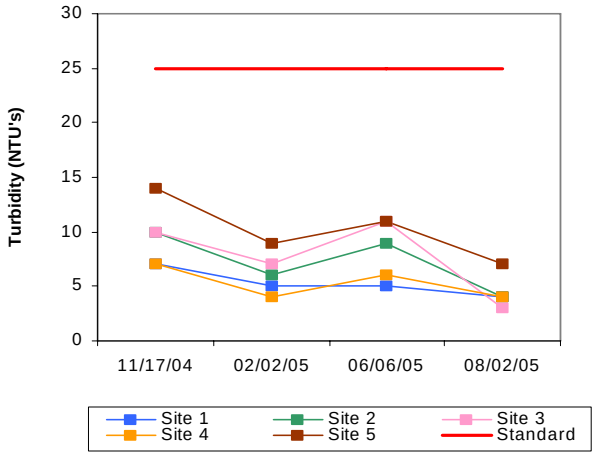
the spring stratification occurred at several 1-meter intervals however dissolved oxygen remained above 2.0 mg/L until the very near the lake bottom. Anoxic conditions constituted less than 10% of the water column at sites 1, 2, and 5 during this sampling interval. Thermal stratification was evident and anoxic conditions were present below the thermocline in the summer (Figure 118f). The lake was stratified between 10 and 11 meters with dissolved oxygen (D.O.) concentrations below 2.0 mg/L for approximately 33 to 48% of the water column sites 1, 2 and 4. If D.O. values are less than 2 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Sooner Reservoir is considered supporting its FWP beneficial use with 48% of the water column experiencing anoxic conditions in the summer sampling quarter. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

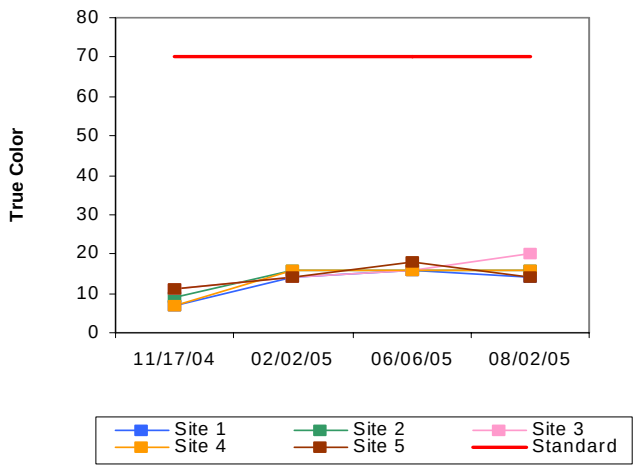
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.40 mg/L at the surface. Surface TN ranged from 0.21 mg/L to 0.83 mg/L, with the highest values reported in the summer and lowest values in the fall quarter. The lake-wide total phosphorus (TP) average was 0.020 mg/L at the surface. Total phosphorus at the surface ranged from 0.018mg/L to 0.027 mg/L. Surface TP was highest in the summer, and the lowest values were recorded during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 20:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Sooner Reservoir was classified as mesotrophic with moderate primary productivity and nutrient conditions (Plate 102). This is same as the 2003 evaluation (TSI=48), therefore no change in productivity has occurred over time. Water clarity was excellent in 2004-2005, based on true color, turbidity and secchi disk depth. The FWP beneficial use is supported based on turbidity, pH, and dissolved oxygen levels reported during the study period. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color with 100% of the collected true color values well below the standard of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Sooner Reservoir, located in Pawnee County, is owned and operated by the Oklahoma Gas and Electric Company (OG&E) as a cooling reservoir.

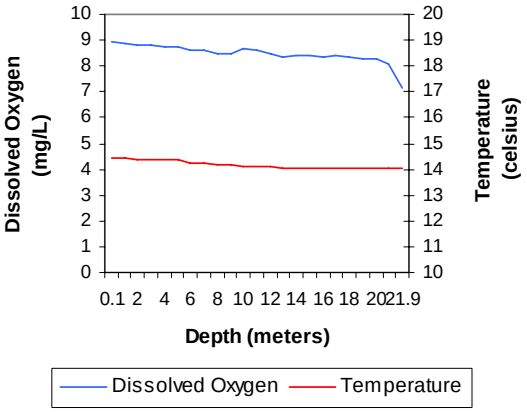
a. Seasonal Turbidity Values for Sooner Reservoir



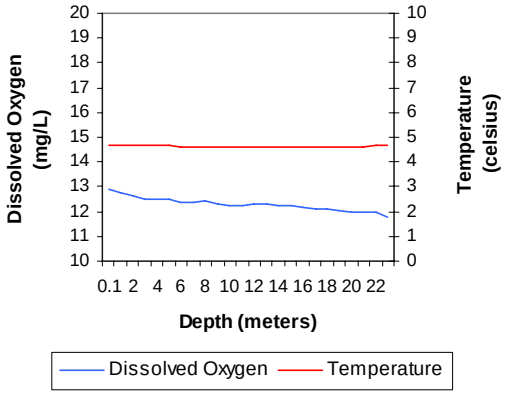
b. Seasonal Color Values for Sooner Reservoir



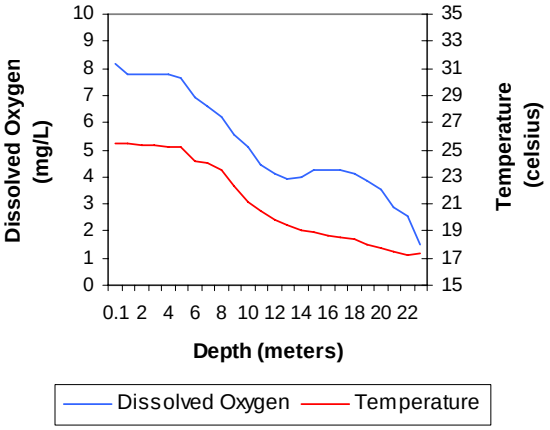
c. Profile of Sooner Reservoir
November 17, 2004



d. Profile of Sooner Reservoir
February 02, 2005



e. Profile of Sooner Reservoir
June 06, 2005



f. Profile of Sooner Reservoir
August 01, 2005

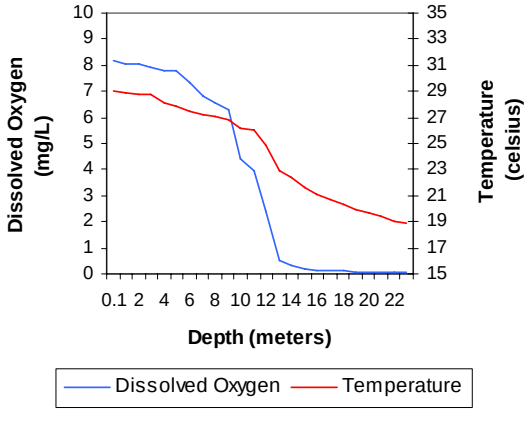
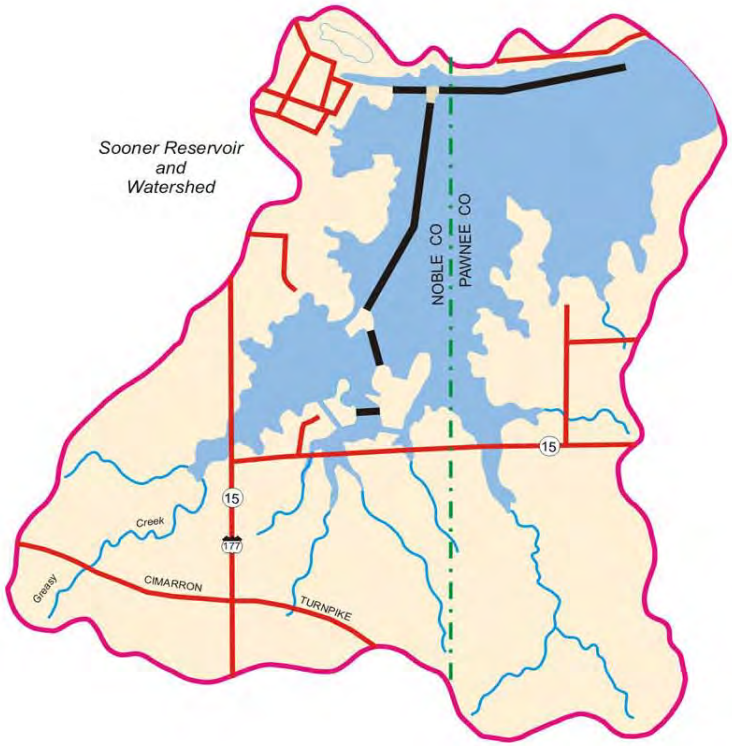


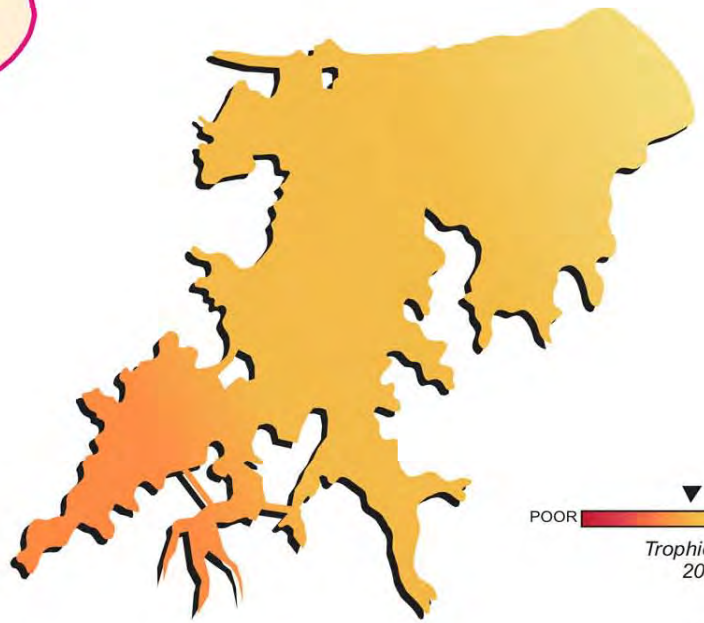
Figure 118a-118f. Graphical representation of data results for Sooner Reservoir.



POOR — EXCELLENT

Turbidity
2005

Sooner Reservoir
Location



POOR — EXCELLENT

Trophic State
2005

Lake Data	
Owner	OG & E*
County	Pawnee (dam)
Constructed	1972
Surface Area	5,400 acres
Volume	149,000 acre/feet
Shoreline Length	42 miles
Mean Depth	27.59 feet
Watershed Area	18,536 acres

*Oklahoma Gas and Electric Co.

Plate 102 - Lake Water Quality for
Sooner Reservoir

LAKES MONITORING PROGRAM

Spavinaw Lake

Spavinaw Lake was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the lake. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam site. The average lake-wide turbidity was 7 NTU (Plate 103), true color was 18 units, and secchi disk depth was 116 centimeters. Based on these three parameters water clarity at Eucha Lake was excellent in sample year 2004-2005. Results for these parameters are similar to that seen in the 2003 evaluation. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The TSI was 61 (Plate 103), indicating the lake was hypereutrophic, indicative of moderate primary productivity and nutrient levels in sample year 2004-2005. The TSI values were primarily hypereutrophic in the fall and winter with the exception of site 2, which was eutrophic in the fall quarter. In the spring the sites were half eutrophic (4,5) and half hypereutrophic (1-3), while all sites were mesotrophic in the summer quarter. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (WQS). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Seasonal turbidity values are displayed in Figure 119a. Turbidity values were well below the Oklahoma Water Quality Standard (WQS) of 25 NTU and ranged from a low of 3 NTU (site 4) to a maximum of 24 NTU (site 2). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the recorded values below 25 NTU, the Fish and Wildlife Propagation (FWP) beneficial use is considered fully supported. Seasonal true color values were all well below the WQS of 70 units and are displayed in Figure 119b. Applying the same default protocol, the Aesthetic beneficial use is considered supported at Spavinaw Lake.

In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.06 parts per thousand (ppt) to 0.14 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductivity ranged from 139.2 µS/cm to 281.8 µS/cm, indicative of low to moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 7.11 to 8.75, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all the collected values within the acceptable range Spavinaw Lake is fully supporting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from -30 mV in the hypolimnion in the summer to 473 mV in the winter quarter. In general, reducing conditions were not present at this reservoir, with all values above 100 mV, with the exception of the one value recorded at the lake bottom at

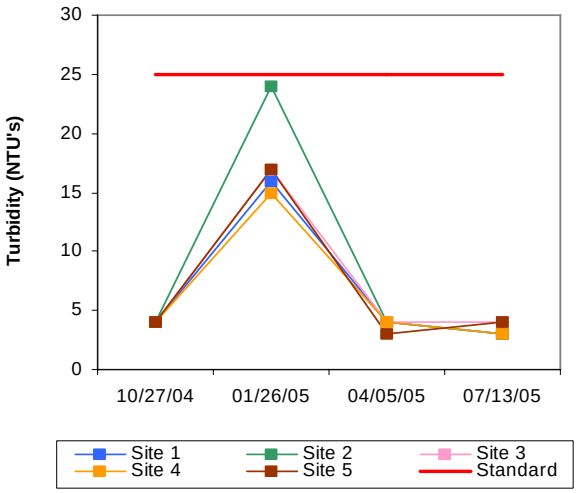
site 1 in the summer when anoxic conditions were present in a large portion of the water column. The lake was not stratified in the fall, winter and spring quarters and the water column was well mixed with dissolved oxygen (D.O.) values generally above 6.0 mg/L (see Figure 119c-119e). Thermal stratification was evident and anoxic conditions were present throughout the lake in the summer (Figure 119f). During the summer sampling interval, stratification occurred between 3 and 4 meters at which point dissolved oxygen dropped below 2.0 mg/L to the lake bottom. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With anoxic conditions accounting for 20 to 62% of the water column, in the summer, Spavinaw Lake is considered to be partially supporting the FWP beneficial use. These conditions could pose a serious concern, threatening fish and wildlife propagation and the lake should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

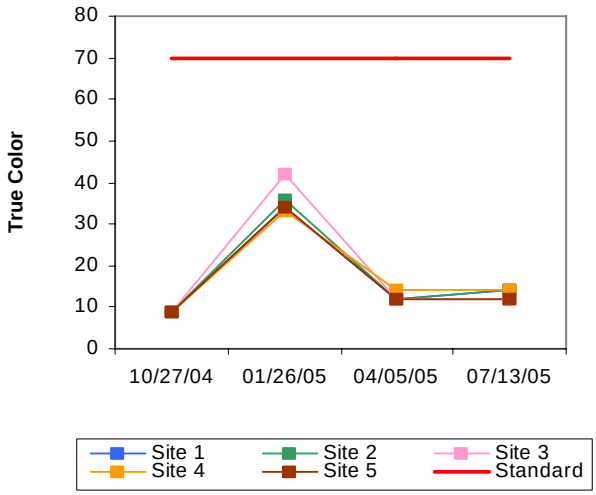
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.20 mg/L at the surface. Surface TN ranged from 0.27 mg/L to 2.19 mg/L, with the highest values reported in the winter and lowest values in the summer quarter. The lake-wide total phosphorus (TP) average was 0.036 mg/L at the surface. Total phosphorus at the surface ranged from 0.020mg/L to 0.072 mg/L. Similar to total nitrogen surface TP was highest in the winter, and the lowest values were recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 34:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Spavinaw Lake was classified as hypereutrophic, with excessive primary productivity and nutrient levels in 2004-2005. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (WQS) and is considered nutrient impaired. A nutrient impairment study should be conducted to determine if uses are impaired. Several studies have been conducted in Eucha/Spavinaw complex by the OWRB and other state agencies and can be referenced for further information. Water clarity was excellent based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on pH and turbidity, but partially supporting based on low dissolved oxygen values occurring in the summer. The Aesthetics beneficial use is currently supported based on the true color, as all collected values were less than the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Spavinaw Lake, located in Mayes County, is owned by the city of Tulsa and utilized for a water supply, recreation, and wildlife reservoir. In 1999, the Tulsa Municipal Authority contracted the OWRB to conduct bathymetric survey of Spavinaw Lake (Figure 120) to determine current lake volume, capacity, and sedimentation rates. The survey information was used to support numerical modeling of proposed water quality improvements by the OWRB. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800.

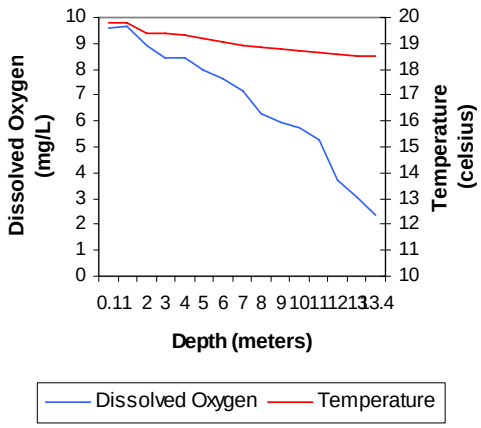
a. Seasonal Turbidity Values for Spavinaw Lake



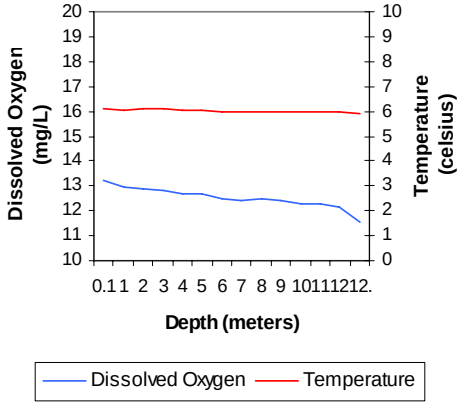
b. Seasonal Color Values for Spavinaw Lake



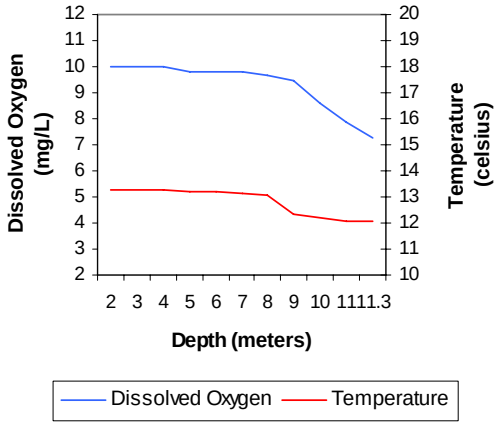
c. Profile of Spavinaw Lake
October 27, 2004



d. Profile of Spavinaw Lake
January 26, 2005



e. Profile of Spavinaw Lake
April 05, 2005



f. Profile of Spavinaw Lake
July 13, 2005

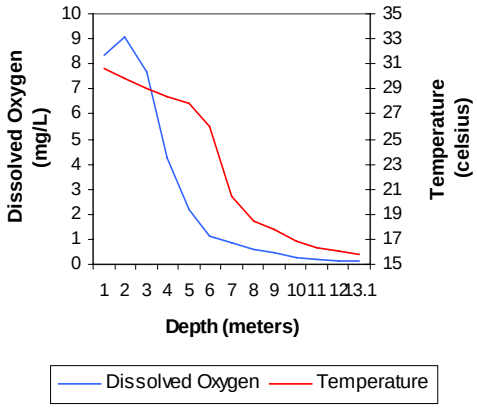
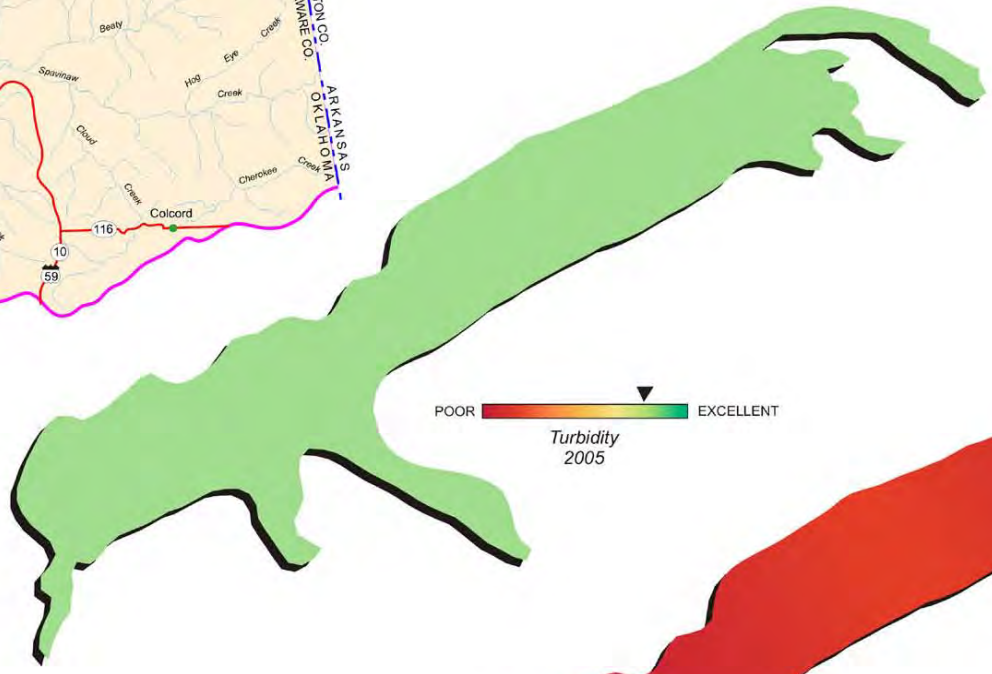


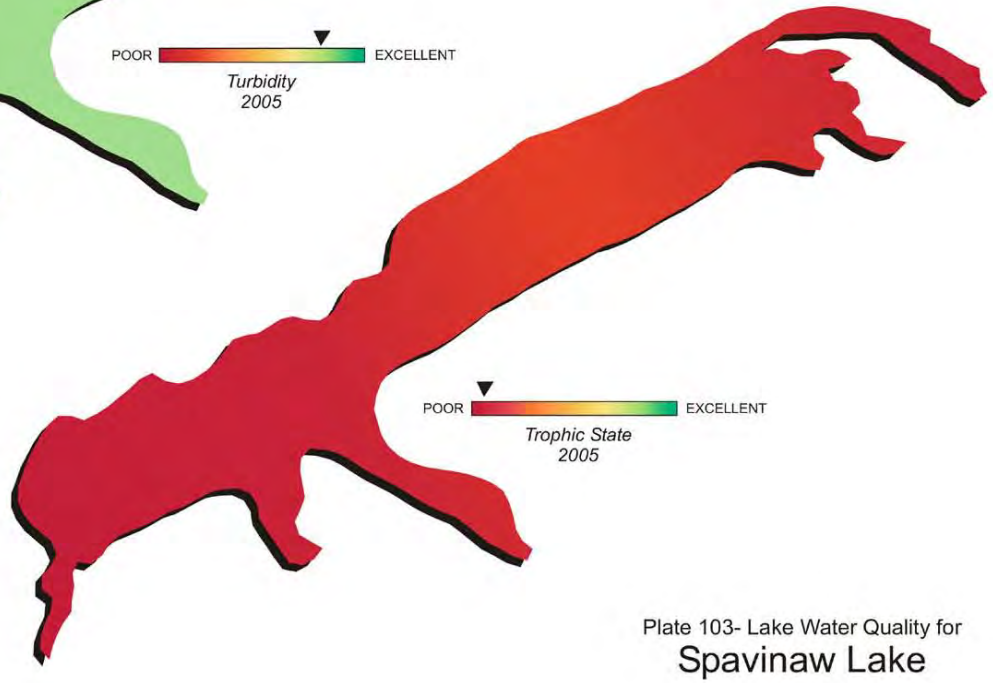
Figure 119a-119f. Graphical representation of data results for Spavinaw Lake.

Spavinaw Lake and Watershed

Spavinaw Lake Location



Turbidity 2005



Trophic State 2005

Lake Data	
Constructed by	City of Tulsa
County	Delaware/Mayes
Constructed in	1924
Surface Area	1,578 acres
Volume	25,941 acre/feet
Shoreline Length	26.71 miles
Mean Depth	16.10 feet
Watershed Area	248 square miles

Plate 103- Lake Water Quality for
Spavinaw Lake

LAKES MONITORING PROGRAM

Figure 120. Bathymetric Map of Spavinaw Lake.

Spiro Lake

New Spiro Lake. Located in Le Flore County, was constructed in 1960 is owned and operated by the City of Spiro and serves as a municipal water supply and offers numerous recreational opportunities to the public. New Spiro Lake was sampled for four quarters, from October 2005 through August 2006.

Water quality samples were collected at three sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all three sites during the study period. The lake-wide annual turbidity value was 18 NTU (Plate 104), true color was 26 units, and secchi disk depth was 47 centimeters in 2005-2006. Based on these three parameters, New Spiro Lake had good water clarity in comparison to other Oklahoma reservoirs. Water clarity is similar to previous collection efforts conducted in 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was calculated at 68 (Plate 104), indicating the lake was hypereutrophic, with excessive primary productivity and nutrient conditions. This is consistent with the TSI calculated in 2004 (TSI=64) and 2002 (TSI=68), which also found the lake to be hypereutrophic. The TSI values were hypereutrophic at all sites throughout the sample year. Based on the trophic classification, the lake is listed in the last Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Seasonal turbidity values are displayed in Figure 121a. Only one (8%) of the twelve samples collected exceeded the WQS of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 92% of the values below the WQS the lake is considered fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 121b. 100% of the true color values were below the aesthetics WQS of 70 units at all times. Applying the same default protocol, the Aesthetics beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.04 parts per thousand (ppt) to 0.07 ppt, indicating low salt content in the lake and were well within the expected range of, if not slightly lower than, salinity values reported for most Oklahoma lakes. Readings for specific conductivity were low, ranging from 106.8 µS/cm to 155.4 µS/cm, indicating the minimal presence of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to alkaline in nature with values ranging from 7.09 units in the spring quarter to 9.24 in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 10% values greater than 9.0 units the lake is

partially supporting its FWP beneficial use based on pH values. Oxidation-reduction potentials (redox) ranged from 121 mV at the water-sediment interface in the spring to 155.4 mV in the fall, indicating an absence of reducing conditions in the lake. New Spiro Lake was not stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 7.0 mg/L throughout the water column. (See Figure 121c-121d). The lake was thermally stratified and anoxic conditions were present in both spring and summer quarters. In the spring the lake was stratified between 3-4 meters with dissolved oxygen levels below 2.0 mg/L for 33% of the water column at site 1 (Figure 121e-121f). During the summer quarter, the lake was thermally stratified between 1 and 2 meters at all sites (see Figure 121f). Anoxic conditions were present below the 2-meter depth at all three sites and D.O. readings were below 1.0 mg/L from 3 meters to the lake bottom at 3.1 meters. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, with 17-33% of the water column less than 2.0 mg/L during the spring and summer sampling intervals, the FWP beneficial use is considered supported at New Spiro Lake. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

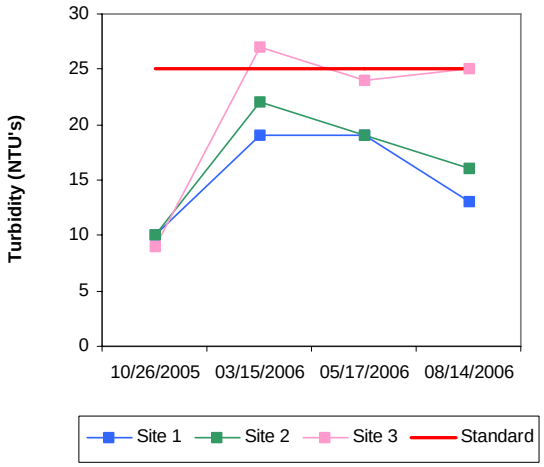
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average for sample year 2005-2006 was 1.22 mg/L at the lake surface. The TN at the surface ranged from 0.98 mg/L to 1.68 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average for sample year was 0.111 mg/L at the lake surface. The surface TP ranged from 0.076 mg/L to 0.170 mg/L. Similar to TN the highest surface TP value was reported in the summer quarter and the lowest occurred in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 11:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

New Spiro Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

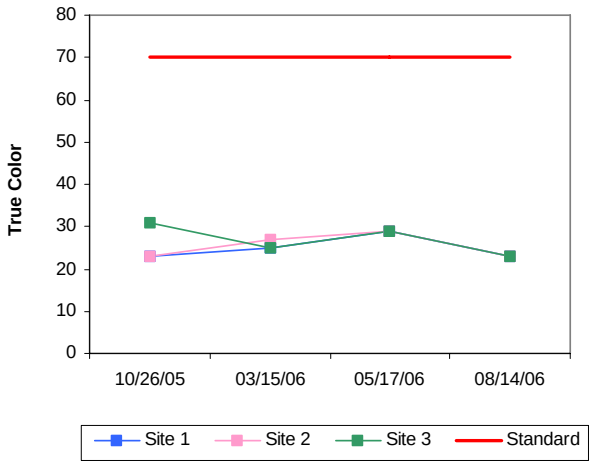
In summary, New Spiro Lake was classified as hypereutrophic, with excessive primary productivity and nutrient levels in sample year 2006 (Plate 104). This is consistent with the TSI calculated in 2004 (TSI=64) and 2002 (TSI=68), which also found the lake to be hypereutrophic. The TSI values were hypereutrophic at all sites throughout the sample year. Based on the trophic classification, the lake was recommended for listing in the last Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. With 100% of the reported values below the WQS of 70 units the lake was fully supporting its Aesthetics beneficial use as it relates true color. New Spiro Lake was fully supporting its FWP beneficial use based on turbidity and

dissolved oxygen concentrations. With 10% values greater than 9.0 units the lake is partially supporting its FWP beneficial use based on pH values.. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

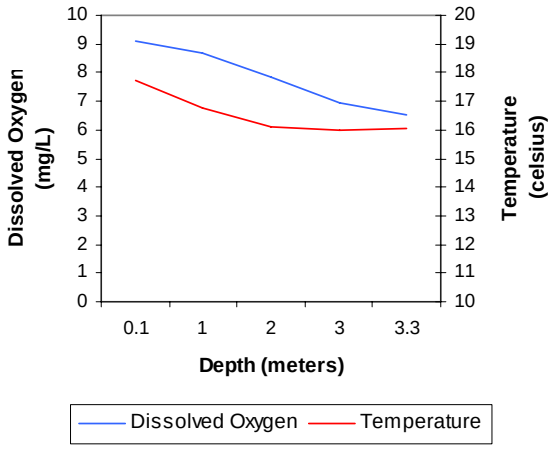
a. Seasonal Turbidity Values for New Spiro Lake



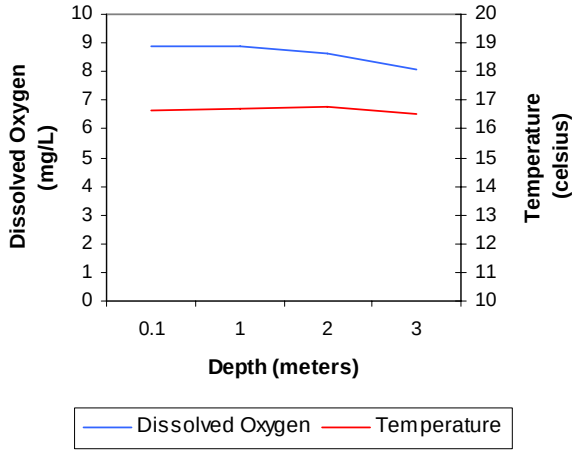
b. Seasonal Color Values for New Spiro Lake



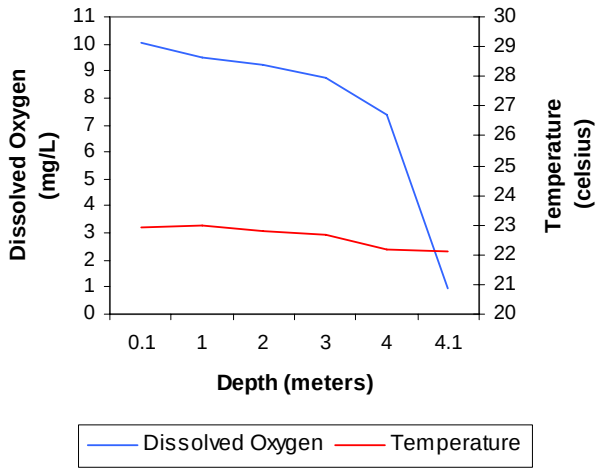
c. Profile of New Spiro Lake
October 26, 2005



d. Profile of New Spiro Lake
March 15, 2006



e. Profile of New Spiro Lake
May 17, 2006



e. Profile of New Spiro Lake
August 14, 2006

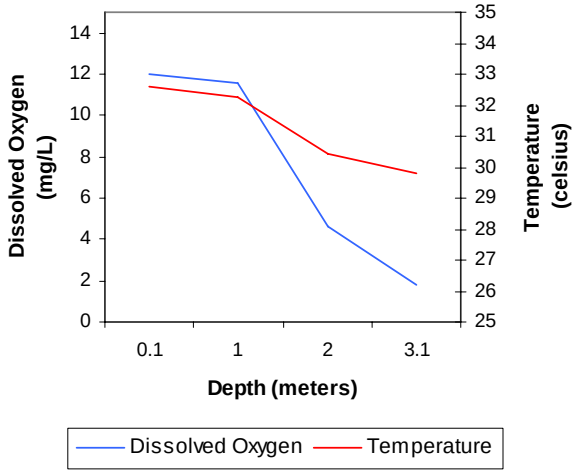


Figure 121a-121f. Graphical representation of data results for New Spiro Lake.

New Spiro Lake
and
Watershed

New Spiro Lake
Location

Trophic State
2006

Turbidity
2006

Lake Data	
Owner	City of Spiro
County	LeFlore
Constructed	1960
Surface Area	254 acres
Volume	2,160 acre/feet
Shoreline Length	5 miles
Mean Depth	8.50 feet
Watershed Area	14 square miles

Plate 104 - Lake Water Quality for
Spiro (New) Lake

LAKES MONITORING PROGRAM

Sportsman Lake

Sportsman Lake was sampled for four quarters, from November 2004 through September 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water quality samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 16 NTU (Plate 105), true color was 59 units, and secchi disk depth was 82 centimeters in 2004-2005. Water clarity was average based on these three parameters. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 40 (Plate 105), classifying the lake as oligotrophic bordering mesotrophic, indicative of low to moderate levels of primary productivity and nutrient conditions. This is similar to the 2003 evaluation, which had a calculated TSI of 41. The TSI values varied seasonally from oligotrophic in the fall and spring quarter to lower mesotrophy in the winter and summer quarters. Seasonal turbidity values are displayed in Figure 122a. Turbidity values ranged from a low of 6 NTU to a maximum of 30 NTU. Turbidity at site 5 exceeded the standard in three of the four sampling intervals. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 20% of the values exceeding 25 NTU, Sportsman Lake is partially supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to nephelometric turbidity. Seasonal true color values are displayed in Figure 122b. Of the twenty values collected, seven (35%) exceeded the WQS of 70 units. Applying the same default protocol, the Aesthetic beneficial use is considered not supported.

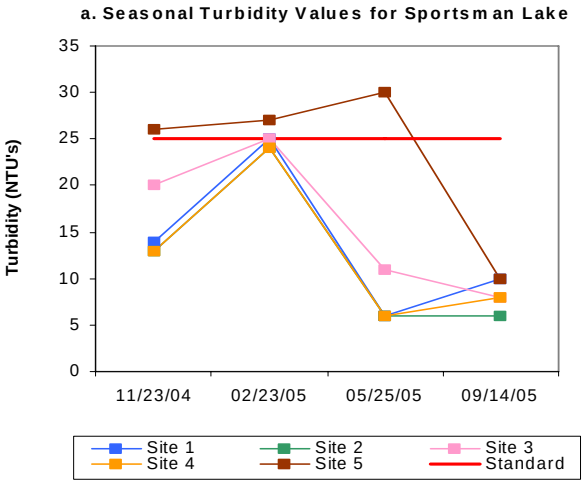
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature; specific conductivity, oxidation-reduction potential, and salinity were recorded at all three water chemistry sample sites. The salinity values ranged from 0.05 parts per thousand (ppt) to 0.19 ppt, which is within the expected range of salinity values, reported for most Oklahoma lakes. Specific conductivity ranged from 118.3 µS/cm in the fall quarter to 382.4 µS/cm in the summer, indicating low to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral, ranging from 6.76 to 7.85 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range, Sportsman was fully supporting its FWP beneficial use as it relates to pH. Oxidation-reduction potentials (redox) ranged from 165 mV at the sediment-water interface in the summer to 449 mV in the spring quarter. Redox readings indicated that reducing conditions were not present in the reservoir during any of the sampling events. The lake was not thermally stratified in the fall or winter quarter and dissolved oxygen (D.O.) values were above 7.0 mg/L throughout the water column (see Figure 122c-122d). In the spring, the lake was stratified at several 1-meter

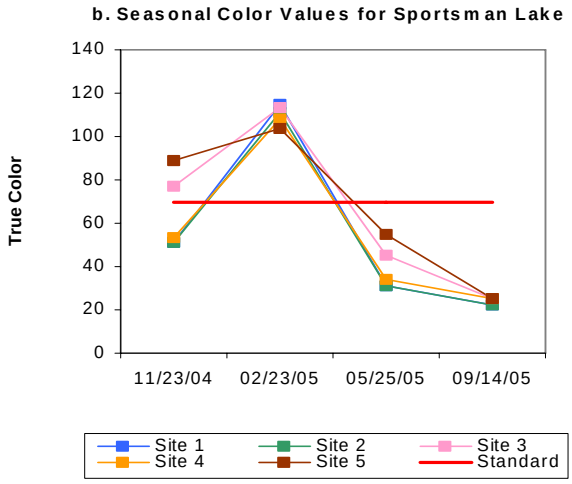
intervals, the first one between 2 and 3 meters at sites 1 and 2 and again between 7 and 8 meters at site 1 (see Figure 122e). Below the 7-meter depth at sites 1 and 2, the D.O. concentrations were less than 2.0 mg/L extending to the lake bottom at 8.2 meters (see Figure 122e). In the summer, the lake was strongly thermally stratified between 5 and 6 meters, at which point D.O. values were less than 2.0 mg/L all the way to the lake bottom at 9.9 meters (see Figure 122f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at as in the spring only 22% of the water column was less than 2.0 mg/L and in the summer only 46% of the water column. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

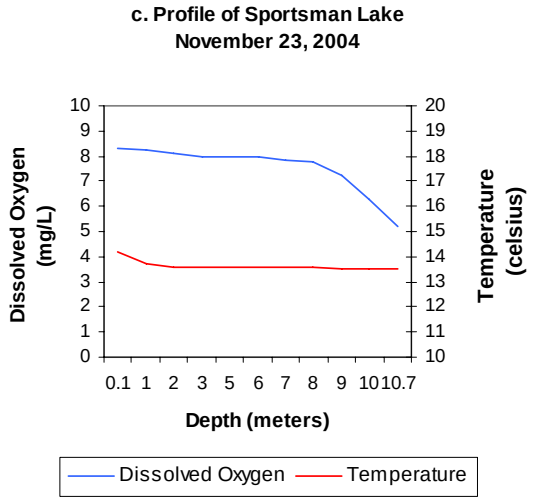
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

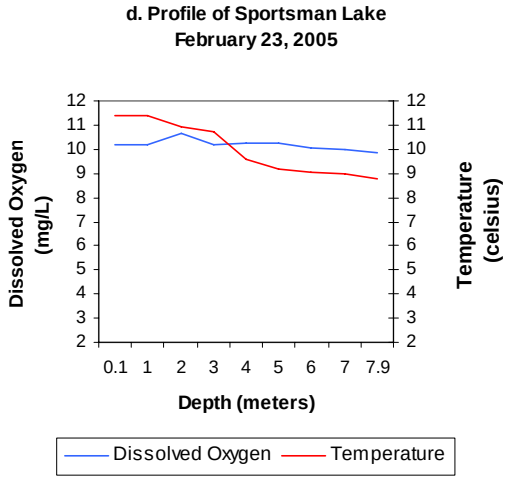
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.43 mg/L at the surface. Surface TN ranged from 0.19 mg/L to 0.82 mg/L, with the highest values reported in the summer and lowest values in the winter quarter. The lake-wide total phosphorus (TP) average was 0.023 mg/L at the surface. Total phosphorus at the surface ranged from 0.015mg/L to 0.032 mg/L. Surface TP was highest in the winter, and the lowest values were recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 18:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

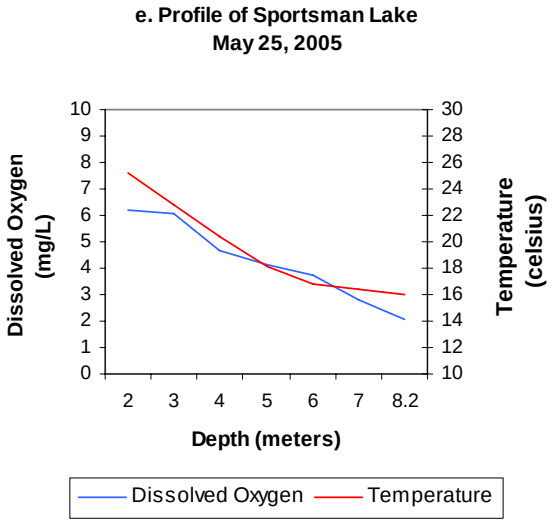
In summary, Sportsman Lake was oligotrophic bordering mesotrophic, indicative of low to moderate to low primary productivity and nutrient conditions (Plate 105). Water clarity was average based on turbidity, true color, and secchi disk depth. Sportsman Lake was fully supporting its Aesthetics beneficial use based on its trophic state and not supporting for true color with 35% of the values greater than the WQS of 70 units. The FWP beneficial use was fully supporting for pH and D.O. in the water column and partially supporting the use based on turbidity. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Sportsman Lake was constructed in 1958 and is owned and operated by the City of Seminole. It is utilized for flood control and offers numerous recreational opportunities to the public.











