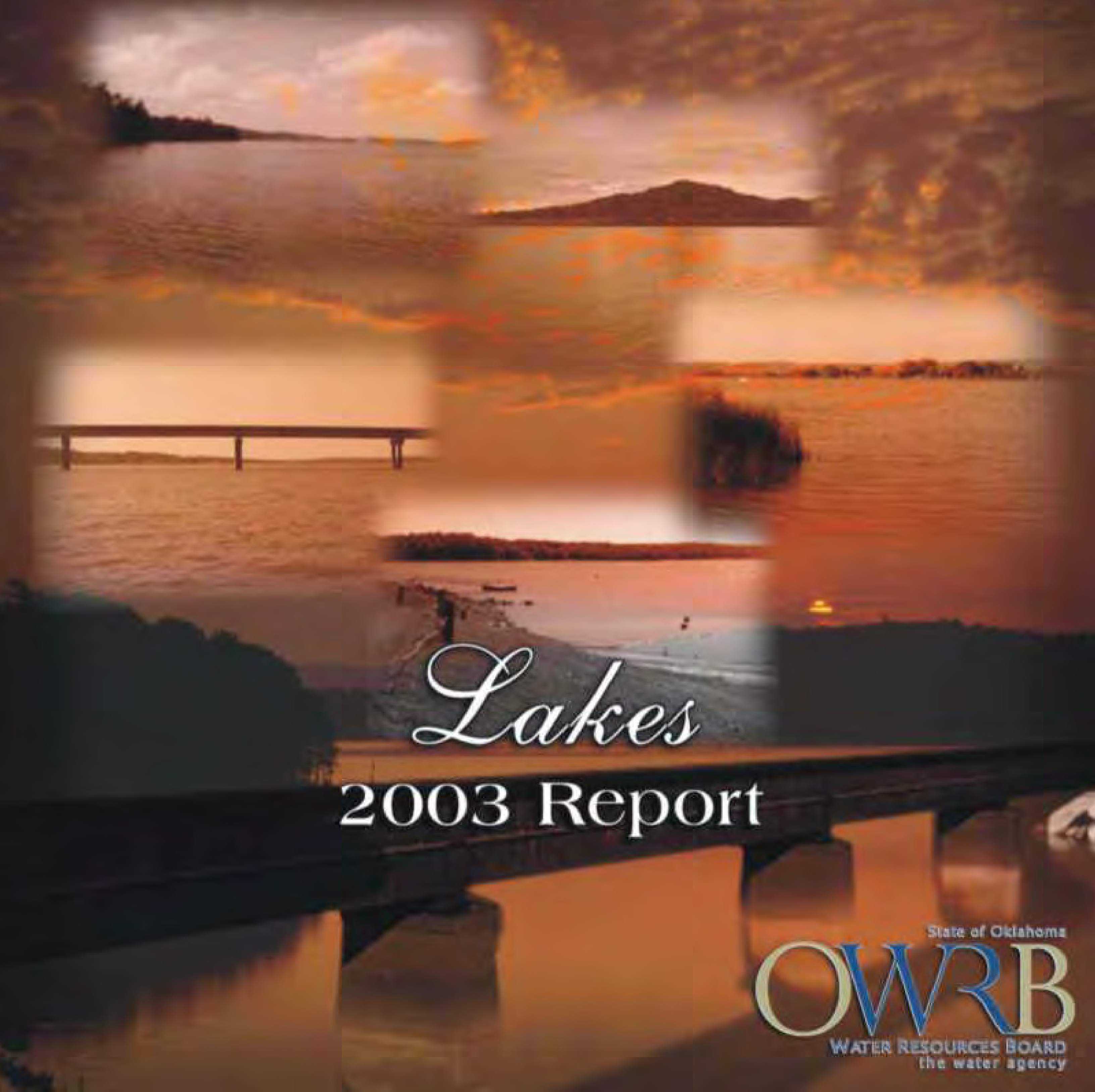
Oklahoma's Beneficial Use Monitoring Program



Lakes

2003 Report

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

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 OWQS, 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's environmental agencies. Specifically, USAPs establish a consistent method to determine if beneficial uses assigned for individual waters through Oklahoma Water Quality Standards (OWQS) are being supported. (Legitimacy of data analyzed following protocols other than those outlined in the USAP must be defended.) 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.

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, OWQS process, lake trophic status determination, water quality impact assessments from nonpoint 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 maintains Oklahoma's Water Quality Standards. The BUMP brings the OWRB's overall water quality management program full circle. From the promulgation of OWQS, to permitting and enforcement of permits stemming from OWQS-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 ihas 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 180 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 with locations that 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 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 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 working jointly with the USGS to conduct flow monitoring on all of our fixed station sites that do not have an automated flow monitoring USGS gage. This cooperative effort allows for loadings to be calculated and provides much needed data for the Use Support Assessment process.

- **Fixed Station Lakes Monitoring** - Quarterly sampling (approximately once every 90 days) of approximately 55-60 lakes annually is currently occurring. This represents approximately a 40% increase in effort over historical BUMP Lake sampling efforts. 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 ther 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 nonpoint 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. Since 1998, both the number of lakes sampled annually and monitored water quality constituents for have increased as the program has continued to adapt to meet the data quality needs for Oklahoma. It is hoped that the program can be further enhanced in the future to increase its usefulness to the environmental decision making process in Oklahoma.

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.

Results of Lakes Sampling Efforts

Data collected by OWRB on a quarterly basis for 54 lakes was used for this report. For the current sample year, data was collected from the September of 2002 through September of 2003. The results of the sampling efforts are summarized below. As shown in Figure 1, a relatively small percentage (4%) 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, 53% 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 two of the 54 lakes sampled were classified as oligotrophic. In this case, Lakes Elmer Thomas and Talawanda Lake No. 2 were classified as oligotrophic. In this instance, both lakes had very low levels of inorganic turbidity and are very clear and beautiful lakes. Based on the results for trophic state index calculations, 44% of the waters sampled were exhibiting high to excessive levels of primary productivity and nutrient rich conditions.

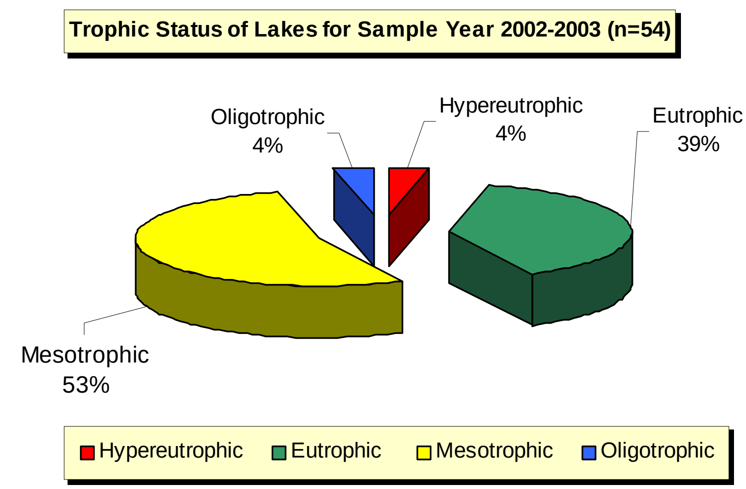


Figure 1. Trophic Status of Lakes Sampled in 2002-2003

The distribution changes when the lake surface acres for each reservoir are classified into the corresponding trophic status. Results in Figure 2 are quite 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, 67% of all surface acres sampled were eutrophic, 31% were mesotrophic, 02% were hypereutrophic, and less than 1% were oligotrophic. The two largest reservoirs sampled in 2002-2003 were classified as eutrophic (Eufaula and Texoma), 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 increases the likelihood of beneficial use impairments being present since a larger surface area is available. During stratification, the larger/deeper reservoirs have a greater

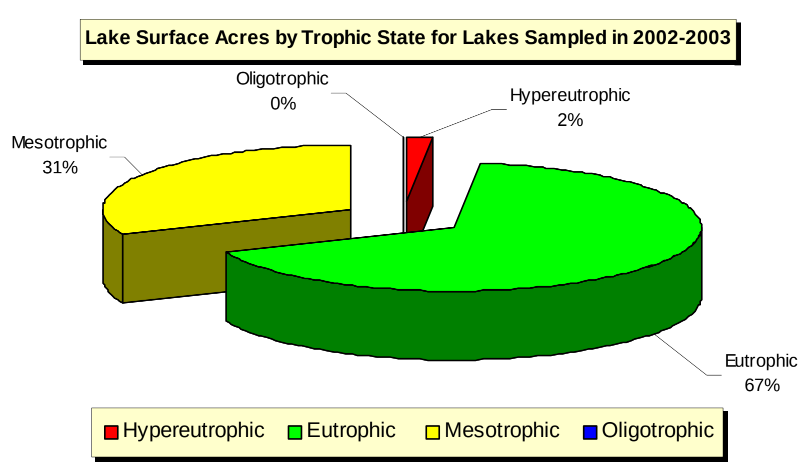


Figure 2. Lakes surface acres segregated by trophic state.