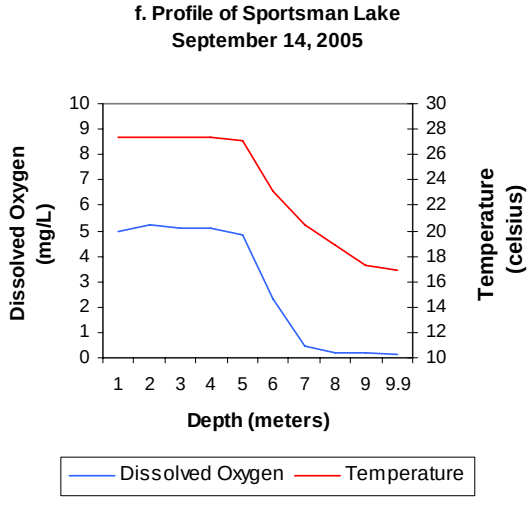
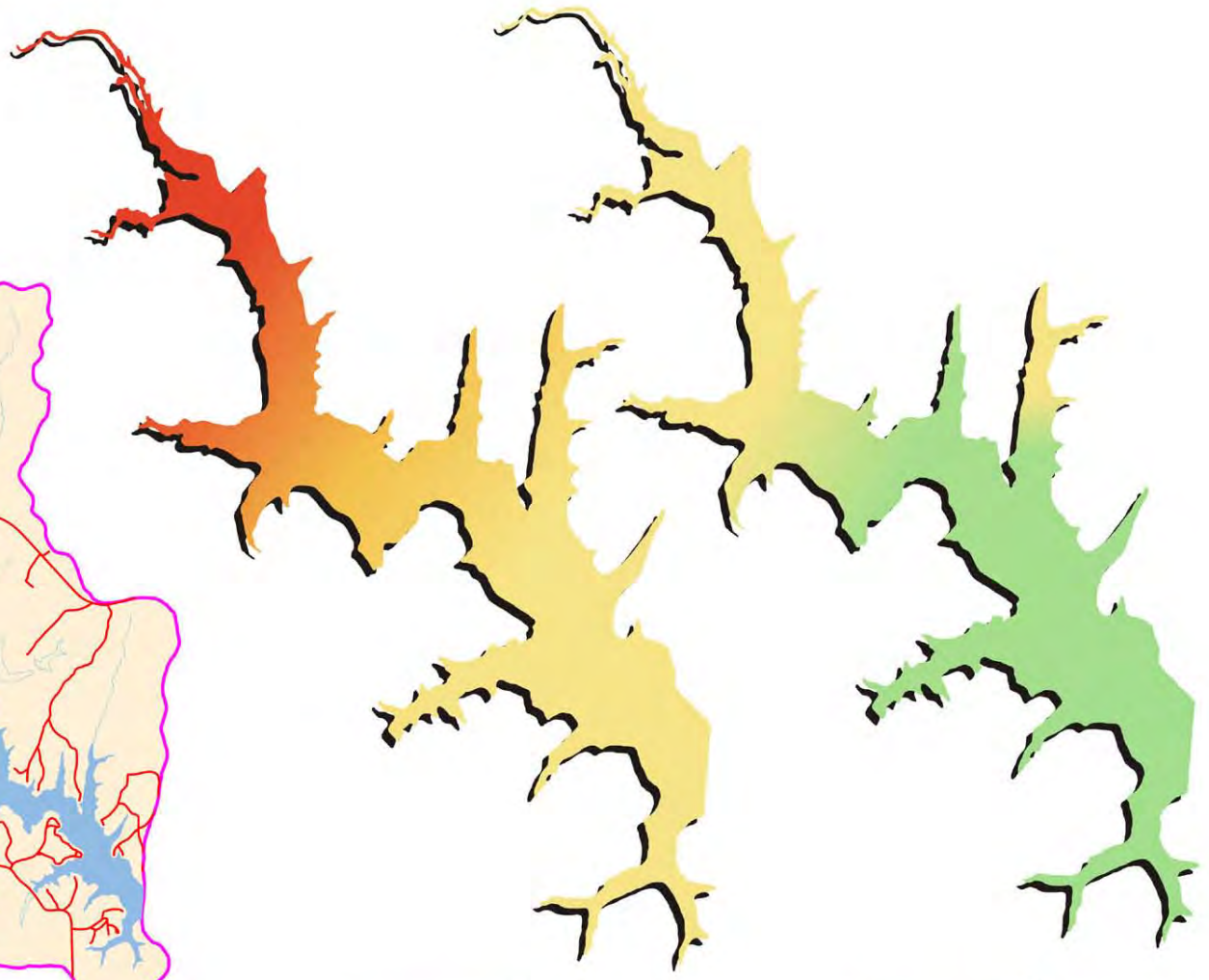


Figure 122a-122f. Graphical representation of data results for Sportsman Lake.

Sportsman Lake Location

Sportsman Lake and Watershed

Lake Data	
Owner	City of Seminole
County	Seminole
Constructed	1958
Surface Area	354 acres
Volume	5,349 acre/feet
Shoreline Length	15 miles
Mean Depth	15.11 feet
Watershed Area	13 square miles



Turbidity 2005

Trophic State 2005

Plate 105 - Lake Water Quality for
Sportsman Lake

LAKES MONITORING PROGRAM

Lake Stanley Draper

Lake Stanley Draper was constructed in 1962 and is owned and operated by the City of Oklahoma City and is utilized as a municipal water supply and for recreational purposes. The lake is "filled" via pipeline, which flows from Atoka Lake in S.E. Oklahoma. Lake Stanley Draper was sampled for four quarters, from November 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major lake arms. Samples were collected at the lake surface at all sample sites during the study period. The lake-wide annual turbidity value was 7 NTU (Plate 106), true color was 28 units, and secchi disk depth was 133 centimeters in 2005-2006. Water clarity was good based on these three parameters, better than that observed in previous data collection efforts conducted in sample year 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 40 (Plate 106), classifying the lake as Oligotrophic bordering mesotrophic, indicative of low levels of primary productivity and nutrient conditions. The calculated TSI for 2004 (TSI=39) and 2002 (TSI=40), are very similar indicating that no significant change in productivity has occurred. The TSI values were fairly consistent ranging from oligotrophic in the fall, winter and summer quarters to lower mesotrophy in the spring quarter. Seasonal turbidity values are displayed in (Figure 123a) and ranged from a low of 4 NTU to a maximum of 13 NTU all below the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the of the turbidity values below the criteria of 25 NTU, the lake is considered supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 123b. Similar to turbidity, all color values were below the WQS of 70 units, therefore the Aesthetics beneficial use is considered supported for sample year 2006.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.03 parts per thousand (ppt) to 0.09 ppt, indicating low salt content and values were well within the expected range of salinity values reported for most Oklahoma lakes if not slightly lower. Specific conductivity ranged from 95 µS/cm in the summer to 191.5 µS/cm in the fall quarter, indicating very low levels of electrical conducting compounds (salts) were present in the lake system, corresponding with the recorded salinity values. In general, pH values were neutral to slightly alkaline, ranging from 6.90 units to 8.18 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Stanley Draper was fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 356 mV in the summer quarter to 445 mV at the sediment-water interface in the spring. Redox readings indicate that reducing

conditions were not present in the reservoir during the sample period. Thermal stratification was not evident in the fall, winter or spring quarters and the water column was well mixed. Dissolved oxygen (D.O.) remained above 7.0 mg/L throughout the water column during these first three sampling intervals (Figure 123c-123e). In the summer quarter the lake was thermally stratified and anoxic conditions were present. Stratification occurred at several 1-meter intervals with D.O. less than 2.0 mg/l from 11 meters below the surface to the lake bottom of 21.7 meters at site 1, the dam (Figure 123f). The same pattern was also observed at sites 2 and 3 with anoxic conditions present in 31-45% of the water column. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The FWP beneficial use is considered partially supported at Lake Stanley Draper with 52% of the water column experiencing anoxic conditions at site 1 in the summer quarter. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

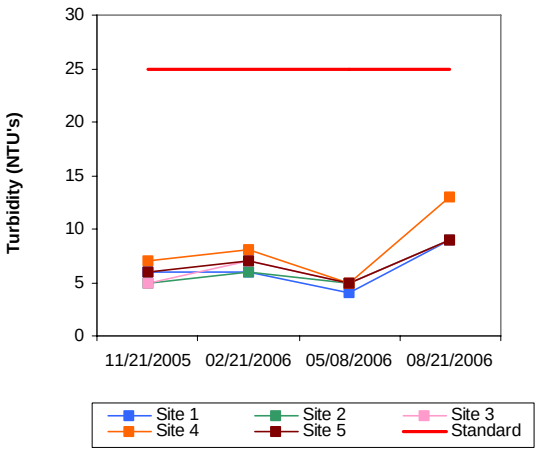
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average for sample year 2005-2006 was 0.24mg/L at the lake surface. The TN at the surface ranged from 0.16 mg/L to 0.33mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average for sample year was 0.012 mg/L at the lake surface. The surface TP ranged from 0.010 mg/L to 0.015 mg/L. Similar to TN the highest surface TP value was reported in the summer, however the lowest occurred in the spring quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 20:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2001 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. Lake Stanley Draper was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Lake Stanley Draper was oligotrophic, indicative of low primary productivity (Plate 106). This is consistent with previous data collection efforts conducted in 2002 and 2004, indicating no significant change in productivity has occurred. Water clarity was good based on turbidity, true color and secchi disk depth and was better than that observed in sample year 2004. The lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use for turbidity, pH and partially supporting the use based on anoxic conditions present during the summer sampling interval. The lake was fully supporting its Aesthetics use based on both the trophic state and on true color. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through

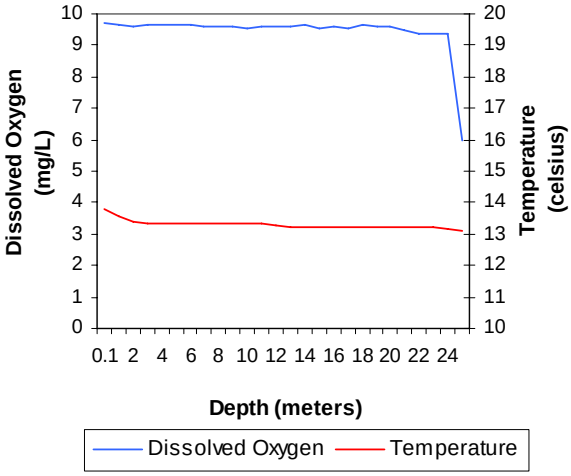
September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported. In 1997 the Oklahoma Legislature directed the OWRB to conduct a study on the impact of Confined Animal Feeding Operations (CAFO) in watersheds that supply potable water to municipalities with a population over 250,000. As part of this study a bathymetric survey was completed on Oklahoma City's water supply reservoirs. A bathymetric map (Figure 124) was generated to determine current storage capacity and identify areas of extreme sedimentation. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800.

a. Seasonal Turbidity Values for Lake Stanley Draper

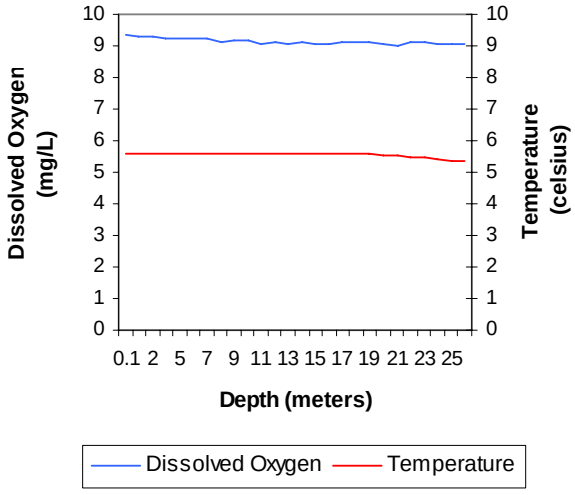


b. Seasonal Color Values for Lake Stanley Draper

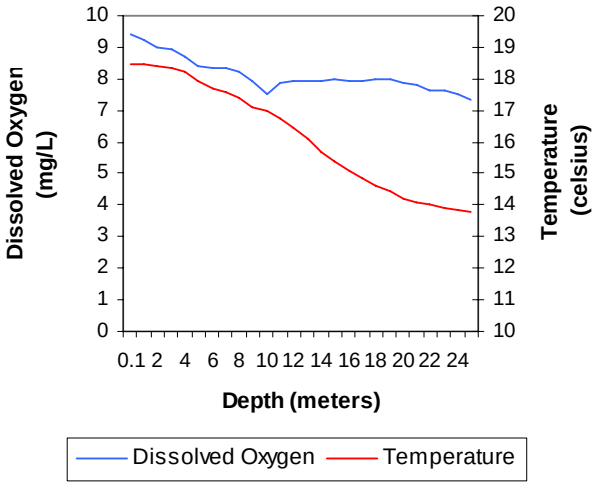
c. Profile of Lake Stanley Draper
November 21, 2005



d. Profile of Lake Stanley Draper
February 21, 2006



e. Profile of Lake Stanley Draper
May 8, 2006



f. Profile of Lake Stanley Draper
August 21, 2006

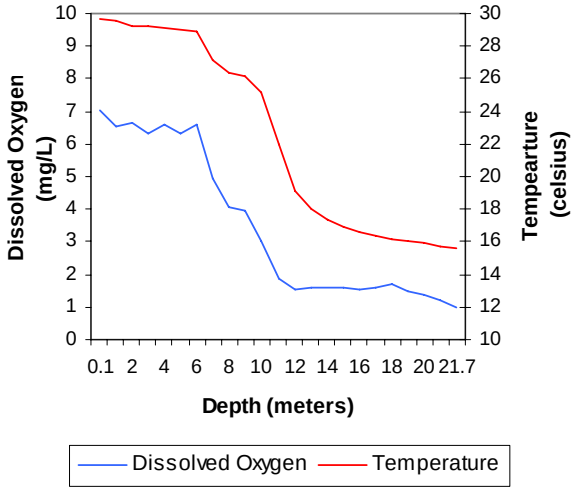
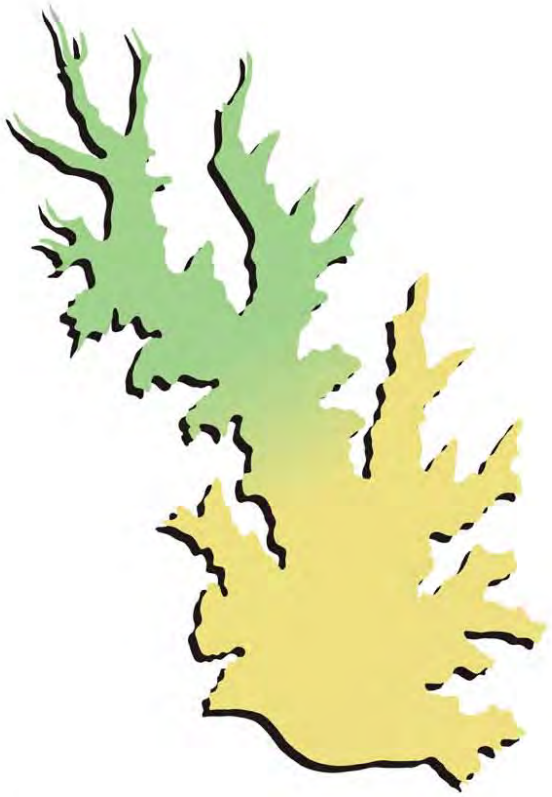


Figure 123a-123f. Graphical representation of data results for Lake Stanley Draper.

Stanley Draper Lake and Watershed

Turbidity 2006



Trophic State 2006

Lake Data	
Owner	City of Oklahoma City
County	Cleveland
Constructed in	1962
Surface Area	2,519 acres
Volume	87,296 acre/feet
Shoreline Length	33.8 miles
Mean Depth	34.6 feet
Watershed Area	12 square miles

Stanley Draper Lake Location

Plate 106 - Lake Water Quality for
Stanley Draper Lake

LAKES MONITORING PROGRAM

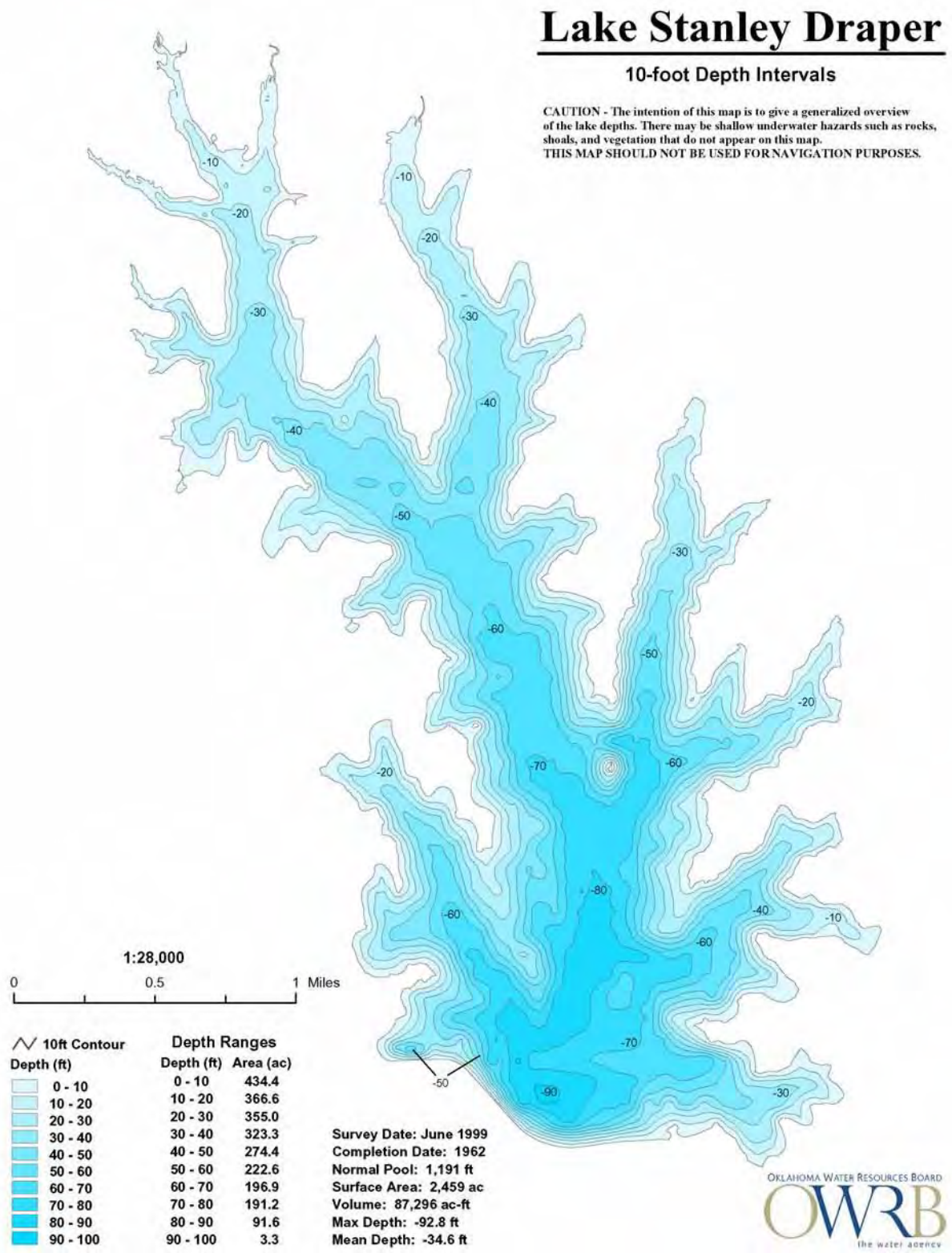


Figure 124. Bathymetric map of Lake Stanley Draper.

Stilwell City Lake

Stilwell Lake, located in Adair County, was constructed in 1965 and is owned and operated by the City of Stilwell. The lake is approximately 4 miles south of the city of Stilwell and serves as a municipal water supply, for flood control and offers numerous recreational opportunities to the public. This is one of the nicer small municipal lakes in Oklahoma. Stilwell City Lake was sampled for three quarters, from October 2005 through August 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites during the study period. The lake-wide annual turbidity value was 6 NTU (Plate 107), true color was 14 units, and secchi disk depth was 161 centimeters in 2005-2006. Based on these three parameters water clarity was excellent in comparison to other Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=9). Due to low lake levels OWRB staff were unable to access the lake during the winter data collection efforts. The average TSI was 54 (Plate 107), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions. Although the current value is based on three quarters of data, the value is very similar to the one calculated in 2004 (TSI=55), indicating little or no change in trophic status over time. The TSI values varied seasonally, from upper mesotrophic in the fall to eutrophic in the spring and summer. The only exception to this was site 1, which was hypereutrophic in the spring quarter. Seasonal turbidity values were all low ranging from 3 NTU to 9 NTU and are displayed in Figure 125a. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the values below the numerical criteria of 25 NTU, Stilwell City Lake is considered supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 125b. Applying the same default protocol, Stilwell City Lake is considered fully supporting the Aesthetics beneficial use with 100% of the true color values below the Aesthetics numeric criteria of 70 units.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.14 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most Oklahoma lakes. Specific conductivity ranged from 159.1 µS/cm in the spring to 297.2 µS/cm in the summer, indicating low levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral to slightly alkaline, ranging from 6.87 to 8.53 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The lake is fully supporting its FWP beneficial as it relates to pH. Oxidation-reduction potentials (redox) ranged from 88 mV at the sediment-water interface in the summer to 452 mV in the fall quarter. Redox values less than 100 are not uncommon when large portions of the water column are anoxic as was the case during the summer. Thermal stratification was evident and anoxic conditions were present to some extent in all three sampling intervals. In the fall stratification occurred between 6 and 7 meters with dissolved

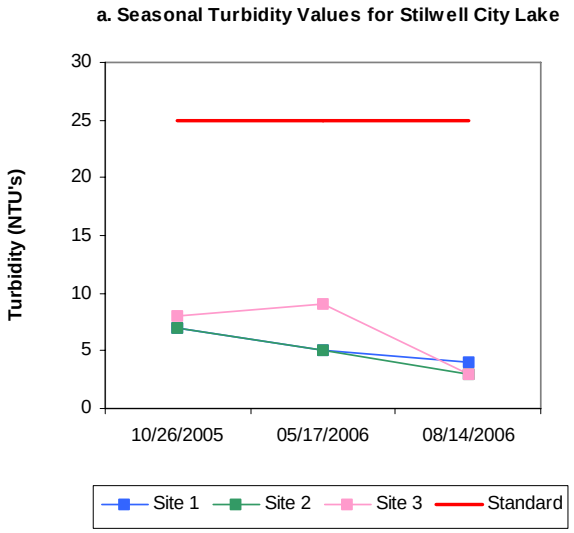
oxygen (D.O.) below 2.0 mg/L from 8 meters to the lake bottom of 11.7 meters at site 1, the dam Figure 125c). During the spring stratification occurred between 4 and 5 meters with approximately 46% of the water column less than 2.0 mg/L (Figure 125d). In the summer, the lake was strongly thermally stratified between 3 and 4 meters below the lake surface at both sites 1 and 2. Water column D.O. values were less than 2.0 mg/L from 5 meters in depth to the lake bottom at 11.3 meters accounting for 50 to 64% of the water column to be anoxic (See Figure 125f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Stilwell City Lake, as 38 to 64% of the water column was anoxic among the three sampling intervals. These conditions could pose a serious concern, threatening fish and wildlife propagation and the lake should be monitored closely in the future. The lake was sampled for, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

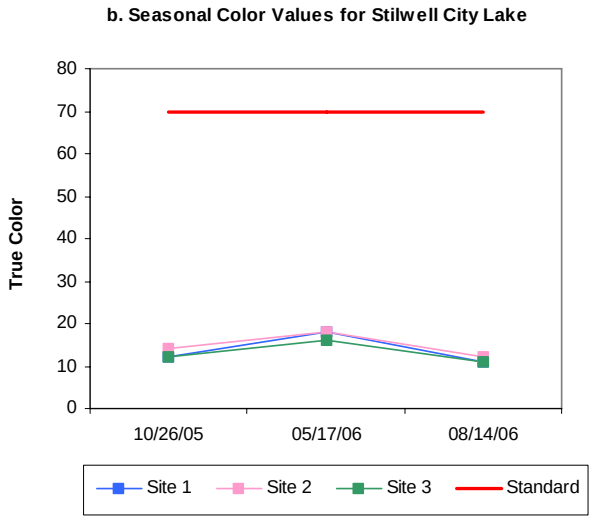
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

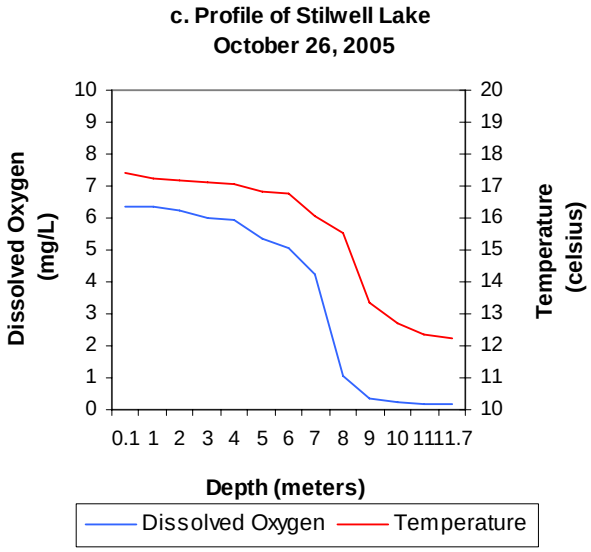
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.51 mg/L at the lake surface during the study period. The TN at the surface ranged from 0.32 mg/L to 0.88 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was recorded in the fall. The lake-wide total phosphorus (TP) average was 0.025 mg/L at the lake surface. The surface TP ranged from 0.019 mg/L to 0.044 mg/L. The highest surface TP value was reported in the spring and similar to TN, the lowest was reported in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 20:1 for sample year 2005-2006. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

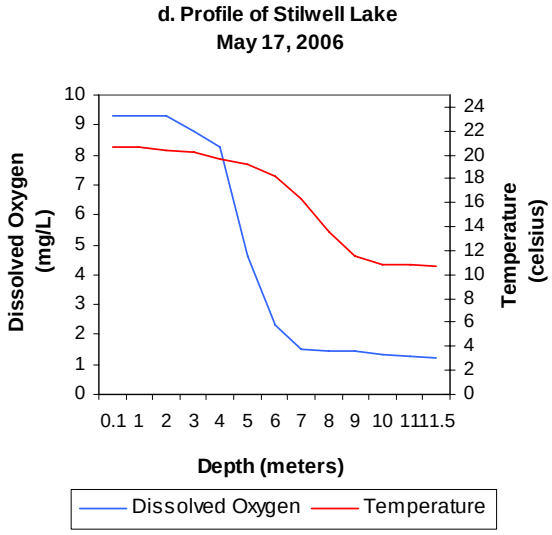
Stilwell City Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Stilwell Lake was eutrophic, indicative of high primary productivity and nutrient conditions (Plate 107). This is consistent with results from 2004 data collection efforts (TSI=55), indicating no significant increase or decrease in productivity has occurred. Water clarity was excellent at this lake during the study period. The lake was fully supporting its Aesthetics beneficial use based on its trophic state and true color with 100% of the values below the numeric criteria of 70 units. The lake was fully supporting its FWP beneficial use based on turbidity and pH and partially supporting based on low D.O. values in the summer quarter. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.









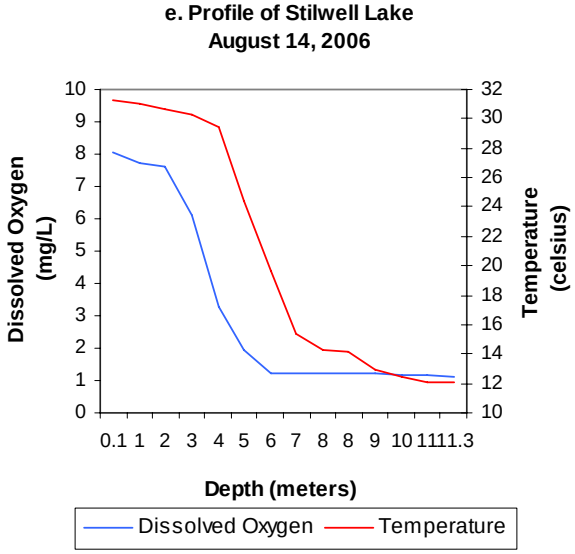
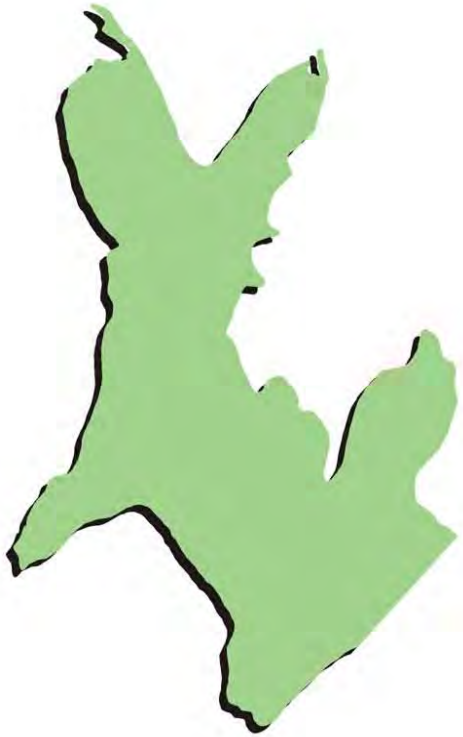


Figure 125a- 125e. Graphical representation of data results for Stilwell Lake.

Lake Stilwell Location

Lake Stilwell and Watershed

Lake Data	
Owner	City of Stilwell
County	Adair
Constructed	1965
Surface Area	188 acres
Volume	3,110 acre/feet
Shoreline Length	4 miles
Mean Depth	16.54 feet
Watershed Area	4,693 acres



POOR EXCELLENT

Turbidity 2006

POOR EXCELLENT

Trophic State 2006

Plate 107 - Lake Water Quality for
Stilwell Lake

LAKES MONITORING PROGRAM

Stroud Lake

Stroud Lake was constructed in 1968 and is owned and operated by the City of Stroud. The lake serves as a municipal water supply, for flood control and offers numerous recreational opportunities to the public. Stroud Lake was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones as well as any major arms of the reservoir. Water quality samples were collected at the lake surface at all sample sites during the study period. The lake-wide annual turbidity value was 5 NTU (Plate 108), true color was 15 units, and secchi disk depth was 126 centimeters in. Based on these three parameters the lake had excellent water clarity in comparison to other Oklahoma lakes. The results for these parameters are consistent with previous data collection efforts conducted in 2003-2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 41 (Plate 108), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. The TSI values varied seasonally with the lake being oligotrophic in the spring to mesotrophic the remainder of the year. All turbidity values collected were well below the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 126a) with values ranging from a low of 4 NTU to a maximum of 9 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Stroud Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 126b. All of the true color values were below the numeric criteria of 70 units, therefore the Aesthetics beneficial use is considered supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.08 parts per thousand (ppt) to 0.10 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most Oklahoma lakes. Specific conductivity ranged from 178.6 µS/cm in the winter quarter to 214.5 µS/cm in the spring, indicating low levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral, ranging from 7.03 to 8.90 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 155 mV at the sediment-water interface in the summer to 500 mV in the winter quarter. Redox readings indicate that reducing conditions were not present in the reservoir during sampling events in 2005-2006. The lake was thermally stratified in the fall near the lake bottom

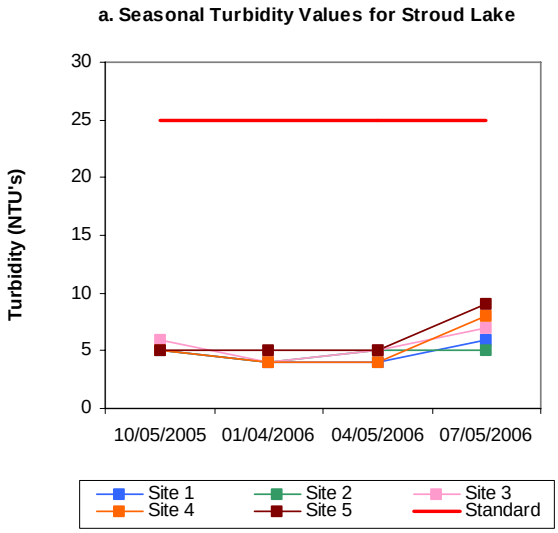
at site 1 between 9 and 10 meters with dissolved oxygen (D.O.) falling below 2.0 mg/L to the lake bottom of 10.9 (see Figure 126c). The lake was well mixed in the winter and spring sampling intervals with D.O. generally above 7.0 mg/L (Figure 126d-126e). In the summer quarter, the lake was thermally stratified and anoxic conditions present at both sites 1 and 2. The water column was stratified between 6 and 7 meters below the lake surface at site 1 and between 5 and 6 meters at site 2, accounting for 30-60% of the water column to be experiencing anoxic conditions (Figure 126f). If D.O. values are less than 2.0 mg/L for greater than 70% of the lake volume, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Stroud Lake with up to 60% of the water column anoxic during summer sampling. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use not supported based on numerical criteria for sulfates located in OAC 785:45 – Appendix F.

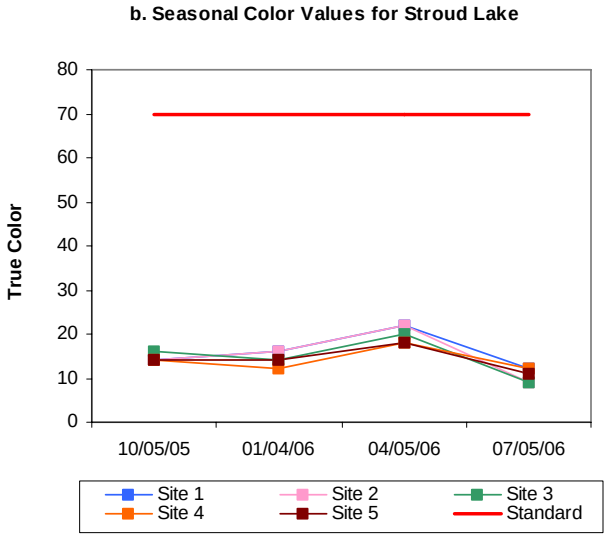
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

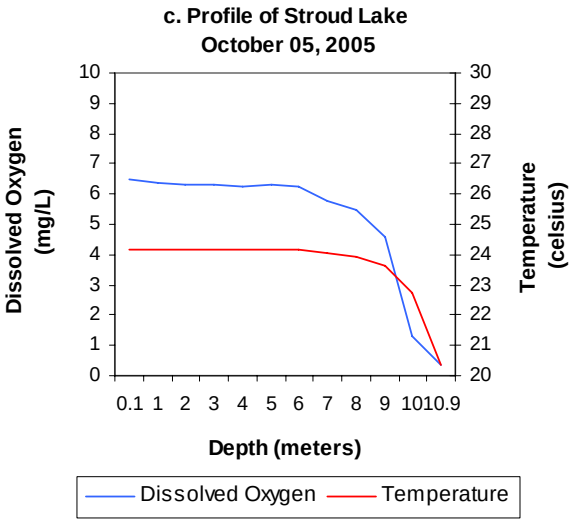
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average during the study period was 0.28 mg/L at the lake surface. The TN at the surface ranged from 0.10 mg/L to 0.41 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was also recorded in the fall. The lake-wide total phosphorus (TP) average was 0.013 mg/L at the lake surface. The surface TP ranged from 0.008 mg/L to 0.020 mg/L. Similar to TN, the highest surface TP value was reported in the summer and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 22:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

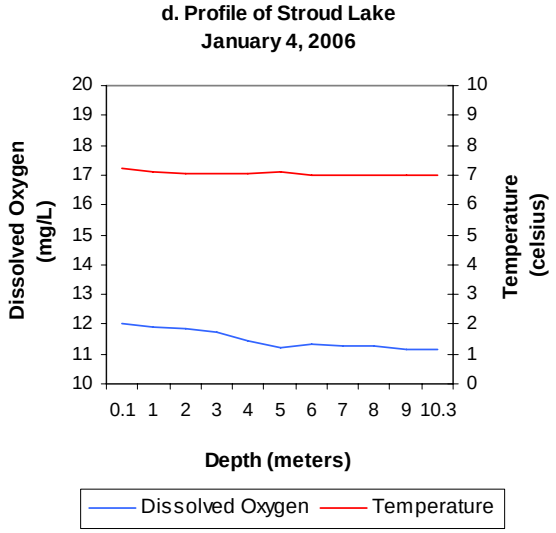
Stroud Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

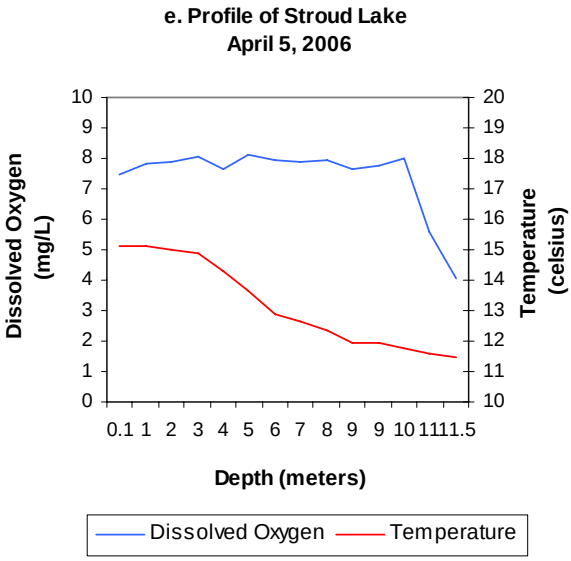
In summary, Stroud Lake was mesotrophic, indicative of moderate primary productivity and nutrient conditions (Plate 108). Although the current TSI is lower than that of 2004 (TSI=47) it is with the same trophic category, indicating no significant change in productivity has occurred. Water clarity continues to be excellent based on secchi disk depth, turbidity and true color values. The lake was fully supporting its Aesthetics beneficial use based on its trophic state and for true color. The lake was also fully supporting its FWP beneficial use based on nephelometric turbidity, pH and is partially supporting based on dissolved oxygen. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported. The Agriculture beneficial use was found to be not supporting based on sulfate values which exceed the numerical criteria supply, located in OAC 785:45 – Appendix F.











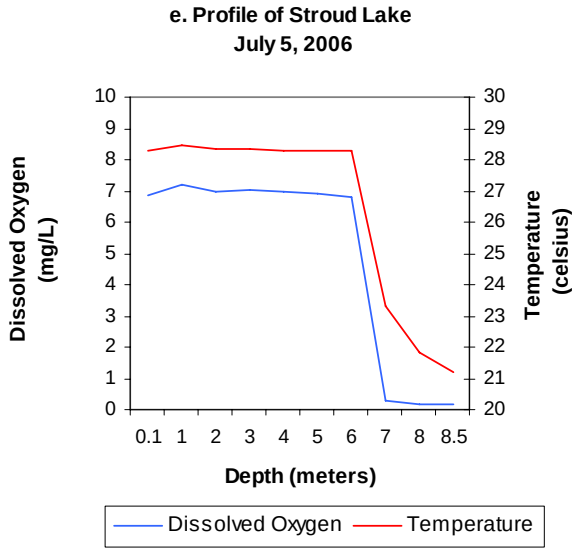
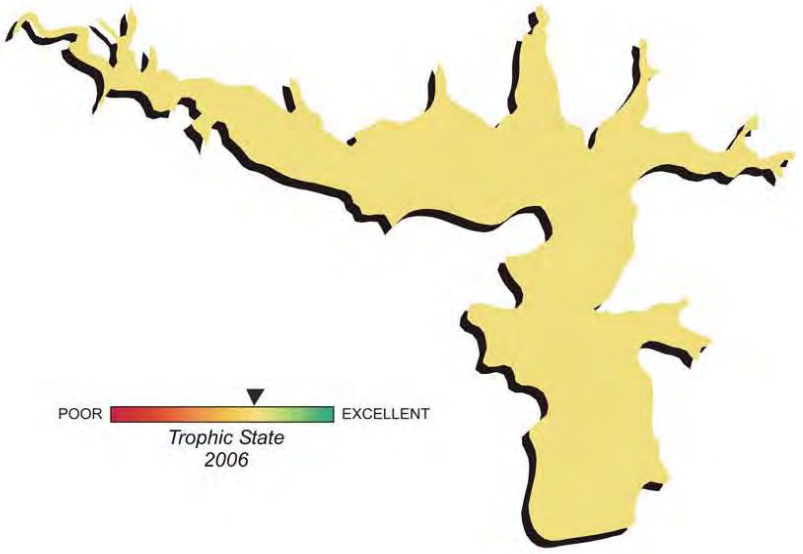


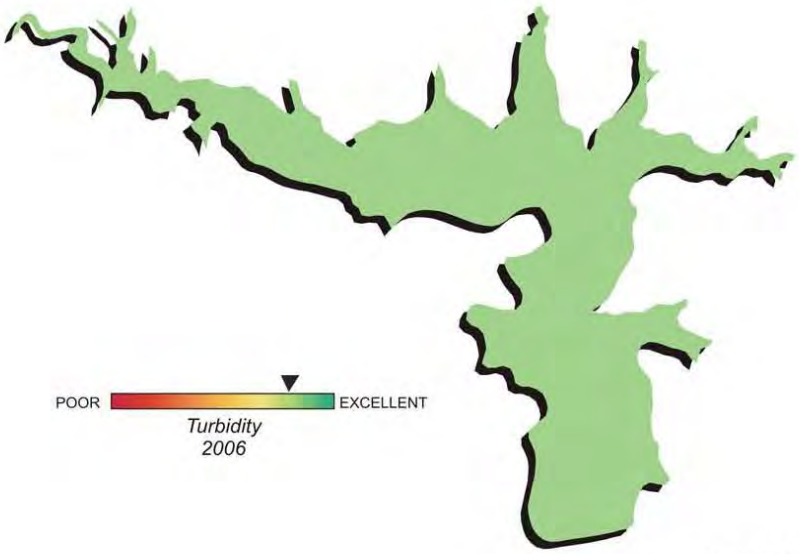
Figure 126a-126f. Graphical representation of data results for Stroud Lake.

Stroud Lake and Watershed



Trophic State 2006

Stroud Lake Location



Turbidity 2006

Lake Data	
Owner	City of Stroud
County	Lincoln
Constructed in	1968
Surface Area	600 acres
Volume	8,800 acre/feet
Shoreline Length	13 miles
Mean Depth	14.67 feet
Watershed Area	16 square miles

Plate 108 - Lake Water Quality for
Stroud Lake

LAKES MONITORING PROGRAM

Talawanda Lake No.1

Talawanda Lake No.1 was sampled for four quarters, from September 2004 through May 2005. Water quality samples were collected at 3 sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The average lake-wide turbidity value was 2 NTU (Plate 109), true color was 19 units, and secchi disk depth was 230 centimeters. Based on these three parameters, Talawanda Lake No.1 had excellent water clarity, very similar to values in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 44 (Plate 109), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. This value is similar to the one calculated in 2001 (TSI=45) indicating no significant change in productivity has occurred since the last evaluation. The TSI values were primarily mesotrophic during sample year 2004-2005. The exception to this pattern occurred in the spring quarter when sites 1 and 3 were oligotrophic and site 2 was eutrophic. All turbidity values were well below the Oklahoma Water Quality Standard (WQS) of 25 NTU and are displayed in Figure 127a. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Due to a post-processing error turbidity was not run for any of the summer samples. Although 100% of the samples collected in 2005 were below the WQS of 25 NTU and assessment of the Fish and Wildlife Propagation (FWP) beneficial use cannot be made due to minimum data requirements not being met. Based upon current and historical data sets, it is likely that the use would be fully supported. Seasonal true color values are displayed in Figure 127b. All of the true color values were well below the numeric criteria of 70 units therefore, the Aesthetics beneficial use is considered fully supported.

In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.06 ppt, which is lower than the range of values commonly observed in Oklahoma reservoirs. Specific conductivity ranged from 64.4 µS/cm to 141.4 µS/cm; indicative of low levels of current conducting ions (salts) in the lake system. The pH values at were slightly acidic, ranging from 6.12 in the summer to 7.48 in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 23.8 % of the values recorded being less than 6.5 the lake will be listed as partially supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction

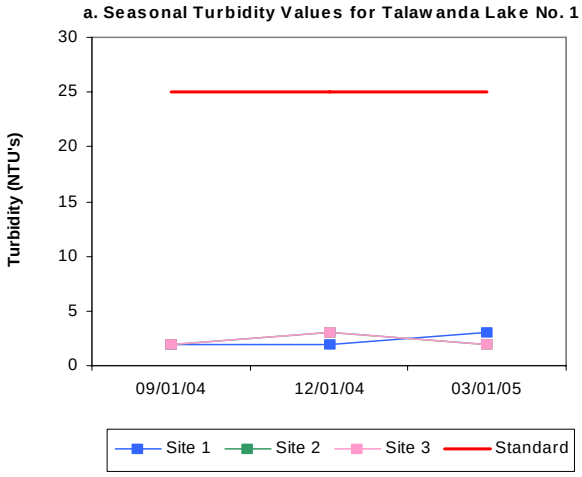
potentials (ORP) ranged from 170 mV to 469 mV indicating reducing conditions were not present at this reservoir during the study period. Due equipment failure in the fall, a vertical profile of the water column is not available and an assessment cannot be made for this sampling interval. In the winter and spring quarters the water column was well mixed with dissolved oxygen (D.O.) values generally above 8.0 mg/L (see Figure 127c-127d). Thermal stratification was evident and anoxic conditions were present throughout the lake in the summer. Stratification occurred between 3 and 4 meters, accounting for 33 to 40 % of the water column to be anoxic (Figure 127f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Talawanda Lake No.1 is considered to be partially supporting the FWP beneficial use based on anoxic conditions present in the summer. These conditions could pose a serious concern, threatening fish and wildlife propagation and the lake should be monitored closely in the future. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

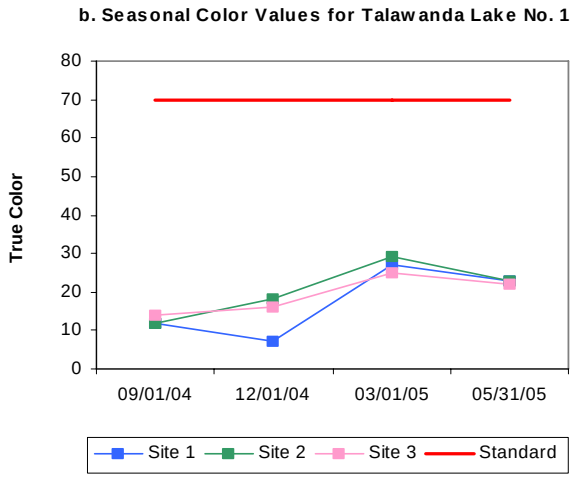
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

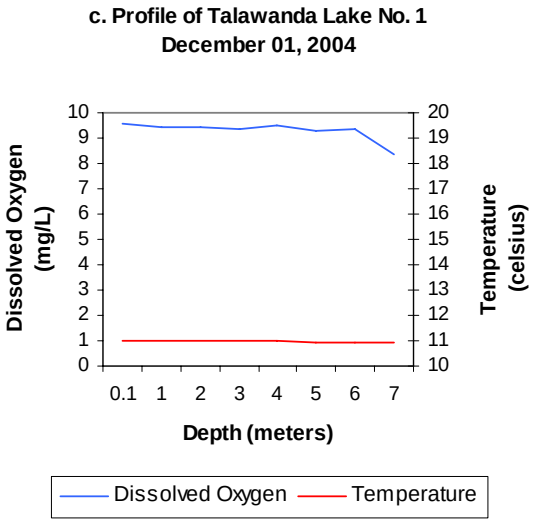
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.56 mg/L at the surface. Surface TN ranged from 0.30 mg/L to 0.91 mg/L, with the highest values reported in the spring and lowest values in the fall quarter. The lake-wide total phosphorus (TP) average was 0.015 mg/L at the surface. Total phosphorus at the surface ranged from 0.011mg/L to 0.019 mg/L. Surface TP was highest in the spring, and the lowest values were recorded during the spring winter. The nitrogen to phosphorus ratio (TN:TP) was approximately 39:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

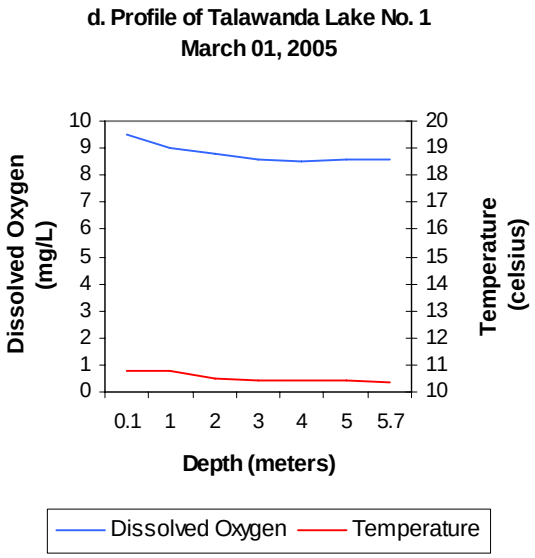
In summary, Talawanda Lake No.1 was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in sample year 2005. This is consistent with historical data collection efforts, indicating no significant increase or decrease in productivity has occurred. Water clarity was excellent based on turbidity, true color, and secchi disk depth. The FWP beneficial use is partially supported based on dissolved oxygen values recorded during the study period. Although 100% of the samples collected in 2005 were below the WQS of 25 NTU and assessment of the Fish and Wildlife Propagation (FWP) beneficial use cannot be made due to minimum data requirements not being met. Based upon current and historical data sets, it is likely that the use would be fully supported. With 23.8 % of the values recorded being less than 6.5 the lake will be listed as partially supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color values with all values well below the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made

at this time. Talawanda Lake No. 1, owned by the City of McAlester, was constructed in 1902 for the purpose of recreation.









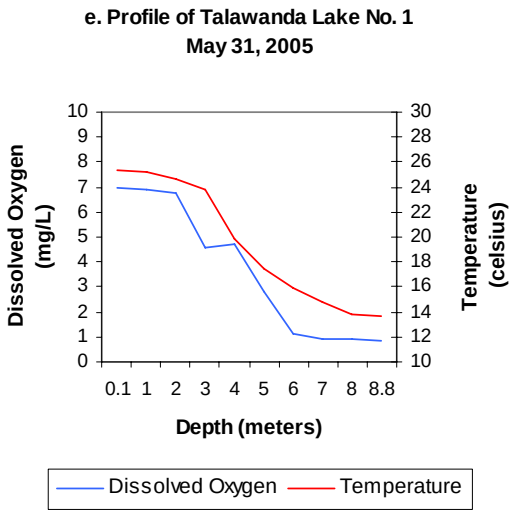
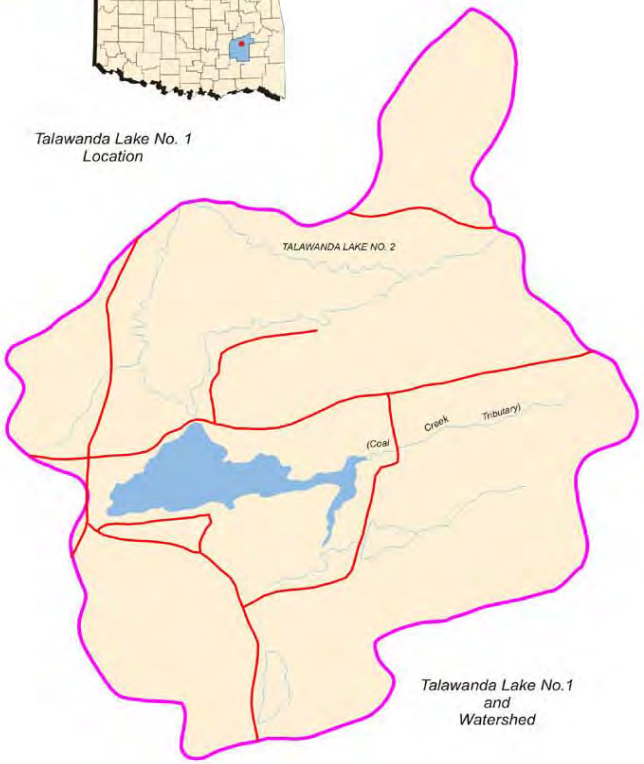


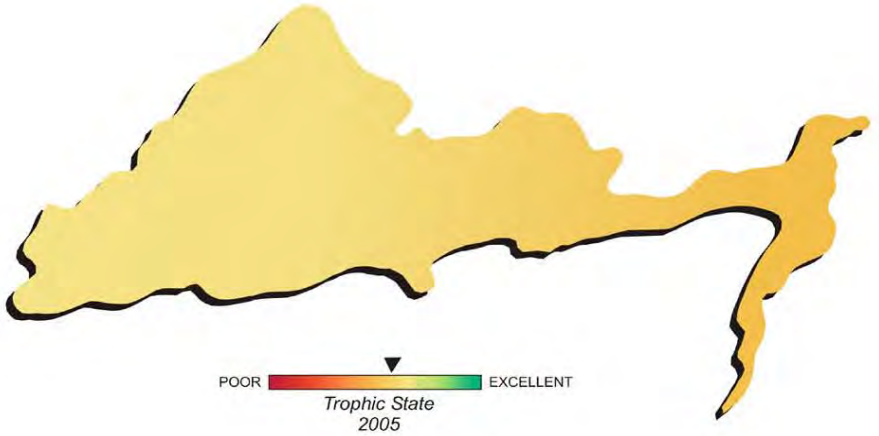
Figure 127a-127e. Graphical representation of data results for Talawanda Lake No.1

Talawanda Lake No. 1
Location

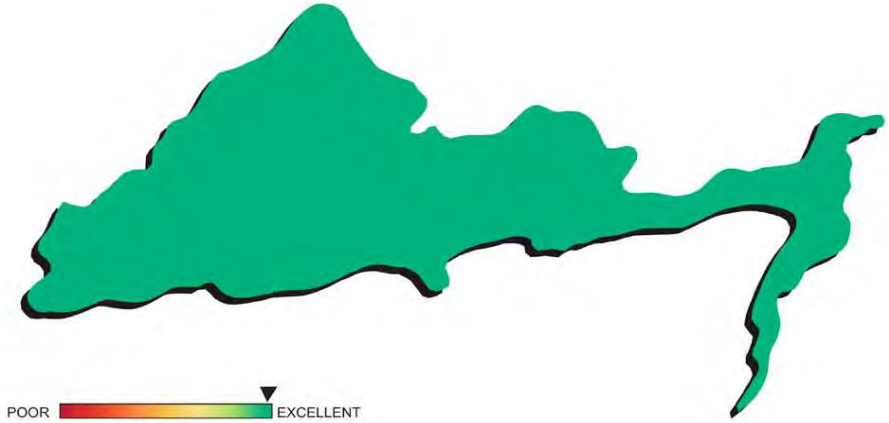


Talawanda Lake No.1
and
Watershed

Lake Data	
Owner	City of McAlester
County	Pittsburg
Constructed	1902
Surface Area	91 acres
Volume	1,200 acre/feet
Shoreline Length	3 miles
Mean Depth	14.10 feet
Watershed Area	1,271 acres



Trophic State
2005



Turbidity
2005

Plate 109 - Lake Water Quality for
Talawanda Lake No. 1

Talawanda Lake No. 2

Talawanda Lake No. 2 was sampled for four quarters, from September 2004 through May 2005. Water quality samples were collected at 3 sites to represent the reservoir. Samples were collected at the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity value was 7 NTU (Plate 110), true color was 16 units, and secchi disk depth was 138 centimeters. Based on these three parameters, Talawanda Lake No. 2 had excellent water clarity, similar to the values reported in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 38 (Plate 110), classifying the lake as oligotrophic, indicative of low levels of primary productivity and nutrients. This value is similar to the one calculated in 2003 (TSI=39) indicating no significant increase or decrease in productivity has occurred since the previous evaluation. TSI values were primarily oligotrophic with site 3 in the mesotrophic category in both spring and summer sampling intervals. Seasonal turbidly values are displayed in Figure 128a. All turbidity values ranged from a low of 3 NTU to a maximum of 10 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the turbidity values below the standard the Fish and Wildlife Propagation (FWP) beneficial use is considered supported as it relates to turbidity. Seasonal true color values are displayed in Figure 128b. All of the true color values were well below the numeric criteria of 70 units therefore, the Aesthetics beneficial use is considered fully supported.

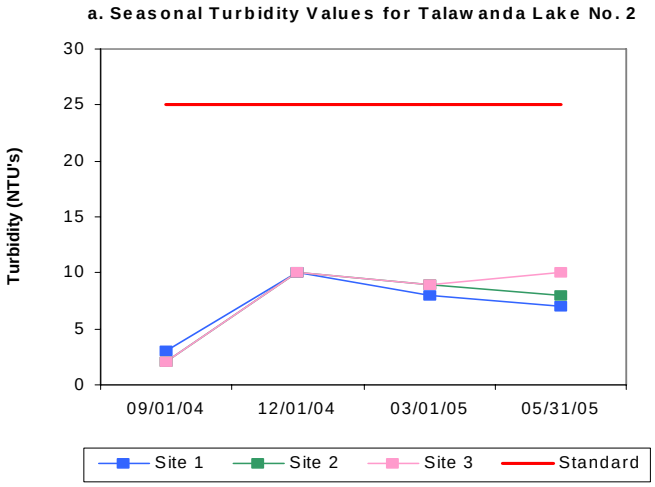
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.05 ppt, which is lower than the range of values observed in Oklahoma reservoirs. Specific conductivity ranged from 51.8 µS/cm to 122.4 µS/cm, indicative of extremely low levels of current conducting ions (salts) in the lake system. The pH values at were slightly acidic, ranging from 6.19 in the summer to 7.87 in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 12.6 % of the values recorded being less than 6.5 the lake will be listed as partially supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (ORP) ranged from 388 mV to 489 mV indicating reducing conditions were not present at this reservoir at the time of sampling. In the fall, the lake was stratified at site 1 between 7 and 8 meters at which point dissolved oxygen (D.O.) dropped below 2.0 mg/L to the lake bottom of 12.4 meters (Figure 128c). At this time approximately 43% of the water column at site was

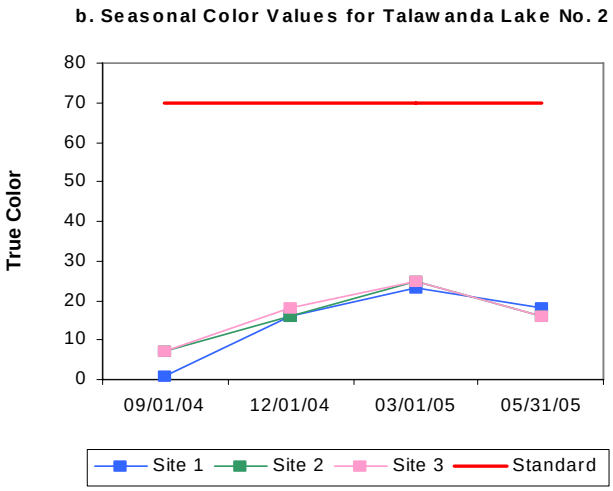
experiencing anoxic conditions. In the winter and spring quarters the water column was well mixed with dissolved oxygen (D.O.) values generally above 8.0 mg/L (see Figure 128d-128e). Thermal stratification was evident and anoxic conditions were present throughout the lake in the summer. The temperature at site 1 ranged from 25.5 ^{0} C at the surface to 14.51 ^{0} C at the lake bottom. Stratification occurred between 4 and 5 meters, with 18 to 36 % of the water column experiencing anoxic conditions. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Based on recorded D.O. values present in the summer and fall the FWP use is considered supported. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

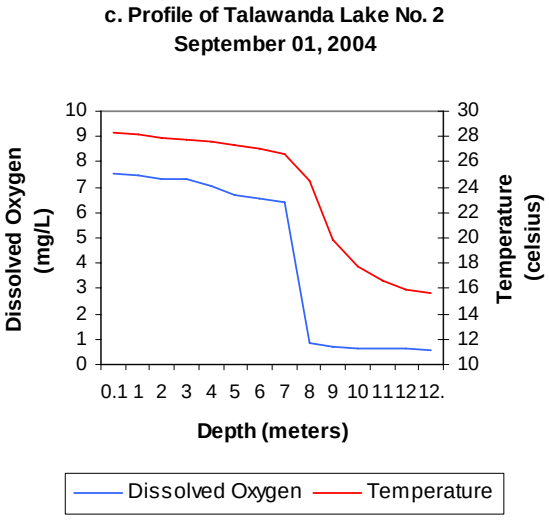
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

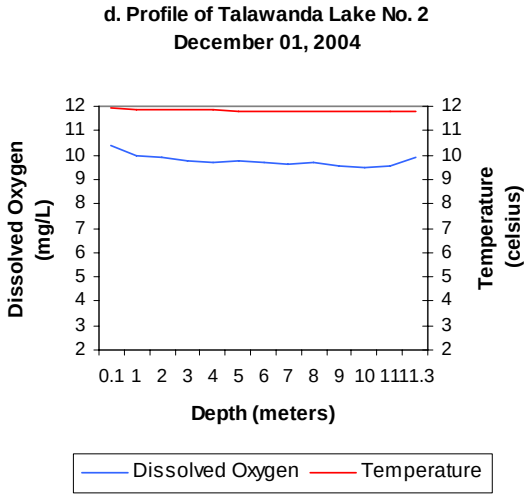
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.30 mg/L at the surface. Surface TN ranged from 0.18 mg/L to 0.46 mg/L, with the highest values reported in the spring and lowest values in the winter quarter. The lake-wide total phosphorus (TP) average was 0.014 mg/L at the surface. Total phosphorus at the surface ranged from 0.011mg/L to 0.015 mg/L. Surface TP was highest in the winter, and the lowest values were recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 22:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

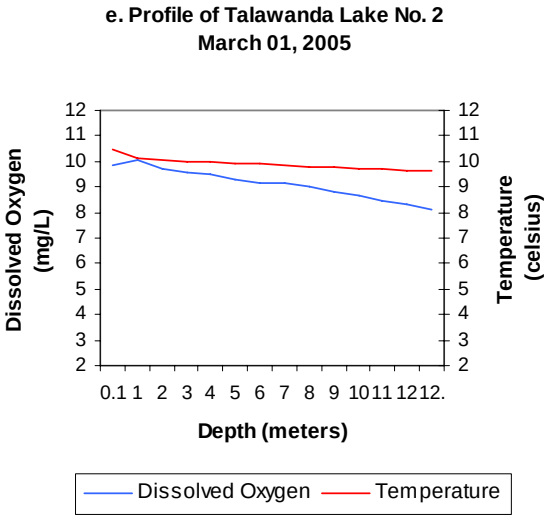
In summary, Talawanda Lake No.2 was classified as oligotrophic, indicative of low primary productivity and nutrient conditions (Plate110). This is consistent with historical data collection efforts, indicating no significant increase or decrease in productivity has occurred. Water clarity continues to be excellent based on turbidity, true color, and secchi disk depth. The FWP beneficial use is supported based on turbidity and dissolved oxygen values recorded during the study period. With 12.6 % of the values recorded being less than 6.5 the lake will be listed as partially supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color values as 100% of the values were well below the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Talawanda Lake No. 2, owned by the City of McAlester, serves as a water supply and recreational reservoir.











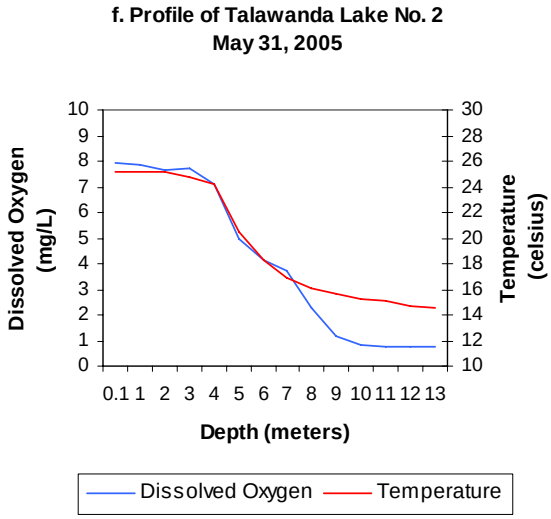
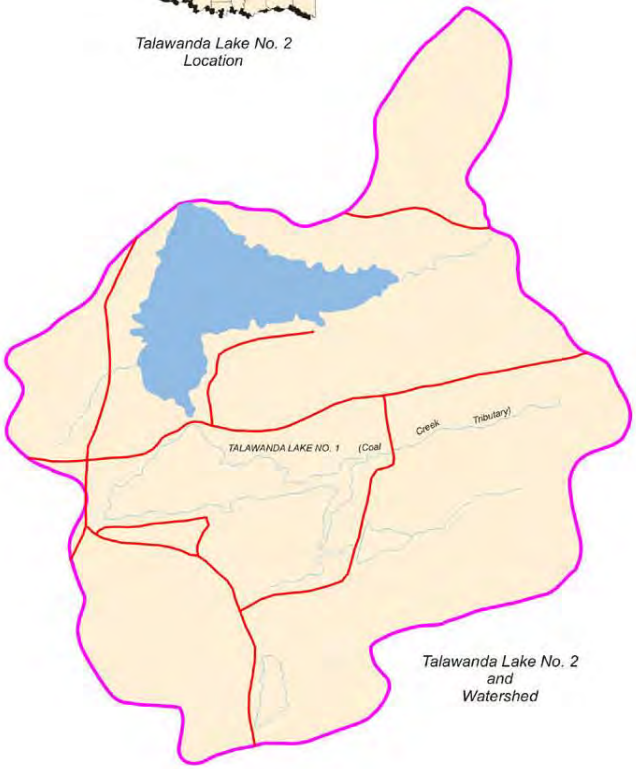


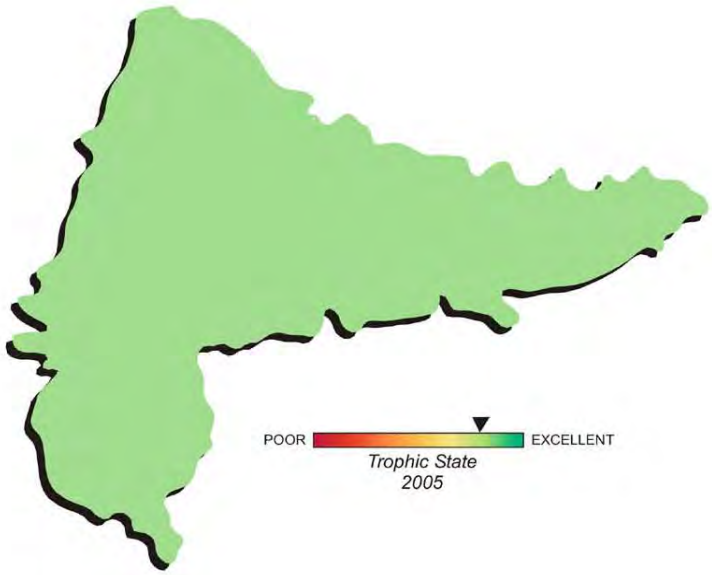
Figure 128a-128f Graphical representation of data results for Talawanda Lake No.2

Talawanda Lake No. 2
Location

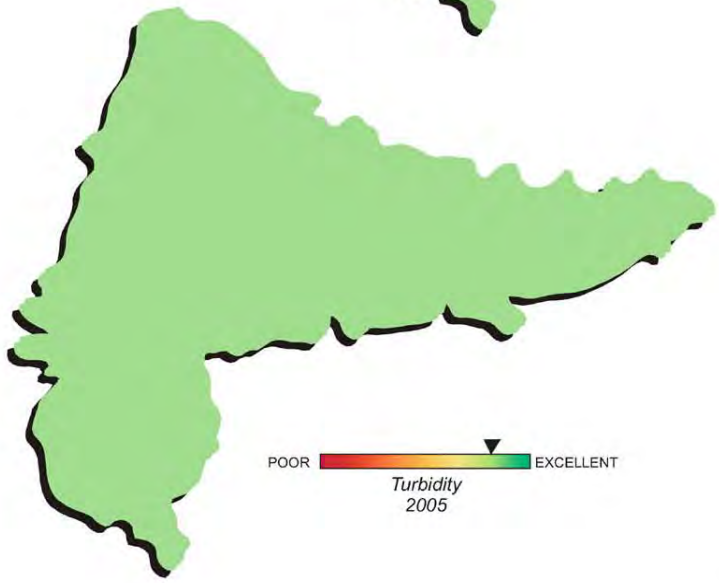


Talawanda Lake No. 2
and
Watershed

Lake Data	
Owner	City of McAlester
County	Pittsburg
Constructed	1924
Surface Area	195 acres
Volume	2750 acre/feet
Shoreline Length	4 miles
Mean Depth	14.10 feet
Watershed Area	2,304 acres



Trophic State
2005



Turbidity
2005

Plate 110 - Lake Water Quality for
Talawanda Lake No. 2

LAKES MONITORING PROGRAM

Taylor Lake

Taylor Lake was sampled for four quarters, from November 2004 through July 2005. Water quality samples were collected from three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 14 NTU (Plate 111), true color was 19 units, and average secchi disk depth was 57 centimeters. Based on these three parameters, Taylor Lake had average water clarity in comparison to other Oklahoma reservoirs. Results are similar to those observed in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 63 (Plate 111), classifying the lake as hypereutrophic, indicative of excessive primary productivity and nutrient levels. This value is similar to the one calculated in 2003 (TSI=62) indicating no significant increase or decrease in productivity has occurred since the previous evaluation. TSI values were fairly consistent with values ranging from upper eutrophic in the spring to hypereutrophic the remainder of the year. Currently, the lake listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (WQS). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Seasonal turbidity values are displayed in Figure 129a. Turbidity values ranged from a low of 2 NTU to a maximum of 10 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the Oklahoma Water Quality Standard (WQS) of 25 NTU for turbidity. If 10 to 25% of the turbidity samples exceed the criteria of 25 NTU, the lake is considered to be partially supporting beneficial uses. The Fish and Wildlife Propagation (FWP) beneficial use is considered supported at Taylor Lake with 100% of the values below the turbidity standard of 25 NTU. Seasonal true color values were all well below the WQS of 70 and are displayed in Figure 129b. Applying the same default protocol, the Aesthetics beneficial use is fully supported based on true color values.

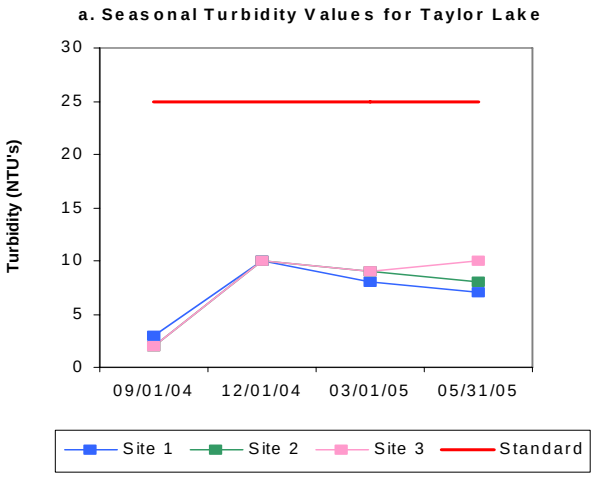
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.26 parts per thousand (pp t) to 0.35 ppt, which is within the range of values recorded in Oklahoma reservoirs. Specific conductivity ranged from 508.3 µS/cm to 676.3 µS/cm, indicative of moderate levels of current conducting ions (salts) in the lake system. The pH values were neutral to slightly alkaline ranging from 7.06 to 8.49 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Oxidation-reduction potentials (ORP) ranged from 242 mV to 401 mV indicating the absence of reducing conditions during the study. The lake was not stratified during the fall, winter, or spring sampling quarters and the water column was well mixed (see Figure 129c-129e). In the summer, thermal stratification was evident and anoxic conditions were present (Figure 129f). Stratification occurred between 3 and 4 meters, with 33% of the water column experiencing anoxic conditions. If D.O. values are less than 2.0 mg/L for

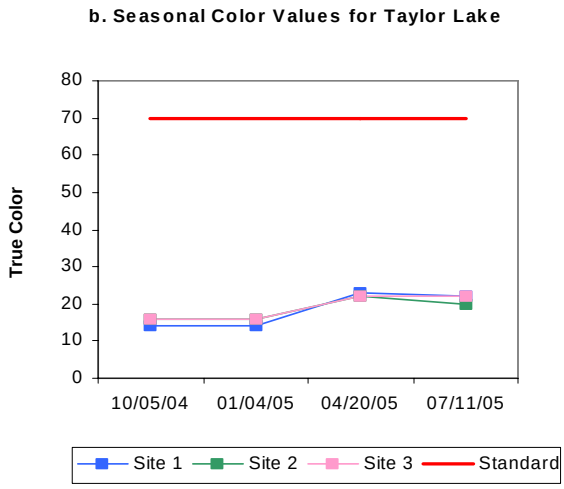
greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With only 33% of the collected dissolved oxygen values below 2.0 mg/L, Taylor Lake is considered supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

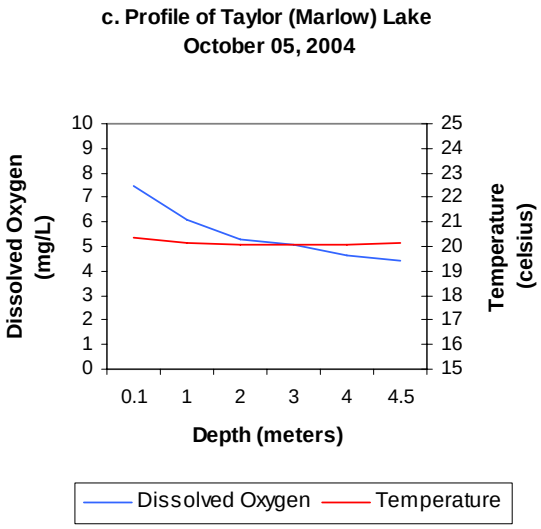
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

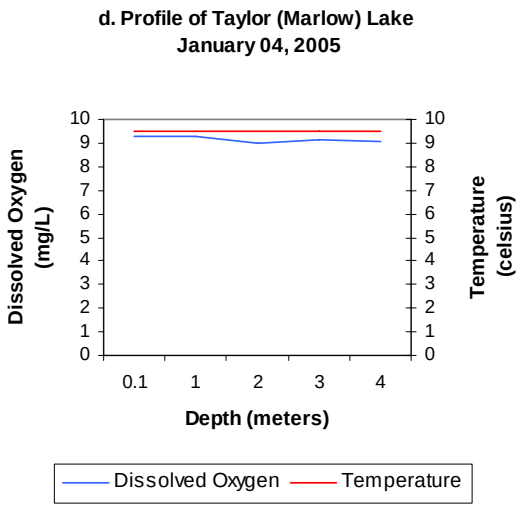
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.03 mg/L at the surface. Surface TN ranged from 0.88 mg/L to 1.25 mg/L, with the highest values reported in the summer and lowest values in the winter quarter. The lake-wide total phosphorus (TP) average was 0.104 mg/L at the surface. Total phosphorus at the surface ranged from 0.067mg/L to 0.138 mg/L. Surface TP was highest in the fall, and the lowest values were recorded during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

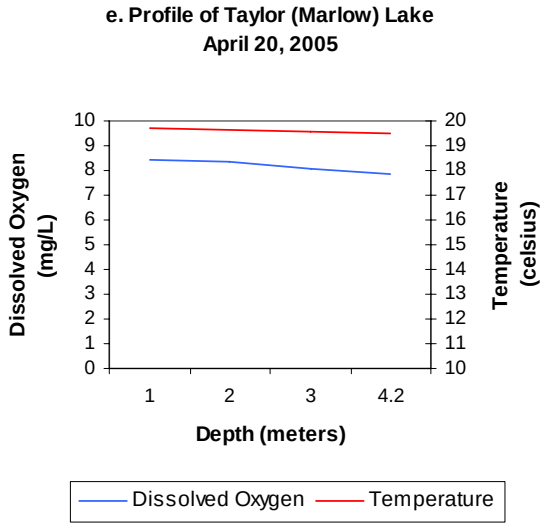
In summary, Taylor Lake was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels in sample year 2005. The calculated TSI was similar to that in 2003 (TSI=62), indicating no significant increase or decrease has occurred since the last evaluation. Water clarity was average based on true color, turbidity, and secchi disk depth. The FWP beneficial use is supported based on pH, turbidity, and dissolved oxygen values recorded during the study period. With 100% of the values well below the WQS of 70 units, the Aesthetics beneficial use is considered supported based on true color. Currently, the lake listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (WQS). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Taylor Lake is leased to the City of Marlow and serves as a flood control, water supply, and recreational reservoir.











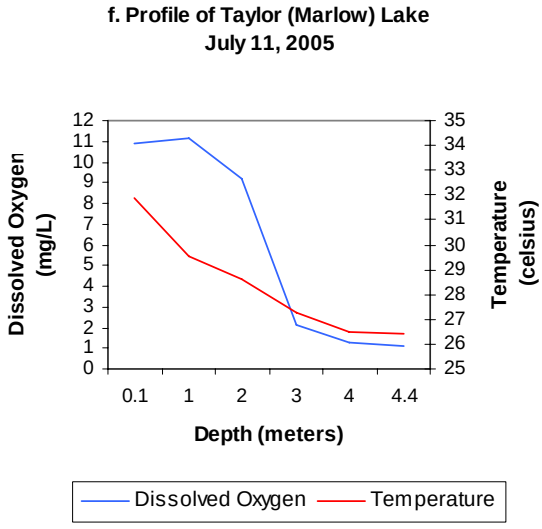
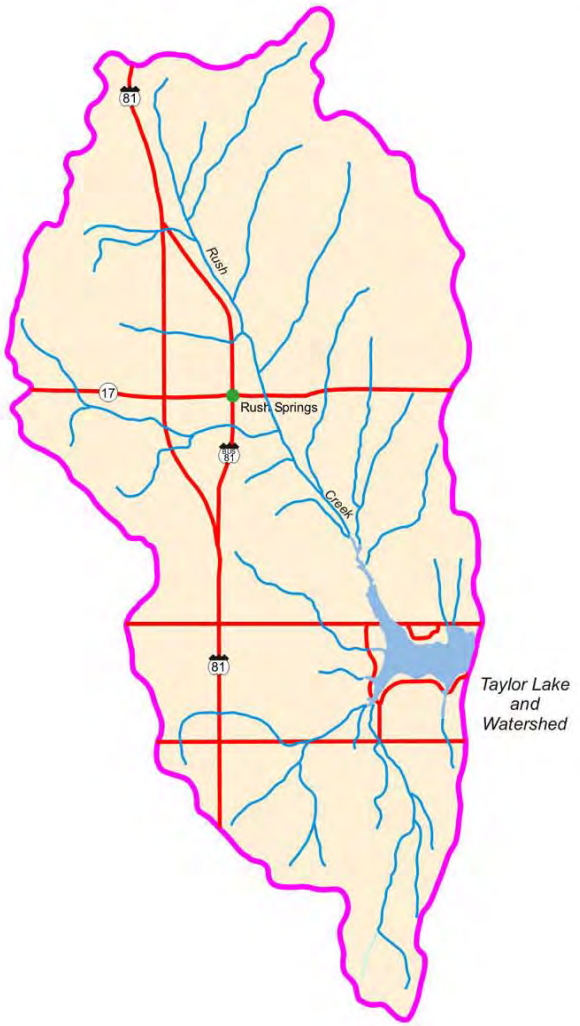


Figure 129a-129f. Graphical representation of data results for Taylor Lake.



Lake Data	
Owner	Leased to City of Marlow
County	Grady
Constructed in	1960
Surface Area	227 acres
Volume	1,877 acre/feet
Shoreline Length	7 miles
Mean Depth	8.27 feet
Watershed Area	21 square miles

Plate 111 - Lake Water Quality for

Taylor Lake

LAKES MONITORING PROGRAM

Tecumseh Lake

Tecumseh Lake was constructed in 1934 and is owned and operated by the City of Tecumseh. The lake is managed as a municipal water supply and offers recreational opportunities to the public. The lake was scheduled for sampling during the 2005-2006 sample year however due to the drought conditions lake levels were too low for OWRB staff to launch a boat. The lake will be placed on the next sample rotation once water levels rise enough for staff to access the lake safely.

Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 87 NTU (Plate 112), true color was 106 units, and secchi disk depth was 18 centimeters. Based on these three parameters, Tecumseh Lake had poor water clarity. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=9). The average TSI was 57 (Plate 112), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. Although based on a smaller data set this value is similar to the one calculated in 2002 (TSI=51), indicating that no significant change in productivity has occurred since the last evaluation. TSI values for this lake varied seasonally from hypereutrophic to oligo-mesotrophic in the spring and to meso-eutrophic in the summer quarter. Unlike the vast majority of Oklahoma reservoirs, Tecumseh Lake was most productive in the late fall early winter, which is not commonly seen. This correlates with the fact that turbidity readings were much lower than those seen in both spring and summer quarters. With the increased availability of light to the biota the lake became much more productive. All turbidity values were above the Oklahoma Water Quality Standard (WQS) of 25 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although the minimum data requirements for a lake of this size were not met it is likely that Tecumseh Lake would not be supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. With 66% of the true color values well above the numeric criteria of 70 units, the lake should be listed as not supporting its Aesthetics beneficial use based on true color values; however due to data requirements not being met a definitive assessment can not be made at this time.

Please refer to the "Beneficial Use Monitoring Report 2004 Draft Final Report" for the full discussion of monitoring results for this lake. The report may be access via the OWRB's web page at http://www. owrb.state.ok.us or you may contact the Water Resources for a copy of the 2004 BUMP Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the address below:

Oklahoma Water Resources Board
3800 N. Classen Blvd.
Oklahoma city, Oklahoma 73118
Attn: Nikki Cole

Tecumseh Lake Location

Tecumseh Lake and Watershed

Turbidity 2004

Trophic State 2004

Lake Data	
Owner	City of Tecumseh
County	Pottawatomie
Constructed	1934
Surface Area	127 acres
Volume	1,118 acre/feet
Shoreline Length	3 miles
Mean Depth	8.80 feet
Watershed Area	3,124 acres

Plate 112 - Lake Water Quality for
Tecumseh Lake

LAKES MONITORING PROGRAM

Tenkiller Ferry Lake

The United States Army Corps of Engineers constructed Tenkiller Ferry Lake in 1953. The lake was authorized to serve for flood control and hydroelectric power. Today the lake serves many other purposes and is one of the most heavily used recreational lakes in Oklahoma. Tenkiller Ferry Lake is one of the lake jewels of Oklahoma and it should be managed and maintained in that fashion. Tenkiller Ferry Lake was sampled for four quarters, from October 2005 through July 2006.

Water quality samples were collected at seven (7) sites to represent the riverine, transitional, and lacustrine zones of the lake as well as major arms. Samples were collected at the lake surface at all sites during the study period. Tenkiller Ferry Lake is a larger reservoir with many tributaries, including the Illinois River flowing into the waterbody and has been split into two management segments. The following discussion will briefly summarize each segment with a lake-wide summary included at the end of the narrative.

Tenkiller Ferry Lake, Lower Lake

This portion of Tenkiller Ferry Lake (segment # 121700020020) extends from the dam up to the Sixshooter Camp area of the reservoir and includes BUMP sites 1 (dam), 2 (Chicken Ck.) and 7 (Blackgum Landing) see Figure 131. The segment-wide average turbidity was 2 nephelometric turbidity units (NTU), true color was 11 units and secchi disk depth was 217 centimeters in sample year 2006. Based on these three parameters water clarity is excellent in this segment of the lake. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 48, classifying the segment as mesotrophic, indicative of moderate primary productivity and nutrient conditions. Chlorophyll-a values were generally mid-mesotrophic to mid-eutrophic throughout the sample year. Turbidity values ranged from a low of 1 NTU to a maximum of 6 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered partially supported if 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 100% of the values are below 25 NTU an assessment of the Fish & Wildlife Propagation (FWP) beneficial use cannot be made due to minimum data requirements not being met. Like turbidity, all true color values were below the Aesthetics criteria 70 units however like turbidity there are not enough data for this segment to assess the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.05 parts per thousand (ppt) to 0.42 ppt, indicating low to moderate salt content compared to most Oklahoma lakes. Specific conductivity ranged from 135.3 µS/cm to 806.2 µS/cm in the spring, indicating minimal to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral to slightly alkaline, ranging from 6.57 to 10.45 units, with elevated values recorded at sites 1 and 2 in the spring quarter.

According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 10% of the pH values outside the acceptable range this segment Tenkiller Ferry Lake is partially supporting its FWP beneficial use based on pH. This is the first instance that this has occurred and will be looked at closely in the future to see if this is an actual impairment or an equipment malfunction. The lake was not thermally stratified in the winter or spring quarters and dissolved oxygen (D.O.) readings were generally above 6.0 mg/L in the majority of the water column (Figure 130d-130e). The lake was thermally stratified in the fall quarter between 13 and 14 meters below the lake surface and D.O. values were below 2.0 mg/L from the 14 meter depth to the lake bottom at 33.7 meters at sites 1, 2 and 7 (Figure 130d), with 52% of the water column at site 1 experiencing anoxic conditions. In the summer, stratification occurred between the 7 and 8-meters depth, accounting for a larger portion of the water column to have D.O. values less than 2.0 mg/L. At site 1, stratification occurred between 7 and 8 meters as mentioned above; however D.O. rose to above 2.0 mg/l between 10 and 20 meters and dropped below 2.0 mg/L from 28 meters to the lake bottom at 38.5 meters (see Figure 130f). This is the first time this metalimnetic minimum has been observed at this reservoir and should be looked into more closely in the future. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Tenkiller Ferry Lake as 17 to 52% of the water column was anoxic in the fall at sites 1, 2 and 7. In the summer quarter, the percent of the water column experiencing anoxic conditions was much greater ranging from 52% (site 2) to 69% at (site 7), which is also a partially supporting designation.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of (Nutrient Limited Watershed) NLW lakes and nutrient criteria development for lakes and reservoirs. In this segment of the lake the average total nitrogen (TN) was 0.28 mg/L, with values ranging from 0.11 mg/L in the fall to 0.46 mg/l in the winter quarter. The average total phosphorus (TP) was 0.012, with values ranging from 0.009 mg/L in the fall to 0.0.022 mg/L in the winter. The nitrogen to phosphorus ratio (TN:TP) for sample year 2005-2006 was 23:1. This value is higher than 7:1, characterizing for this portion of the lake as phosphorus limited (Wetzel, 1983).