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, 14 lakes have been identified by the OWRB as "Nutrient-Limited Watersheds" (NLW) in the OWQS 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 #	YEAR SAMPLED	FWP	PPWS	PBCR	AG	AES
AMERICAN HORSE	BLAINE		2003	D.O.				
ARBUCKLE	MURRAY	310800	2003	D.O.				
ARCADIA	OKLAHOMA	520710	2003	D.O. TURBIDITY				
ARDMORE CITY	CARTER	310800	2003	D.O.				
ATOKA	ATOKA	410400	2002	TURBIDITY				TRUE COLOR
BELLCOW	LINCOLN	520700	2002	PH – PL				
BIRCH	OSAGE	121300	2003	D.O. TURBIDITY				TRUE COLOR
BIXHOMA	WAGONER		2002	D.O. PH – PL				
BLUESTEM	OSAGE	121300	2002	D.O. TURBIDITY				TRUE COLOR
BOOMER	PAYNE	620900	2002	TURBIDITY				
BROKEN BOW	MCCURTAIN	410210	2001	PH – PL				
BRUSHY CREEK	SEQUOYAH	220200	2001	D.O. PH – PL				
BURTSCHI ‡	GRADY		2002					
CANTON	BLAINE	720500	2002	TURBIDITY PH – PL				
CARL ALBERT	LATIMER	410310	2001	D.O. PH – PL				
CARL BLACKWELL	PAYNE	620900	2002	D.O.				
CARTER	MARSHALL	310800	2001					
CEDAR (MENA)	LEFLORE	410210, 410300	2001	D.O. PH – PL				
CHANDLER	LINCOLN	520700	2003	D.O.				
CHICKASHA ‡	CADDO	310830	2003					
CLAREMORE	ROGERS	121500	2002	D.O.				NLW
CLEAR CREEK	STEPHENS	310810	2003	D.O.		ENTERO.		
CLEVELAND CITY	PAWNEE		2002	D.O.				
CLINTON	WASHITA	310830	2002	TURBIDITY				

Lake Name	County	W.Q. Segment #	Year Sampled	FWP	PPWS	PBCR	AG	AES
Coalgate City	Coal	410400	2002	D.O. Turbidity				
Comanche	Stephens	311300	2003	D.O.				
Copan	Washington	121400	2003	Turbidity D.O.				
Crowder	Washita	310830	2002	D.O.				NLW
Cushing Municipal	Payne	620900	2002	D.O. Turbidity				
Dave Boyer (Walters)	Cotton	311300	2001	Turbidity				True Color
Dripping Springs	Okmulgee	520700	2002	D.O.				
Duncan	Stephens	310810	2003	D.O.				
El Reno	Canadian		2003	Turbidity				
Elk City	Beckham	311500	2002	Turbidity				NLW
Ellsworth	Comanche	311300	2002	Turbidity				
Elmer Thomas	Comanche	311300	2003	D.O.				
Etling, Carl	Cimarron	720900	2001	Turbidity				
Eucha ●	Delaware	121600	2003	D.O.				NLW
Eufaula	Haskell	220600	2003	D.O. Turbidity				True Color
Fairfax City	Osage	621200	2002					
Fort Cobb ‡	Caddo	310830	2002					NLW
Fort Gibson ◘	Cherokee	121600	2001	Turbidity				
Fort Supply †	Woodward	720500	2002	Turbidity pH – PL				NLW
Foss	Custer	310800, 310810 310820, 310830 310840	2003	D.O. Turbidity				
Frederick	Tillman	311310	2003	Turbidity				
Fuqua	Stephens	310810	2003	D.O.		Entero.		True Color
Grand Lake	Mayes	121600	2001	D.O. Turbidity				
Great Salt Plains	Alfalfa	621010	2002	Turbidity pH – PL			Sulfates & Chlorides	NLW
Greenleaf	Muskogee	120400	2001	D.O.				
Guthrie	Logan	620910	2002					NLW
Healdton City	Carter	311100	2001					
Hefner	Oklahoma	520520, 520530	2002	D.O.				
Henryetta ♦	Okmulgee	520700	2003	D.O.				
Heyburn	Creek	120420	2003	D.O. Turbidity		Entero.		
Holdenville	Hughes	520800	2002	D.O.				
Hominy Municipal	Osage	121300	2002	D.O.				

Lake Name	County	W.Q. Segment #	Year Sampled	FWP	PPWS	PBCR	AG	AES
Hudson	Osage		2002					
Hudson	Mayes	121600	2003	D.O.				
Hugo	Choctaw	410300	2003	Turbidity D.O.				True Color
Hulah	Osage	121400	2003	Turbidity				NLW
Humphreys	Stephens	310810	2003	D.O.				
Jean Neustadt	Carter	310800	2003	D.O.				
John Wells	Haskell	220200	2002	D.O. pH – PL				
Kaw	Osage	621210	2003	Turbidity D.O.				True Color
Keystone	Tulsa	621200	2002	Turbidity				NLW
Konawa	Seminole		2002					
Langston	Logan	620900	2002	D.O.				
Lawtonka	Comanche	311300	2002					
Liberty	Logan	620910	2002	D.O.				
Lloyd Church	Latimer	220100	2001	D.O. pH – PL Turbidity				
Lone Chimney	Pawnee	621200	2002	D.O.				
Lugert-Altus ◘	Greer	311500, 311510	2003	pH – PL				NLW
Maysville/Wiley Post	McClain		2002	D.O. Turbidity				
McAlester	Pittsburg	220600	2003	Turbidity D.O.				
McGee Creek	Atoka	410400	2002	D.O. pH – PL				True Color
McMurtry	Noble	620900	2002	D.O.				
Meeker	Lincoln	520700	2002	Turbidity				True Color
Murray	Love	311100	2001	D.O.				
Nanih Waiya	Pushmataha		2003	D.O.				
New Spiro	LeFlore	220100	2001	D.O.				
Okemah	Okfuskee	520700	2002	D.O.				
Okmulgee	Okmulgee	520700	2002	D.O.				
Oologah	Rogers	121510	2003	Turbidity D.O.				
Overholser	Oklahoma	520520, 520530	2002	D.O. Turbidity				NLW
Ozzie Cobb	Pushmataha	410300	2003	D.O. pH – PL				NLW
Pauls Valley City	Garvin	310810	2003	D.O.				
Pawhuska	Osage	121600	2003	D.O.				
Pawnee	Pawnee	621200	2002					

Lake Name	County	W.Q. Segment #	Year Sampled	FWP	PPWS	PBCR	AG	AES
Perry	Noble	621200	2003	Turbidity				
Pine Creek	McCurtain	410210	2002	D.O. Turbidity pH – PL				True Color
Ponca	Kay	621200	2003	D.O.				
Prague City	Lincoln	520510	2003	D.O.				
Purcell	McClain	520610	2002	D.O.				
Raymond Gary	Choctaw	410300	2000	D.O. pH – PL				
R.C. Longmire	Garvin	310810	2003	D.O.				
Robert S. Kerr	Sequoyah	220200	2003	Turbidity				True Color
Rock Creek	Carter	310800	2003	D.O.				
Rocky (Hobart) ‡	Washita	311500	2001					
Sahoma	Creek	120420	2002	D.O. Turbidity				
Sardis	Pushmataha	410310	2003	D.O.				
Shawnee Twin # 1	Pottawatomie	520510	2002					
Shawnee Twin # 2	Pottawatomie	520510	2002					
Shell	Osage	120420	2002	D.O.				
Skiatook	Osage	121300	2003	D.O.				
Sooner	Pawnee		2003	D.O.				
Spavinaw ●	Mayes	121600	2003	D.O.				NLW
Sportsman	Seminole	520500	2002					
Stanley Draper	Cleveland		2002	Turbidity				True Color
Stilwell City	Adair	220200	2001	D.O.				
Stroud	Creek	520700	2002	D.O.				
Talawanda # 1	Pittsburg	220600	2003	D.O. pH – PL				
Talawanda # 2	Pittsburg	220600	2003	D.O.				
Taylor (Marlow) ◘	Grady	310840	2003	Turbidity D.O.				NLW
Tecumseh	Pottawatomie	520510	2002	Turbidity				True Color
Tenkiller Ferry	Sequoyah	121700	2002	D.O.				
Texoma	Bryan	311100, 310800	2003	D.O. Turbidity				
Thunderbird	Cleveland	520810	2001	D.O. Turbidity				True Color
Tom Steed	Kiowa	311500	2003	Turbidity pH – PL				
Vanderwork	Washita	310830	2002	D.O.				NLW
Vincent, Loyd	Ellis	720500	2000					

Lake Name	County	W.Q. Segment #	Year Sampled	FWP	PPWS	PBCR	AG	AES
W.R. Holway	Mayes		2003	D.O.				
Waurika	Jefferson	311210	2003	D.O. Turbidity				
Waxhoma	Osage		2002	D.O. pH – PL				
Wayne Wallace	Latimer	220100	2003	D.O. pH – PL				
Webbers Falls	Muskogee	121400	2001	Turbidity				
Wes Watkins	Pottawatomie	520510	2002					
Wetumka	Hughes		2001	Turbidity				
Wewoka	Seminole	520500	2002	Turbidity				
Wister ♣	LeFlore	220100	2003	pH – PL Turbidity				NLW True Color
Yahola ●	Tulsa	121300	1999					

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

‡ These Lakes will not be recommended for listing as part of the next WQS revision due to insufficient data

♣ Lake Listed Based Upon OWRB Phase I Clean Lakes Study

♦ Lake does not fit the classic definition of oligotrophy, as inorganic particulates are the controlling factor in 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	PL = Provisionally Listed

Acronyms	
NLW = Nutrient Limited Water	D.O. = Dissolved Oxygen
Entero. = Enterococci	

Assigned OWQS 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 groundwaters 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 groundwaters 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 (OWQS) 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 OWQS as outlined by the OWRB through development of Implementation plans. Protecting our waters is a cooperative effort between many state agencies, and because the OWQS 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 OWQS are housed in OAC 785:45 and consist of three main components: beneficial uses, criteria to protect beneficial uses, and an antidegradation policy. An additional component, which is not directly part of the OWQS but necessary to water resource protection, is a monitoring program. A monitoring program is required in order to ensure that beneficial uses are

[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*.