Tenkiller Ferry Lake, Illinois River Arm

This portion of Tenkiller Ferry Lake (segment # 121700020220) extends from the Cookson Bend area up-lake to where the Illinois River enters the reservoir and includes BUMP sites 3, 4 (Elk Ck. Landing), 5 (Caney Ridge) and 6 (Illinois River). The segment-wide average turbidity was 7 nephelometric turbidity units (NTU), true color was 13 units and secchi disk depth was 106 centimeters in sample year 2006. Based on these three parameters water clarity is excellent in this segment of the lake. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=16). The average TSI was 59, classifying the segment as upper-eutrophic, indicative of high primary productivity and nutrient conditions. Chlorophyll-a values were generally mid to upper-eutrophic throughout the sample year, with higher values generally reported in the spring and summer. Turbidity values ranged from a low of 3 NTU to a maximum of 12 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered partially supported if 10% to 25% of the turbidity

values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although 100% of the values are below 25 NTU an assessment of the Fish & Wildlife Propagation (FWP) beneficial use cannot be made due to minimum data requirements not being met. Like turbidity, all true color values were below the Aesthetics criteria 70 units however like turbidity there are not enough data for this segment to assess the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.41 ppt, indicating low to moderate salt content compared to most Oklahoma lakes. Specific conductivity ranged from 159.3 µS/cm in the fall to 786.4 µS/cm in the spring, indicating minimal to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral to slightly alkaline, ranging from 7.02 to 9.23 units, with elevated values recorded at site 3 in the spring quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With only six (4%) of the pH values outside the acceptable range, this segment of Tenkiller Ferry Lake is supporting its FWP beneficial use based on pH. The upper segment of the lake was not thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) readings were generally above 6.0 mg/L. In the spring, the water column was weakly stratified however dissolved oxygen remained above 5.0 mg/L. In the summer, stratification occurred between the 2 and 3 meters below the surface, accounting for a larger portion of the water column to have D.O. values less than 2.0 mg/L. Approximately 50-60% of the water column was experiencing anoxic conditions at all four sites within this segment of the lake. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Tenkiller Ferry Lake, Illinois River arm with dissolved oxygen readings less than 2.0 mg/L in 50 to 60% of the water column during the summer sampling interval.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of (Nutrient Limited Watershed) NLW lakes and nutrient criteria development for lakes and reservoirs. In this segment of the lake the average total nitrogen (TN) was 0.45 mg/L, with values ranging from 0.19 mg/L in the fall to 0.79 mg/l in the winter quarter. The average total phosphorus (TP) was 0.044, with values ranging from 0.015 mg/L in the winter to 0.085 mg/L in the fall. The nitrogen to phosphorus ratio (TN:TP) for sample year 2005-2006 was 10:1. This value is higher than 7:1, characterizing for this portion of the lake as phosphorus limited (Wetzel, 1983).

Lake Summary

The lake was also sampled for chlorides and sulfates, to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported in all three management segments based on numerical criteria located in OAC 785:45 – Appendix F.

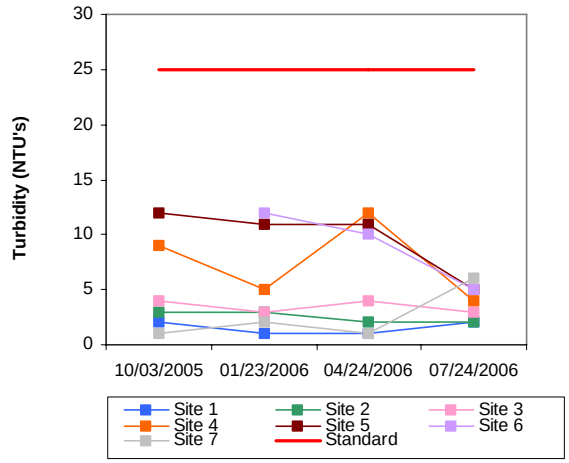
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites throughout the lake for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. Although all sample results were below both the screening level and geometric mean, the

minimum data requirements for each segment were not met and an assessment of the PBCR beneficial use cannot be made at this time.

The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1999 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or fish consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use. Tenkiller Ferry Lake was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

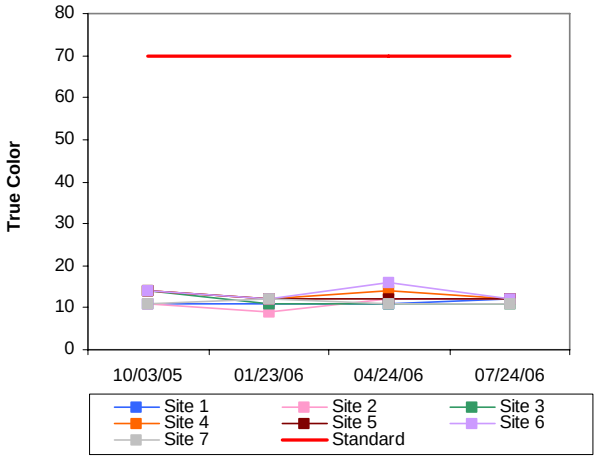
In summary, Tenkiller Ferry Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 113). Water clarity was excellent during the study period and may be attributed to the absence of inorganic turbidity (Plate 113) levels that are commonly seen in most Oklahoma reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=28). The average TSI was 55 classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. This value is similar to the TSI calculated in both 2004 and 2002 (TSI=56), indicating no significant change in productivity. TSI values varied by site and season with lower values generally occurring in the lower end of the lake near the dam. At the upper end of the lake TSI values were generally mid to upper-eutrophic throughout the year. All turbidity values were well below the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 130a), therefore meeting the FWP beneficial use as it relates to turbidity. Seasonal true color values are displayed in Figure 130b. All of the true color values were well below the numeric criteria of 70 units and the Aesthetics beneficial use is considered fully supported. Tenkiller Ferry Lake was supporting its FWP beneficial use based on nephelometric turbidity and partially supporting the beneficial use based on low D.O. concentrations in the water column. The low D.O. values observed in the summer at several sites are a cause for concern and should be studied further. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites throughout the lake for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. Although all sample results were below both the screening level and geometric mean, the minimum data requirements for each segment were not met and an assessment of the PBCR beneficial use cannot be made at this time.

a. Seasonal Turbidity Values for Tenkiller Ferry Lake

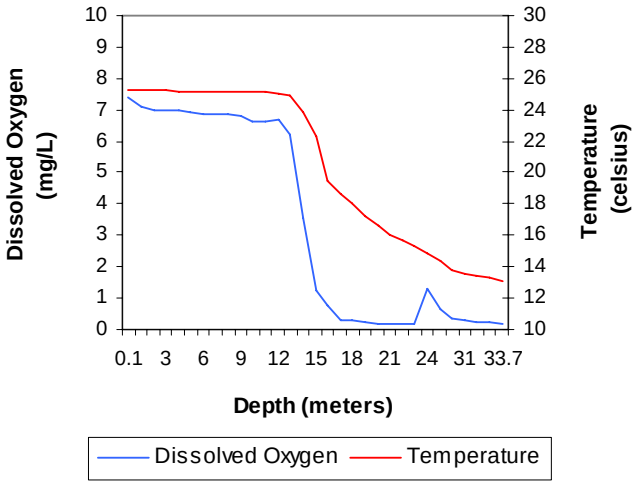


on of

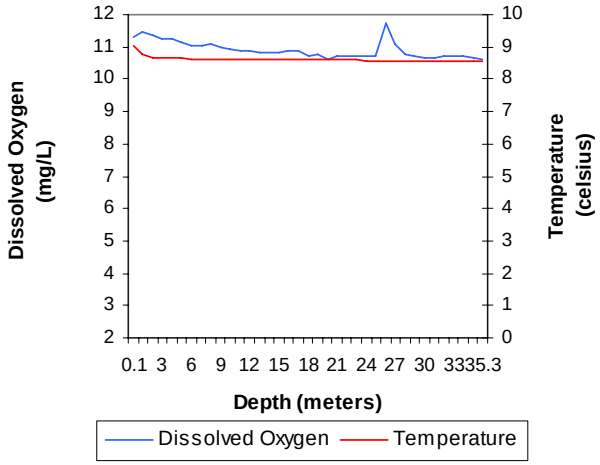
b. Seasonal Color Values for Tenkiller Ferry Lake



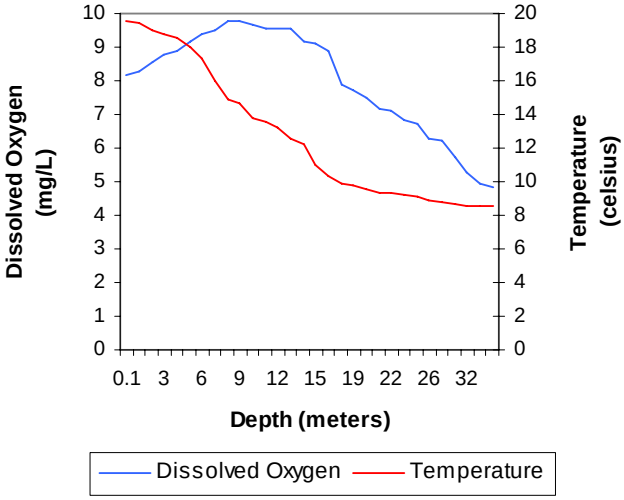
c. Profile of Tenkiller Ferry Lake
October 03, 2005



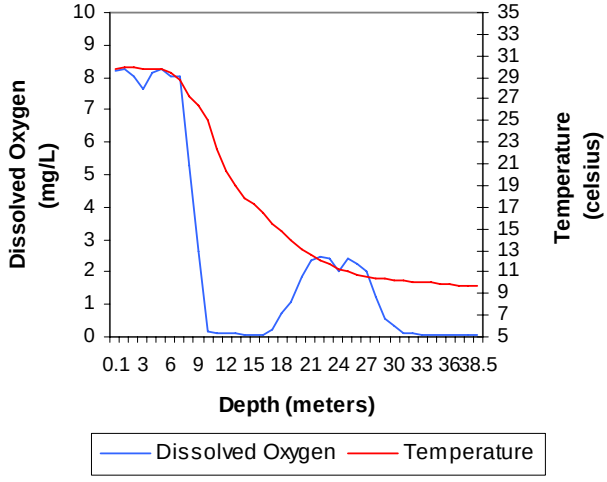
d. Profile of Tenkiller Ferry Lake
January 23, 2006



e. Profile of Tenkiller Ferry Lake
April 24, 2006



f. Profile ofTenkiller Ferry Lake
July 24, 2006



Lake Data	
Constructed by	Corps of Engineers
County	Sequoyah
Constructed in	1953
Surface Area	12,900 acres
Volume	654,100 acre/feet
Shoreline Length	130 miles
Mean Depth	50.7 feet
Watershed Area	1,610 square miles

Plate 113 - Lake Water Quality for
Tenkiller Ferry Lake

LAKES MONITORING PROGRAM

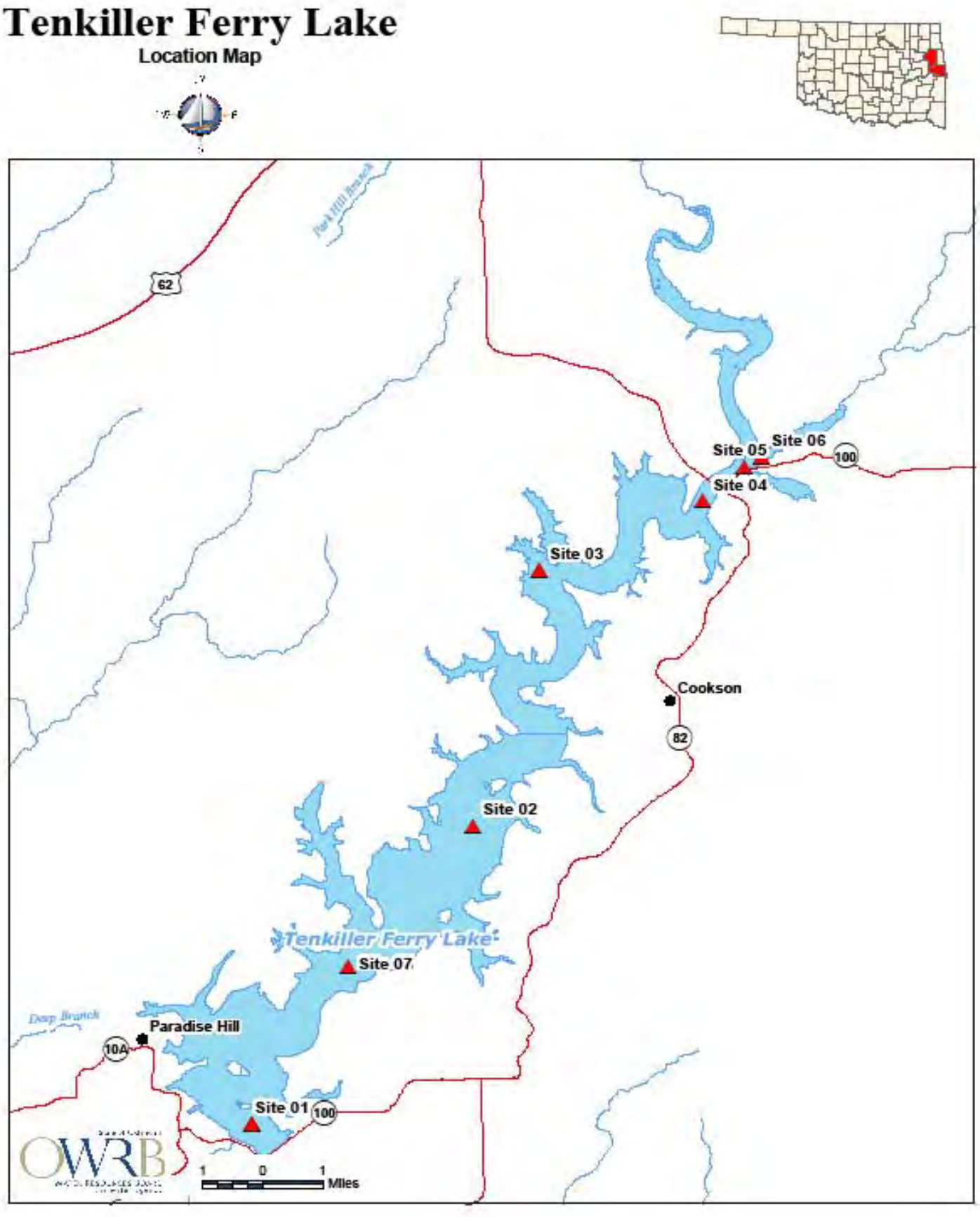


Figure 131. Tenkiller Ferry Lake Site Map

Lake Texoma

Lake Texoma was sampled for four quarters, from November 2004 through August 2005. Water quality samples were collected from thirteen (13) sites to represent the riverine, transition, and lacustrine zones and major arms of the reservoir. Samples were collected at the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The average lake-wide turbidity value was 18 NTU (Plate 114), true color was 30 units, and secchi disk depth was 76 centimeters. Based on these three parameters, Lake Texoma had average water clarity compared to other Oklahoma lakes. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=52). The average TSI was 56 (Plate 114), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient conditions. This is similar to the TSI from 2003 (TSI=54), indicating no significant increase or decrease in productivity has occurred since the last evaluation. The TSI values varied by site and season ranging from mesotrophic to hypereutrophic. Sites 8-13 (Red River arm) were generally eutrophic to hypereutrophic throughout the sample year. Site 4 had a very low chlorophyll-a value reported during the winter, placing it in the oligotrophic category. In the summer quarter, sites were generally divided between the eutrophic and hypereutrophic categories. Seasonal turbidity values ranged from a low of 2 NTU to a maximum of 128 NTU and are displayed in Figure 132a. Turbidity was generally higher at sites 10-13, located in the Red River arm of the lake. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Texoma is partially supporting its Fish and Wildlife Propagation (FWP) beneficial use with 18% of the collected turbidity values exceeding the standard. Seasonal true color values are displayed in Figure 132b. Of the 52 values collected, 5 (10%) were well above the numeric criteria of 70 units therefore the Aesthetics beneficial use is considered partially supported.

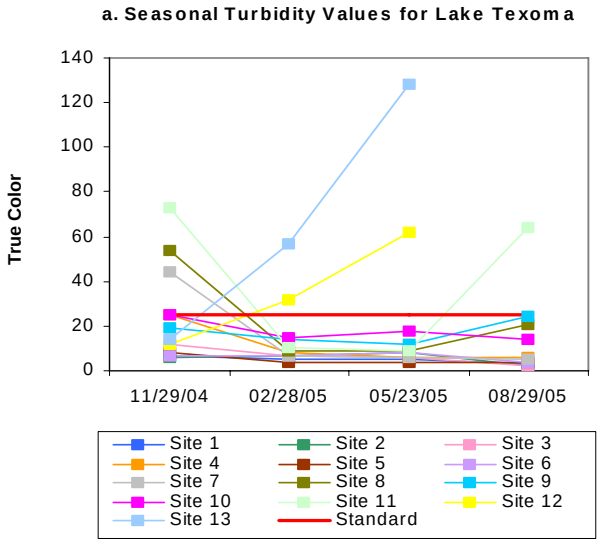
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.53 parts per thousand (ppt) at site 4 (Washita River arm) to 2.06 ppt at site 12 (Red River arm), which is higher than the range of values recorded in Oklahoma reservoirs. Specific conductivity ranged from 1005 µS/cm in the fall to 3781 µS/cm in the spring, indicative of high levels of current conducting ions (chlorides and salts) in the lake system, consistent with salinity values. The recorded values for pH ranged from 6.26 to 8.4, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With less than 1% of the collected values less than 6.5, the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from -80 mV in the hypolimnion during the summer to 561 mV in the winter. In general reducing conditions were not present at

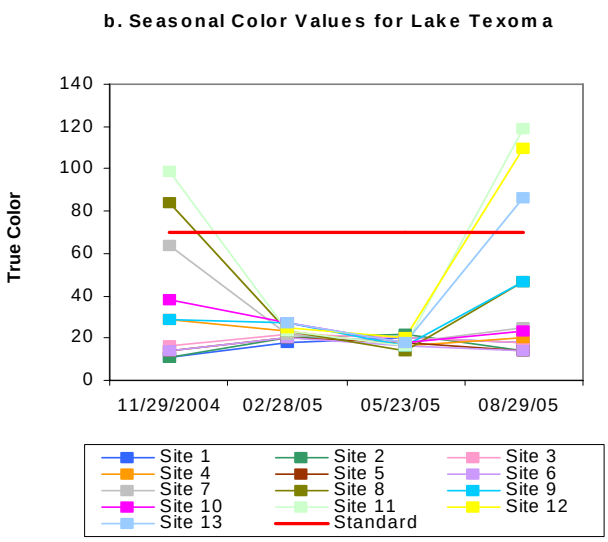
this reservoir with values above 100 mV except at sites 1, 3, and 5 during the summer when a large portion of the water column experiencing anoxic conditions. Stratification was not evident during the fall and winter sampling quarters and the water column was well mixed (see Figure 132c-132d). During the spring, the lake was stratified at several 1-meter intervals throughout the lake with dissolved oxygen (D.O.) falling below 2.0 mg/L between 18 and 19 meters, accounting for 5 to 15 % of the water column to be anoxic (Figure 132e). In the summer, strong thermal stratification was evident and anoxic conditions were present below the thermocline. Stratification occurred at varying depths throughout the lake, with 8 to 76% of the water column experiencing anoxic conditions (Figure 132f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Lake Texoma is considered partially supporting the FWP beneficial use based on low dissolved oxygen values recorded during the summer. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

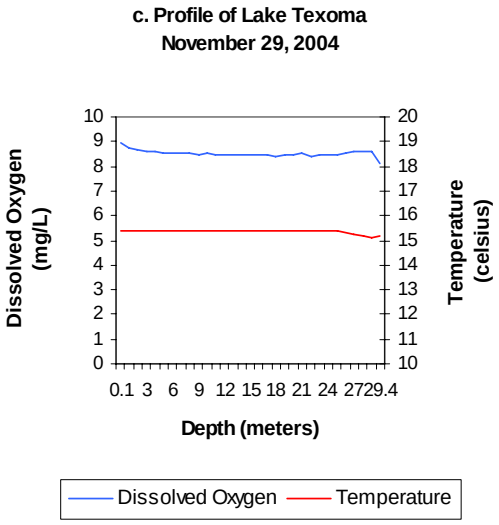
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

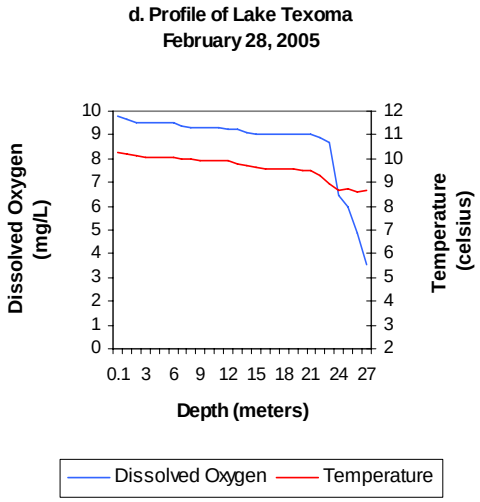
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.81 mg/L at the surface. Surface TN ranged from 0.47 mg/L to 1.38 mg/L, with the highest values reported in the summer and lowest values in the fall quarter. The lake-wide total phosphorus (TP) average was 0.062 mg/L at the surface. Total phosphorus at the surface ranged from 0.025 mg/L to 0.277 mg/L. Surface TP was highest in the summer, and the lowest values were recorded during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 13:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

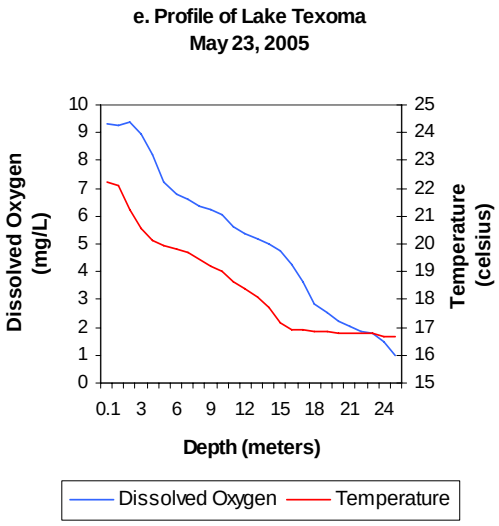
In summary, Lake Texoma was classified as eutrophic, indicative of high primary productivity and nutrient conditions in sample year 2004-2005. These results are similar to those of 2003 (TSI=54), indicating no significant increase or decrease in productivity has occurred over time. Water clarity was average based on turbidity, true color, and secchi disk depth. The FWP beneficial use is fully supported based on pH, but partially supported based on turbidity and dissolved oxygen values. The Aesthetics beneficial use is supported based on its trophic status and partially supported with 10% true color values exceeding the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake Texoma, constructed by the United States Army Corps of Engineers (USACE) is utilized for flood control, water supply, hydroelectric power, flow regulation, navigation, and recreation purposes.











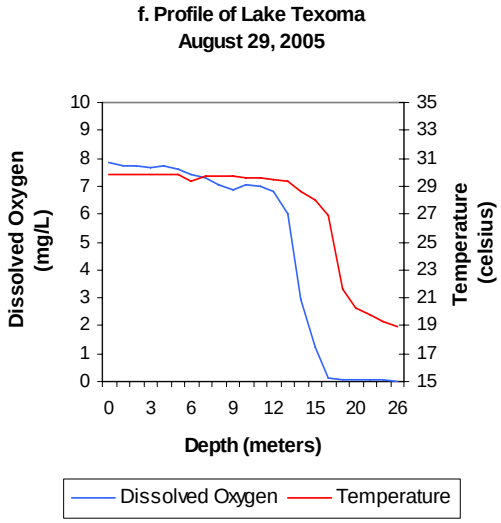
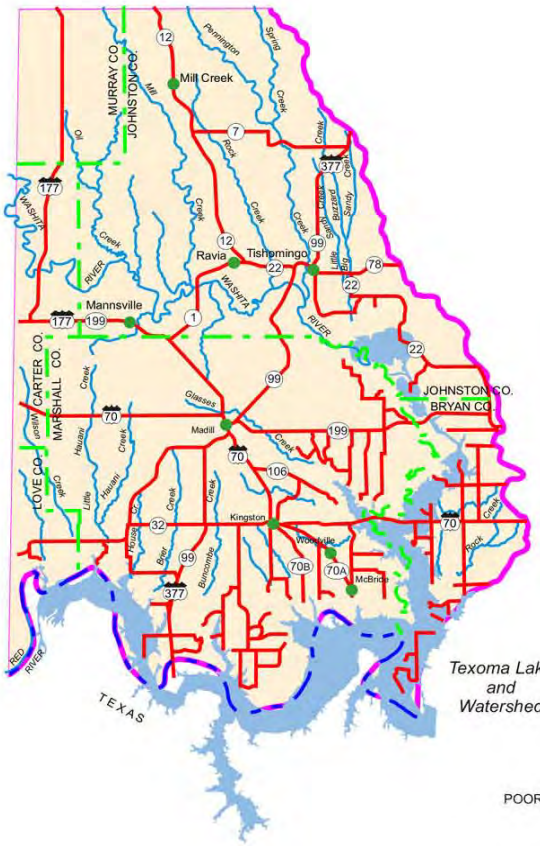
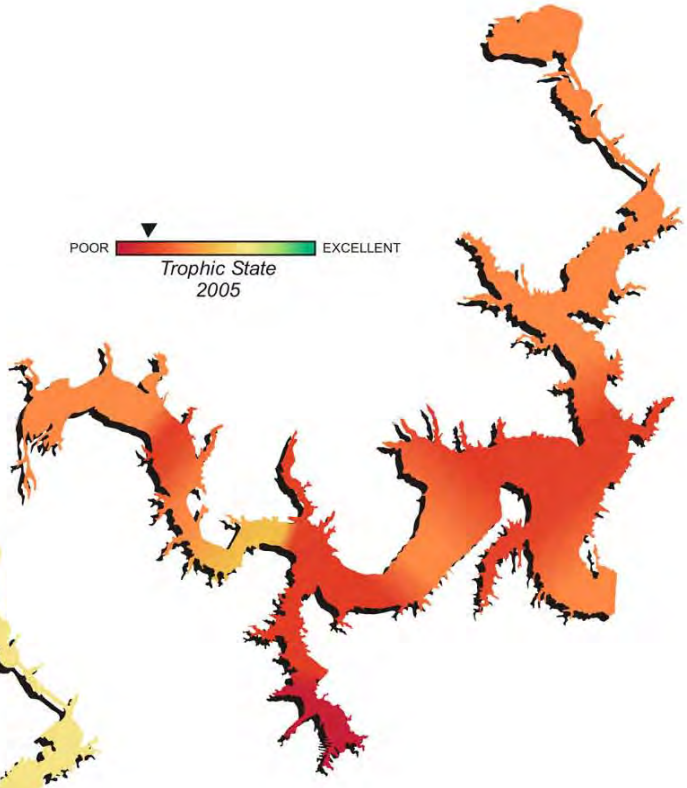


Figure 132a-132f. Graphical representation of data results for Lake Texoma.

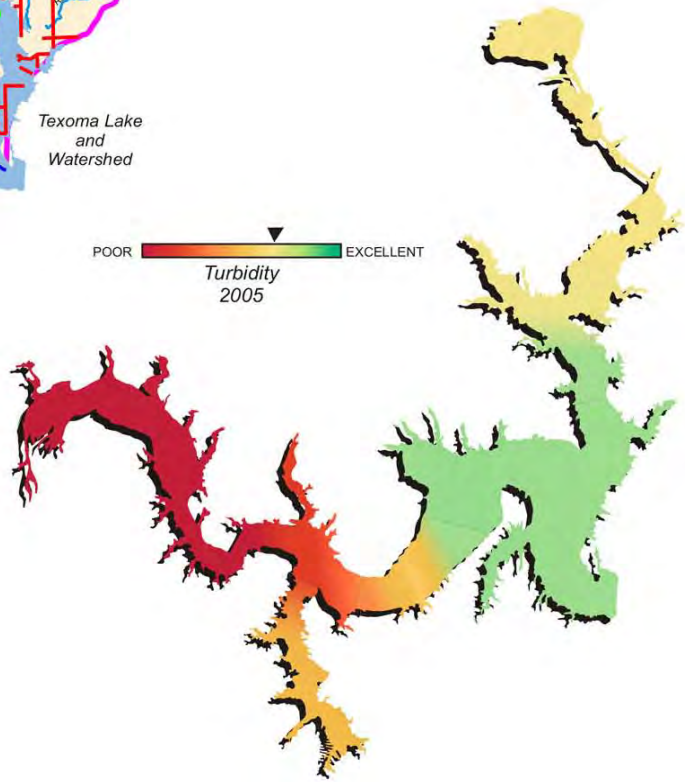


Texoma Lake and Watershed

Texoma Lake Location



Trophic State 2005



Turbidity 2005

Lake Data	
Constructed by	Corps of Engineers
County	Bryan
Constructed in	1949
Surface Area	88,000 acres
Volume	2,643,300 acre/feet
Shoreline Length	580 miles
Mean Depth	30.6 feet
Watershed Area	39,719 square miles

Plate 114 - Lake Water Quality for
Texoma Lake

LAKES MONITORING PROGRAM

Lake Thunderbird

Lake Thunderbird was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at seven (7) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major arms. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 24 NTU (Plate 115), true color was 15 units, and secchi disk depth was 55 centimeters in 2003-2004. Based on these three parameters, Lake Thunderbird had average water clarity, similar to water clarity in 2001. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=28). The average TSI was 58 (Plate 115), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is slightly higher than the TSI in 2001 (TSI=56), although in the same trophic category. The TSI varied seasonally from hypereutrophic in the fall and summer to mesotrophic and eutrophic in the winter and spring quarters. The chlorophyll-a concentrations were generally lower at the dam site and lacustrine areas of the lake (sites 1, 2, and 4) and higher at the upper end, or riverine zones of the lake (sites 5, 6, and 7). Seasonal turbidity values are displayed in (Figure 133a). Only six of the 28 turbidity values exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU; however, this constitutes a listing as partially supporting the Fish & Wildlife Propagation (FWP) beneficial use as 22% of the samples were above the criteria. According to USAP (OAC 785:46-15-5), a beneficial use is considered not supported if ≥25% of the samples exceeds the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Seasonal true color values are displayed in (Figure 133b). All true color values were below the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.16 parts per thousand (ppt) to 0.23 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most Oklahoma lakes. Specific conductivity ranged from 308.6 µS/cm in the fall quarter to 461.3 µS/cm in the spring, indicating low to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral to slightly alkaline, ranging from 7.19 to 8.38 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. The lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 326 mV at the sediment-water interface in the winter to 551 mV in the spring quarter. Redox readings indicate that reducing conditions were not present in the reservoir during sampling events. The lake was thermally stratified in the fall near the lake bottom at sites 1,2 and 4, between 8 and 9 meters with dissolved oxygen (D.O.) falling below 2.0 mg/L from 9 meters in depth to the lake bottom of 10.3, (see Figure 133c). In the summer quarter, the lake was thermally stratified between 8 and 9 meters and again between 10 and 11 meters below the lake surface at site 1, the dam. Water column D.O. values were less than 2.0 mg/L from 11 meters in depth to the lake bottom at 12.6 meters (see Figure 133f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered

supported at Lake Thunderbird, as 25% of the water column was anoxic at site 1 in the fall and 20% was anoxic in the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

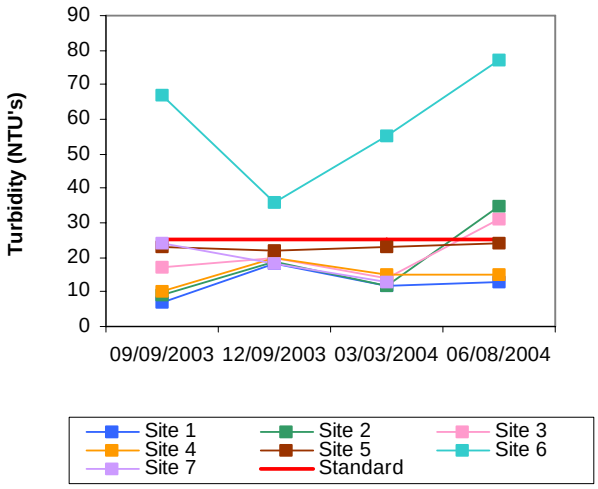
Bacteriological samples were also collected to assess the Primary Body contact Recreation (PBCR) beneficial use. Samples were collected at five sites for E. coli, fecal coliform and enterococci during the recreation season of May through September. Of the 10 samples collected one (1) or 10% of the samples exceed the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.11 mg/L at the lake surface and 0.83 mg/L at the lake bottom. The TN at the surface ranged from 0.49 mg/L to 1.25 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was recorded in the summer. The lake-wide total phosphorus (TP) average was 0.041 mg/L at the lake surface and 0.038 mg/L at the lake bottom. The surface TP ranged from 0.025 mg/L to 0.087 mg/L. The highest surface TP value was reported in the fall and the lowest was in the spring quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 27:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

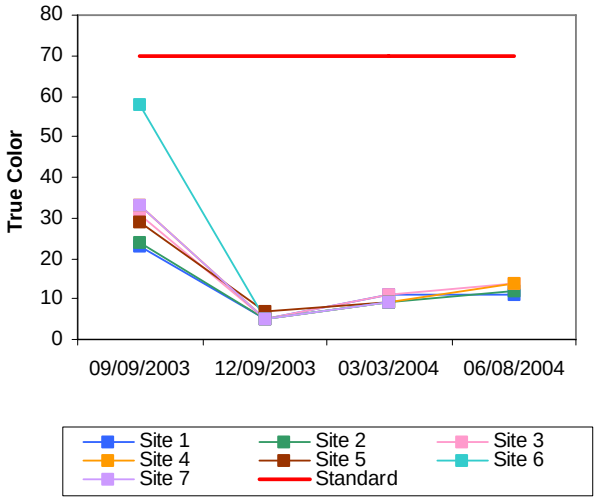
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1999 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Thunderbird was eutrophic, indicative of high primary productivity and nutrient conditions (Plate). The calculated TSI was very similar to that sample year 2002 (TSI=56), indicating no significant change in productivity has occurred. Water clarity was average based on secchi disk depth, turbidity and true color values. The lake was fully supporting its Aesthetics beneficial use based on its trophic state and true color. The lake was also fully supporting its FWP beneficial use based on pH and dissolved oxygen; however it is partially supporting based on turbidity readings. Bacteriological samples were also collected to assess the Primary Body contact Recreation (PBCR) beneficial use. Of the 10 samples collected one (1) or 10% of the samples exceed the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Lake Thunderbird was constructed in 1965 and is owned by the Bureau of Reclamation. The lake serves as a municipal water supply for flood control, fish and wildlife and offers numerous recreational opportunities to the public. In 2001 a bathymetric survey (Figure 134) was conducted to determine current capacity and assess sedimentation rates due to lake Thunderbird's turbidity problems. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800.

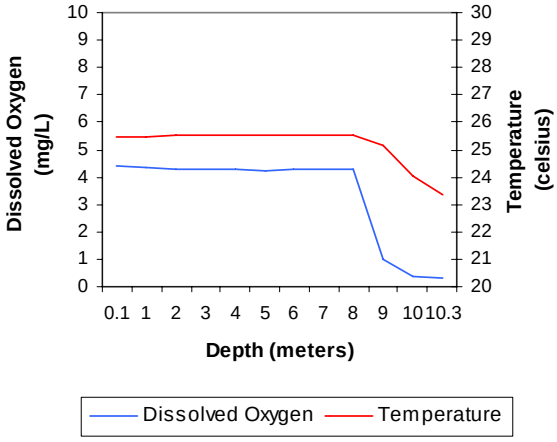
a. Seasonal Turbidity Values for Lake Thunderbird



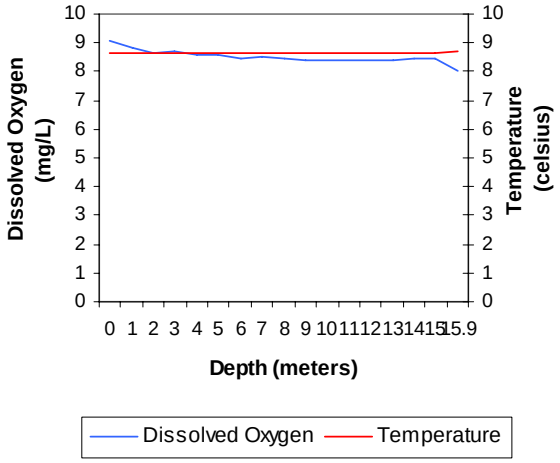
b. Seasonal Color Values for Lake Thunderbird



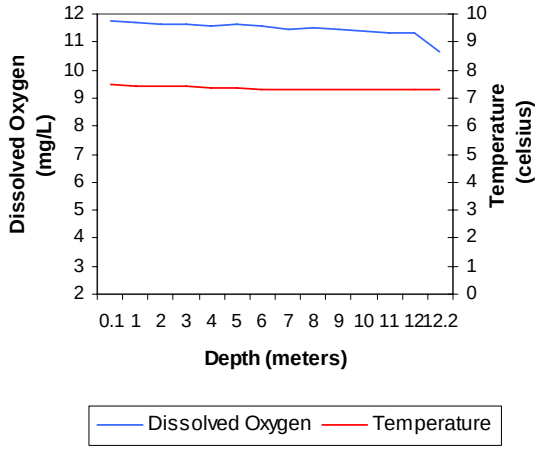
c. Profile of LakeThunderbird September 09, 2003



d. Profile of LakeThunderbird Decmber 09, 2003



e. Profile of LakeThunderbird March 03, 2004



f. Profile of LakeThunderbird June 08, 2004

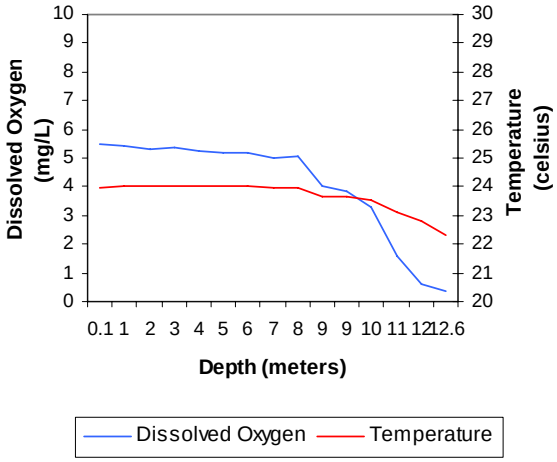
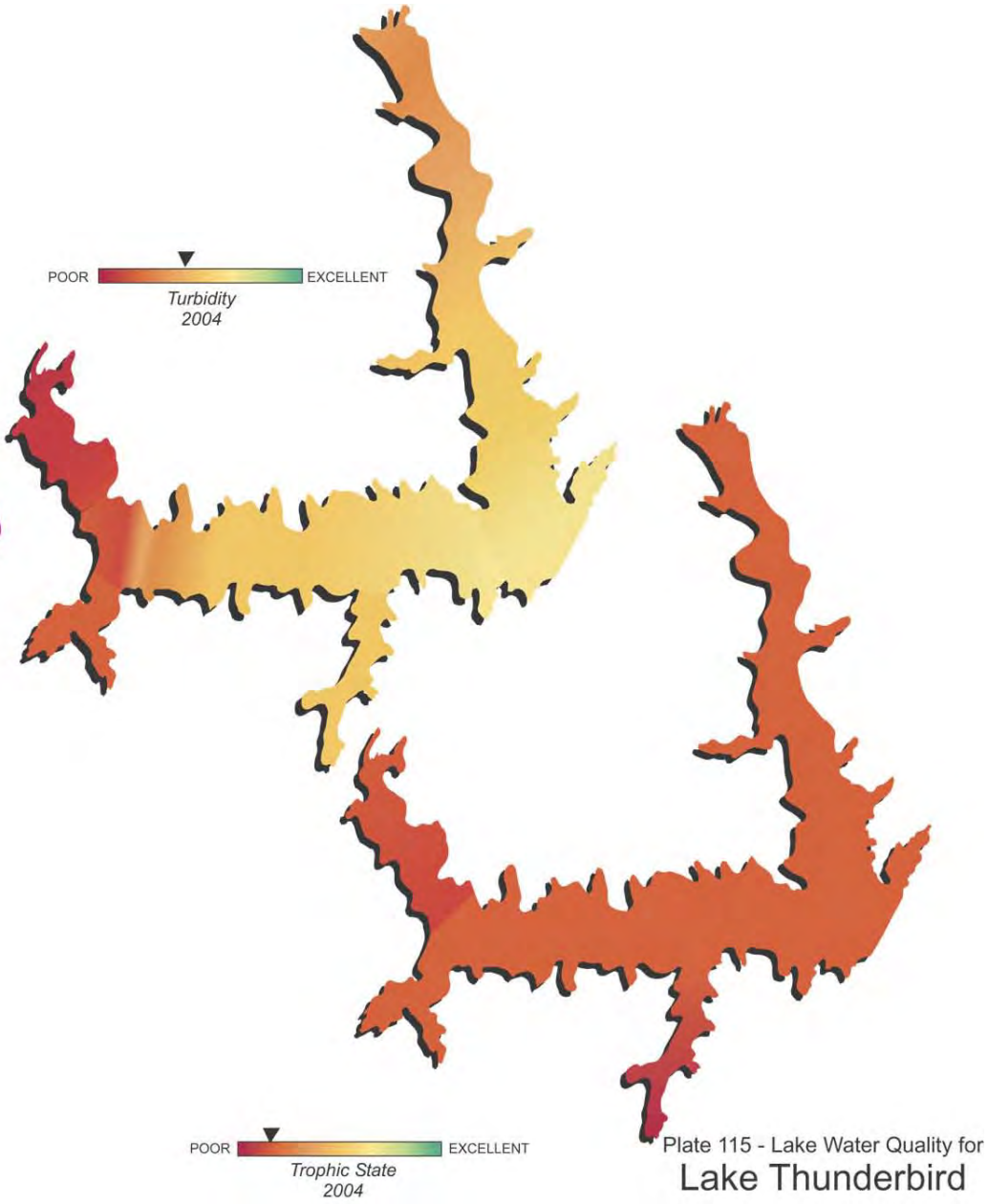


Figure 133a-133f. Graphical representation of data results for Lake Thunderbird.



Lake Data	
Constructed by	Bureau of Reclamation
County	Cleveland
Constructed	1965
Surface Area	6,070 acres
Volume	119,600 acre/feet
Shoreline Length	86 miles
Mean Depth	19.70 feet
Watershed Area	256 square miles

Plate 115 - Lake Water Quality for
Lake Thunderbird

LAKES MONITORING PROGRAM

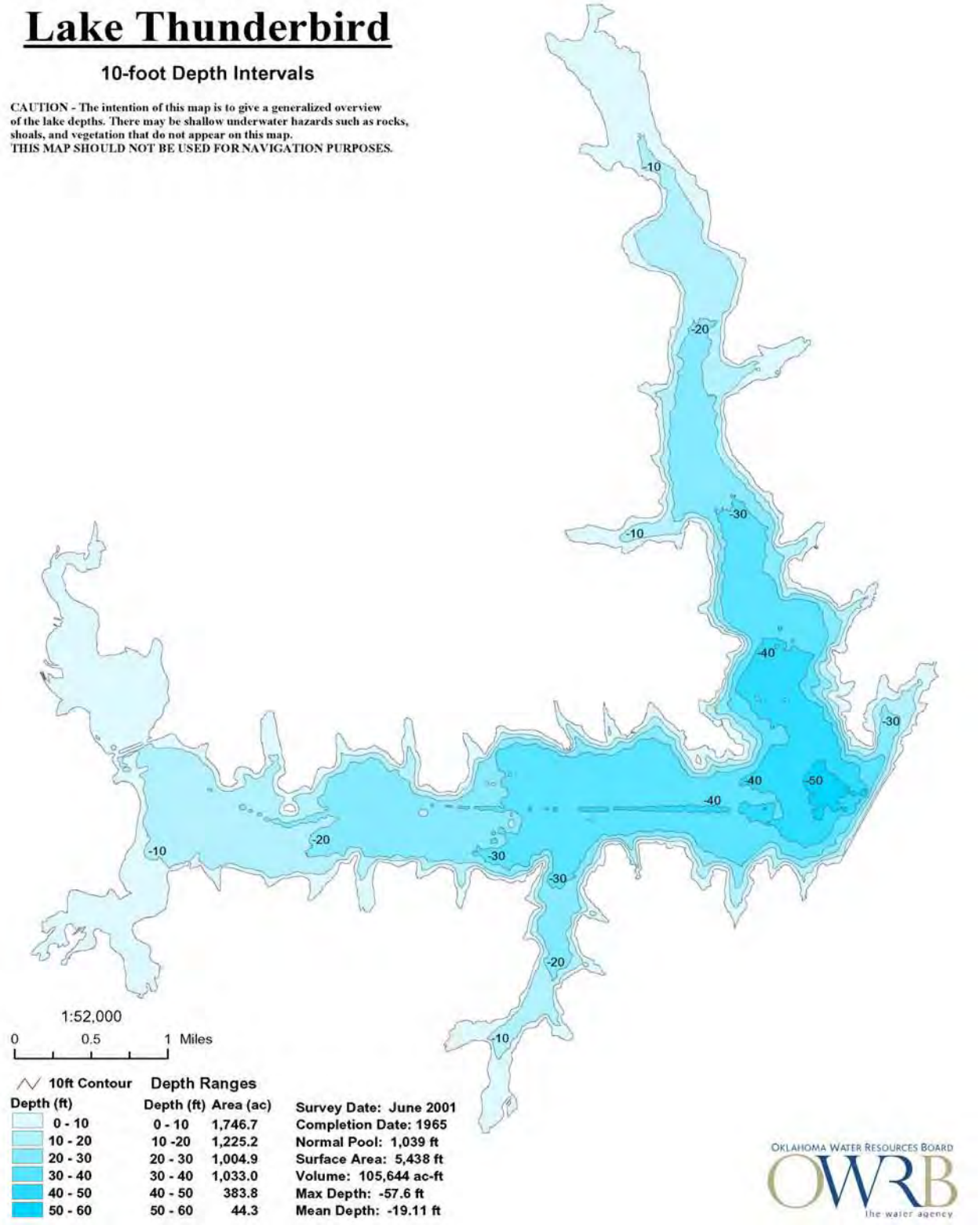


Figure 134. Bathymetric map of Lake Thunderbird.

Tom Steed Reservoir

Tom Steed Reservoir was sampled for four quarters, from September 2004 through June 2005. Water quality samples were collected from five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and from 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 39 NTU (Plate 116), true color was 46 units, and average secchi disk depth was 38 centimeters. Based on these three parameters Tom Steed Reservoir had poor water clarity in sample year 2005. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a) was calculated using values collected at all sites four quarters (n=20). The TSI was 70 (Plate 116), indicating the lake was hypereutrophic with excessive primary productivity and nutrient conditions. This is higher than the TSI in 2003 (TSI=52). The TSI values were generally upper mesotrophic to eutrophic during the sample year. The exception to this pattern occurred in the winter quarter when a large peak in chlorophyll-a values was reported for all sites placing all sites in the hypereutrophic category. Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Seasonal turbidity values are displayed in Figure 135a. Turbidity values ranged from a low of 25 NTU to a maximum of 64 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if $\geq$ 25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (WQS) of 25 NTU for turbidity. With 100% of the samples exceeding 25 NTU, the beneficial use of Fish and Wildlife propagation (FWP) should be considered not supported in regards to turbidity. Seasonal true color values are displayed in Figure 135b. All color values were well below the aesthetics WQS of 70 units. Only one (5%) of the true color values reached the standard of 70 units. Applying the same default protocol the Aesthetics beneficial use is considered fully supported.

In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.38 parts per thousand (ppt) to 0.45 ppt for this sample year. Specific conductivity ranged from 733.2 to 867.2 µS/cm, which is higher than most Oklahoma reservoirs. These values are indicative of moderate to high levels of electrical current conducting compounds (salts) in the lake, consistent with elevated salinity concentrations. The pH values at Tom Steed Reservoir were generally neutral to slightly alkaline, ranging from 7.95 in the spring to 8.21 in the summer. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range, the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials ranged from 341 mV in the spring to 440 mV in the summer, indicating the absence of reducing conditions during the study period. Profile data for the fall quarter is not available due to equipment failure and an assessment of this sampling interval cannot be made.

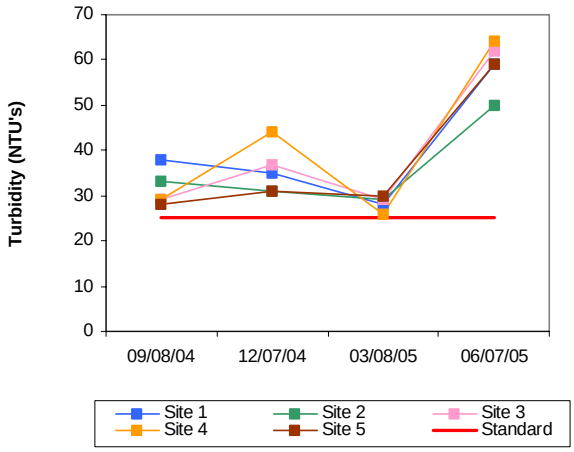
Due to the shallow nature of the lake thermal stratification was not present during any of the remaining sampling quarters and the water column was well mixed with dissolved oxygen (D.O.) values generally above 6 mg/L (see Figure 135c-135e). With 100% of the collected values greater than 2.0 mg/L, the lake is considered fully supporting its FWP beneficial use based on dissolved oxygen. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

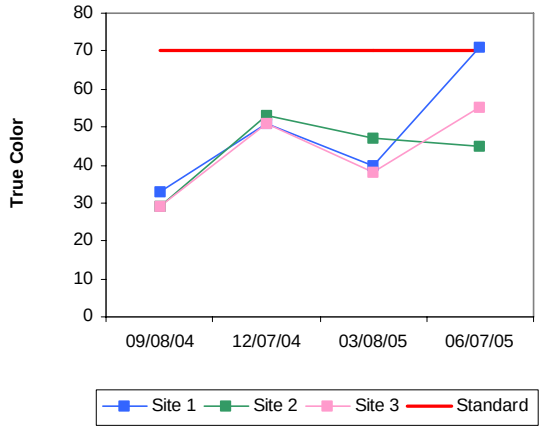
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.73 mg/L at the surface. Surface TN ranged from 0.48 mg/L to 0.97 mg/L, with the highest values reported in the winter and lowest values in the summer quarter. The lake-wide total phosphorus (TP) average was 0.102 mg/L at the surface. Total phosphorus at the surface ranged from 0.064mg/L to 0.141 mg/L. Similar to TN, surface TP was highest in the winter, and the lowest during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 7:1 for sample year 2004-2005. This is the same as the 7:1 ratio used to determine the limiting nutrient, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Tom Steed Reservoir was classified as hypereutrophic with excessive primary productivity and nutrient conditions. This is higher than the TSI in 2003 (TSI=52). Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (WQS) revision process as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Water clarity was poor based on turbidity, true color, and secchi disk depth in 2004-2005. The lake is supporting the FWP beneficial use based on dissolved oxygen and pH, however is not supporting the use with 100% of the turbidity values exceeding the WQS of 25 NTU. The Aesthetics beneficial use is considered supported based on true color values reported during the study period. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. The Bureau of Reclamation constructed Tom Steed Reservoir for municipal and industrial water supply, flood control, and fish and wildlife purposes.

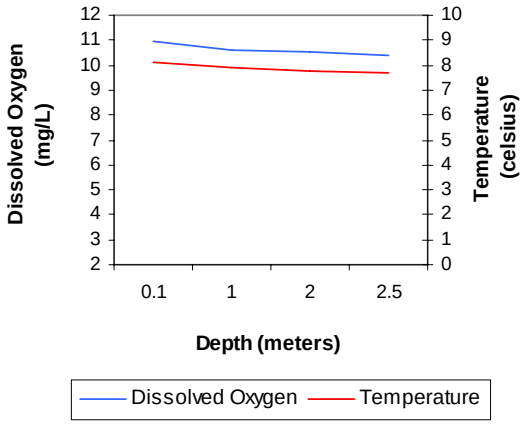
a. Seasonal Turbidity Values for Tom Steed Reservoir



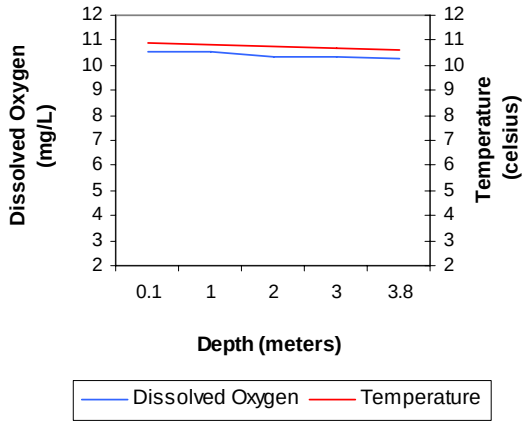
b. Seasonal Color Values for Tom Steed Reservoir



c. Profile of Tom Steed Reservoir
December 07, 2004



d. Profile of Tom Steed Reservoir
March 08, 2005



e. Profile of Tom Steed Reservoir
June 06, 2005

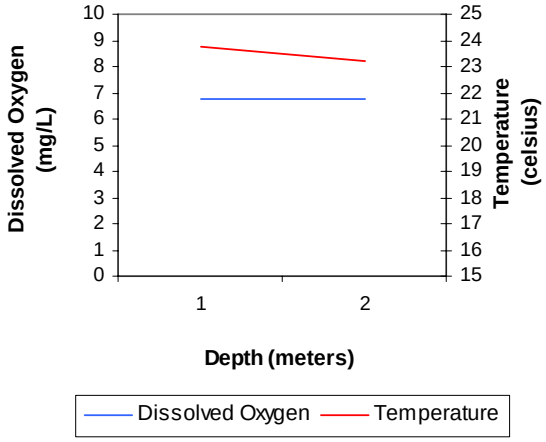
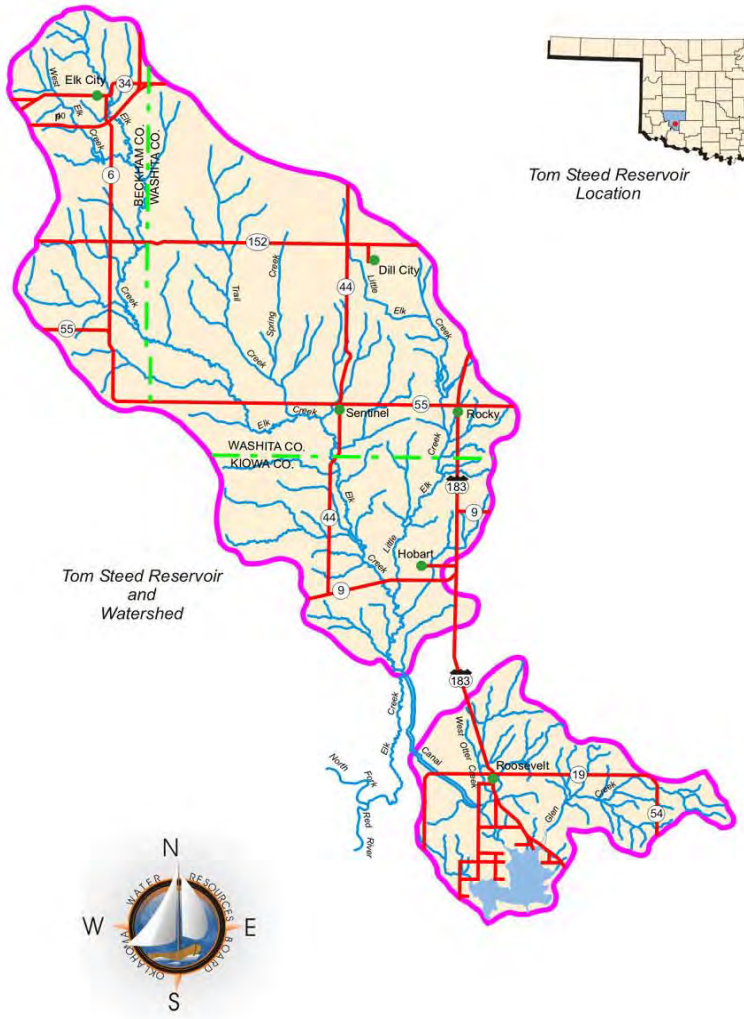
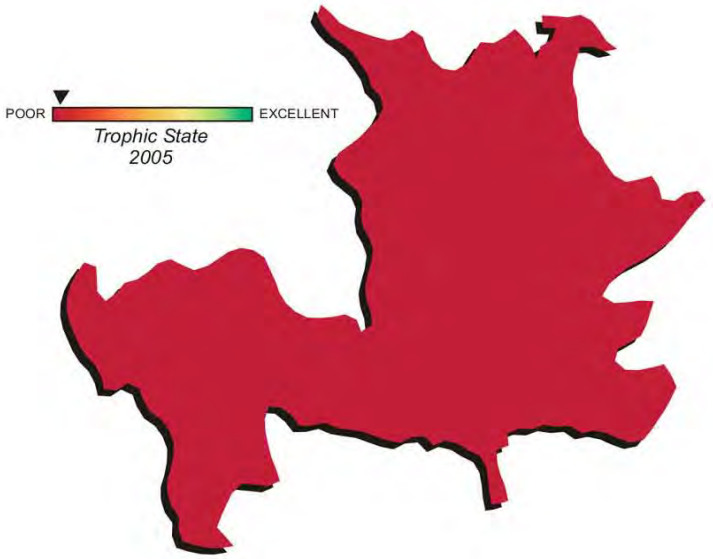


Figure 135a-135f. Graphical representation of data results for Tom Steed Reservoir.

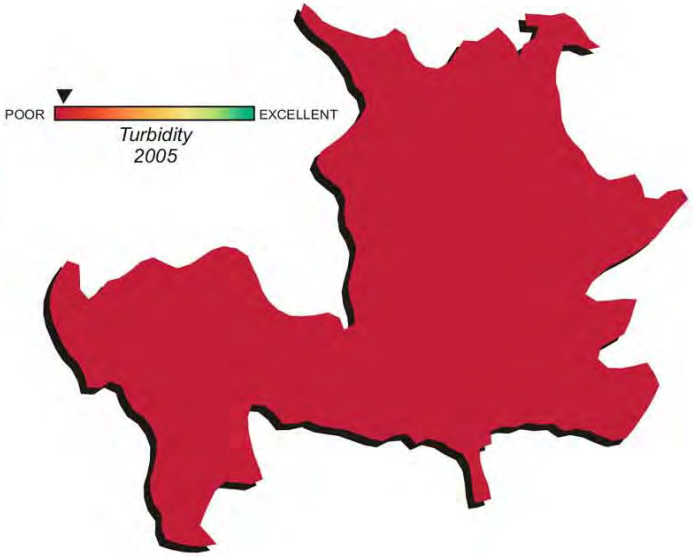


Tom Steed Reservoir and Watershed

Tom Steed Reservoir Location



Trophic State 2005



Turbidity 2005

Lake Data	
Constructed by	Bureau of Reclamation
County	Kiowa
Constructed in	1980
Surface Area	6,400 acres
Volume	88,970 acre/feet
Shoreline Length	31 miles
Mean Depth	15.08 feet
Watershed Area	681 square miles

Plate 116 - Lake Water Quality for
Tom Steed Reservoir

LAKES MONITORING PROGRAM

Lake Vanderwork

Lake Vanderwork was sampled for four quarters, from September 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 8 NTU (Plate117), true color was 11 units, and secchi disk depth was 71 centimeters in 2003-2004. Based on these three parameters, Lake Vanderwork had average to good water clarity in comparison to other Oklahoma lakes. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 60 (Plate 117), classifying the lake as eutrophic bordering hypereutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values varied seasonally with the fall quarter characterized by hypereutrophic conditions and the other three quarters at the upper end of eutrophy bordering at hypereutrophic. These results are slightly lower than in the previous evaluation in 2002 (TSI=63). Lake Vanderwork is currently listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited Watershed (NLW). This listing means the lake is considered threatened due to nutrients and a nutrient impairment study should be initiated to determine if the Aesthetics beneficial use is supporting or not supporting. All turbidity values were below the WQS of 25 NTU (see Figure 136a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Vanderwork is fully supporting its Fish and Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 136b. All true color values were less than the Aesthetics criteria of 70 units, therefore, the use is considered fully supported.

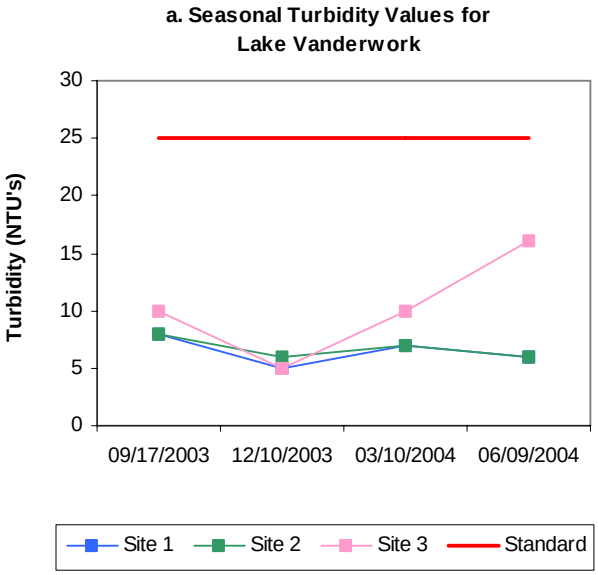
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 1.03 parts per thousand (ppt) to 1.09 ppt. Values were higher than the range of expected values for Oklahoma lakes, reflecting the presence of high concentrations of chlorides or other salts in the lake. Specific conductivity values were also elevated above the expected range for Oklahoma reservoirs, indicative of high salinity concentrations. Values ranged from 1923 µS/cm in the spring quarter to 2031 µS/cm at site 1 in the winter, indicating that high levels of electrical conducting compounds (salts) were present in the lake system. Oxidation-reduction potentials (redox) ranged from 377 mV at the sediment-water interface in the winter to 528 mV in the spring, indicating reducing conditions were not present in the lake during the study period. The pH values were neutral to slightly alkaline with values ranging from 7.36 units in the spring quarter to 8.07 recorded in the fall quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. None of the collected pH values were outside the acceptable range;

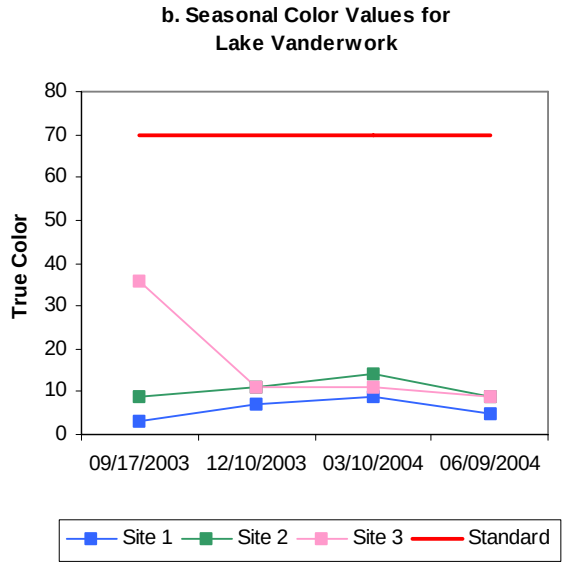
therefore the lake is fully supporting its FWP beneficial use based on pH. Thermal stratification was not evident in the fall, winter, or spring quarters and dissolved oxygen (D.O.) values were above 6.0 mg/L throughout the water column (see Figure 136c-136e). Due to equipment failure there is no profile data available for the summer sampling interval. However it is likely that thermal stratification occurred and anoxic conditions would be present based on seasonality and previous evaluations. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered fully supported at Lake Vanderwork with all values in the first three quarters well above 2.0 mg/L. Because the summer profile data is missing an assessment for that season cannot be made at this time. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

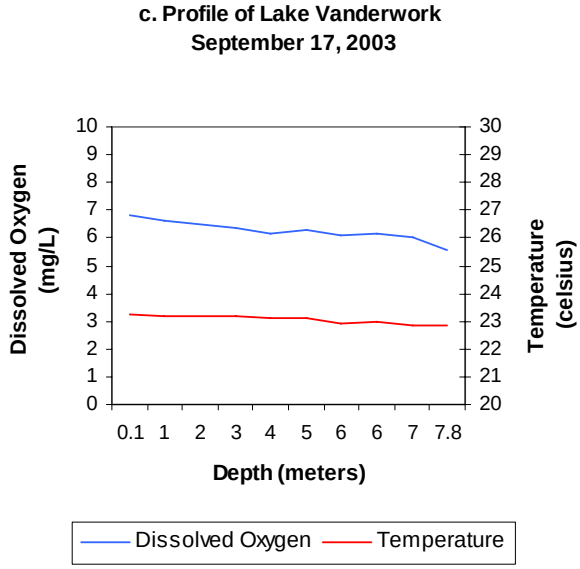
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for E. coli, fecal coliform and enterococci analysis during the recreation season of May through September. Of the 10 samples collected one (1) or 10% of the samples collected exceed the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

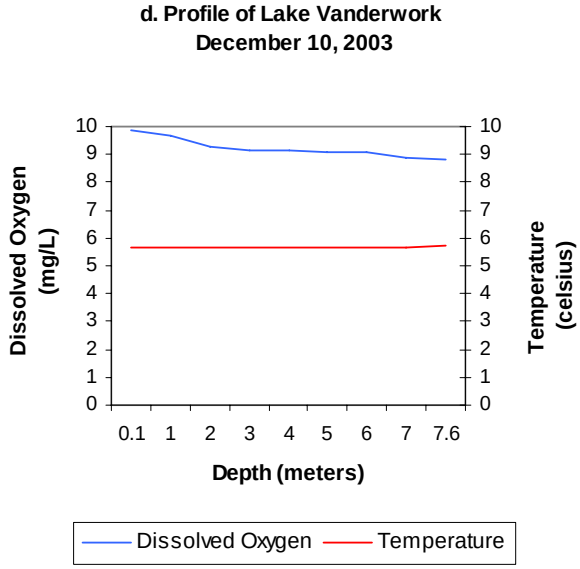
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 1.40 mg/L at the lake surface and 1.56 mg/L at the lake bottom. The TN at the surface ranged from 1.01 mg/L to 1.77 mg/L. The highest surface TN value was reported in the winter quarter and the lowest was in the summer. The lake-wide total phosphorus (TP) average was 0.044 mg/L at the lake surface and 0.049 mg/L at the lake bottom. The surface TP ranged from 0.007 mg/L to 0.63 mg/L. Both the highest and lowest reported values occurred in the summer. The nitrogen to phosphorus ratio (TN: TP) was approximately 32:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Vanderwork was classified as eutrophic bordering hypereutrophic, indicative of excessive primary productivity and nutrient rich conditions (Plate). The Aesthetics beneficial use is considered fully supported based on true color values, however a determination cannot be made based on trophic status. Currently, the lake is listed in the WQS as a NLW indicating that the Aesthetics beneficial use is considered threatened by nutrients. The lake should be monitored intensively to determine if the Aesthetics beneficial use is supported for nutrients. The FWP beneficial use is fully supported based on nephelometric turbidity, pH, and D.O. concentrations in the water column. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the 10 samples collected one (1) or 10% of the samples collected exceed the screening level of 61cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Lake Vanderwork was constructed in 1968 and is owned and operated by the State of Oklahoma. This lake is managed by the Oklahoma Department Wildlife Conservation and serves as a fishery.









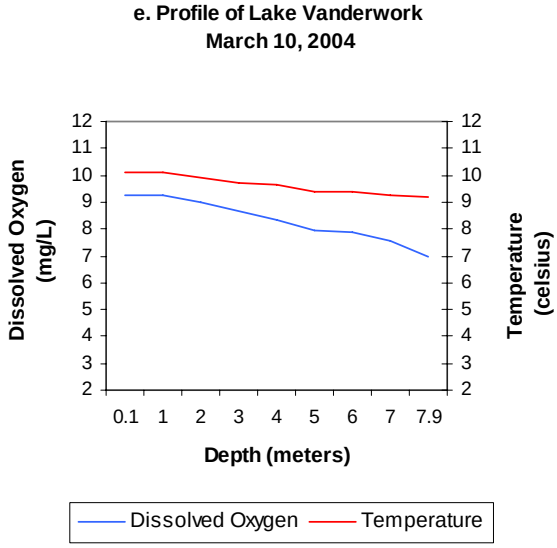


Figure 136a-136e. Graphical representation of data results for Lake Vanderwork.

Vanderwork Lake
and
Watershed

Lake Data	
Owner	State of Oklahoma
County	Washita
Constructed in	1968
Surface Area	135 acres
Volume	1,578 acre/feet
Shoreline Length	6 miles
Mean Depth	11.69 feet
Watershed Area	10 square miles

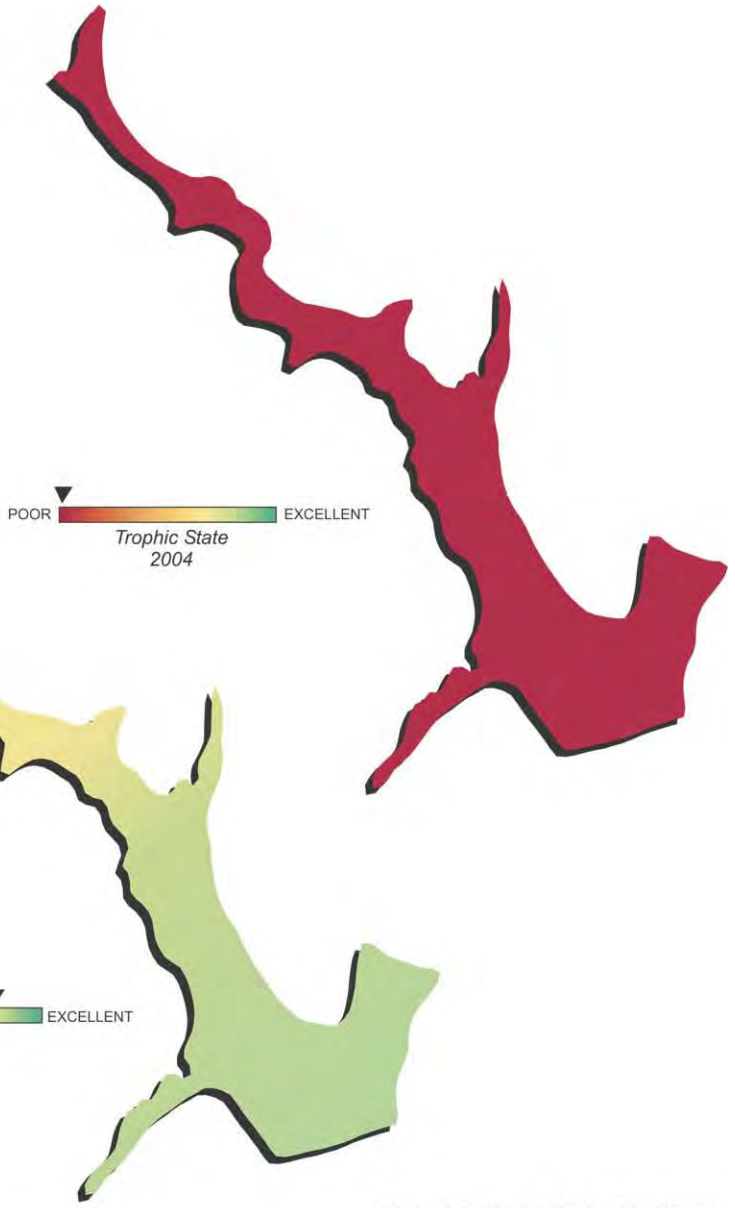


Plate 117 - Lake Water Quality for
Vanderwork Lake

LAKES MONITORING PROGRAM

Lake Vincent

Lake Vincent was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The average lake-wide turbidity value was 15 NTU (Plate 118), true color was 21 units, and secchi disk depth was 66 centimeters. Based on these three parameters, Lake Vincent had good water clarity in comparison to other Oklahoma lakes. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 44 (Plate 118), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. This is similar to results in 2003 (TSI=42), indicating no significant increase or decrease in productivity has occurred over time. The TSI values were at the upper end of mesotrophy in both fall and summer and oligotrophic during winter and spring sampling intervals Seasonal turbidity values are displayed in Figure 137a. Turbidity values ranged from a low of 6 NTU to a maximum of 34 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the collected values below the WQS of 25 NTU, Lake Vincent is fully supporting its Fish and Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 137b. All true color values were less than the Aesthetics criteria of 70 units, therefore, the use is considered fully supported.

In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.39 parts per thousand (ppt) to 0.41 ppt, which is higher than the average range of values recorded in Oklahoma reservoirs. Specific conductivity ranged from 746.4 µS/cm to 784.5 µS/cm, indicative of moderate to high levels of current conducting ions (salts) in the lake system. The pH values ranged from 7.38 to 8.48, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all of the collected values within the acceptable range, the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 108 mV in the hypolimnion in the summer to 526 mV in the spring. In general, reducing conditions were not present with recorded values above 100 mV during the study period. The lake was not stratified during the fall, winter, or spring sampling quarters and the water column was well mixed (see Figure 137c-137e). In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline. The lake was stratified between 4 and 5 meters throughout the lake, with dissolved oxygen less than 2.0 mg/L from 6 meters to the lake bottom of 10 meters. Approximately 50% of the water column, at site 1 experienced anoxic conditions during the

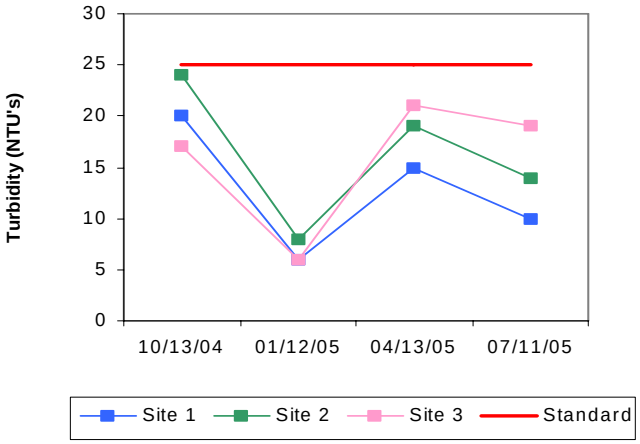
summer quarter (Figure 137f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 50% of the collected dissolved oxygen values below 2.0 mg/L, Lake Vincent is considered partially supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

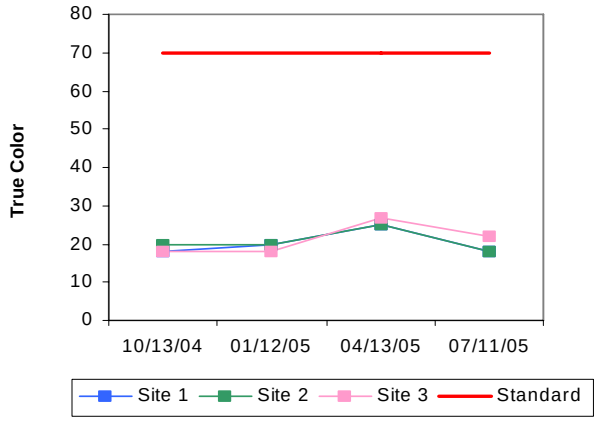
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.52 mg/L at the surface. Surface TN ranged from 0.36 mg/L to 0.70 mg/L, with the highest values reported in the fall and lowest values in the winter quarter. The lake-wide total phosphorus (TP) average was 0.029 mg/L at the surface. Total phosphorus at the surface ranged from 0.020mg/L to 0.038 mg/L. Surface TP was highest in the fall and summer, while the lowest values were recorded during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 18:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Lake Vincent was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions (Plate 118). This is consistent with past data collection efforts in 2003 (TSI=42), indicating that no significant increase or decrease in productivity has occurred over time. Water clarity was good based on true color, turbidity, and secchi disk depth. The FWP beneficial use is fully supported based on turbidity and pH, but only partially supported based on anoxic conditions present in 50% of the water column during the summer. The Aesthetics beneficial use is fully supported based on its trophic status as well as true color with 100% of the reported values less than the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake Vincent is located in Ellis County and is utilized for recreation.

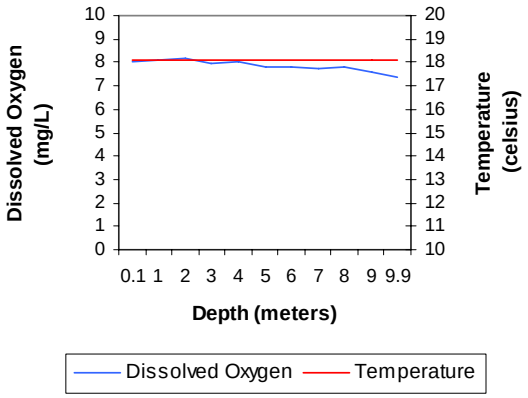
a. Seasonal Turbidity Values for Lake Vincent



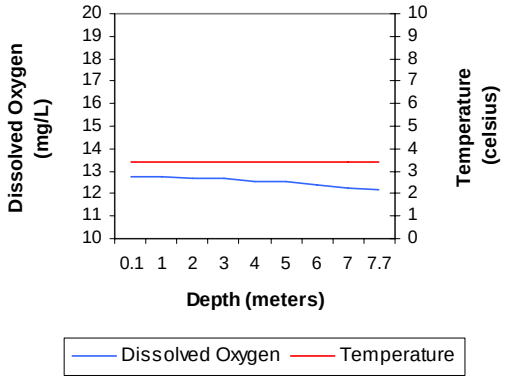
b. Seasonal Color Values for Lake Vincent



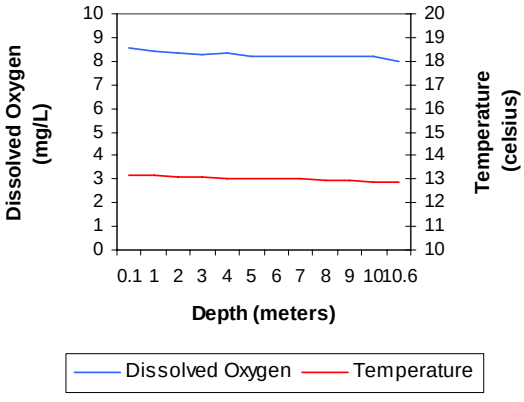
c. Profile of Lake Vincent
October 13, 2004



d. Profile of Lake Vincent
January 12, 2005



e. Profile of Lake Vincent
April 13, 2005



f. Profile of Lake Vincent
July 11, 2005

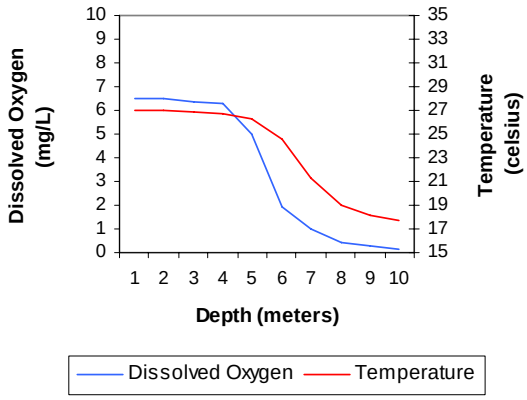


Figure 137a137f. Graphical representation of data results for Lake Vincent.

Lake Data	
Owner	State of Oklahoma
County	Ellis
Constructed in	1961
Surface Area	160 acres
Volume	2,579 acre/feet
Shoreline Length	5 miles
Mean Depth	16.12 feet
Watershed Area	13 square miles

Plate 118 - Lake Water Quality for
Lake Vincent

LAKES MONITORING PROGRAM

W.R. Holway Reservoir

W.R. Holway Reservoir was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected from five (5) sites to represent the riverine, transition, and lacustrine zone of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 5 NTU (Plate 119), true color was 22 units, and average secchi disk depth was 121 centimeters. Based on theses three parameters, W.R. Holway Reservoir had excellent water clarity, similar to that in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 53 (Plate 119), classifying the lake as eutrophic, with moderate levels of productivity and nutrient conditions. The TSI values were fairly consistent with values in the eutrophic category throughout the year. The only exceptions to this were sites 2 and 4 in the fall quarter, which were mesotrophic. Seasonal turbidity values are displayed in Figure 138a. Turbidity values ranged from a low of 2 NTU to a maximum of 8 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With all collected values well below the WQS of 25 NTU, W.R. Holway is fully supporting its Fish and Wildlife Propagation (FWP) beneficial use in regards to turbidity. Seasonal true color values are displayed in Figure 138b. All true color values were less than the Aesthetics criteria of 70 units, therefore the beneficial use is considered supported.

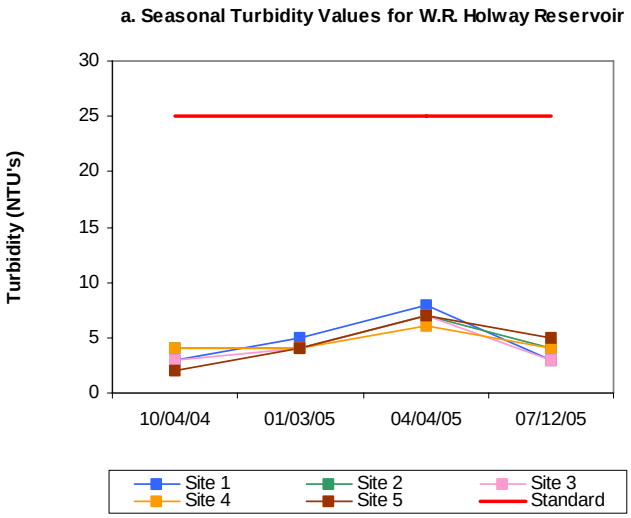
In 2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.10 parts per thousand (ppt) to 0.18 ppt, which is within the average the range of values recorded in Oklahoma reservoirs. Specific conductivity ranged from 231.6 µS/cm to 362.1 µS/cm, indicating the presence of low to moderate levels of current conducting ions (salts) in the lake system. The pH values ranged from 6.92 in the fall to 8.76 in the summer. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the values within the acceptable range, the FWP is supported based on turbidity. Oxidation-reduction potentials (ORP) ranged from 168 mV to 455 mV, indicating reducing conditions were not present at this reservoir during any of the sampling intervals. In the fall quarter the water column was well mixed with dissolved oxygen (D.O.) values generally above 5.0 mg/L (Figure 138c). There was a malfunction with the Hydrolab during the winter and profile data is highly suspect. Although the data is not usable it is likely that the dissolved oxygen would be higher than 2.0 mg/L throughout the water column based on the time of year and water temperatures Figure 138e). The lake was still well mixed during the spring quarter with D.O. levels generally above 7.0 mg/L among all sites. In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline, as is to be expected in a reservoir this deep. Stratification occurred at several 1-

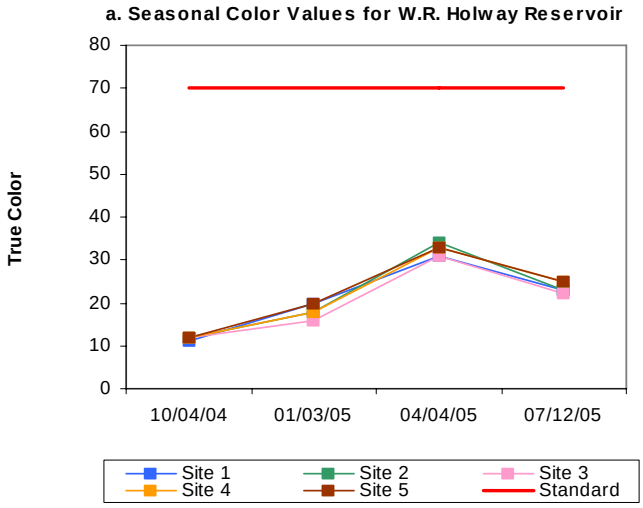
meter intervals throughout the lake, with 22 to 36% of the water column experiencing anoxic conditions (Figure 138f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Currently, W.R. Holway Reservoir considered supporting the FWP beneficial use with up to 36% of the water column experiencing anoxic conditions. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

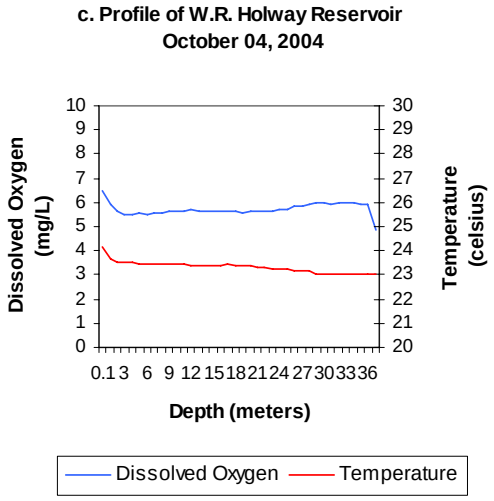
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

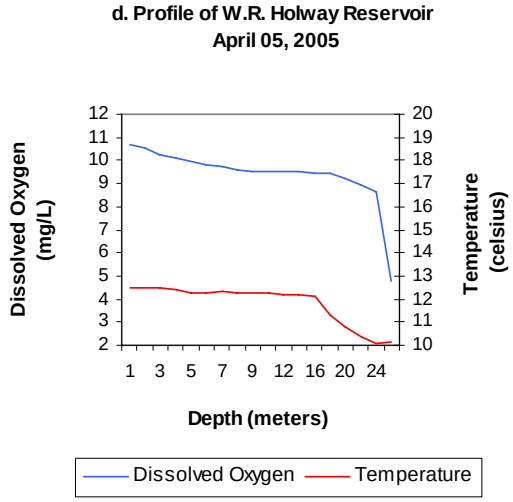
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.81 mg/L at the surface. Surface TN ranged from 0.46 mg/L to 1.49 mg/L, with the highest values reported in the spring and lowest values in the fall quarter. The lake-wide total phosphorus (TP) average was 0.080 mg/L at the surface. Total phosphorus at the surface ranged from 0.036mg/L to 0.104 mg/L. Surface TP was highest in the fall, and the lowest values were recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, W.R. Holway Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2004-2005. Water clarity continues to be excellent based on true color, turbidity, and secchi disk depth. The FWP beneficial use is considered fully supported based on turbidity and pH, dissolved oxygen levels reported during the study period. The Aesthetics beneficial use is supported based on its trophic status and true color as all values were well below the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. W.R. Holway Reservoir is owned by the Grand River Dam Authority (GRDA) and serves as a water supply, hydroelectric, and recreational reservoir.