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 OWQS Implementation, allows the OWQS 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.

Recently, the need for a protocol to determine beneficial use impairment was identified, which 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 OWQS and in developing appropriate numerical and narrative criteria for future OWQS documents. It is essential that our waters meet their assigned uses and that OWQS 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 OWQS 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 Nonpoint 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 OWQS 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.

The state has taken a major step towards coordinating sampling activities with the creation of a "Water Quality Monitoring Council," comprised of representatives from state, local, and federal agencies as well as universities, industries, volunteer groups, Indian tribes, and environmental organizations. The Council serves a useful purpose in providing an avenue for communication between the various groups and allows the state to coordinate water quality monitoring in a more effective manner. The Council focuses on coordinating agency activities to help the state avoid duplication of effort. Coordination between all concerned parties is obviously essential, but a comprehensive basic monitoring initiative to support the OWQS implementation process must be supported in order to identify waters that are not meeting their assigned beneficial uses and thus ensure that Oklahoma's water resources are protected from water quality degradation. The Council is pivotal in ensuring consistency between data collection efforts. The Monitoring Council functions informally in a coordinating capacity, which helps maximize monitoring efforts.

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 OWQS, 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 55 to 60 lakes on a quarterly basis. Under this scenario, repeat sampling on a lake will occur approximately every other year, 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 an 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), 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), 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 OWQS 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 resuspended 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 resuspended 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 2002-2003, 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 OWQS. The OWRB has previously identified 12 lakes that are listed in the OWQS as Nutrient Limited Watersheds (NLW). More intensive work on the twelve 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 OWQS 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 OWQS 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 54 lakes across the state from the fall of 2002 through the summer of 2003. 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 conductance, 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 were established solely for the purpose of determining turbidity and chlorophyll-a concentrations at the lake surface. Thus, at least five sites were monitored at all lakes for turbidity and chlorophyll-a. 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. In addition, metals samples were collected in the spring quarter for analysis. 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 2002-2003 are shown in Figure 3. Lake locations are identified on the map and are shaded in different colors based on their calculated TSI values.

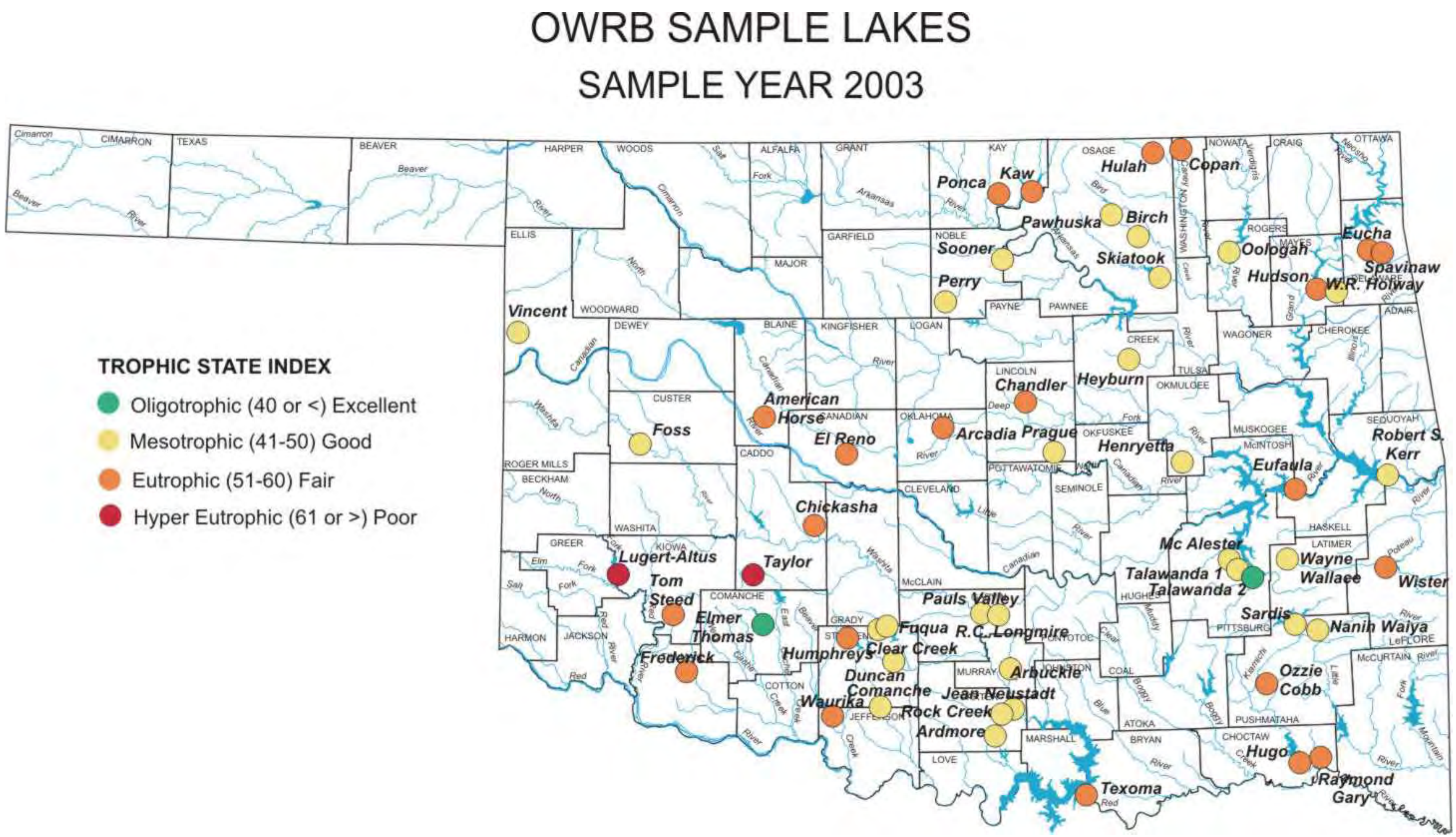


Figure 3. Lakes Sampled by the Beneficial Use Monitoring Program.

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:

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

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 OWQS 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 volume of water 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 volume 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 OWQS 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 OWQS 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 provisionally listed at this point in time as further examination is necessary to determine "natural causes".

Numerical criteria is prescribed for toxicants in OWQS 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 OWQS 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 OWQS means that a lake has been determined 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 OWQS.

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 2002-2003 as well as the percentages of the total. As shown in Table 3, 9 lakes were hypereutrophic, 28 were eutrophic, 18 were mesotrophic, and one was oligotrophic. Of the total 101,493 surface acres sampled, 48,958 acres were classified as eutrophic. TSI results, county, surface area, and volume for lakes sampled in 2002-2003 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	**2**	**4%**	**6,487**	**2%**
Eutrophic	**21**	**39%**	**274,557**	**67%**
Mesotrophic	**29**	**53%**	**127,587**	**31%**
Oligotrophic	**2**	**4%**	**510**	**0%**
Totals =	**54**	**100%**	**409,141**	**100%**

Table 4. List of Lakes Sampled in Sample Year 2002-2003.

	Lake Name	County	Surface Area (Acres)	Volume (Acre/Ft.)	TSI	Carlson's Trophic State
1	American Horse	Blaine	100	2,200	55	Eutrophic
2	Arbuckle	Murray	2,350	72,400	48	Mesotrophic
3	Arcadia	Oklahoma	1,820	27,520	59	Eutrophic
4	Ardmore City Lake	Carter	142	600	45	Mesotrophic
5	Birch	Osage	1,137	19,200	47	Mesotrophic
6	Chandler	Lincoln	129	2,778	52	Eutrophic
7	Chickasha	Caddo	820	41,080	59	Eutrophic
8	Clear Creek	Stephens	722	7,710	49	Mesotrophic
9	Comanche	Stephens	184	2,500	45	Mesotrophic
10	Copan	Washington	4,850	43,400	59	Eutrophic
11	Duncan	Stephens	500	7,200	47	Mesotrophic
12	El Reno	Canadian	170	709	59	Eutrophic
13	Elmer Thomas	Comanche	315	12,000	34	Oligotrophic
14	Eucha	Delaware	2,860	79,600	50	Mesotrophic
15	Eufaula	Haskell	105,500	2,314,60	52	Eutrophic
16	Foss	Custer	8,800	256,220	48	Mesotrophic
17	Frederick	Tillman	925	9,526	51	Eutrophic
18	Fuqua	Stephens	1,500	1,100	47	Mesotrophic
19	Henryetta	Okmulgee	450	6,600	43	Mesotrophic
20	Heyburn	Creek	880	7,105	46	Mesotrophic
21	Hudson	Mayes	10,900	200,300	55	Eutrophic
22	Hugo	Choctaw	13,250	157,600	55	Eutrophic
23	Hulah	Osage	3,570	31,160	55	Eutrophic
24	Humphreys	Stephens	882	14,041	56	Eutrophic
25	Jean Neustadt	Carter	462	6,106	47	Mesotrophic
26	Kaw	Osage	17,040	428,600	53	Eutrophic
27	Kerr, Robert S.	Sequoyah	43,380	525,700	45	Mesotrophic