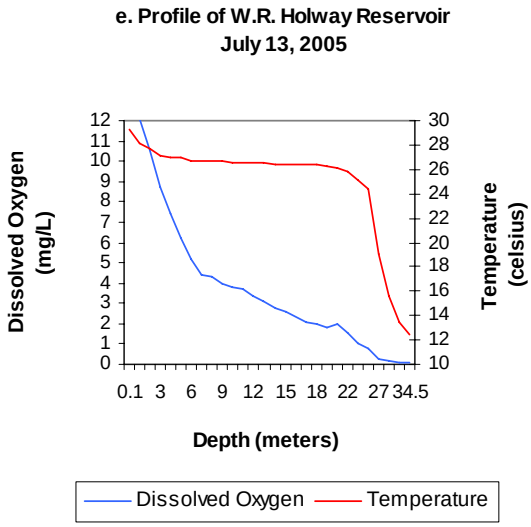
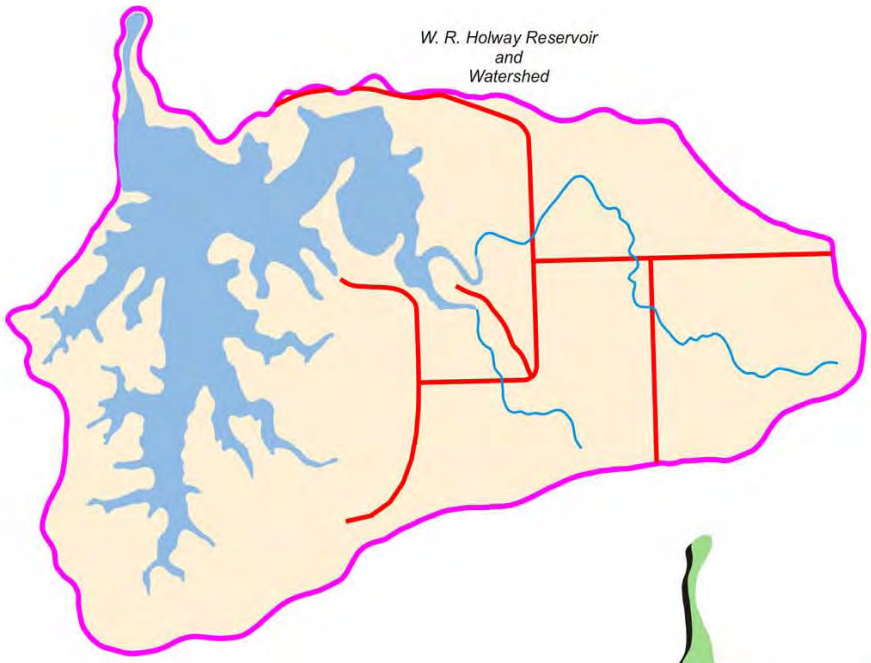


Figure 138a-138e. Graphical representation of data results for W.R. Holway Reservoir.



Lake Data	
Owner	GRDA
County	Mayes
Constructed in	1968
Surface Area	712 acres
Volume	48,000 acre/feet
Shoreline Length	21 miles
Mean Depth	67.42 feet
Watershed Area	3490 acres

Plate 119- Lake Water Quality for

W. R. Holway Reservoir

LAKES MONITORING PROGRAM

Waurika Lake

Waurika Lake was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected from five (5) sites to represent the riverine, transition, and lacustrine zone of the reservoir. Samples were collected from the lake surface at all sites and at 0.5 meters from the lake bottom at site 1, the dam. The average lake-wide turbidity was 22 NTU (Plate 121), true color was 27 units, and average secchi disk depth was 59 centimeters. Based on these three parameters, Waurika Lake had average water clarity in 2004-2005. Results are similar to those reported during the previous evaluation in 2003. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 60 (Plate 121), classifying the lake as eutrophic bordering hypereutrophic, with high levels of primary productivity and nutrient conditions. This is higher than results in 2003 (TSI=56), however it is still in the same trophic category. The TSI values were primarily upper eutrophic to hypereutrophic throughout the sample year. The only exception being site 4, which had a low chlorophyll-a value reported in the winter quarter, placing the site in the mesotrophic category for this sampling interval. Turbidity values ranged from a low of 5 NTU to a maximum of 94 NTU with higher values reported at sites 4 and 5 in the upper end of the reservoir (Figure 139a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 20% of the values exceeding the WQS of 25 NTU, Waurika Lake is partially supporting its Fish and Wildlife Propagation (FWP) beneficial use in regards to turbidity. Seasonal true color values are displayed in Figure 139b. Only 1 of the true color values exceeded the Aesthetics criteria of 70 units, therefore the beneficial use is considered supported.

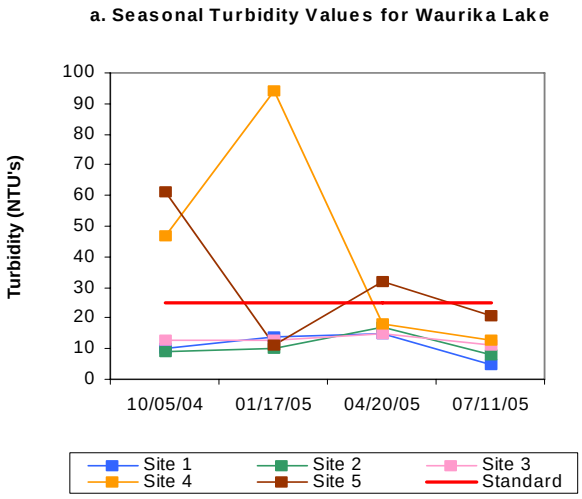
In 2004-2005, vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.22 parts per thousand (ppt) to 0.35 ppt, which is slightly higher than the average range of values recorded in Oklahoma reservoirs. Specific conductivity ranged from 443.3 µS/cm to 684.9 µS/cm, indicating the presence moderate levels of current conducting ions (salts) in the lake system. The pH values ranged from 7.24 to 8.75representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the collected values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 86 mV to 451 mV, indicating reducing conditions were not present in this reservoir the time of sampling. The only instance an ORP value was below 100 mV occurred at site 1 during the fall quarter and is likely the result of the Hydrolab probe resting on the lake bottom. In the fall winter, and spring intervals stratification was not evident and the water column was well mixed with dissolved

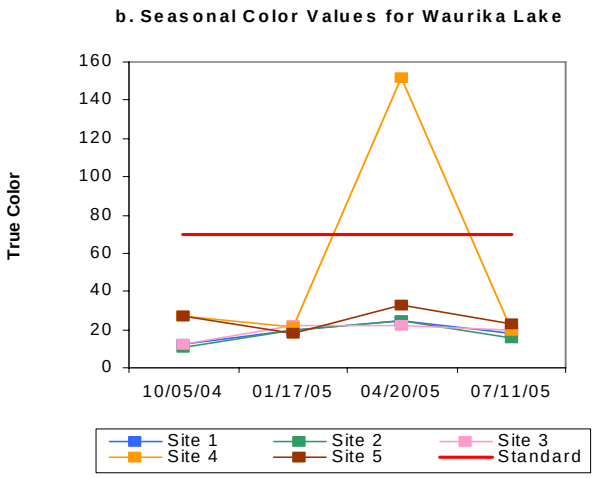
oxygen (D.O.) values generally above 5.0 mg/L (Figure 139c-139e). In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline, at both sites 1 and 2 (Figure 139f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With 10 to 28.6% of the water column less than 2.0 mg/L in the summer, Waurika Lake is considered supporting the FWP beneficial use. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

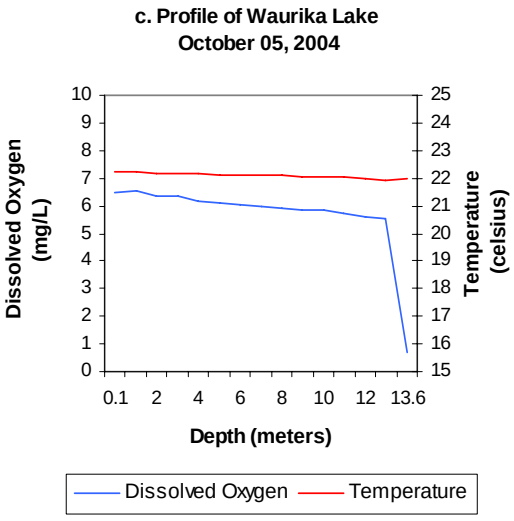
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

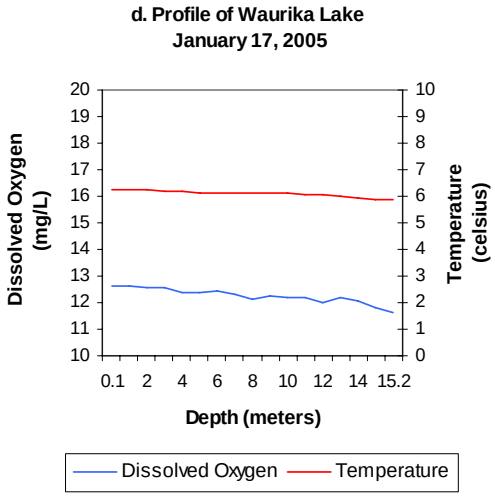
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.78 mg/L at the surface. Surface TN ranged from 0.64 mg/L to 1.05 mg/L; with the highest value reported at site 4 in the winter and lowest value occurred at site 1 in the summer quarter. The lake-wide total phosphorus (TP) average was 0.085 mg/L at the surface. Total phosphorus at the surface ranged from 0.052mg/L to 0.143 mg/L. Surface TP was highest in the winter, and the lowest values were recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 9:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

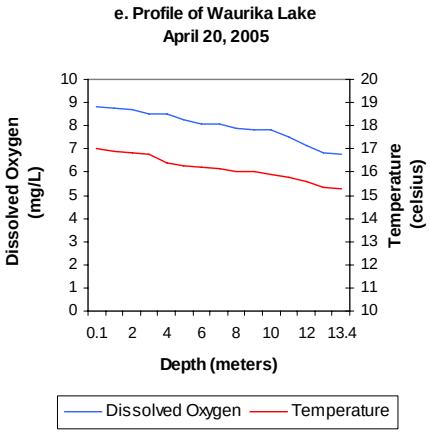
In summary, Waurika Lake was classified as eutrophic, classifying the lake as eutrophic bordering hypereutrophic, with high levels of primary productivity and nutrient conditions (Plate 121). This is higher than results in 2003 (TSI=56), however it is still in the same trophic category. Based on turbidity, true color, and secchi disk depth, water clarity was average in comparison to other Oklahoma reservoirs. The FWP beneficial use is supported based on pH and dissolved oxygen, but only partially supporting the use based on turbidity with 20% of the reported values greater than 25 NTU. The lake is supporting the Aesthetics beneficial use based on its trophic status and reported true color values, as 95% of the color values were less than the WQS of 70 units. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Waurika Lake, located in Jefferson County, was constructed by the United States Army Corps of Engineers (USACE) and is utilized for flood control, irrigation, water supply and quality and recreational purposes.











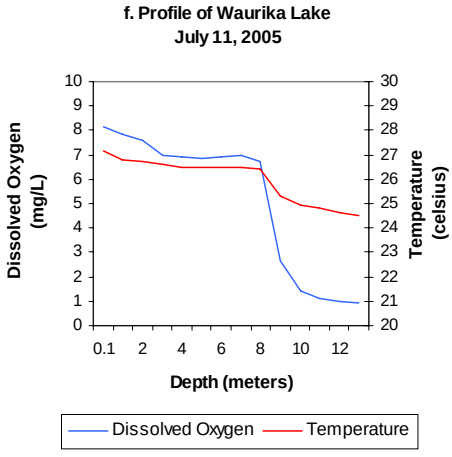
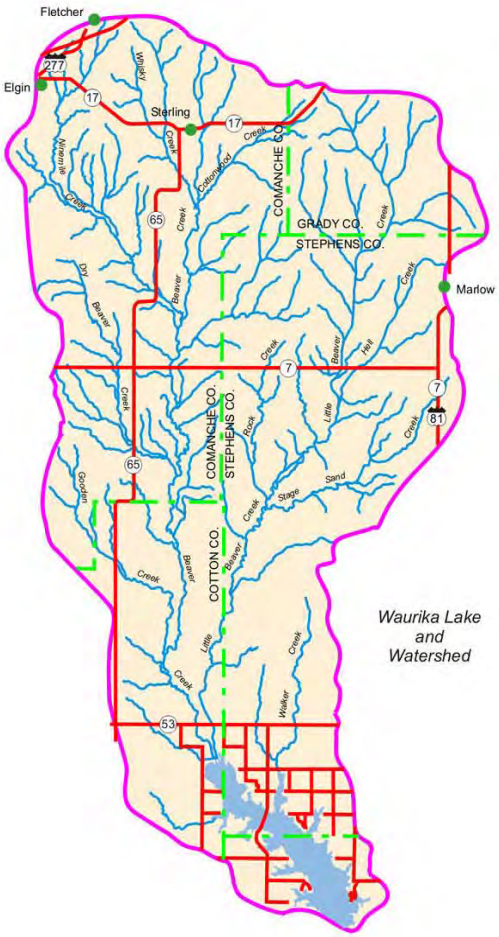


Figure 139a-139f. Graphical representation of data results for Waurika Lake.



Waurika Lake and Watershed

Waurika Lake Location

Trophic State 2005

Turbidity 2005

Lake Data	
Constructed by	Corps of Engineers
County	Jefferson
Constructed in	1980
Surface Area	10,100 acres
Volume	203,100 acre/feet
Shoreline Length	80 miles
Mean Depth	19.4 feet
Watershed Area	562 square miles

Plate 121 - Lake Water Quality for
Waurika Lake

LAKES MONITORING PROGRAM

Lake Waxhoma

Lake Waxhoma, located in Osage County, was constructed in 1955 and is owned and operated by the City of Barnsdall. The lake is managed as a municipal water supply and offers numerous recreational opportunities to the public. Lake Waxhoma was sampled for four seasons extending from October 2005 through July 2006.

Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 5 NTU (Plate 122), true color was 18 units, and secchi disk depth was 153 centimeters. Based on these three parameters, Lake Waxhoma had excellent water clarity, better than that observed in sample year 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=11). The average TSI was 45 (Plate 122), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient rich conditions. Due to a laboratory accident no data is available for site 2 from winter data collection efforts. The current TSI value is consistent with previous monitoring results from 2003-2004 where the calculated TSI was also mesotrophic (TSI=43). The TSI varied seasonally with the lake being at the lower end of mesotrophy in the fall and winter quarters and oligotrophic in the spring. During the summer quarter the lake was again experiencing mesotrophic conditions. The exception this occurred at site 2, which had slightly higher a chlorophyll-a concentration, placing it in the eutrophic category during the spring sampling interval. None of the 12 turbidity samples collected for the nephelometric turbidity exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 140a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the values below 25NTU, the lake is considered supporting the Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 140b. Similar to turbidity, all true color values wee below the numeric criteria, therefore the Aesthetics beneficial use is considered supported at Lake Waxhoma.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites in during the sample year. Salinity values ranged from 0.09 parts per thousand (ppt) to 0.111 ppt. Salinity readings were within the range of expected values for Oklahoma lakes and reflected the presence of minimal amounts of chlorides or other salts in the lake. Specific conductivity values were also well within the range of values recorded in Oklahoma reservoirs, if not slightly lower. Values ranged from 187.6 µS/cm recorded in the winter quarter to 231.6 µS/cm in the summer, indicating low levels of electrical conducting compounds (salts) were present in the lake. Oxidation-reduction potentials (redox) ranged from 135 mV at the sediment-water interface in the summer to 438 mV in the fall. Redox showed that reducing conditions were not present in the lake during the study period. The pH values were neutral to slightly alkaline with values ranging from 6.77 to 8.27 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. Lake Waxhoma is supporting its FWP beneficial use for pH as all collected data fell within the allowable range. Thermal stratification was not evident in the lake in the winter or spring quarters and dissolved oxygen

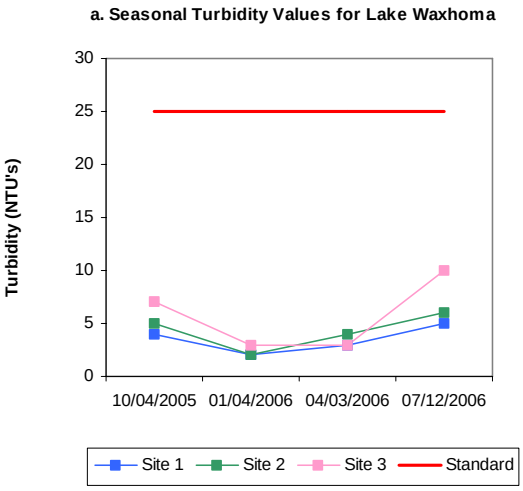
(D.O.) values were above 8.0 mg/L throughout the water column at all sites (see Figure 140d-140e). In the fall quarter the lake was thermally stratified between 6 and 7 meters below the lake surface, with D.O. values falling below 2.0 mg/L at site 1, the dam (see Figure 140c). The lake was also strongly thermally stratified in the summer quarter between 3 and 4 meters below the lake surface. From the 5-meter depth at site 1 to the lake bottom at 11.4 meters, all recorded D.O. values were less than 2.0 mg/L (see Figure 140f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is partially supported at Lake Waxhoma as 36% of the water column had D.O. values less than 2.0 mg/L in the fall and 14-62% in the summer. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F

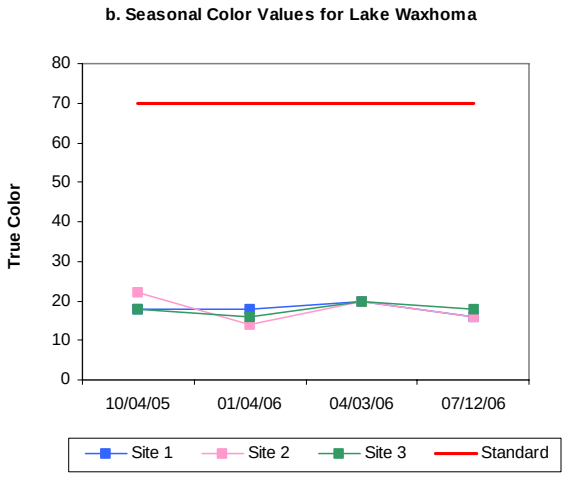
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

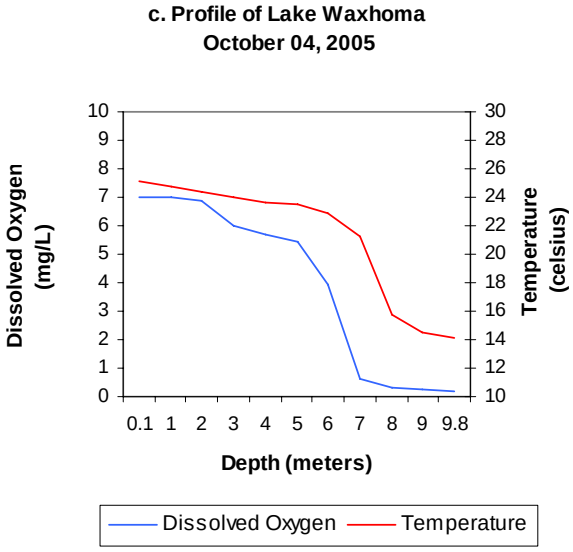
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.32 mg/L for sample year 2006. The TN at the surface ranged from 0.15 mg/L to 0.49 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the fall. The lake-wide total phosphorus (TP) average was 0.023 mg/L at the lake surface. The surface TP ranged from 0.011 mg/L to 0.023 mg/L. The highest surface TP value was reported in the summer and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 14:1 for sample year 2003-2004. This value is higher than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

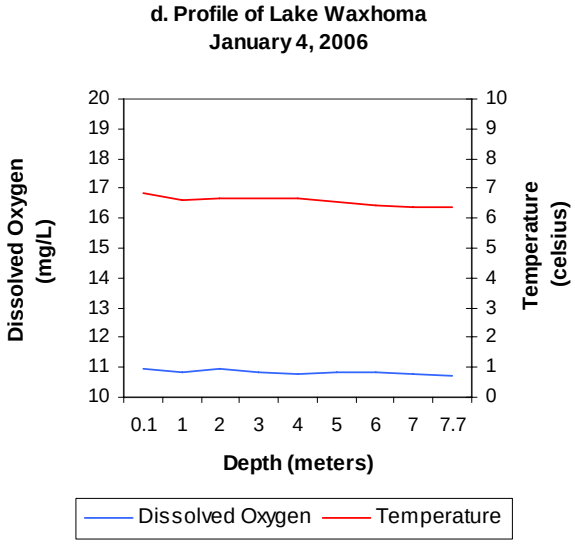
Lake Waxhoma was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

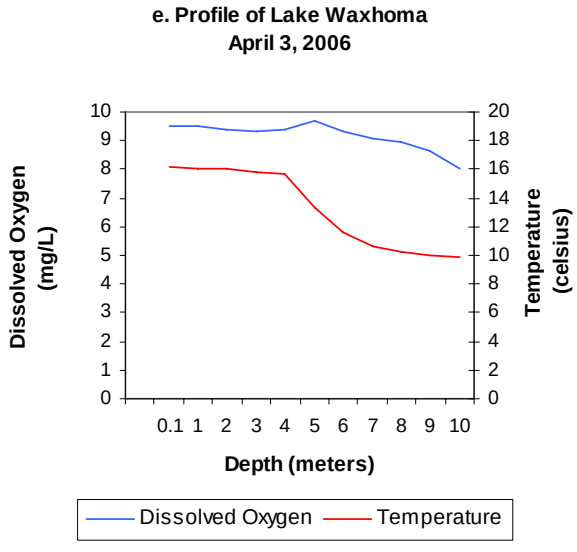
In summary, Lake Waxhoma was classified as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions (Plate 122). Based on turbidity, true color, and secchi disk depth water clarity, Lake Waxhoma had excellent water clarity, better than that observed in sample year 2004. The lake was fully supporting its FWP beneficial use for pH and turbidity, however is partially supported based on anoxic conditions present in the summer sampling interval. The lake was fully supporting its Aesthetics beneficial use based on its trophic status as well as true color with 100% of the color values were well below the numerical criteria of 70 units. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.











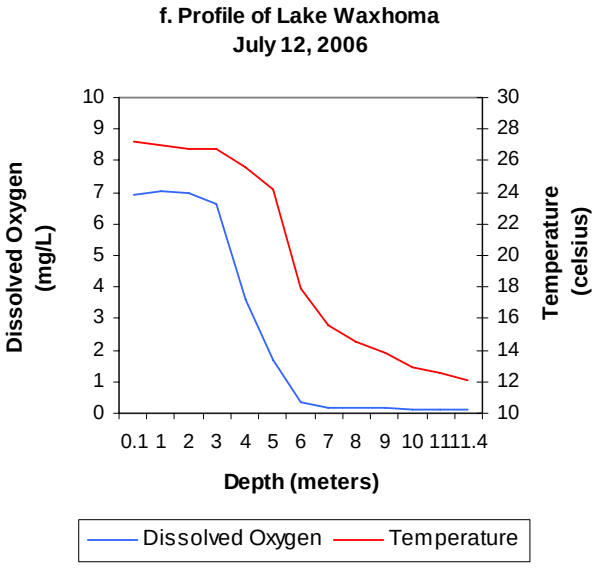
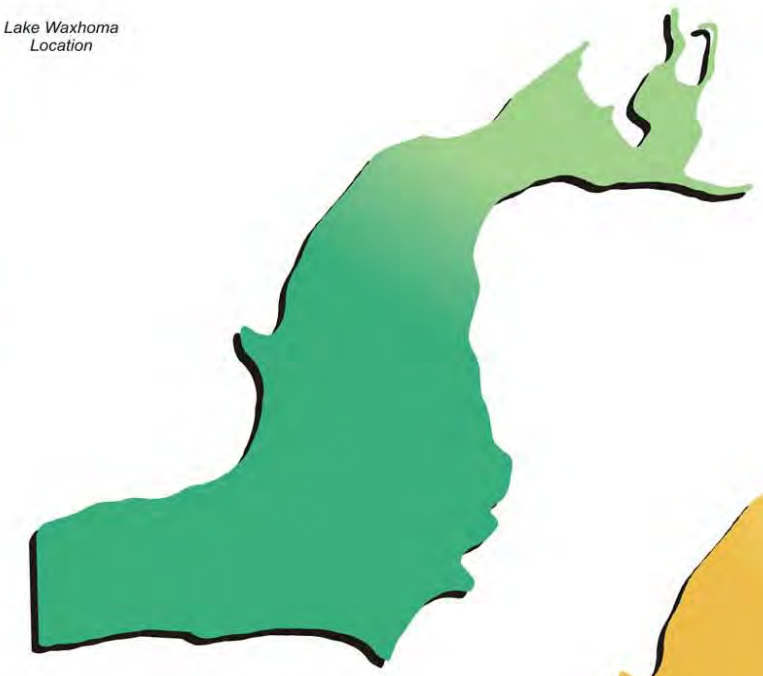


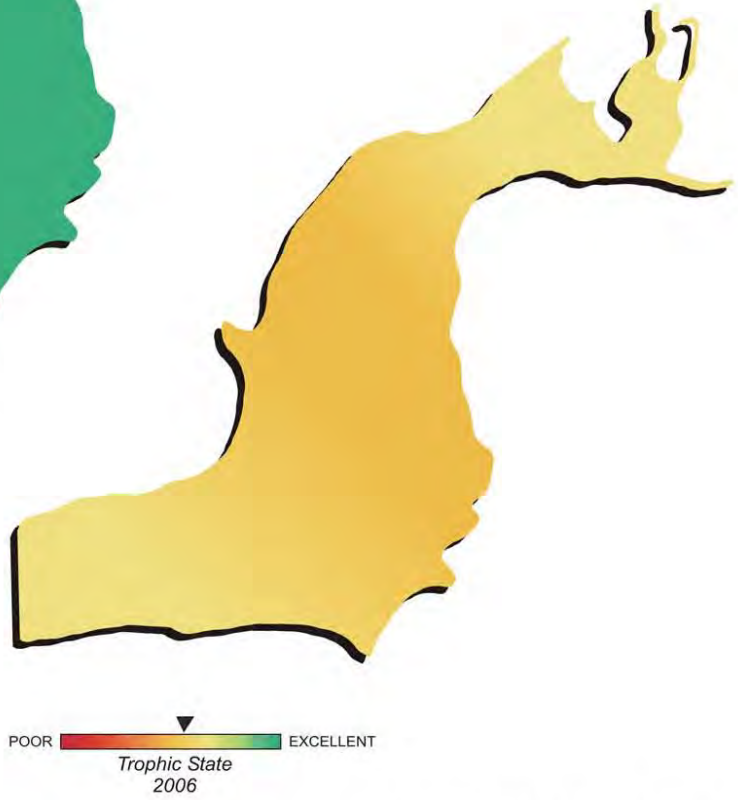
Figure 140a-140f. Graphical representation of data results for Lake Waxhoma.

Lake Waxhoma Location



POOR EXCELLENT

Turbidity 2006



POOR EXCELLENT

Trophic State 2006

Lake Data	
Owner	City of Barnsdall
County	Osage
Constructed	1955
Surface Area	197 acres
Volume	2,000 acre/feet
Shoreline Length	3 miles
Mean Depth	10.15 feet
Watershed Area	2,467 acres

Plate 122 - Lake Water Quality for
Lake Waxhoma

Lake Wayne Wallace

Lake Wayne Wallace was sampled for four quarters, from October 2004 through July 2005. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The average lake-wide turbidity was 16 NTU (Plate 123), true color was 70 units, and average secchi disk depth was 81 centimeters. Based on these three parameters, Lake Wayne Wallace had good water clarity. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 41 (Plate 123), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. This classification is similar to that in 2003 (TSI=44), indicating no significant change in productivity has occurred since the last evaluation. The TSI values were fairly consistent ranging from mesotrophic in the fall, spring and summer sampling quarters to oligotrophic during the winter. Seasonal turbidity values are displayed in Figure 141a. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Lake Wayne Wallace is currently supporting Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 141b. Of the twelve true color values collected, five (42%) were above the WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered not supported.

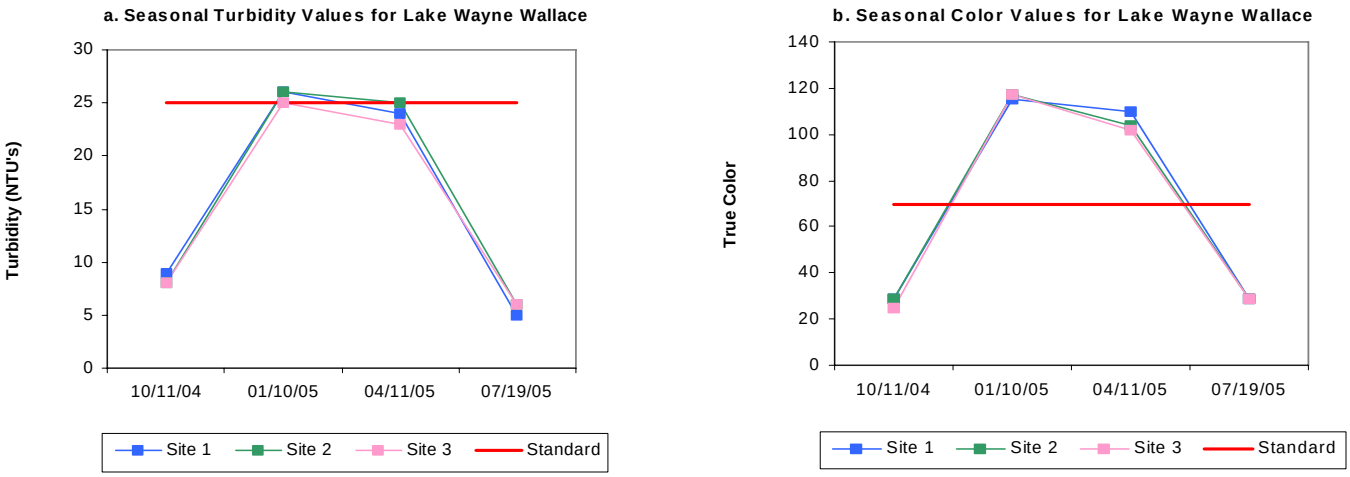
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.00 parts per thousand (ppt) to 0.02 ppt in sample year 2004-2005. This is lower than the average the range of values recorded in Oklahoma reservoirs. Specific conductivity ranged from 31.2 µS/cm to 67.3 µS/cm, indicating the presence low levels of current conducting ions (salts or chlorides) in the lake system. The pH values ranged from 6.01 to 6.96 representing a slightly acidic to neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With approximately 17% of the values recorded being less than 6.5 the lake should be listed as not supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (ORP) ranged from 312 mV to 481 mV, indicating reducing conditions were not present at this reservoir during the study period. During the fall, winter and spring sampling intervals stratification was not evident and the water column was well mixed with dissolved oxygen (D.O.) values generally above 5.0 mg/L (Figure 141c-141e). In the summer, thermal

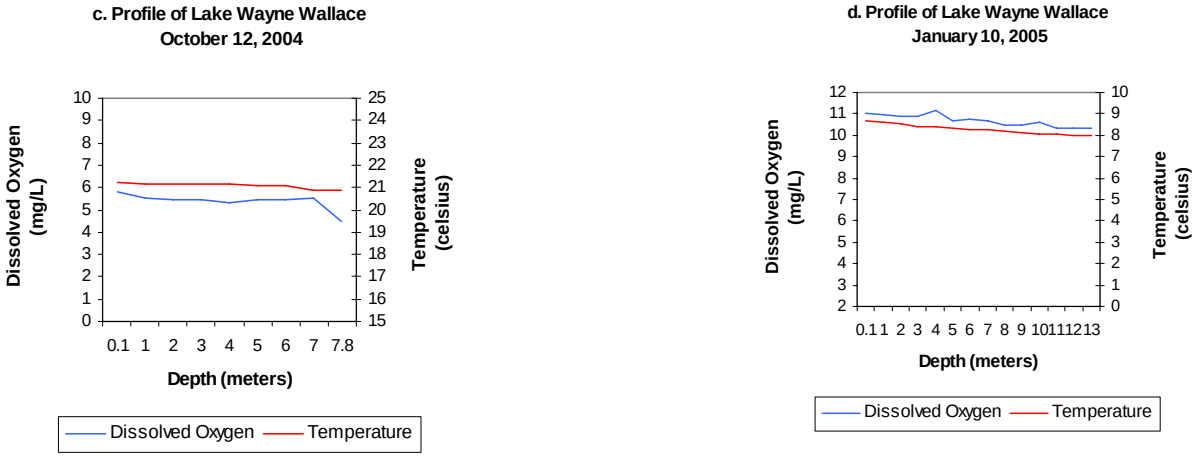
stratification was evident and anoxic conditions were present below the thermocline, at both sites 1 and 2 (Figure 141f). Dissolved oxygen was less than 2.0 mg/L from 5 meters to the lake bottom, accounting for 37.5 to 61.5 % of the water column to be experiencing anoxic conditions. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to UASP, Lake Wayne Wallace is considered partially supporting the FWP beneficial use based on anoxic conditions present during the summer quarter. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.32 mg/L at the surface. Surface TN ranged from 0.15 mg/L to 0.64 mg/L, with both highest and lowest values reported in the summer quarter. The lake-wide total phosphorus (TP) average was 0.030 mg/L at the surface. Total phosphorus at the surface ranged from 0.022mg/L to 0.039 mg/L. Surface TP was highest in the winter, and the lowest values were recorded during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 11:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Lake Wayne Wallace was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in 2002-2005. This classification is consistent with the previous evaluation in 2003 (TSI=44). Water clarity was good based on turbidity, true color, and secchi disk depths. The FWP beneficial use is supported based on turbidity and partially supported based on dissolved oxygen. With 17% of the pH values less than 6.5 the lake will is partially supporting the FWP based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial use is considered supported in regards to trophic status and true color. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time. Lake Wayne Wallace, located in Latimer County is owned by the State of Oklahoma and is utilized for flood control and recreation purposes.





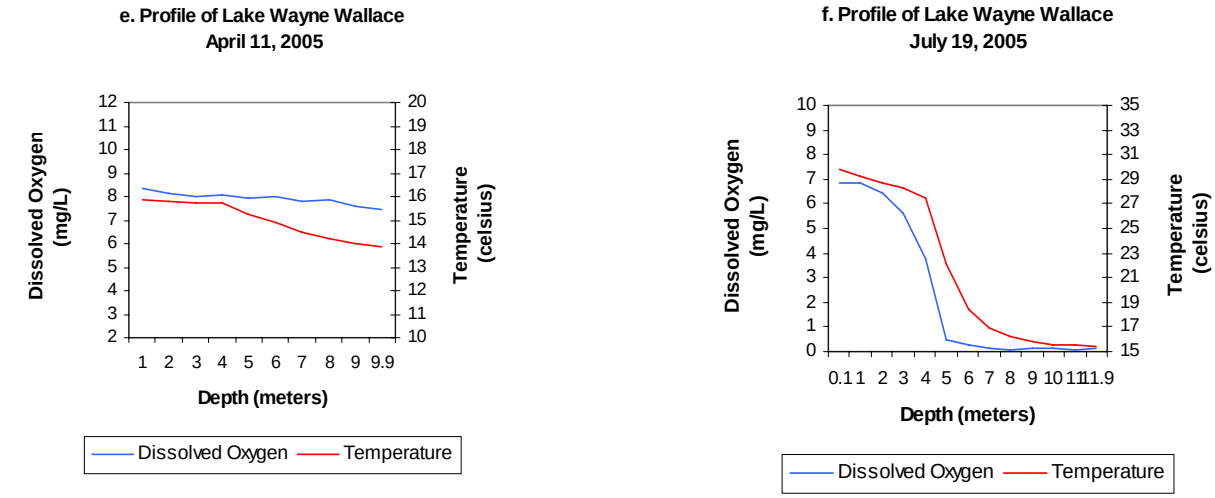
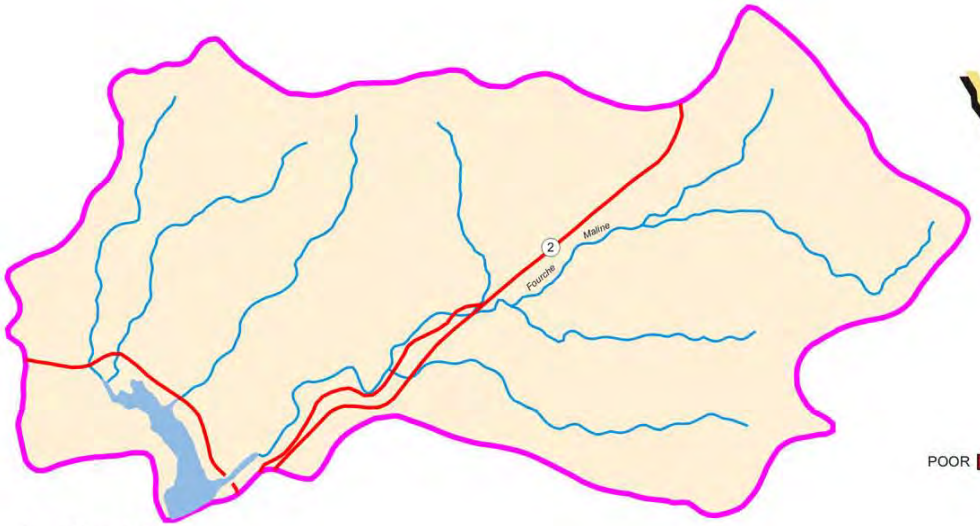
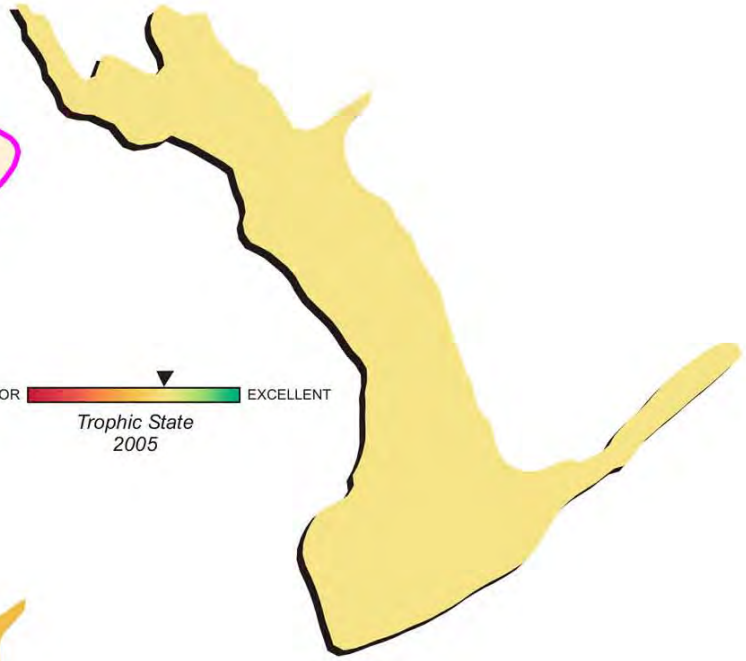


Figure 141a-141f. Graphical representation of data results for Lake Wayne Wallace.

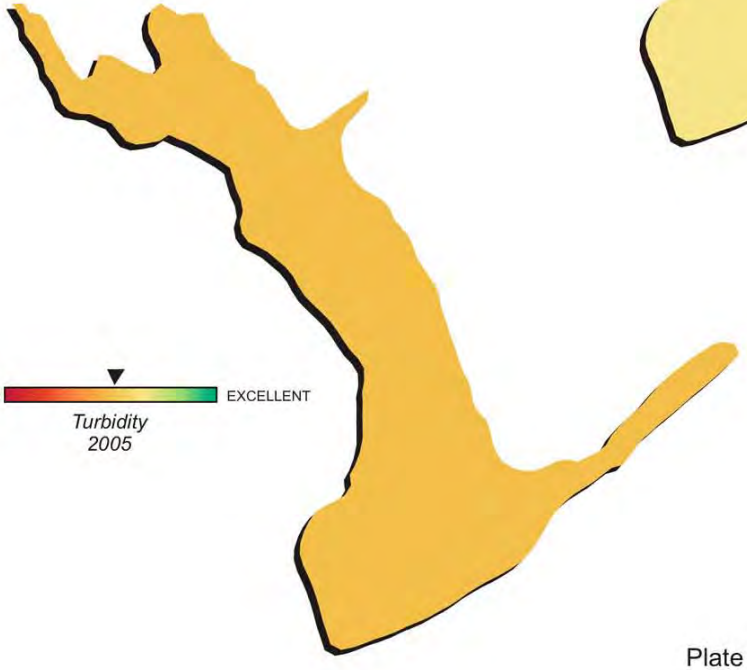


Lake Wayne Wallace and Watershed

Lake Wayne Wallace Location



Trophic State 2005



Turbidity 2005

Lake Data	
Owner	State of Oklahoma
County	Latimer
Constructed in	1969
Surface Area	94 acres
Volume	1,746 acre/feet
Shoreline Length	3 miles
Mean Depth	18.57 feet
Watershed Area	11 square miles

Plate 123 - Lake Water Quality for
Lake Wayne Wallace

LAKES MONITORING PROGRAM

Webbers Falls Reservoir

The Webbers Falls lock and dam was constructed by the United States Army Corps of Engineers (USACE) on the Arkansas River for the purpose of navigation and generation of hydroelectric power. Webbers Falls Reservoir was sampled from November 2005 through September 2006.

Water quality samples were collected at six (6) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major arms. Samples were collected from the lake surface at all sites and 0.5 meters during the study period. The lake-wide annual turbidity value was 21 NTU (Plate 124), true color was 32 units, and secchi disk depth was 53 centimeters in 2006. Results for these parameters were consistent with previous data collections efforts if not slightly better. Based on these three parameters, Webbers Falls Reservoir had average water clarity in comparison to other reservoirs. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=24). The average TSI was 56 (Plate 124), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is similar to the TSI in 2004 (TSI=59) and 2001 (TSI=57), indicating no significant change in productivity has occurred over time. The majority of the TSI values were eutrophic although all trophic categories were represented at some time during the sample year. Site 1 exhibited the most variability throughout the year, which can be expected, as this is the location of the lock and dam on the Arkansas River. Seasonal turbidity values ranged from a low of 9 NTU to a maximum of 54 NTU and are displayed in Figure 142a. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Seven of the 23 turbidity values (30%) exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU, however available flow and rainfall data suggest that the peak in turbidity, which occurred in May is likely due to seasonal storm events, therefore Webbers Falls Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 142b. Approximately 4% (1) of the collected values exceeded the WQS numeric criteria of 70 units. Applying the same default protocol, the Aesthetics beneficial use is therefore considered supported.

Vertical profiles for dissolved oxygen, pH, temperature; specific conductivity, oxidation-reduction potential, and salinity were recorded at all six sample sites throughout the sample year. Salinity values ranged from 0.37 parts per thousand (ppt) to 1.47 ppt. This is higher than the average the range of values recorded in most Oklahoma reservoirs and indicative of moderate to high levels of salts. Specific conductivity ranged from 718 µS/cm in the fall to 2733 µS/cm in the winter, indicating the presence moderate to high levels of current conducting ions (salts or chlorides) in the lake system. The pH values ranged from 7.32 to 8.56 representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With all recorded values within the acceptable range, the lake is supporting the FWP beneficial use as it relates to pH. Oxidation-reduction potentials (ORP) ranged from 346 mV in the summer to 451 mV during the fall, indicating reducing conditions were not present at this reservoir in sample year 2005-2006. Thermal stratification was not evident during any of the sampling

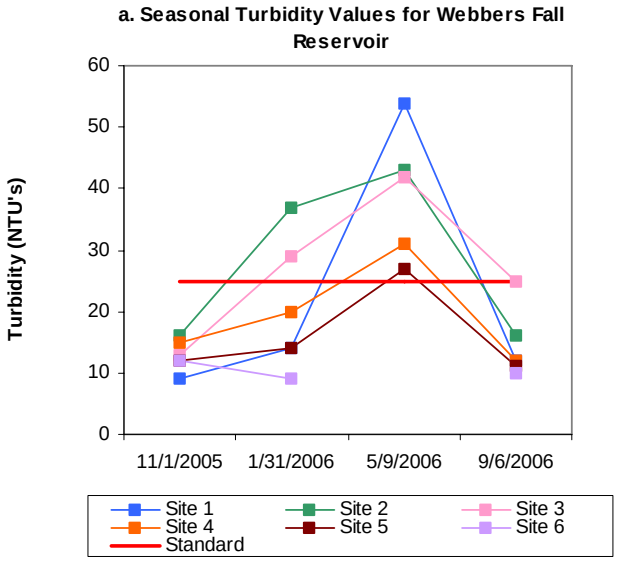
intervals and dissolved oxygen levels remained above 4.0 mg/L throughout the water column at all sites (see Figure 142c-139f). This may be attributed to the fact that Webbers Falls Reservoir is very riverine in nature as it is a portion of the Arkansas River. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With the absence of anoxic conditions throughout the entire study period the lake is considered supporting the FWP beneficial use. The lake was also sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F

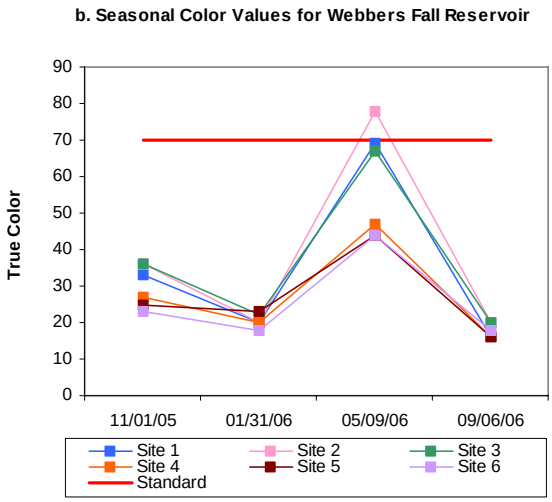
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

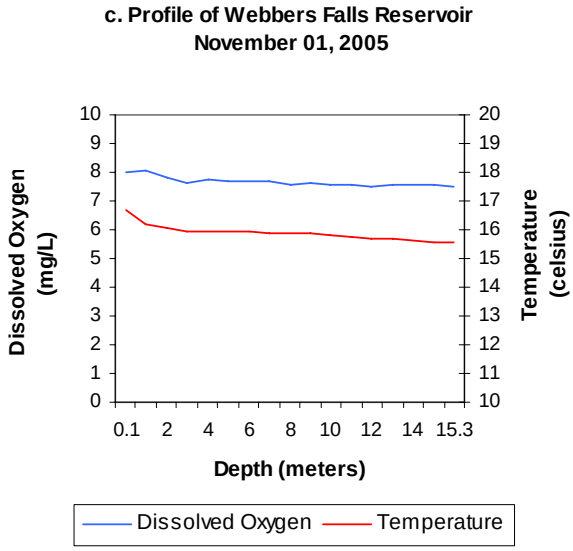
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.99 mg/L at the surface for the current sample year. Surface TN ranged from 0.73 mg/L to 1.39 mg/L with the highest values recorded in the winter quarter and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.172 mg/L at the surface. Both the high and low TP values occurred during the winter sampling interval with values ranging from 0.117 mg/L to 0.230 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 6:1 for sample year 2005-2006 This value is slightly less than 7:1, characterizing the lake possibly co- limited (Wetzel, 1983).

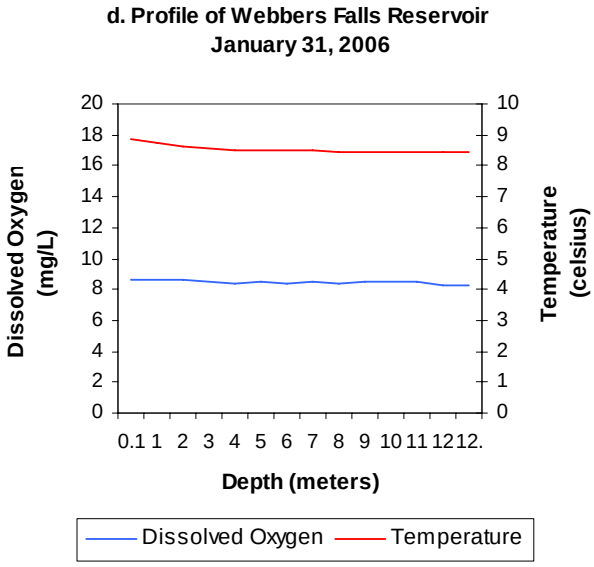
The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 2000 as part of their Toxics Monitoring Program and detected no compounds at the ODEQ screening level or consumption advisory level. The lake is fully supporting its Fish Consumption beneficial use. Webbers Falls Reservoir was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

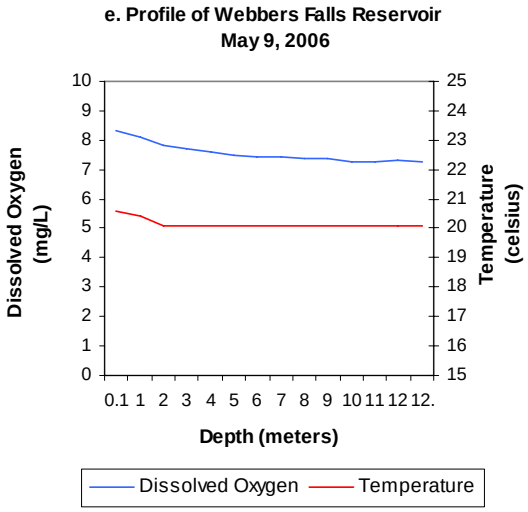
In summary, Webbers Falls Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2005-2006. This classification is consistent with both 2004 (TSI=59) and 2001 (TSI=57), indicating little or no significant change has occurred since the previous evaluations. Water clarity was average based on turbidity, true color, and secchi disk depths. The FWP beneficial use is supported based on D.O and pH readings recorded throughout the study period. Seven of the 23 turbidity values (30%) exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU, however available flow and rainfall data suggest that the peak in turbidity, which occurred in May is likely due to seasonal storm events, therefore Webbers Falls Lake will be listed as supporting its Fish & Wildlife Propagation (FWP) use. The Aesthetics beneficial use is considered supported in regards to both trophic status and true color. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.











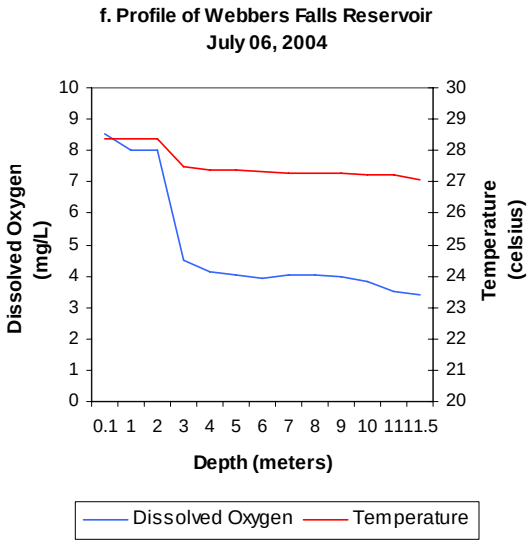
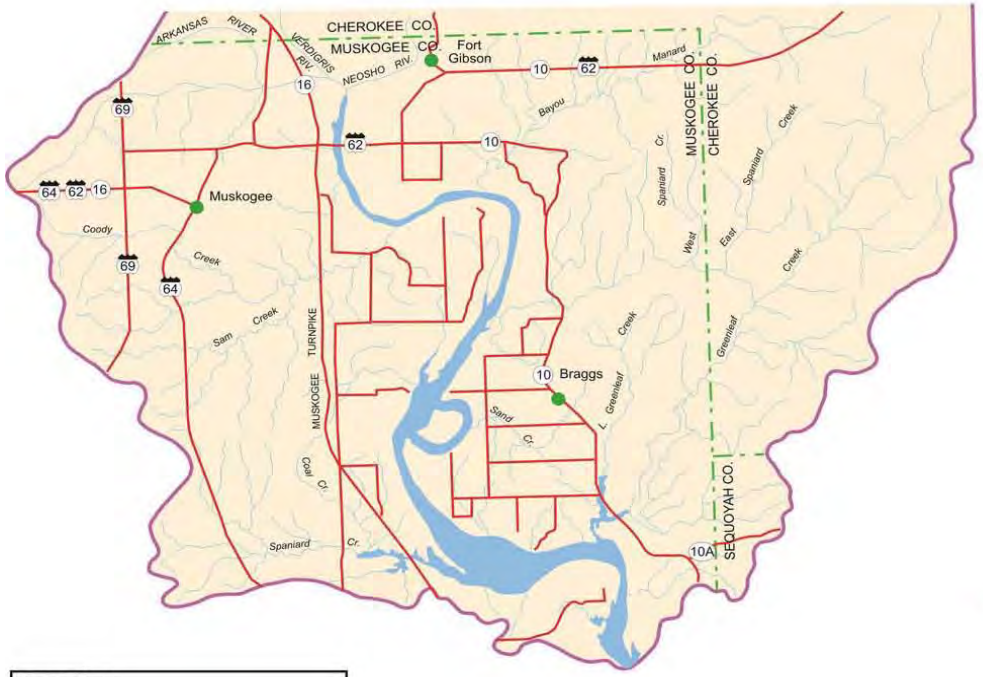


Figure 142a-142f. Graphical representation of data results for Webbers Falls Reservoir.

Webbers Falls Lake Location



Webbers Falls Lake and Watershed

Lake Data	
Constructed by	Corps of Engineers
County	Muskogee
Constructed in	1970
Surface Area	11,600 acres
Volume	170,100 acre/feet
Shoreline Length	175 miles
Mean Depth	15.2
Watershed Area	97,033 square miles

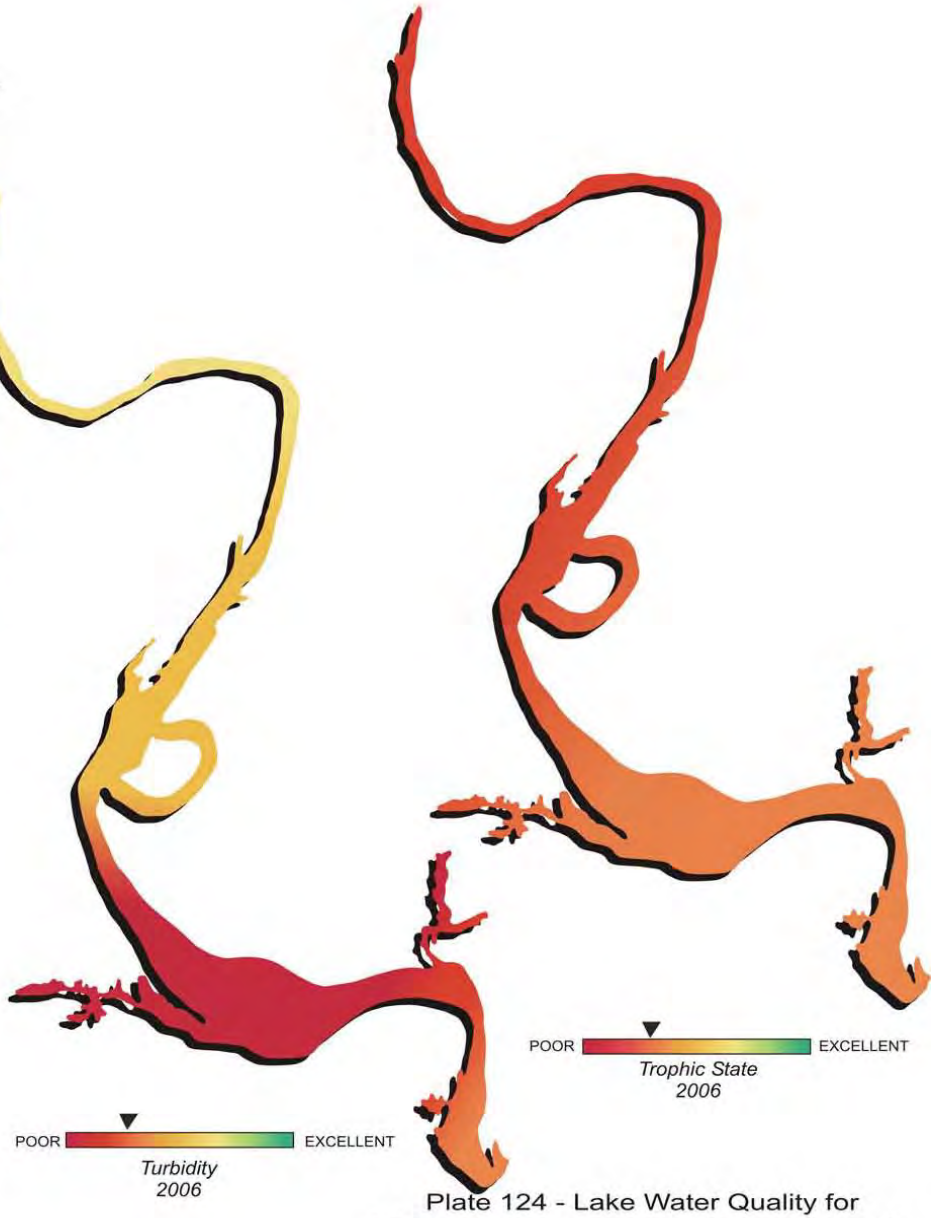


Plate 124 - Lake Water Quality for
Webbers Falls Reservoir

LAKES MONITORING PROGRAM

Wes Watkins (North Deer Creek) Reservoir

Wes Watkins Reservoir is located in Pottawatomie County, just south of the town of McCloud. The Natural Resource Conservation Service (NRCS) constructed Wes Watkins Reservoir for the purpose of flood control, water supply, recreation and fish and wildlife purposes. Wes Watkins (North Deer Creek) Reservoir was sampled for four quarters from October 2005 through August 2006.

Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir as well as any major arms. Samples were collected from the lake surface at all sites during the study period. The lake-wide annual turbidity value was 8 NTU (Plate 125), true color was 19 units, and secchi disk depth was 92 centimeters. Based on these three parameters, Wes Watkins (North Deer Creek) Reservoir had good water clarity, slightly better than that in 2004. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=19). Due to low lake levels OWRB staff were unable to reach site 5, which is located in a heavily wooded portion area in the upper reaches of the lake. The average TSI was 53 (Plate 125), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions. The TSI values were primarily eutrophic with mesotrophic conditions present at sites 1-3 during the spring quarter. 100% of the turbidity values collected were below the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 143a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Although all turbidity values were below the numeric criteria, minimum data requirements were not met due to a lack of data collected at site 5 during spring data collection efforts and therefore an assessment of the FWP beneficial use cannot be made at this time in regards to turbidity. Seasonal true color values are displayed in Figure 143b. All true color values throughout the year were below the Aesthetics criteria of 70 units; however like turbidity minimum data requirements were not met therefore the Aesthetics beneficial use cannot be assessed. Upon reviewing past data it is likely that both parameters would be meeting there respective uses.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.13 parts per thousand (ppt) to 0.15 ppt, well within the range of expected values for Oklahoma lakes, reflecting moderate levels of chlorides or other salts in the lake. Specific conductivity values were also within the range of expected values recorded in Oklahoma reservoirs. Values ranged from 262.4 µS/cm in the fall quarter to 313.7 µS/cm in the spring quarter, indicating that moderate levels of electrical conducting compounds (salts) were present in the lake system. Oxidation-reduction potentials ranged from 377 mV in the summer to 452 mV in the fall quarter, indicating that reducing conditions were absent during the study period. The pH values were neutral to slightly alkaline with values ranging from 7.38 units to 8.13 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the

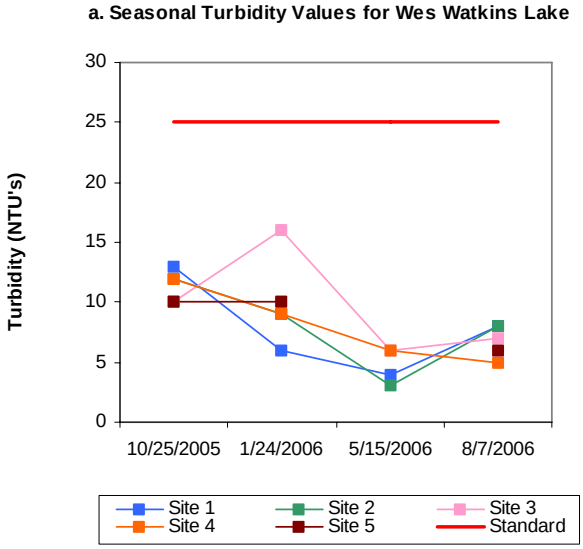
range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With 100% of the pH values within the acceptable range, the lake is fully supporting its FWP beneficial use based on pH. Thermal stratification was not evident in the fall, winter or spring quarters (see Figure 143c-143e). Generally the water column was well oxygenated and mixed with dissolved oxygen (D.O.) remaining above 5.0 mg/L. In the summer a power failure occurred with the Hydrolab and only a partial profile for site 1 was completed. Without profile information available for the remainder of the lake an assessment of summer conditions cannot be made. If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is fully supported based on D.O. levels present in the first three sampling intervals at Wes Watkins (North Deer Creek) Reservoir. The lake was also sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2005-2006 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F

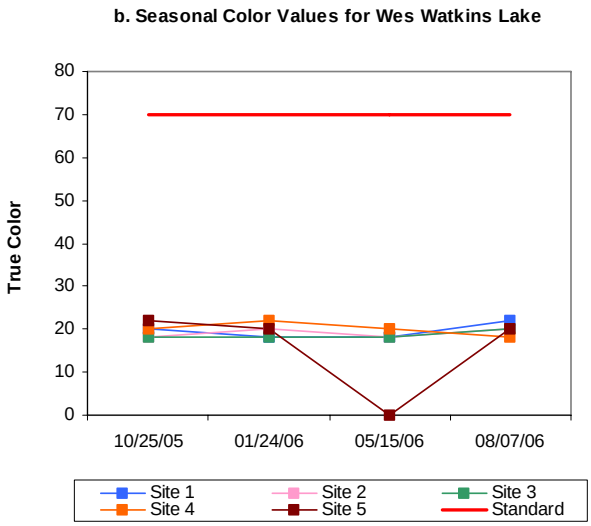
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.

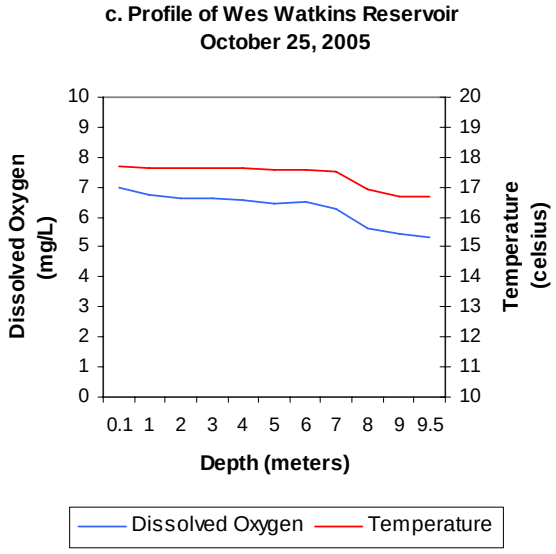
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.93 mg/L at the lake surface. The TN at the surface ranged from 0.57 mg/L to 1.25 mg/L. The highest surface TN value was reported in the winter quarter and the lowest was in the fall. The lake-wide total phosphorus (TP) average for sample was 0.027 mg/L at the lake surface. The surface TP ranged from 0.016 mg/L to 0.043 mg/L. Similar to TN, the highest surface TP value was reported in the winter quarter and lowest in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 34:1 for sample year 2005-2006. This value is higher than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

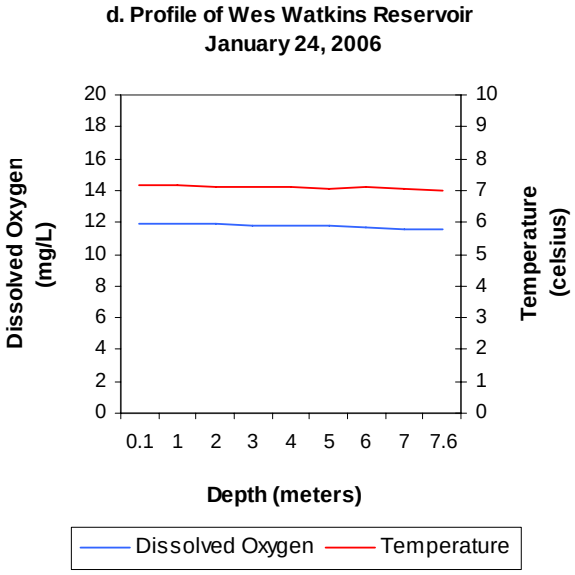
Wes Watkins Reservoir was also sampled for total metals at five sites during the spring of 2006. Results of sampling showed the lake to be fully supporting its FWP beneficial use based on toxic (metals) compounds in the water column.

In summary, Wes Watkins (North Deer Creek) Reservoir was classified as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions (Plate 125). Based on true color, turbidity, and secchi disk depth water clarity was good at Wes Watkins Reservoir, slightly better than that observed in sample year 2004. The lake was fully supporting its Aesthetics beneficial use based on its trophic state, however due to minimum data requirements not being met an assessment based on true color cannot be made at this time. The FWP beneficial use is considered fully supported based on dissolved oxygen and pH reading recorded during the study period. Similar to true color, the minimum data requirements were not met for turbidity assessment of the FWP use based on turbidity cannot be made. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September 2006. All sample results were below both the screening level and geometric mean, therefore the PBCR beneficial use is considered fully supported.









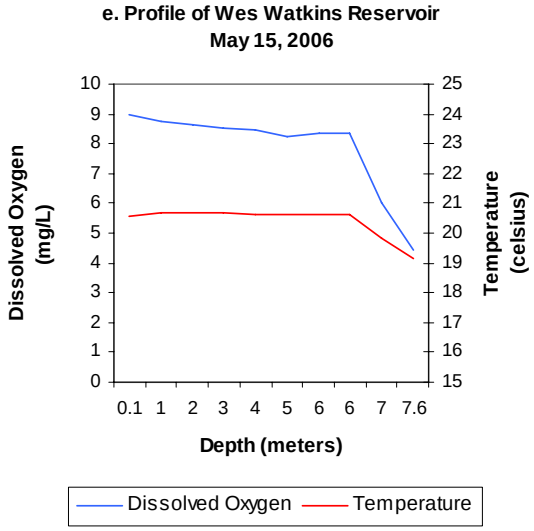
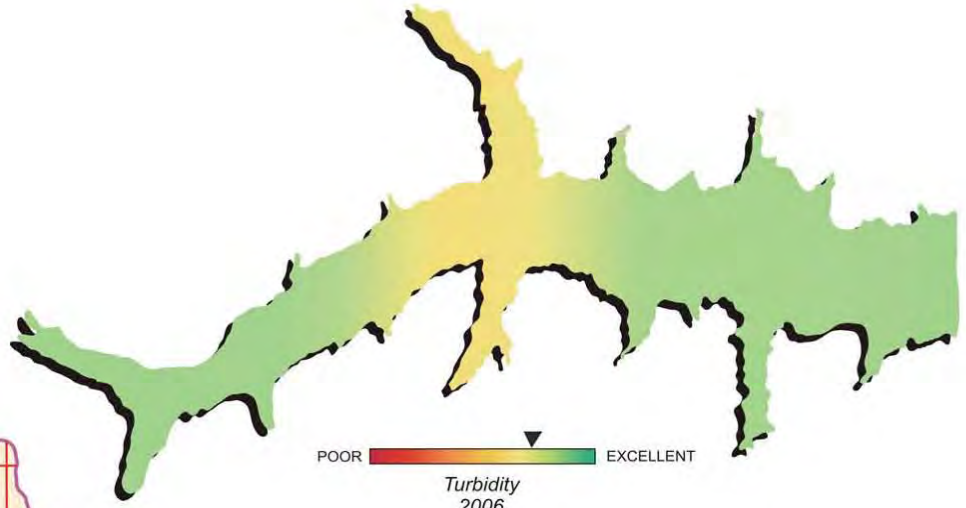


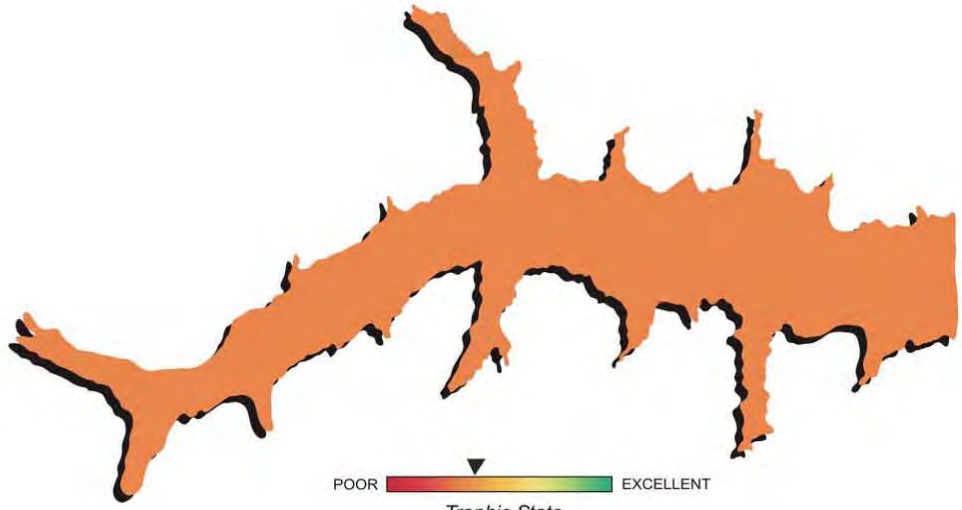
Figure 143a-143e. Graphical representation of data results for Wes Watkins (North Deer Creek) Reservoir.

Wes Watkins Lake Location

North Deer Creek Lake and Watershed



Turbidity 2006



Trophic State 2006

Lake Data

Owner	Pottawatomie Co. Dev. Auth.
County	Pottawatomie
Constructed in	1995
Surface Area	1,132 acres
Volume	14,065 acre/feet
Shoreline Length	17 miles
Mean Depth	12.42 feet
Watershed Area	39 square miles

Plate 125 - Lake Water Quality for
Wes Watkins Reservoir

LAKES MONITORING PROGRAM

Wetumka Lake

Wetumka Lake was sampled for four quarters, from October 2003 through June 2004. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected at the lake surface at all sample sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 12 NTU (Plate 126), true color was 27 units, and secchi disk depth was 76 centimeters. Based on these three parameters, Wetumka Lake had good water clarity, similar to previous values in 2001. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The calculated TSI was 50 (Plate 126), classifying the lake as mesotrophic, bordering on eutrophic, indicative of moderate to high levels of primary productivity and nutrient rich conditions. This value is slightly lower than the one calculated in 2001 (TSI=52). TSI values ranged from mesotrophic in the fall, eutrophic in the winter to mesotrophic/eutrophic in the spring and summer. The peak in chlorophyll-a that occurred in the winter is uncommon in most lakes, but has been seen across the state. Seasonal turbidity values are displayed in Figure 144a. According to USAP (OAC 785:46-15-5), a beneficial use is considered not supported if ≥25% of the samples exceeds the screening level prescribed in WQS (25 NTU for turbidity). If 10 to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the samples collected in 2003-2004 below the standard, the lake is fully supporting the Fish & Wildlife Propagation (FWP) beneficial use. True color values were below the aesthetics WQS of 70 throughout the year (see Figure 144b). Applying the same default protocol, the Aesthetics beneficial use is considered fully supported at Wetumka Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.05 parts per thousand (ppt) to 0.07 ppt, which was well within the expected range for most Oklahoma lakes. Specific conductivity ranged from 113.2 cm/cm in the spring quarter to 167.9 cm/cm in the winter quarter, indicative of minimal levels of electrical current conducting compounds or salts in the lake system. Oxidation-reduction potentials ranged from 353 mV to 652 mV, indicating reducing conditions were not present at any point in the sample year. The pH was neutral to alkaline with values ranging from 6.74 to 7.75 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the range of 6.5 to 9.0 for 25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting beneficial uses. With all values within the acceptable range Wetumka Lake is meeting its FWP beneficial use based on pH. The lake was not thermally stratified and the water column appeared to be well mixed in the fall, winter, and spring sampling events (see Figure 144c-144e). Dissolved oxygen (D.O.) values generally remained above 5.0 mg/L. In the summer, thermal stratification was evident and anoxic conditions were present at two of the three sites. Stratification occurred between 2-3 meters below the lake surface at site 1 at which point D.O. levels fell below 2.0 mg/L to the lake bottom of 6.2 meters (Figure 144f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not

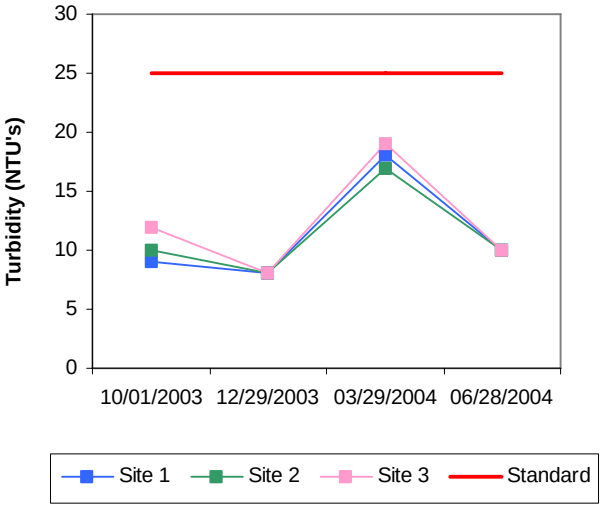
supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Approximately 40-62% of the water column was experiencing anoxic conditions at sites 1 and 2 in the summer sampling interval. Wetumka Lake is considered partially supporting its FWP beneficial use based on D.O. concentrations. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E. coli,* fecal coliform, and enterococci analysis during the recreation season of May through September. Of the ten samples collected three (30%) of the samples exceeded the screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

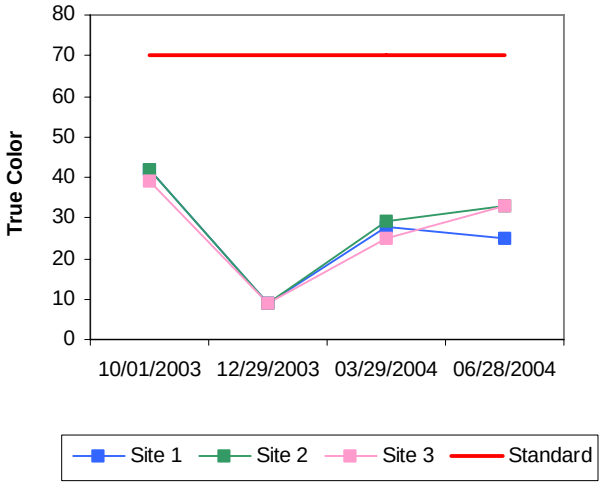
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.46 mg/L at the lake surface and 0.55 at the lake bottom. The TN at the surface ranged from 0.21 mg/L to 0.60 mg/L. The highest surface TN values occurred in the spring quarter and the lowest was reported in the winter quarter. The lake-wide total phosphorus (TP) average was 0.030 mg/L at the lake surface and 0.030 at the lake bottom. The TP ranged from 0.021 mg/L to 0.035 mg/L at the lake surface. Similar to total nitrogen the highest TP values were reported in the spring quarter and the lowest were in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 16:1 for sample year 2003-2004. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Wetumka Lake was classified as mesotrophic bordering eutrophic, indicative of moderate to high primary productivity and nutrient levels (Plate 126). Water clarity was good in sample year 2004 based on turbidity, true color and secchi disk depth. The Aesthetics beneficial use was fully supporting for trophic state and true color with 100% of the collected values below the numeric criteria of 70 true color units. The FWP beneficial use is considered fully supported for pH and turbidity. Based on anoxic conditions present in the summer the lake is considered partially supporting the FWP beneficial use. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the ten samples collected three (30%) of the samples exceeded the screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Wetumka Lake, located in Hughes County, is owned by the city of Wetumka and serves as a water supply and recreational reservoir.

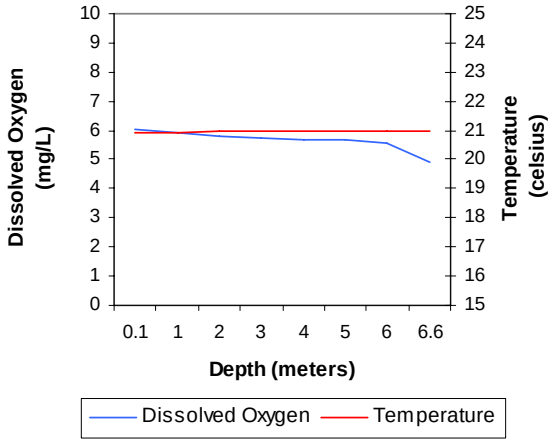
a. Seasonal Turbidity Values for Wetumka Lake



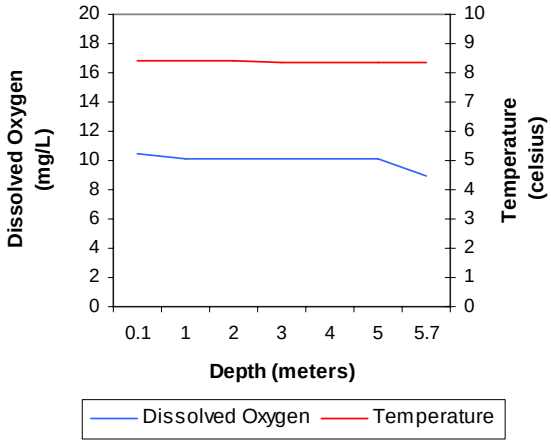
b. Seasonal Color Values for Wetumka Lake



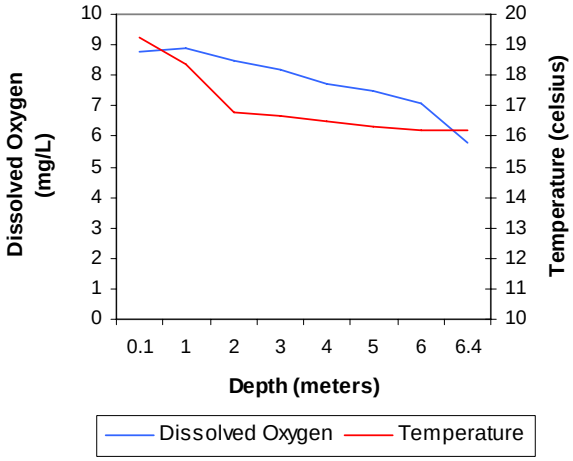
c. Profile of Wetumka Lake October 01, 2003



d. Profile of Wetumka Lake December 29, 2003



e. Profile of Wetumka Lake March 29, 2004



f. Profile of Wetumka Lake June 28, 2004

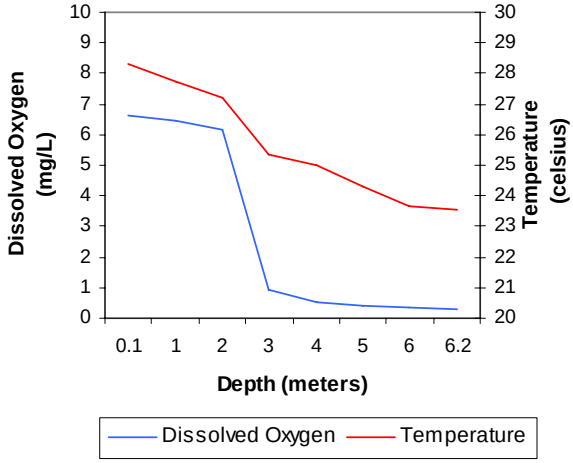
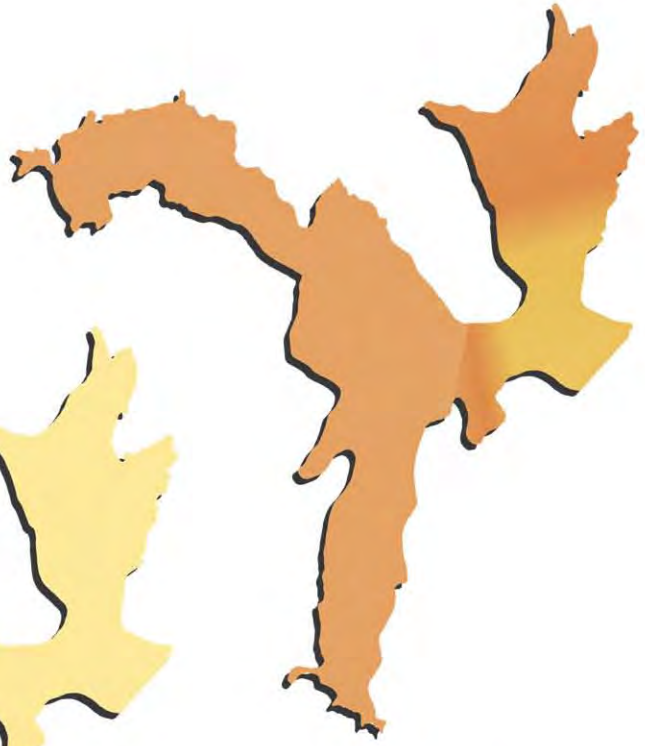


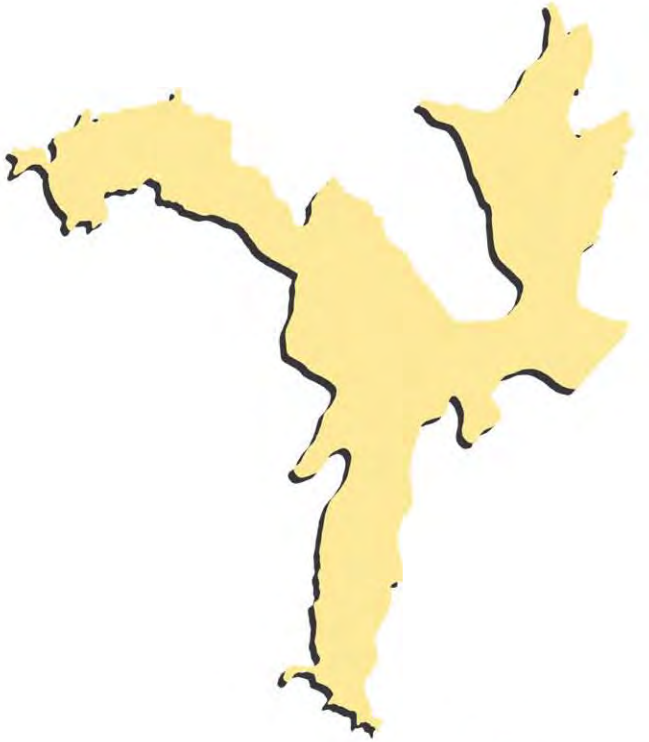
Figure 144a-144f. Graphical representation of data results for Wetumka Lake.

Wetumka Lake and Watershed

Wetumka Lake Location



Trophic State 2004



Turbidity 2004

Lake Data	
Owner	City of Wetumka
County	Hughes
Constructed	1939
Surface Area	169 acres
Volume	1,839 acre/feet
Shoreline Length	6 miles
Mean Depth	10.88 feet
Watershed Area	2,689 acres

Plate 126 - Lake Water Quality for
Wetumka Lake

LAKES MONITORING PROGRAM

Wewoka Lake

Wewoka Lake was sampled from October 2003 through June 2004 for four quarters. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Water chemistry samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 17 NTU (Plate 127), true color was 27 units, and secchi disk depth was 56 centimeters. Based on these three parameters, Wewoka Lake had average to good water clarity, slightly better than that observed in 2001. A trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The calculated TSI was 49 (Plate 127), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. The TSI values for the lake were primarily mesotrophic in the fall, winter and spring quarters with eutrophic conditions present during the summer quarter. Site 3 was eutrophic in three of the four sampling intervals. Of the 20 turbidity values generated, 10% of them exceeded the Oklahoma Water Quality Standard (WQS) of 25 NTU (see Figure 145a). According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. Wewoka Lake is currently supporting its Fish & Wildlife Propagation (FWP) beneficial use for nephelometric turbidity. Seasonal true color values are displayed in Figure 145b. Of the true color values collected, 100% were below the Aesthetics numerical criteria of 70 units. Applying the same default protocol, the lake is supporting the Aesthetics beneficial use for true color.