	Lake Name	County	Surface Area (Acres)	Volume (Acre/Ft.)	TSI	Carlson's Trophic State
28	Longmire	Garvin	918		47	Mesotrophic
29	Lugert-Altus	Greer	6,260	132,830	63	Hypereutrophic
30	McAlester	Pittsburg	1,521	13,398	45	Mesotrophic
31	Nanih Waiya	Pushmataha	131	1,064	45	Mesotrophic
32	Oologah	Rogers	29,460	553,400	48	Mesotrophic
33	Ozzie Cobb	Pushmataha	116	833	54	Eutrophic
34	Pauls Valley	Garvin	750	8,730	41	Mesotrophic
35	Pawhuska	Osage	96	3,600	43	Mesotrophic
36	Perry	Noble	614	6,892	42	Mesotrophic
37	Ponca	Kay	805	14,440	54	Eutrophic
38	Prague	Lincoln	225	2,415	43	Mesotrophic
39	Raymond Gary	Choctaw	263	1,681	55	Eutrophic
40	Rock Creek	Carter	248	3,588	50	Mesotrophic
41	Sardis	Pushmataha	13,610	274,330	45	Mesotrophic
42	Skiatook	Osage	10,190	322,700	45	Mesotrophic
43	Sooner	Pawnee	5,400	149,000	48	Mesotrophic
44	Spavinaw	Mayes	1,584	38,000	52	Eutrophic
45	Talawanda No. 1	Pittsburg	91	1,200	45	Mesotrophic
46	Talawanda No. 2	Pittsburg	195	2,750	39	Oligotrophic
47	Taylor (Marlow)	Grady	227	1,877	62	Hypereutrophic
48	Texoma	Bryan	88,000	2,643,300	54	Eutrophic
49	Tom Steed	Kiowa	6,400	88,970	52	Eutrophic
50	Vincent, Loyd	Ellis	160	2,579	42	Mesotrophic
51	W.R. Holway	Mayes	712	48,000	50	Mesotrophic
52	Waurika	Jefferson	10,100	203,100	56	Eutrophic
53	Wayne Wallace	Latimer	94	1,746	44	Mesotrophic
54	Wister	LeFlore	7,333	62,360	54	Eutrophic

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

$$TSI = 14.42 \times \ln(\text{total phosphorus}) + 4.15.$$

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

$$TSI = 60 - (14.41 \times \ln(\text{secchi depth})).$$

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, two lakes were hypereutrophic, 21 were eutrophic, 29 were mesotrophic, and two 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. Sixteen lakes were hypereutrophic, 13 were eutrophic, 22 were mesotrophic and three were oligotrophic using the total phosphorus variable for TSI. For the secchi disk depth trophic evaluation, 33 lakes were hypereutrophic, 18 were eutrophic and three were mesotrophic. The TSI values calculated using secchi depth were usually highest of the three variables. For example, Lake Henryetta was classified as mesotrophic using chlorophyll-a concentration, yet in both the total phosphorus and secchi disk depth TSI, the lake was classified as hypereutrophic. As stated in the lake summary for Lake Henryetta, the lake is highly turbid and colored, leading to minimal amounts of algal biomass and productivity due to low light availability, although nutrients are still a concern. 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 2001-2002.

Lake Name	Chlor	Trophic State	Total P.	Trophic State	Secchi	Trophic State
Altus	63	Hypereutrophic	58	eutrophic	70	Hypereutrophic
American Horse	55	Eutrophic	48	Mesotrophic	48	Mesotrophic
Arbuckle	48	Mesotrophic	43	Mesotrophic	57	Eutrophic
Arcadia	59	Eutrophic	60	Eutrophic	68	Hypereutrophic
Ardmore City	45	Mesotrophic	44	Mesotrophic	56	Eutrophic
Birch	47	Mesotrophic	51	Eutrophic	62	Hypereutrophic
Chandler	52	Eutrophic	47	Mesotrophic	58	Eutrophic
Chickasha	59	Eutrophic	54	Eutrophic	65	Hypereutrophic
Clear Creek	48	Mesotrophic	48	Mesotrophic	60	Eutrophic
Comanche	45	Mesotrophic	45	Mesotrophic	62	Hypereutrophic

Lake Name	Chlor	Trophic State	Total P.	Trophic State	Secchi	Trophic State
Copan	59	Eutrophic	67	Hypereutrophic	75	Hypereutrophic
Duncan	47	Mesotrophic	48	Mesotrophic	62	Hypereutrophic
El Reno	59	Eutrophic	81	Hypereutrophic	71	Hypereutrophic
Elmer Thomas	34	Oligotrophic	38	Oligotrophic	45	Mesotrophic
Eucha	50	Mesotrophic	52	Eutrophic	58	Eutrophic
Eufaula	52	Eutrophic	60	Eutrophic	62	Hypereutrophic
Foss	48	Mesotrophic	50	Mesotrophic	53	Eutrophic
Frederick	51	Eutrophic	64	Hypereutrophic	85	Hypereutrophic
Fuqua	47	Mesotrophic	44	Mesotrophic	60	Eutrophic
Henryetta	43	Mesotrophic	74	Hypereutrophic	86	Hypereutrophic
Heyburn	46	Mesotrophic	64	Hypereutrophic	77	Hypereutrophic
Hudson	55	Eutrophic	62	Hypereutrophic	60	Eutrophic
Hugo	55	Eutrophic	64	Hypereutrophic	74	Hypereutrophic
Hulah	55	Eutrophic	63	Hypereutrophic	75	Hypereutrophic
Humphreys	56	Eutrophic	58	Eutrophic	71	Hypereutrophic
Jean Neustadt	47	Mesotrophic	49	Mesotrophic	69	Hypereutrophic
Kaw	53	Eutrophic	82	Hypereutrophic	73	Hypereutrophic
Longmire (R.C.)	47	Mesotrophic	50	Mesotrophic	62	Hypereutrophic
McAlester	45	Mesotrophic	72	Hypereutrophic	83	Hypereutrophic
Nanih Waiya	45	Mesotrophic	46	Mesotrophic	56	Eutrophic
Oologah	48	Mesotrophic	60	Eutrophic	73	Hypereutrophic
Ozzie Cobb	54	Eutrophic	59	Eutrophic	66	Hypereutrophic
Pauls Valley City	41	Mesotrophic	46	Mesotrophic	65	Hypereutrophic
Pawhuska	43	Mesotrophic	36	Oligotrophic	45	Mesotrophic
Perry	42	Mesotrophic	68	Hypereutrophic	82	Hypereutrophic
Ponca	54	Eutrophic	56	Eutrophic	64	Hypereutrophic
Prague	43	Mesotrophic	43	Mesotrophic	61	Hypereutrophic
Raymond Gary	55	Eutrophic	54	Eutrophic	64	Hypereutrophic
Robert S. Kerr	45	Mesotrophic	72	Hypereutrophic	71	Hypereutrophic
Rock Creek	50	Mesotrophic	44	Mesotrophic	61	Hypereutrophic
Sardis	45	Mesotrophic	46	Mesotrophic	61	Hypereutrophic
Skiatook	45	Mesotrophic	44	Mesotrophic	55	Eutrophic
Sooner	48	Mesotrophic	47	Mesotrophic	57	Eutrophic
Spavinaw	52	Eutrophic	48	Mesotrophic	57	Eutrophic
Talawanda No. 1	45	Mesotrophic	41	Mesotrophic	51	Eutrophic
Talawanda No. 2	39	Oligotrophic	38	Oligotrophic	53	Eutrophic
Taylor	62	Hypereutrophic	74	Hypereutrophic	71	Hypereutrophic

Lake Name	Chlor	Trophic State	Total P.	Trophic State	Secchi	Trophic State
Texoma	54	Eutrophic	55	Eutrophic	58	Eutrophic
Tom Steed	52	Eutrophic	63	Hypereutrophic	72	Hypereutrophic
Vincent	42	Mesotrophic	47	Mesotrophic	59	Eutrophic
W.R. Holway	50	Mesotrophic	60	Eutrophic	54	Eutrophic
Waurika	56	Eutrophic	66	Hypereutrophic	71	Hypereutrophic
Wayne Wallace	44	Mesotrophic	48	Mesotrophic	59	Eutrophic
Wister	54	Eutrophic	72	Hypereutrophic	79	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 56 lakes with repeat sampling on each reservoir scheduled to occur every two to three years through the BUMP and in cooperation with our partners. 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. Quarterly sampling has resulted 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. At a minimum, data collection efforts should occur monthly during the summer and preferably bi-weekly to gain some degree of understanding of the reservoir system. Minimum data requirements as listed in USAP were closely followed to make beneficial use determinations for the following parameters. All impairments are listed in Table 6, as identified through use of the USAP for turbidity, pH, true color, chlorides, sulfates, total dissolved solids, metals and dissolved oxygen criteria. Toxicity concerns, if present, are listed as provided by the ODEQ as part of their Rotating Lakes Toxics Program and/or through metals sampling conducted by the OWRB through the BUMP.

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

Lake Name	County	W.Q. Segment #	Year Sampled	FWP	PPWS	PBCR	AG	AES
American Horse	Blaine		2003	D.O.				
Arbuckle	Murray	310800	2003	D.O.				
Arcadia	Oklahoma	520710	2003	D.O. Turbidity				
Ardmore City	Carter	310800	2003	D.O.				
Atoka	Atoka	410400	2002	Turbidity				True Color
Bellcow	Lincoln	520700	2002	pH – PL				
Birch	Osage	121300	2003	D.O. Turbidity				True Color
Bixhoma	Wagoner		2002	D.O. pH – PL				
Bluestem	Osage	121300	2002	D.O. Turbidity				True Color
Boomer	Payne	620900	2002	Turbidity				
Broken Bow	McCurtain	410210	2001	pH – PL				
Brushy Creek	Sequoyah	220200	2001	D.O. pH – PL				

Lake Name	County	W.Q. Segment #	Year Sampled	FWP	PPWS	PBCR	AG	AES
Burtschi ‡	Grady		2002					
Canton	Blaine	720500	2002	Turbidity pH – PL				
Carl Albert	Latimer	410310	2001	D.O. pH – PL				
Carl Blackwell	Payne	620900	2002	D.O.				
Carter	Marshall	310800	2001					
Cedar (Mena)	LeFlore	410210, 410300	2001	D.O. pH – PL				
Chandler	Lincoln	520700	2003	D.O.				
Chickasha ‡	Caddo	310830	2003					
Claremore	Rogers	121500	2002	D.O.				NLW
Clear Creek	Stephens	310810	2003	D.O.		Entero.		
Cleveland City	Pawnee		2002	D.O.				
Clinton	Washita	310830	2002	Turbidity				
Coalgate City	Coal	410400	2002	D.O. Turbidity				
Comanche	Stephens	311300	2003	D.O.				
Copan	Washington	121400	2003	Turbidity D.O.				
Crowder	Washita	310830	2002	D.O.				NLW
Cushing Municipal	Payne	620900	2002	D.O. Turbidity				
Dave Boyer (Walters)	Cotton	311300	2001	Turbidity				True Color
Dripping Springs	Okmulgee	520700	2002	D.O.				
Duncan	Stephens	310810	2003	D.O.				
El Reno	Canadian		2003	Turbidity				
Elk City	Beckham	311500	2002	Turbidity				NLW
Ellsworth	Comanche	311300	2002	Turbidity				
Elmer Thomas	Comanche	311300	2003	D.O.				
Etling, Carl	Cimarron	720900	2001	Turbidity				
Eucha ●	Delaware	121600	2003	D.O.				NLW
Eufaula	Haskell	220600	2003	D.O. Turbidity				True Color
Fairfax City	Osage	621200	2002					
Fort Cobb ‡	Caddo	310830	2002					NLW
Fort Gibson ◘	Cherokee	121600	2001	Turbidity				
Fort Supply †	Woodward	720500	2002	Turbidity pH – PL				NLW
Foss	Custer	310800, 310810 310820, 310830 310840	2003	D.O. Turbidity				
Frederick	Tillman	311310	2003	Turbidity				
Fuqua	Stephens	310810	2003	D.O.		Entero.		True Color
Grand Lake	Mayes	121600	2001	D.O. Turbidity				
Great Salt Plains	Alfalfa	621010	2002	Turbidity pH – PL			Sulfates & Chlorides	NLW

Lake Name	County	W.Q. Segment #	Year Sampled	FWP	PPWS	PBCR	AG	AES
Greenleaf	Muskogee	120400	2001	D.O.				
Guthrie	Logan	620910	2002					NLW
Healdton City	Carter	311100	2001					
Hefner	Oklahoma	520520, 520530	2002	D.O.				
Henryetta	Okmulgee	520700	2003	D.O.				
Heyburn	Creek	120420	2003	D.O. Turbidity		Entero.		
Holdenville	Hughes	520800	2002	D.O.				
Hominy Municipal	Osage	121300	2002	D.O.				
Hudson	Osage		2002					
Hudson	Mayes	121600	2003	D.O.				
Hugo	Choctaw	410300	2003	Turbidity D.O.				True Color
Hulah	Osage	121400	2003	Turbidity				NLW
Humphreys	Stephens	310810	2003	D.O.				
Jean Neustadt	Carter	310800	2003	D.O.				
John Wells	Haskell	220200	2002	D.O. pH – PL				
Kaw	Osage	621210	2003	Turbidity D.O.				True Color
Keystone	Tulsa	621200	2002	Turbidity				NLW
Konawa	Seminole		2002					
Langston	Logan	620900	2002	D.O.				
Lawtonka	Comanche	311300	2002					
Liberty	Logan	620910	2002	D.O.				
Lloyd Church	Latimer	220100	2001	D.O. pH – PL Turbidity				
Lone Chimney	Pawnee	621200	2002	D.O.				
Lugert-Altus	Greer	311500, 311510	2003	pH – PL				NLW
Maysville/Wiley Post	McClain		2002	D.O. Turbidity				
McAlester	Pittsburg	220600	2003	Turbidity D.O.				
McGee Creek	Atoka	410400	2002	D.O. pH – PL				True Color
McMurtry	Noble	620900	2002	D.O.				
Meeker	Lincoln	520700	2002	Turbidity				True Color
Murray	Love	311100	2001	D.O.				
Nanih Waiya	Pushmataha		2003	D.O.				
New Spiro	LeFlore	220100	2001	D.O.				
Okemah	Okfuskee	520700	2002	D.O.				
Okmulgee	Okmulgee	520700	2002	D.O.				
Oologah	Rogers	121510	2003	Turbidity D.O.				
Overholser	Oklahoma	520520, 520530	2002	D.O. Turbidity				NLW
Ozzie Cobb	Pushmataha	410300	2003	D.O. pH – PL				NLW

Lake Name	County	W.Q. Segment #	Year Sampled	FWP	PPWS	PBCR	AG	AES
Pauls Valley City	Garvin	310810	2003	D.O.				
Pawhuska	Osage	121600	2003	D.O.				
Pawnee	Pawnee	621200	2002					
Perry	Noble	621200	2003	Turbidity				
Pine Creek	McCurtain	410210	2002	D.O. Turbidity pH – PL				True Color
Ponca	Kay	621200	2003	D.O.				
Prague City	Lincoln	520510	2003	D.O.				
Purcell	McClain	520610	2002	D.O.				
Raymond Gary	Choctaw	410300	2000	D.O. pH – PL				
R.C. Longmire	Garvin	310810	2003	D.O.				
Robert S. Kerr	Sequoyah	220200	2003	Turbidity				True Color
Rock Creek	Carter	310800	2003	D.O.				
Rocky (Hobart)‡	Washita	311500	2001					
Sahoma	Creek	120420	2002	D.O. Turbidity				
Sardis	Pushmataha	410310	2003	D.O.				
Shawnee Twin # 1	Pottawatomie	520510	2002					
Shawnee Twin # 2	Pottawatomie	520510	2002					
Shell	Osage	120420	2002	D.O.				
Skiatook	Osage	121300	2003	D.O.				
Sooner	Pawnee		2003	D.O.				
Spavinaw ●	Mayes	121600	2003	D.O.				NLW
Sportsman	Seminole	520500	2002					
Stanley Draper	Cleveland		2002	Turbidity				True Color
Stilwell City	Adair	220200	2001	D.O.				
Stroud	Creek	520700	2002	D.O.				
Talawanda # 1	Pittsburg	220600	2003	D.O. pH – PL				
Talawanda # 2	Pittsburg	220600	2003	D.O.				
Taylor (Marlow) ◘	Grady	310840	2003	Turbidity D.O.				NLW
Tecumseh	Pottawatomie	520510	2002	Turbidity				True Color
Tenkiller Ferry	Sequoyah	121700	2002	D.O.				
Texoma	Bryan	311100, 310800	2003	D.O. Turbidity				
Thunderbird	Cleveland	520810	2001	D.O. Turbidity				True Color
Tom Steed	Kiowa	311500	2003	Turbidity pH – PL				
Vanderwork	Washita	310830	2002	D.O.				NLW
Vincent, Loyd	Ellis	720500	2000					
W.R. Holway	Mayes		2003	D.O.				
Waurika	Jefferson	311210	2003	D.O. Turbidity				
Waxhoma	Osage		2002	D.O. pH – PL				

Lake Name	County	W.Q. Segment #	Year Sampled	FWP	PPWS	PBCR	AG	AES
Wayne Wallace	Latimer	220100	2003	D.O. pH – PL				
Webbers Falls	Muskogee	121400	2001	Turbidity				
Wes Watkins	Pottawatomie	520510	2002					
Wetumka	Hughes		2001	Turbidity				
Wewoka	Seminole	520500	2002	Turbidity				
Wister♣	LeFlore	220100	2003	pH – PL Turbidity				NLW True Color
Yahola●	Tulsa	121300	1999					

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

‡ These Lakes will not be recommended for listing as part of the next WQS revision due to insufficient data

♣ Lake Listed Based Upon OWRB Phase I Clean Lakes Study

♦ Lake does not fit the classic definition of oligotrophy, as inorganic particulates are the controlling factor in 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	PL = Provisionally Listed

Acronyms	
NLW = Nutrient Limited Water	D.O. = Dissolved Oxygen
Entero. = Enterococci	

Assigned OWQS 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 OWQS for pH, 6.5 to 9 units, listed in 785:45-5. Nine of the 54 lakes sampled in 2002-2003 were provisionally listed as partially supporting the FWP beneficial use based on pH values and 11 lakes were provisionally listed as not supporting (see 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 OWQS 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 54 lakes sampled in 2002-2003, 34