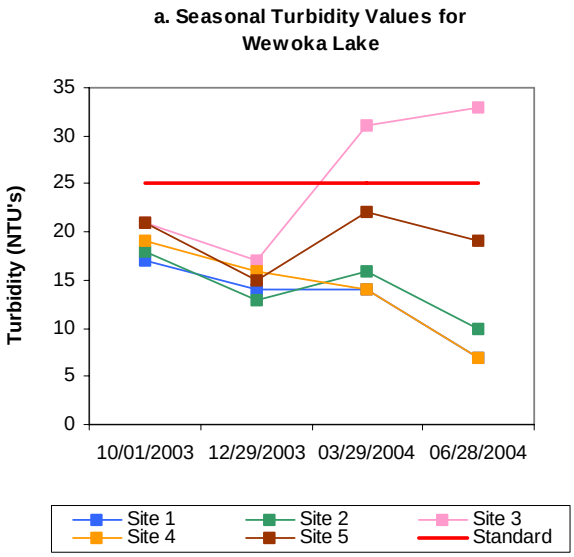
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Lake salinity values ranged from 0.08 parts per thousand (ppt) to 0.11 ppt, which is within the range of expected values for Oklahoma lakes, reflecting minimal amounts of chlorides or other salts in the lake system. Specific conductivity values were also consistent with the expected range of values recorded in Oklahoma reservoirs, if not somewhat lower. Values ranged from 173.4 cm/cm in to 239 cm/cm in the summer quarter near the lake bottom, indicating that low levels of electrical conducting compounds (salts) were present in the lake. Oxidation-reduction potentials (redox) ranged from 362 mV in the winter quarter to 516 mV in the fall quarter, indicating reducing conditions were not present during the study period. The pH values were generally neutral to slightly alkaline with values ranging from 7.20 units to 8.18 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. All recorded pH values were all within the acceptable range supporting the FWP beneficial use. Thermal stratification was not evident in the fall, winter, or spring quarters and dissolved oxygen (D.O.) values never fell below 6.0 mg/L in the water column at any site (see Figure 145c-145e). In the summer quarter, the lake was strongly thermally stratified between 4 and 5 meters below the surface at both sites 1 and 2. From 4 meters to the lake

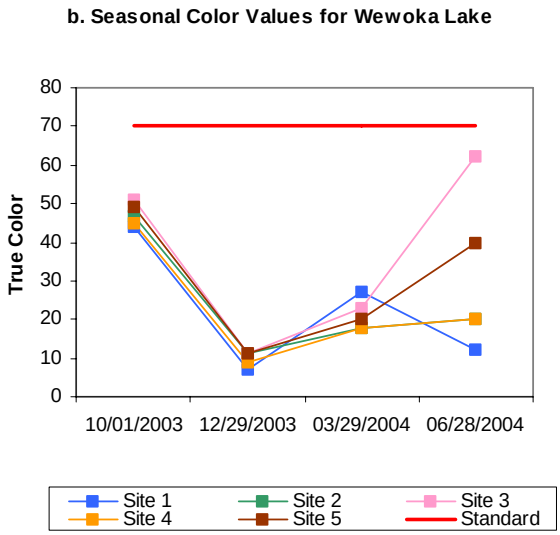
bottom of 7.6 meters, D.O. values were below 2.0 mg/L at site 1; constituting 44% of the water column to be experiencing anoxic conditions (see Figure 145f). If D.O. values are less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. concentrations are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. With only 44% of the water column less than 2.0 mg/L in the summer the FWP beneficial use is fully supported at Wewoka Lake. The lake was sampled for chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2003-2004 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

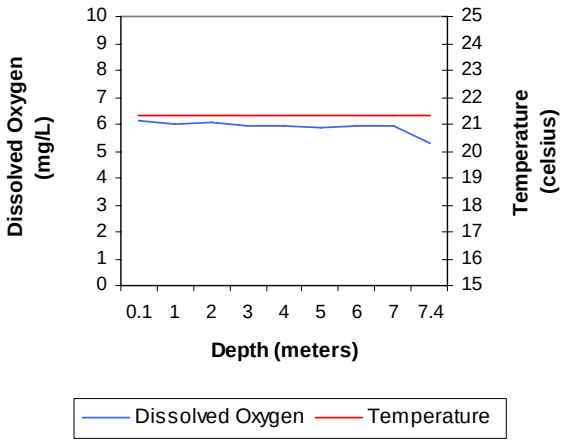
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E. coli,* fecal coliform, and enterococci analysis during the recreation season of May through September. Of the ten samples collected one (10%) of the samples exceeded the screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported.

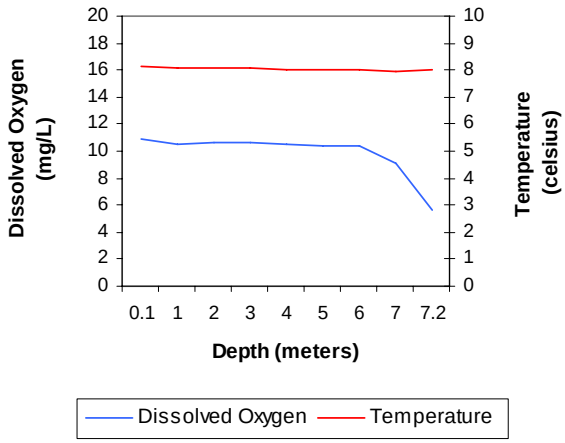
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the lake surface and 0.45 mg/L at the lake bottom. The TN at the surface ranged from 0.15 mg/L to 0.58 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the winter. The lake-wide total phosphorus (TP) average was 0.028 mg/L at the lake surface and 0.029 mg/L at the lake bottom. The surface TP ranged from 0.020 mg/L to 0.040 mg/L. The highest surface TP value was reported in the spring and summer quarters and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 15:1 for sample year 2003-2004. This value is higher than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

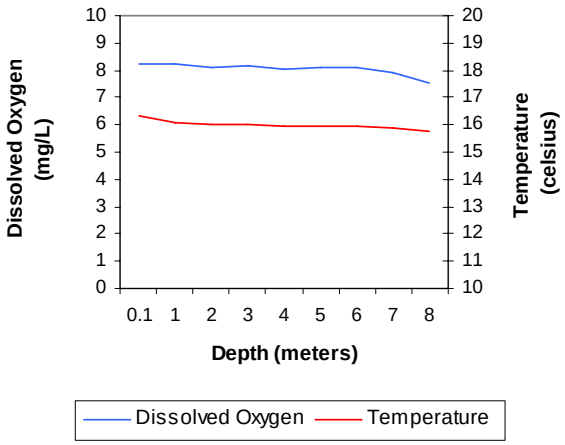
In summary, Wewoka Lake was classified as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions (Plate). This differs from the classification from the 2001 evaluation, which found the lake to be eutrophic (TSI=52). Water clarity was average to good in comparison to other lakes based on turbidity, true color and secchi disk depth. The lake was fully supporting its Aesthetics beneficial use for trophic state and true color as all collected values were below the numeric criteria of 70 color units. Wewoka Lake was fully supporting its FWP beneficial use for nephelometric turbidity and pH. In the summer only 44% of the water column was exhibiting anoxic conditions therefore the FWP is also supported based on D.O. concentrations in the water column. Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Of the ten samples collected one (10%) of the samples exceeded the screening level of 61 cfu/ml, however the geometric was not exceeded. The PBCR beneficial use is therefore considered supported. Wewoka Lake was constructed in 1925 and is owned and operated by the City of Wewoka. The lake is utilized as a municipal water supply and offers numerous recreational opportunities to the public.











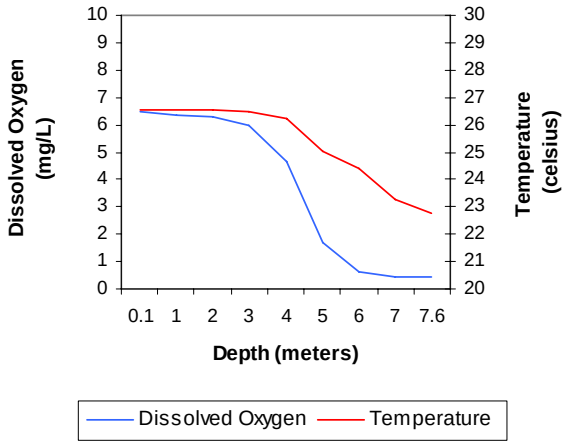


Figure 145a-145f. Graphical representation of data results for Wewoka Lake.

Wewoka Lake Location

Wewoka Lake and Watershed

Lake Data	
Owner	City of Wewoka
County	Seminole
Constructed in	1925
Surface Area	371 acres
Volume	3,301 acre/feet
Shoreline Length	10 miles
Mean Depth	8.90 feet
Watershed Area	16 square miles

POOR EXCELLENT

Turbidity 2004

POOR EXCELLENT

Trophic State 2004

Plate 127 - Lake Water Quality for
Wewoka Lake

LAKES MONITORING PROGRAM

Wister Lake

Wister Lake was sampled for four quarters, October 2004 through July 2005. Water quality samples were collected at five (5) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at sample site 1, the dam. The average lake-wide turbidity was 62 NTU (Plate 129), true color was 150 units, and average secchi disk depth was 24 centimeters. Based on these three parameters, Wister Lake had poor water clarity in comparison to other Oklahoma reservoirs. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 52 (Plate 129), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient conditions. This is similar to 2003 (TSI=54), indicating no change in productivity has occurred since the previous evaluation. The TSI values were fairly consistent ranging from eutrophic in the fall, spring and summer quarters to mesotrophic in the winter. The only exception was site 3, which was classified oligotrophic in both fall and winter sampling intervals. Wister Lake is listed in the Oklahoma Water Quality Standards (WQS) as a Nutrient Limited Watershed (NLW). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Seasonal turbidity values are displayed in Figure 146a. Turbidity values ranged from a low of 25NTU to a maximum of 124 NTU. According to the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-5, a beneficial use is considered not supported if ≥25% of the samples exceed the screening level prescribed in the WQS (25 NTU for turbidity). If 10% to 25% of the turbidity values exceed the numeric criteria of 25 NTU, the lake should be listed as partially supporting beneficial uses. With 100% of the collected values exceeding the standard Wister Lake is considered not supporting the Fish and Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 146b. All true color values were above the WQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered not supported based on true color.

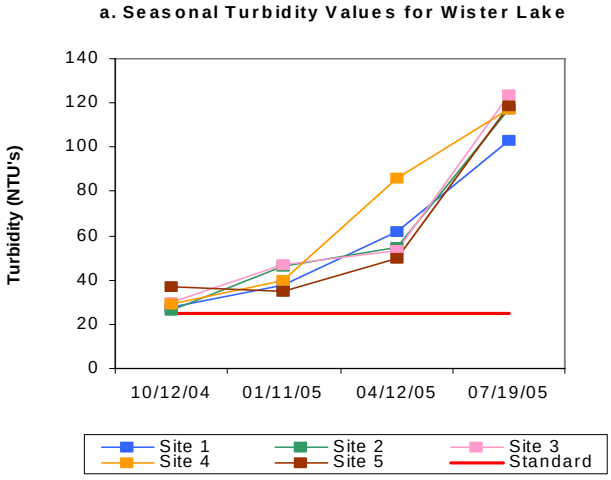
Vertical profiles for dissolved oxygen, pH, temperature, specific conductivity, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.04 ppt in sample year 2004-2005. This is lower than the average the range of values recorded in Oklahoma reservoirs. Specific conductivity ranged from 41.4 cm/cm to 96.9 cm/cm, indicating the presence of low levels of current conducting ions (salts or chlorides) in the lake system. The pH values ranged from 6.32 to 7.42 representing a slightly acidic to neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if 25% of the values fall outside the range of 6.5 to 9.0 and the waterbody should be listed as not supporting its FWP beneficial use. If 10 to 25% of the pH values fall outside the range of 6.5 to 9.0, the lake should be listed as partially supporting its FWP beneficial use. With approximately 9.5% of the values recorded being less than 6.5 the lake is supporting based on pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. Oxidation-reduction potentials (ORP) ranged from 217 mV to 501 mV, indicating reducing conditions were not present at this reservoir during the study period. During the fall, winter, and spring sampling intervals, stratification was not evident and the water column was well mixed (Figure 146c-146e). In the summer, the lake exhibited weak stratification with dissolved oxygen (D.O.) levels only dropping below 2.0 mg/L at the sediment-water interface (Figure 146f). If D.O. values are

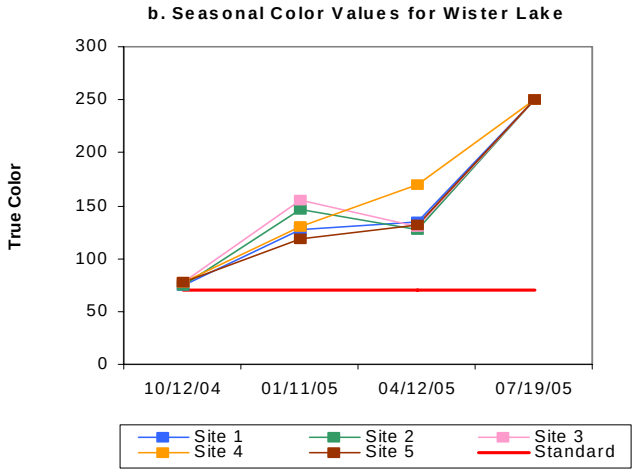
less than 2.0 mg/L for greater than 70% of the water column, the FWP beneficial use is deemed not supported (OAC 785:46-15-5). If D.O. values are less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Wister Lake is considered to be partially supporting the FWP beneficial use with 54.5% of the recorded values falling below 2.0 mg/L. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2004-2005 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

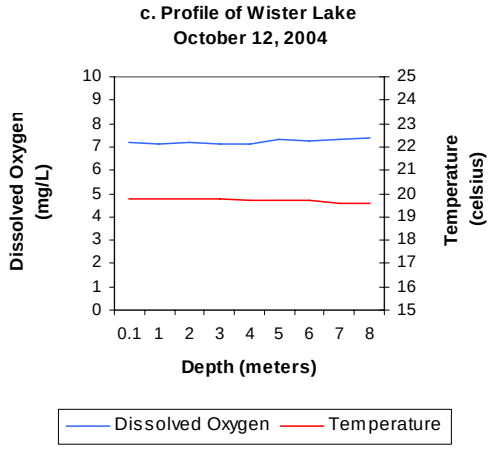
Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.

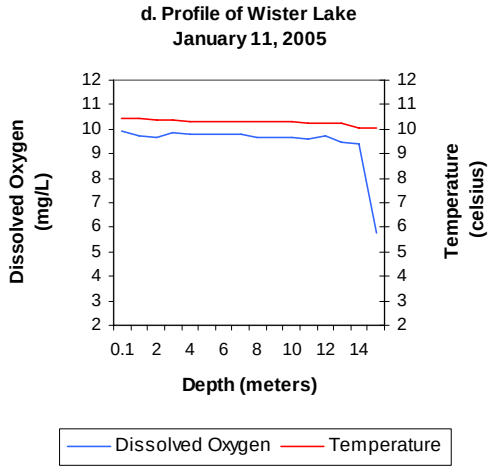
Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus. These data will be used to aid in future identification of NLW lakes and nutrient criteria development for lakes and reservoirs. The lake-wide total nitrogen (TN) average was 0.57 mg/L at the surface. Surface TN ranged from 0.38 mg/L to 0.85 mg/L, with the highest values reported in the summer and lowest values in the spring quarter. The lake-wide total phosphorus (TP) average was 0.118 mg/L at the surface. Total phosphorus at the surface ranged from 0.069mg/L to 0.201 mg/L. Surface TP was highest in both spring and summer quarters, and the lowest values were recorded during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 5:1 for sample year 2004-2005. This is higher than 7:1, characterizing the lake as nitrogen limited (Wetzel, 1983).

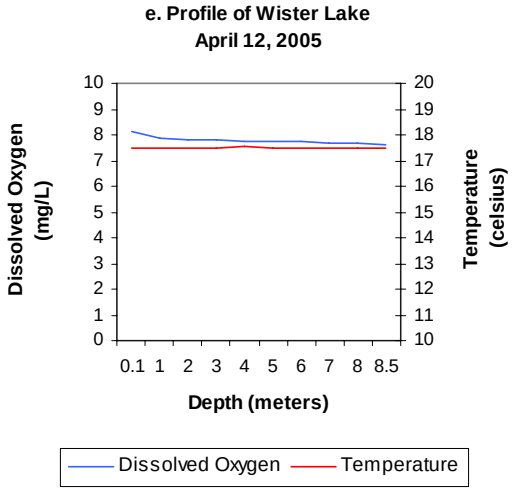
In summary, Wister Lake was classified as eutrophic, indicative of high primary productivity and nutrient conditions. This is similar to 2003 (TSI=54), indicating no significant increase or decrease in productivity has occurred since the 2000 evaluation. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (WQS). This listing means that the lake is considered threatened from nutrients until a more intensive study can confirm the Aesthetics beneficial use non-support status. Water clarity was poor based on turbidity, true color and secchi disk depth. The FWP beneficial use is partially supported based on dissolved oxygen during the summer, but not supported based on high turbidity values recorded throughout the year. With 9.5% of the recorded pH values less than 6.5 the lake is also supporting the FWP as it relates to pH. Slightly acidic conditions are not unusual in this part of the state due to relatively low soil pH and lack of soluble bedrock. Because of these conditions it is likely that the low pH values may be due to natural causes; therefore the Water Board is looking at the applicability of developing site-specific criteria for waters in the southeastern portion of the state. The Aesthetics beneficial use is considered not supported based on true color values. Bacteriological samples were not collected during the 2005 recreation season therefore an assessment of the Primary Body Contact Recreation (PBCR) beneficial use cannot be made at this time.
In 2002, the OWRB conducted a bathymetric survey of Wister Lake (Figure 147) to obtain current conservation pool elevations to assist in identifying management alternatives to improve conditions such as nutrient reduction at Wister Lake. Outputs of this study included the annual hydraulic residence time, identification of sediment suspension zones, depth-selective flow-routed outflow and aeration techniques. For further information on bathymetric mapping please visit our website at www.owrb.state.ok.us or contact Jody Cason at (405) 530-8800. Wister Lake, constructed by the United States Army Corps of Engineers (USACE), is utilized for flood control, water supply, low flow augmentation, water conservation and sedimentation purpose.











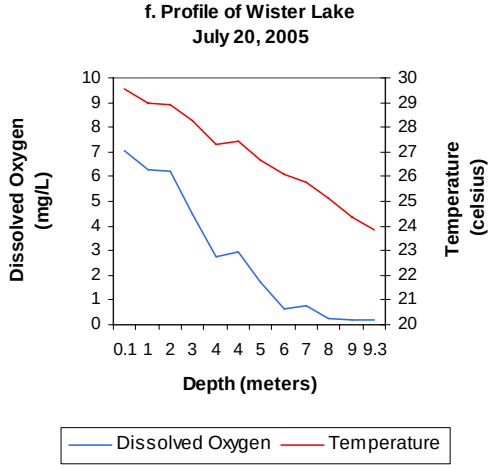
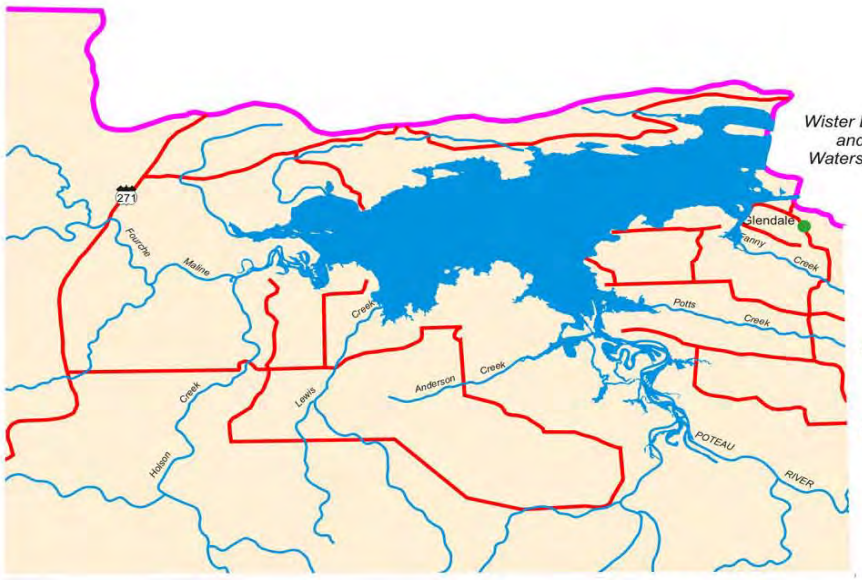
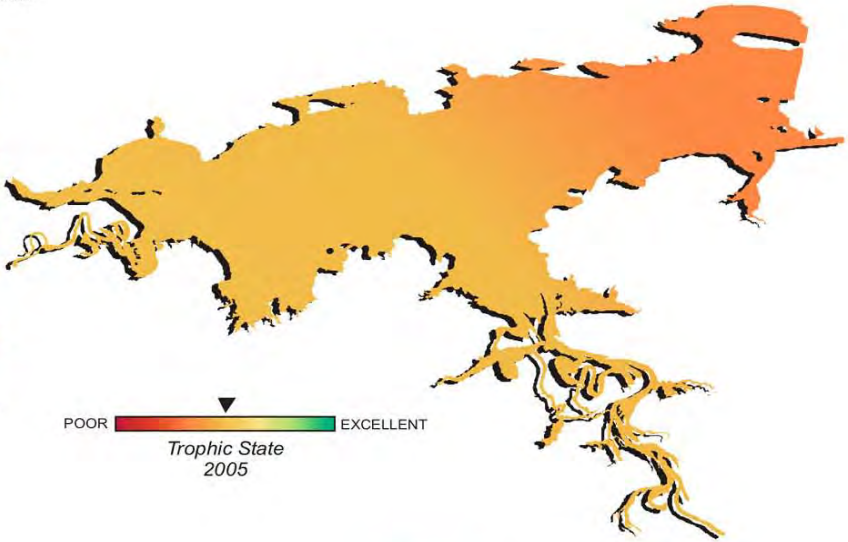


Figure 146a-146f. Graphical representation of data results for Wister Lake.

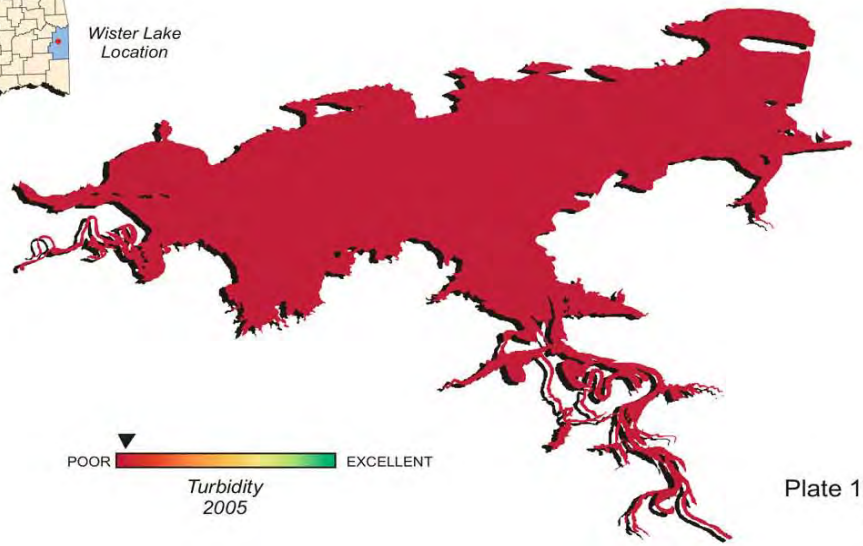


Wister Lake and Watershed



Trophic State 2005

Wister Lake Location



Turbidity 2005

Lake Data	
Owner	Corps of Engineers
County	LeFlore
Constructed in	1949
Surface Area	6,077 acres
Volume	47,414 acre/feet
Shoreline Length	93.89 miles
Mean Depth	7.40 feet
Watershed Area	993 square miles

Plate 129- Lake Water Quality for
Wister Lake

LAKES MONITORING PROGRAM

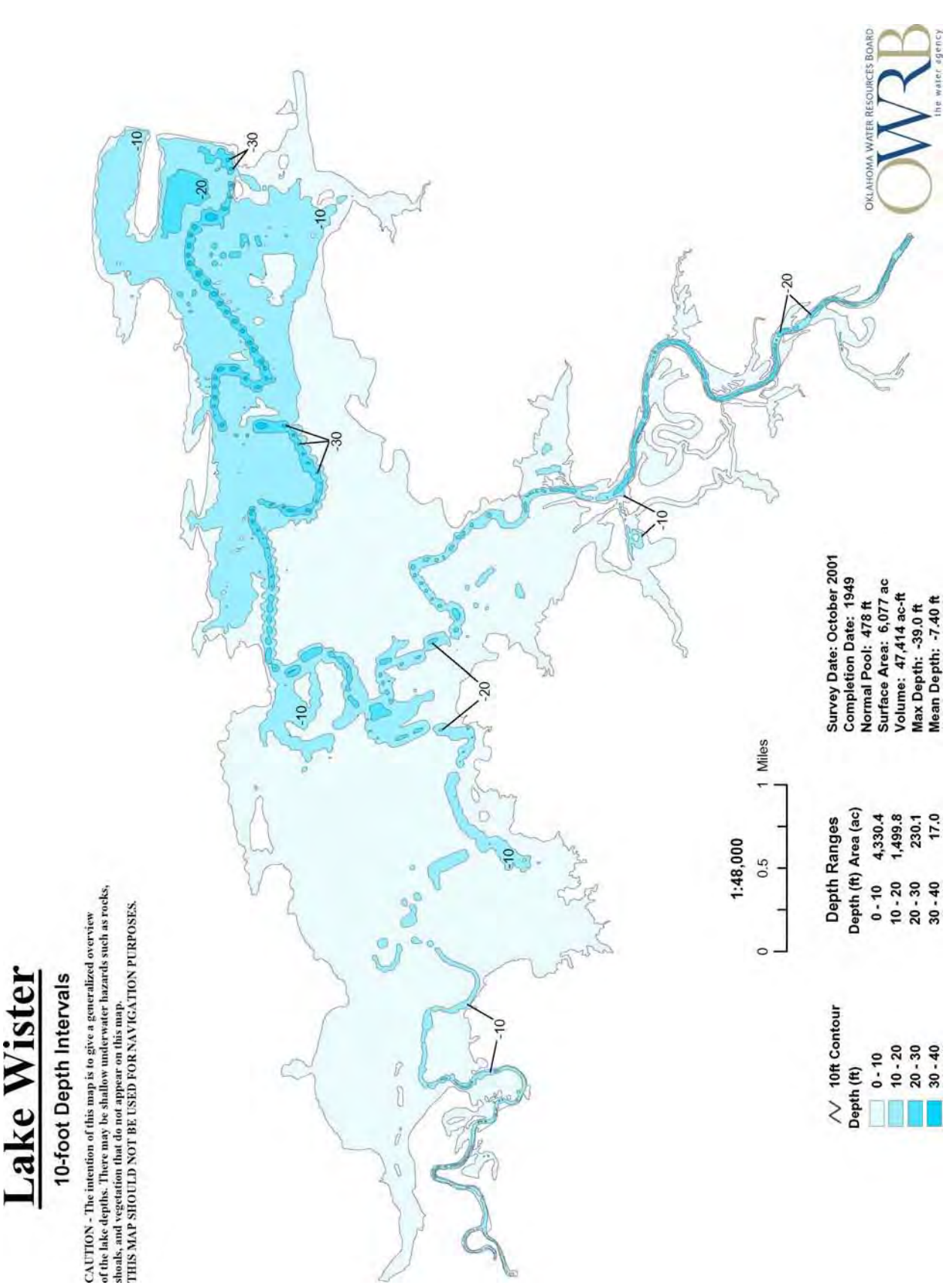


Figure 147. Bathymetric Map of Wister Lake.

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APPENDIX A

Oklahoma's Use Support Assessment Protocols

[UNOFFICIAL]

Proposed Amendments as of 11/17/2003
Under consideration for adoption in 2004

TITLE 785. OKLAHOMA WATER RESOURCES BOARD
CHAPTER 46. IMPLEMENTATION OF OKLAHOMA'S WATER QUALITY STANDARDS

SUBCHAPTER 15. USE SUPPORT ASSESSMENT PROTOCOLS

785:46-15-1. Scope and applicability

(a) **General.** The rules in this Subchapter provide protocols, which shall be used on and after October 1, 2000 to determine whether certain beneficial uses of waters of the state designated in OAC 785:45 are being supported. Such determinations shall be made only to the extent that pertinent provisions of OAC 785:45 apply to a waterbody or its designated uses. The rules in this Subchapter are not intended and should not be construed to limit any actions by federal or state agencies or citizens to prevent pollution or to limit remedies to abate pollution from a single incident or activity or series of incidents or activities.

(b) **Significance of assessment that a use is other than fully supported.** A determination based upon application of the rules in this Subchapter that a waterbody's beneficial use is not supported or is partially supported creates a presumption that the use is impaired or not attained for that waterbody and that the waterbody segment is a water quality limited segment.

785:46-15-5. Assessment of Fish and Wildlife Propagation support

(a) **Scope.** The provisions of this Section shall be used to determine whether the beneficial use of Fish and Wildlife Propagation or any subcategory thereof designated in OAC 785:45 for a waterbody is supported.

(b) **Dissolved oxygen.**

(1) **Screening levels for DO in streams.**

(A) Screening levels for DO in habitat limited aquatic communities shall be 4.0 mg/L from April 1 through June 15 each year and 3.0 mg/L for the remainder of the year.

(B) Screening levels for DO in warm water aquatic communities shall be 4.0 mg/L from June 16 through October 15 each year and 5.0 mg/L for the remainder of the year.

(C) Screening levels for DO in cool water aquatic communities and trout fisheries shall be 5.0 mg/L from June 1 through October 15 each year and 6.0 mg/L for the remainder of the year.

(2) **Screening levels for DO in lakes.**

(A) If greater than 70% of the water column at any given sample site in a lake or an arm of a lake is less than 2 mg/L due to other than naturally occurring conditions, the Fish and Wildlife Propagation beneficial use shall be deemed to be not supported.

(B) If 50% or more, but not greater than 70%, of the water column at any given sample site in a lake or arm of a lake is less than 2 mg/L due to other than naturally occurring conditions, the Fish and Wildlife Propagation beneficial use shall be deemed to be partially supported.

(C) The screening level for surface DO in a lake or arm of a lake shall be 4 mg/L from June 16 through October 15 each year and 5.0 mg/L for the remainder of the year.

(3) **Support tests.**

(A) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be fully supported with respect to the DO criterion if no more than 10% of the samples from a waterbody are less than the screening level for DO prescribed in (b)(1) or (b)(2)(C) of this Section and such result is due to other than naturally occurring conditions.

(B) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be partially supported with respect to the DO criterion if greater than 10% but less than 25% of the samples from a waterbody are less than the screening level for DO prescribed in (b)(1) or (b)(2)(C) of this Section.

(C) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be not supported with respect to the DO criterion if at least 5% of the samples from a waterbody are less than the screening level for DO prescribed in (b)(1) or (b)(2)(C) of this Section.

(c) **Toxicants.**

(1) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be fully supported with respect to any individual toxicant parameter if no more than one of the sample concentrations from the waterbody exceeds the acute or chronic criterion for that toxicant prescribed in the numerical criteria for toxic substances in OAC ~~785:45-5-12(f)(6)(G)~~ 785:45-5-12(f)(6)(D), (E) and (G) and 785:45 Appendix G, Table 2.

(2) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be partially supported with respect to any individual toxicant parameter if more than one but not greater than 10% of the sample concentrations from the waterbody exceed the acute or chronic criterion for that toxicant prescribed in the numerical criteria for toxic substances in OAC ~~785:45-5-12(f)(6)(G)~~ 785:45-5-12(f)(6)(D), (E) and (G) and 785:45 Appendix G, Table 2.

(3) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be not supported with respect to any individual toxicant parameter if greater than 10% of the sample concentrations from that waterbody exceed the acute or chronic criterion for that toxicant prescribed in the numerical criteria for toxic substances in OAC ~~785:45-5- 12(f)(6)(G)~~ 785:45-5-12(f)(6)(D), (E) and (G) and 785:45 Appendix G, Table 2.

(d) **pH.**

(1) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be fully supported with respect to pH occurring other than by natural causes if no more than 10% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(f)(3).

(2) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be partially supported with respect to pH occurring other than by natural causes if greater than 10% but less than 25% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(f)(3).

(3) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be not supported with respect to pH occurring other than by natural causes if at least 25% of the sample concentrations from that waterbody fall outside the screening interval prescribed in 785:45-5-12(f)(3).

(e) **Biological criteria.**

(1) If data demonstrate that an assemblage of fish or macro invertebrates from a waterbody is significantly degraded, according to 785:45-5-12(f)(5), from that expected for the subcategory of Fish and Wildlife Propagation designated in OAC 785:45 for that waterbody, then that subcategory may be deemed by the appropriate state environmental agency to be not supported.

(2) All physical assessments and biological collections shall be performed in accordance with the requirements set forth in OWRB Technical Report No. 99-3 entitled "Standard Operating Procedures for Stream Assessments and Biological Collections Related to Biological Criteria in Oklahoma".

(3) Evaluation of the biological collections shall include identification of fish samples to species level. Determinations of tolerance level shall be made according to Jester et al. 1992, "The Fishes of Oklahoma, Their Gross Habitats, and Their Tolerance of Degradation in Water Quality and Habitat", Proceedings of Oklahoma Academy of Sciences, 72:7-19.

(4) The determination of whether the use of Fish and Wildlife Propagation is supported in wadable streams in Oklahoma ecoregions shall be made according to all of the requirements of this subsection (e), the application of Appendix C of this Chapter, and the special provisions in subsections (g)(h) through (i) (l), where applicable, of this Section. Streams with undetermined use support status shall be subject to additional investigation that considers stream order, habitat factors and local reference streams before the use support determination is made.

(f) **Turbidity.** The criteria for turbidity stated in 785:45-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 785:46-15-4(b).

(g) **Oil and grease.**

(1) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be fully supported with respect to oil and grease if a visible sheen or bottom deposits of oil or grease are observed on that waterbody in 10% or less of the observations.

(2) The Fish and Wildlife Propagation beneficial use designated for a waterbody shall be deemed to be not supported with respect to oil and grease if a visible sheen or bottom deposits of oil or grease are observed on that waterbody in more than 10% of the observations.

(h) **Special provisions for Ouachita Mountains wadable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadable streams located in the Ouachita Mountains ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 35 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 24 or less. If a score is 25 to 34 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(2) Where designated, the subcategory of Habitat Limited Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 27 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 18 or less. If a score is 19 to 26 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

~~(h)~~(i) **Special provisions for Arkansas Valley wadable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadable streams located in the Arkansas Valley ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 35 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 24 or less. If a score is 25 to 34 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(2) Where designated, the subcategory of Habitat Limited Aquatic Community shall be

deemed fully supported if the application of Appendix C produces a score of 27 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 18 or less. If a score is 19 to 26 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

~~(i)~~(j) **Special provisions for Boston Mountains and Ozark Highlands wadable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadable streams located in the Boston Mountains and Ozark Highlands ecoregions shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Where designated, the subcategory of Cool Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 37 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 29 or less. If a score is 30 to 36 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(2) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 31 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 22 or less. If a score is 23 to 30 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

~~(j)~~(k) **Special provisions for Central Irregular Plains wadable streams.** The determination of whether the use of Fish and Wildlife Propagation is supported for wadable streams located in the Central Irregular Plains ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Where designated, the subcategory of Cool Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 35 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 28 or less. If a score is 29 to 34 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(2) Where designated, the subcategory of Warm Water Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 30 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 22 or less. If a score is 23 to 29 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(3) Where designated, the subcategory of Habitat Limited Aquatic Community shall be deemed fully supported if the application of Appendix C produces a score of 25 or more. Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 16 or less. If a score is 17 to 24 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

(l) **Special provisions for Central Oklahoma - Texas Plains wadable streams.** The determination of whether the Warm Water Aquatic Community subcategory of the Fish and Wildlife Propagation beneficial use is supported for wadable streams located in the Central Oklahoma - Texas Plains ecoregion shall be made according to the application of Appendix C of this Chapter, together with this subsection, as follows:

(1) Such subcategory shall be deemed fully supported if the application of Appendix C produces a score of 26 or more.

(2) Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 19 or less.

(3) If the application of Appendix C produces a score of 20 to 25 inclusive, the issue of whether this subcategory is supported shall be deemed undetermined.

785:46-15-6. Assessment of Primary Body Contact Recreation support

(a) **Scope.** The provisions of this Section shall be used to determine whether the subcategory of Primary Body Contact of the beneficial use of Recreation designated in OAC 785:45 for a waterbody is supported during the recreation season from May 1 through September 30 each year. Where data exist for multiple bacterial indicators on the same waterbody or waterbody segment, the determination of use support shall be based upon the use and application of all applicable tests and data.

(b) **Screening levels.**

(1) The screening level for fecal coliform shall be a density of 400 colonies per 100ml.

(2) The screening level for Escherichia coli shall be a density of 235 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(3) The screening level for enterococci shall be a density of 61 colonies per 100 ml in streams designated in OAC 785:45 as Scenic Rivers and in lakes, and 406 colonies per 100 ml in all other waters of the state designated as Primary Body Contact Recreation.

(c) **Fecal coliform.**

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is met and no greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section.

(2) The parameter of fecal coliform is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to fecal coliform if the geometric mean of 400 colonies per 100 ml is not met, or greater than 25% of the sample concentrations from that waterbody exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(d) **Escherichia coli (*E. coli*).**

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to *E. coli* if the geometric mean of 126 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The parameter of *E. coli* is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to *E. coli* if the geometric mean of 126 colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

(e) **Enterococci.**

(1) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be fully supported with respect to enterococci if the geometric mean of 33 colonies per 100 ml is met, or the sample concentrations from that waterbody taken during the recreation season do not exceed the screening level prescribed in (b) of this Section, or both such conditions exist.

(2) The parameter of enterococci is not susceptible to an assessment that Primary Body Contact Recreation is partially supported.

(3) The Primary Body Contact Recreation subcategory designated for a waterbody shall be deemed to be not supported with respect to enterococci if the geometric mean of 33

colonies per 100 ml is not met and any of the sample concentrations from that waterbody taken during the recreation season exceed a screening level prescribed in (b) of this Section.

785:46-15-7. Assessment of Public and Private Water Supply support

(a) **Scope.** The provisions of this Section shall be used to determine whether the beneficial use of Public and Private Water Supply or any subcategory thereof designated in OAC 785:45 for a waterbody is supported.

(b) **Toxicants.**

(1) The Public and Private Water Supply beneficial use designated for a waterbody shall be deemed to be fully supported with respect to any substance with criteria for such use listed in ~~785:45-5-10(1) or 785:45-5-10(6)~~ OAC 785:45 Appendix G if the sample concentrations from that waterbody do not exceed the criterion for that substance prescribed in ~~785:45-5-10~~ OAC 785:45 Appendix G more than 10% of the time, or drinking water use restrictions are not in effect, or both such conditions exist.

(2) The Public and Private Water Supply beneficial use designated for a waterbody shall be deemed to be partially supported with respect to any substance with criteria for such use listed in ~~785:45-5-10(1) or 785:45-5-10(6)~~ OAC 785:45 Appendix G if the sample concentrations from that waterbody exceed the criterion for that substance prescribed in ~~785:45-5-10~~ OAC 785:45 Appendix G more than 10% but less than 25% of the time, or drinking water use restrictions imposed by an agency with jurisdiction in effect require more than conventional treatment, or both such conditions exist.

(3) The Public and Private Water Supply beneficial use designated for a waterbody shall be deemed to be not supported with respect to any substance with criteria for such use listed in ~~785:45-5-10(1) or 785:45-5-10(6)~~ OAC 785:45 Appendix G if the sample concentrations from that waterbody exceed the criterion for that substance prescribed in ~~785:45-5-10~~ OAC 785:45 Appendix G more than 25% of the time, or drinking water use restrictions imposed by an agency with jurisdiction in effect require closure of the water supply, or both such conditions exist.

(c) **Bacteria.** The screening level for fecal coliform bacteria shall be 5000 colonies per 100 ml. The tests for use support shall follow the default protocol in 785:46-15-4.

(d) **Threatened water supplies.** Waters of the state designated in OAC 785:45 as Public and Private Water Supply shall be presumed to be threatened when toxicants are detected but do not exceed the applicable criteria prescribed in ~~785:45-5-10~~ OAC 785:45 Appendix G, or some drinking water use restrictions have been put into effect by an agency with jurisdiction, or the potential for adverse impacts to water quality exists, or more than one such conditions exist.

(e) **Oil and grease.**

(1) The Public and Private Water Supply beneficial use designated for a waterbody shall be deemed to be fully supported with respect to oil and grease if a visible sheen or bottom deposits of oil or grease are observed on that waterbody in 10% or less of the observations, and drinking water use restrictions that require more than conventional treatment related to oil and grease have not been put into effect by an agency with jurisdiction.

(2) The Public and Private Water Supply beneficial use designated for a waterbody shall be deemed to be not supported with respect to oil and grease if a visible sheen or bottom deposits of oil or grease are observed on that waterbody in more than 10% of the observations, or drinking water use restrictions that require more than conventional treatment related to oil and grease has been put into effect by an agency with jurisdiction.

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 ~~phosphorous~~ 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 ~~phosphorous~~ 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 ~~phosphorous~~ 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 ~~phosphorous~~ 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 Carlson's 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 in a lake.** If it is demonstrated that nutrient loading in a lake may be adversely impacting a beneficial use designated for that waterbody, then the Board may determine that the lake and its watershed is an NLW, and shall identify the lake and watershed as NLW in Appendix A of OAC 785:45.

(e) **Consequence of identification as NLW; results of study.** If a lake 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 NLW Impairment Study to be performed. The beneficial uses designated for lakes identified in OAC 785:45 Appendix A as NLW shall be presumed to be fully supported but threatened, unless an NLW Impairment Study demonstrates that the uses are partially supported or not supported; provided, if an NLW 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 NLW Impairment Study if a lake or an impairment study if a stream must be completed by the appropriate state environmental agency.

(g) **Result of impairment study.**

(1) **Impaired or threatened.** If, independent of or in addition to the process set forth in (b) of this Section, an impairment study of a waterbody demonstrates that a waterbody is impaired or threatened 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.

(2) **Not threatened nor impaired.** If, independent of or in addition to the process set forth in (b) of this Section, an impairment study of a waterbody demonstrates that a waterbody is neither threatened nor 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.

785:46-15-11. Assessment of Hydroelectric Power Generation support

The Hydroelectric Power Generation beneficial use designated for a waterbody shall be deemed to be fully supported for the purpose of water quality reporting.

785:46-15-12. Assessment of Industrial and Municipal Process and Cooling Water support

The Industrial and Municipal Process and Cooling Water beneficial use designated for a waterbody shall be deemed to be fully supported for the purpose of water quality reporting.

785:46-15-13. Assessment of Navigation support

The Navigation beneficial use designated for a waterbody shall be deemed to be fully supported for the purpose of water quality reporting.