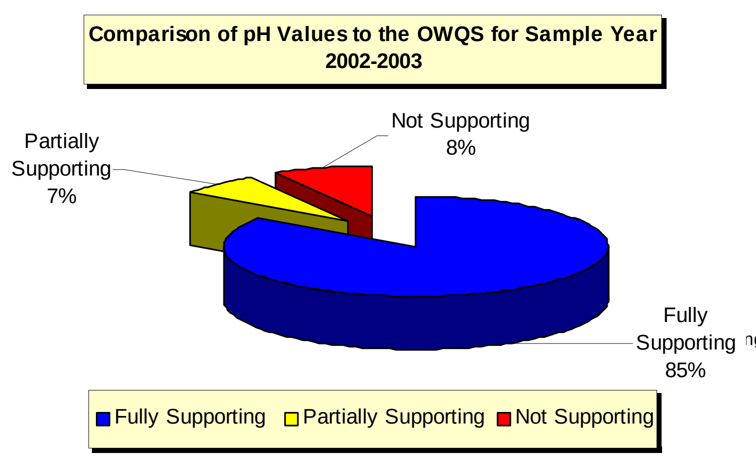


Figure 4. Percent of lakes assessed that exceeds or meets the OWQS for pH

lakes were not supporting their Fish & Wildlife Propagation (FWP) beneficial use, 14 were partially supporting the and 82 were fully supporting the FWP beneficial use based on turbidity values (see Figure 6). True color units were also averaged for the year to compare to the OWQS of 70 units. Seasonal true color values per site are displayed graphically for each lake (see Figure 5). In 2002-2003, 14 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 54 lakes sampled in 2002-2003, seven were not supporting the FWP beneficial use based on anoxic conditions, primarily in the summer season (see Figure 7). Metals were sampled beginning in 2001-2002 to look at toxicant levels in our lake resources. This is a new initiative added to the lakes monitoring program and it is hoped that it can be continued in the future. Results from metals sampling indicated that metals concentrations in the water column were not a problem in any of the lakes sampled in 2001-2002 or 2002-2003. To more fully address the toxics issues in our reservoirs it is hoped that the OWRB and ODEQ can work cooperatively in the future to increase the number of lake fish communities sampled for toxics in fish tissue. Chloride and sulfate water quality parameters were also added to the lake sampling program in year 2001-2002. 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 revealed that only one sampled lake was not supporting its agriculture beneficial use (See Figure 8). The lake not

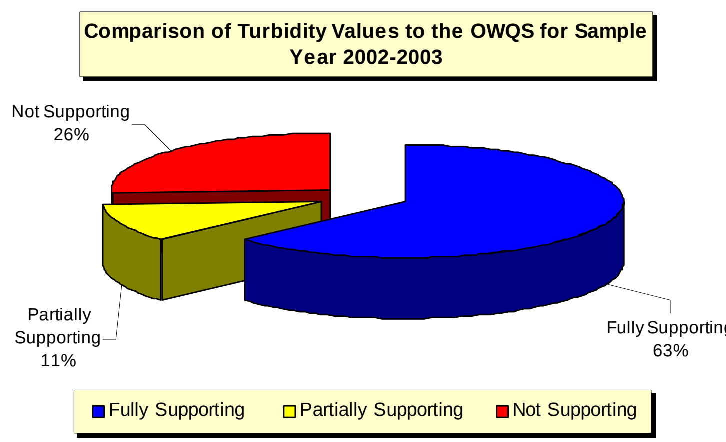


Figure 6. Percent of lakes assessed that exceeds or meets the OWQS for turbidity.

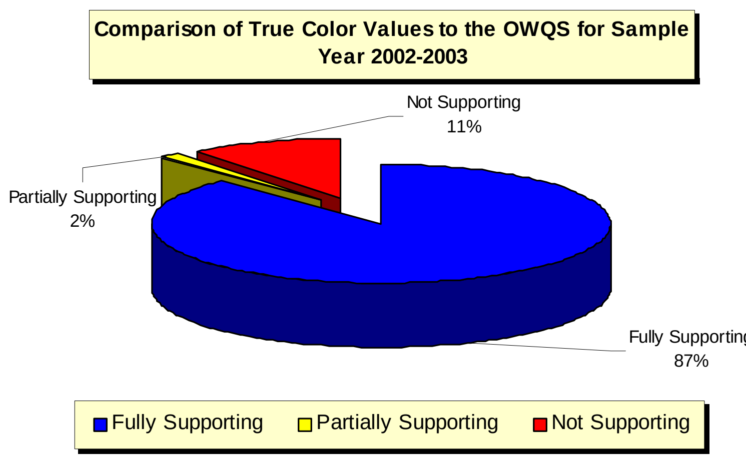


Figure 5. Percent of lakes assessed that exceeds or meets the OWQS for true color

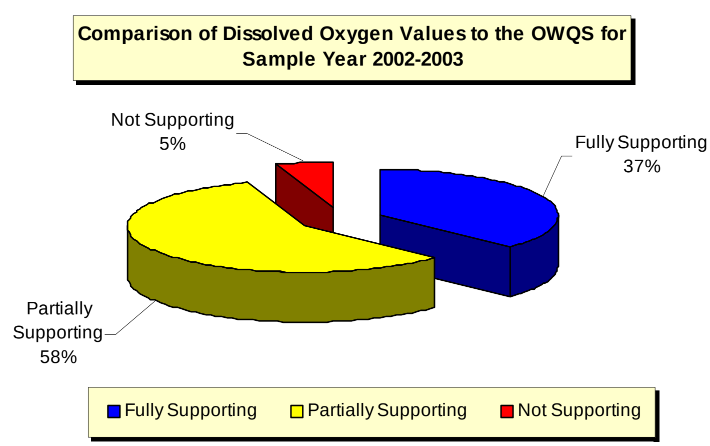


Figure 7. Percent of lakes assessed and their support status of the OWQS for dissolved oxygen

supporting was Great Salt Plains Reservoir. This was not an unexpected result. Analysis of the bacteria data indicated that three lakes were not supporting their Primary Body Contact Recreation beneficial use (See Figure 9).

It is the intent of the OWRB monitoring program to pursue adding additional monitoring parameters to the lake sampling initiative in the future to allow all beneficial uses to be assessed. This includes adding such parameters as bacteria and pesticide sampling. It is 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 56 lakes is presented on the following pages. The importance of long-term monitoring is imperative in making trend assessments for water quality and documenting changes over time especially due to changes in weather patterns and climate. A short discussion and analysis of the field data collected on each lake sampled is included for each of the 54 lakes, discussed in alphabetical order.

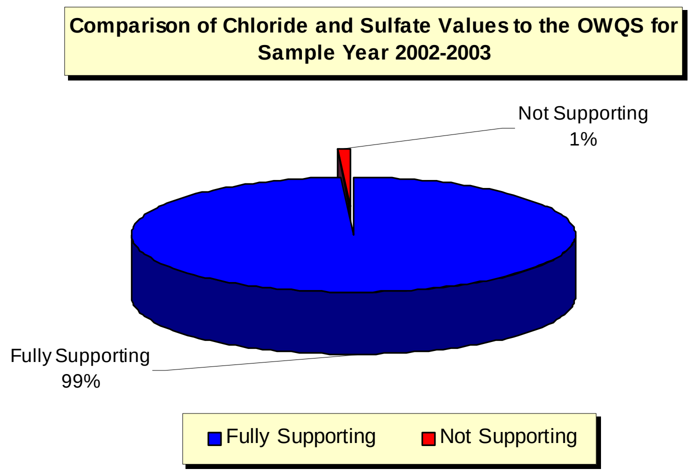


Figure 8. Percent of lakes assessed and their support status of the OWQS for chlorides & sulfates.

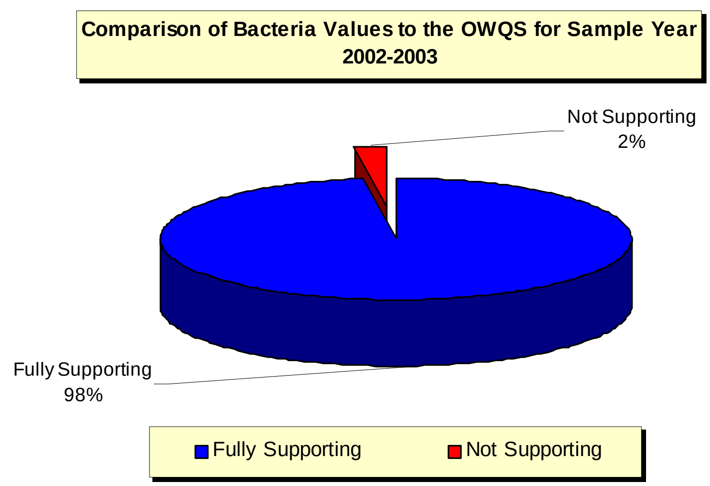


Figure 9. Percent of lakes assessed and their support status of the OWQS for bacteria.

American Horse Lake

American Horse Lake was sampled for four quarters, from October 2002 through July 2003. 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 3 NTU (Plate 1), true color was 13 units and secchi disk depth was 228 centimeters in sample year 2003. 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=12). The result was a TSI of 55 (Plate 1), classifying the lake as eutrophic, indicative of high primary productivity and nutrient rich conditions. Although this is slightly higher than the value calculated in 2000 (TSI=52), the lake remains in the same trophic category. The TSI values varied seasonally at American Horse Lake throughout 2003 from upper eutrophic in the fall to hypereutrophic in the winter and mesotrophic in both spring/summer quarters (Figure 10). Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU meeting the beneficial use of Fish and Wildlife Propagation. Seasonal true color values are displayed in (Figure 11b). All color values were well below the aesthetics OWQS of 70 units.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 0.16 parts per thousand (ppt) to 0.18 ppt for this sample year. Specific conductance ranged from 321 mS/cm to 370 mS/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 7.15 to 8.49, representing a neutral to slightly alkaline system. Oxidation-reduction potentials ranged from 245 mV in the spring to 470 mV in the fall. Reducing conditions were not present in this reservoir during the 2002-2003-sample year. During the fall and winter quarters stratification was not present (Figure 11c-10d). Thermal stratification was evident in both spring and summer quarters. In the spring stratification occurred at several 1-meter intervals throughout the water column and dissolved oxygen ranged from 8.62 mg/L at the surface to 0.28 mg/l at the lake bottom. During the summer quarter the lake exhibited strong thermal stratification between 6 and 7 meters at which point the dissolved oxygen dropped below 2 mg/L for the remainder of the water column (Figure 11f). 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

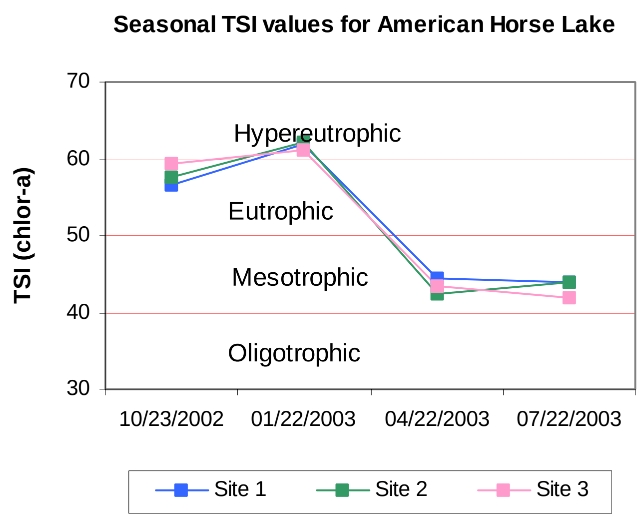


Figure 10. TSI values for American Horse Lake

50 to 70 % of the water column, the FWP beneficial use is deemed partially supported. With 30% of the water column in the spring and 65% percent of the water column in the summer falling below 2.0 mg/L the FWP Benicia use is partially supported at American Horse Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 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 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

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.51mg/L at the surface and 1.08 mg/L at the lake bottom. The TN at the surface ranged from 0.45 mg/L to 0.72 mg/L. The lake-wide total phosphorus (TP) average was 0.022 mg/L at the surface and 0.104 at the lake bottom. The total phosphorus at the surfaced ranged from 0.016 mg/L to 0.029 mg/L with lower values occurring in the spring quarter. The nitrogen to phosphorus ration (TN:TP) was 24:1 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 eutrophic, indicative of high primary productivity and nutrient conditions consistent with the results from the 2000 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 spring 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 55 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 purpose of recreation.

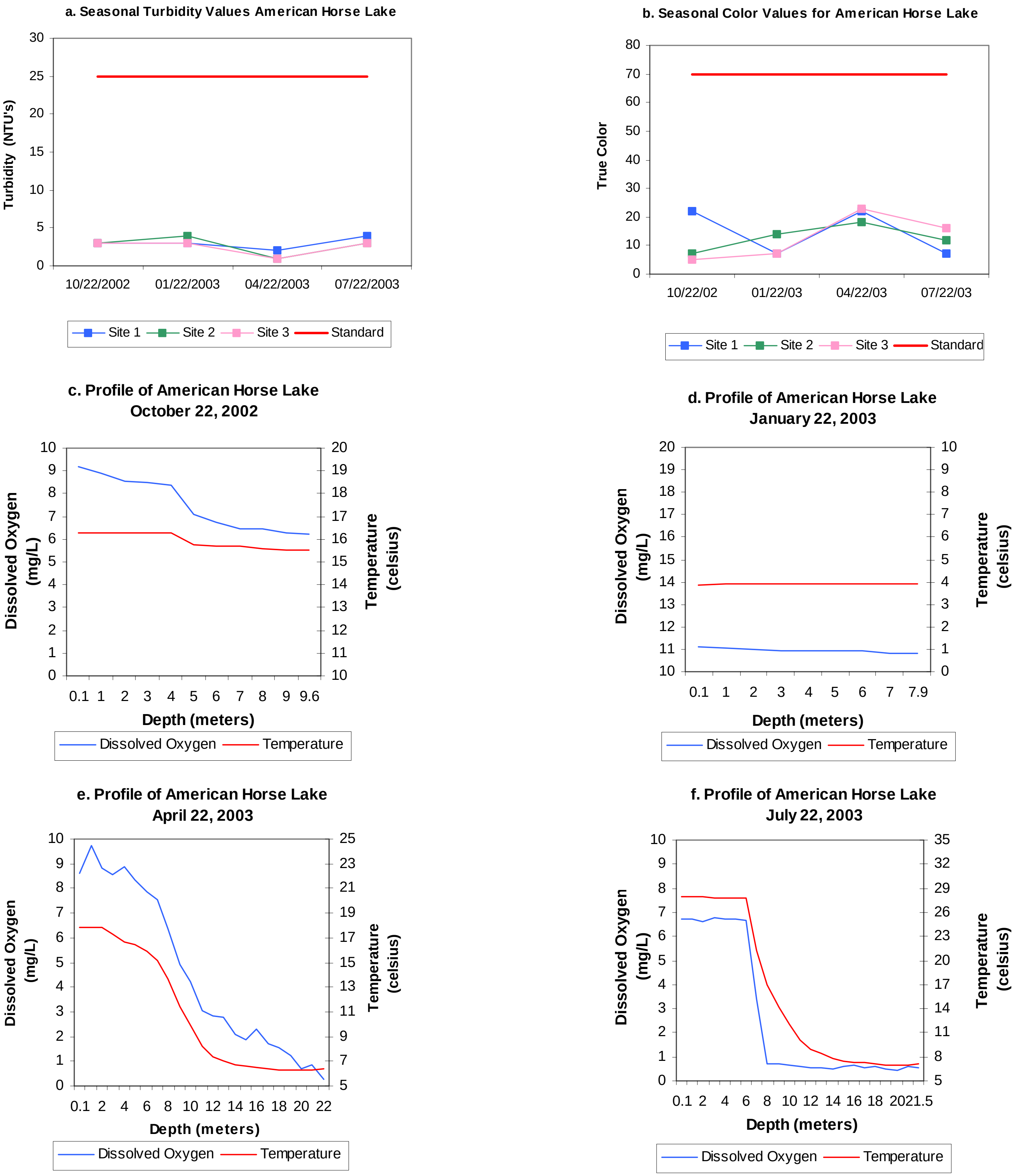
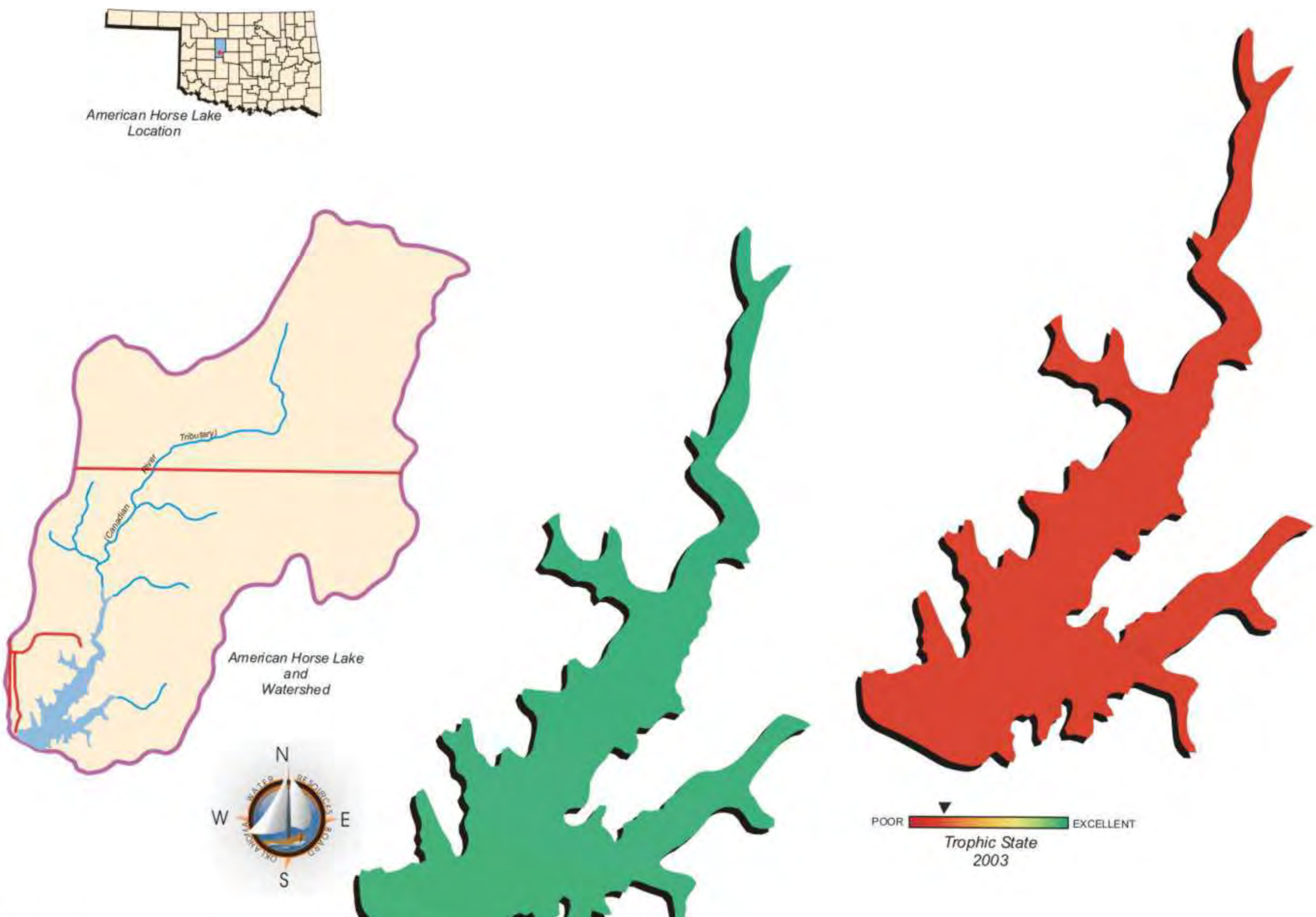


Figure 11a-11f. Graphical representation of data results for American Horse Lake.



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

Arbuckle Reservoir

Arbuckle Reservoir was sampled for four quarters from October 2002 through July 2003. 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 16 units and average secchi disk depth was 127 centimeters. Based on these parameters water clarity at Arbuckle Reservoir was excellent in sample year 2003. 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 48 (Plate 2), indicating the lake was mesotrophic in sample year 2003. The TSI values were fairly consistent and ranged from mesotrophic in the fall, spring and summer quarters to during the winter (Figure 12). Based on spring and summer values only the calculated TSI in 2000 was eutrophic (TSI=55). The lower trophic value in 2003 is probably a more accurate depiction since it is based on data collected year round as opposed to the growing season only. Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. Due to an accident in the lab the minimum data requirements of 20 samples for lakes greater than 250 surface acres were not met and an assessment of the Fish and Wildlife propagation (FWP) beneficial use for turbidity cannot be made at this time; however upon reviewing current and historical data it is likely that the beneficial use would be fully supported. Seasonal true color values are displayed in Figure. All color values were well below the aesthetics OWQS of 70 units (Figure 13b).

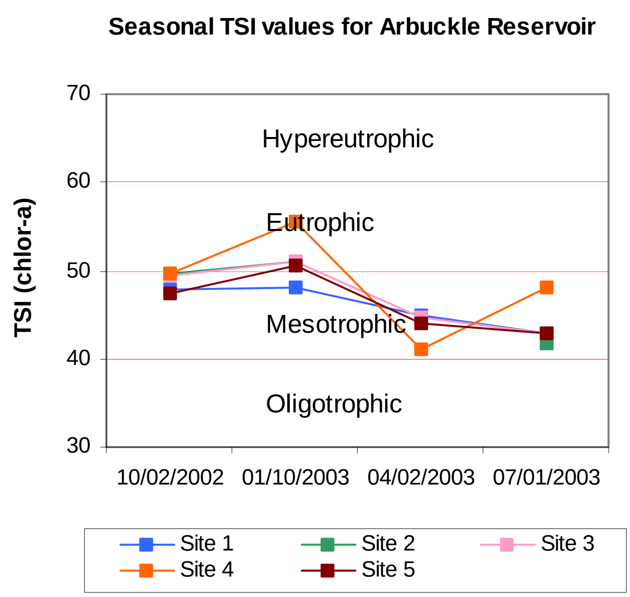


Figure 12. TSI values for Arbuckle Reservoir

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential and salinity were recorded at all sample sites. Salinity ranged from 0.16 ppt to 0.19 ppt. This value is within the average range recorded for Oklahoma lakes. Specific conductivity ranged from 327.7 mS/cm to 394.5 mS/cm, indicating moderate levels of current conducting ions were present in the lake system. The pH values at Arbuckle Reservoir ranged from 6.98 in the fall quarter to 8.27 in the spring representing a neutral to slightly alkaline system. Oxidation-reduction potentials (ORP) ranged from –31 mV at the lake bottom in the fall to 660 mV in the winter. Reducing conditions were present in the fall quarter when anoxic conditions were present for much of the water column. Dissolved oxygen (D.O) levels remained above 7.0 mg/L during the winter and spring sampling quarters (Figure 13d-13e) when the water column was evenly mixed. Thermal stratification was evident and anoxic conditions were present in both the fall and summer quarters (Figure 13c and 13f). In the fall stratification occurred between 10 and 11 meters with dissolved oxygen levels falling below 2.0 mg/L to the lake bottom of 23.8 meters accounting for 60% of the water column at site 1, to be experiencing anoxic conditions. During the summer sampling interval, stratification occurred between 6 and 7 meters at site 1 accounting for 70% of the water column being 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. 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 60% of the water column in the fall and 70% 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 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Arbuckle Reservoir was also sampled for bacteria to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five (5) sites 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 to be supporting.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the surface and 0.97 mg/L at the lake bottom. Surface TN ranged from 0.33mg/L to 0.53 mg/L, with the highest values seen in the fall and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.015 mg/L at the surface and 0.073 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.008 mg/L to 0.019 mg/L. Similar to nitrogen, surface TP was highest in the fall quarter but the low values varied seasonally for both parameters. The nitrogen to phosphorus ratio (TN:TP) was 13:1 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 2002-2003. This classification differs from that in 2000 when the TSI was 55, indicative of eutrophic conditions; however the current classification is based on a larger data set and is likely a more accurate depiction of productivity within the lake. 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 dissolved oxygen levels. Turbidity values were all well below the OWQS of 25 NTU however minimum data requirements were not met and an assessment of the FWP beneficial use cannot be made at this time. Reviewing both current and historical data it is likely that the beneficial use would be fully supported. 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.

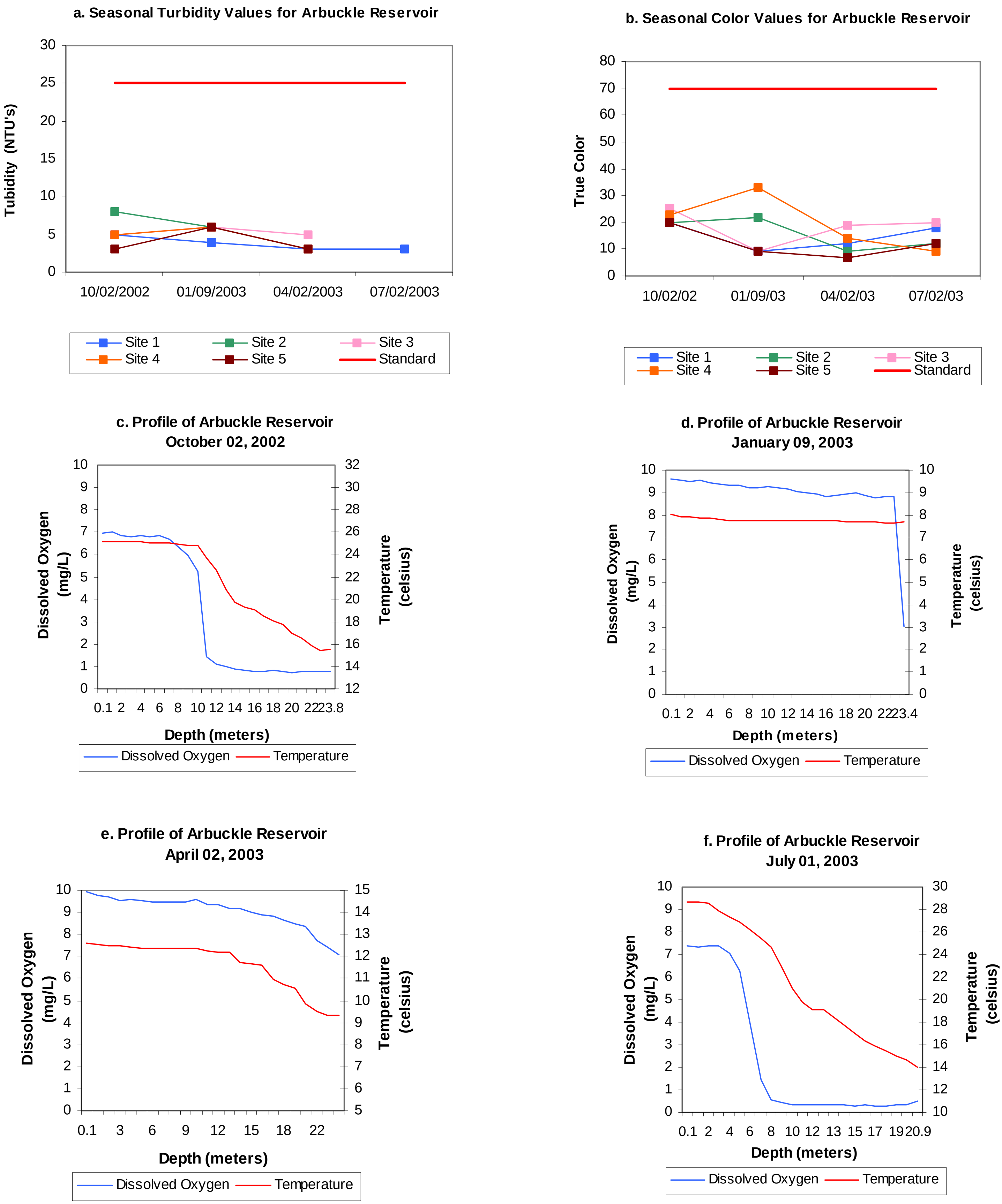
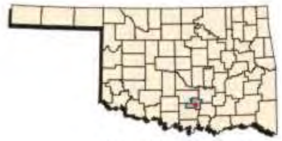
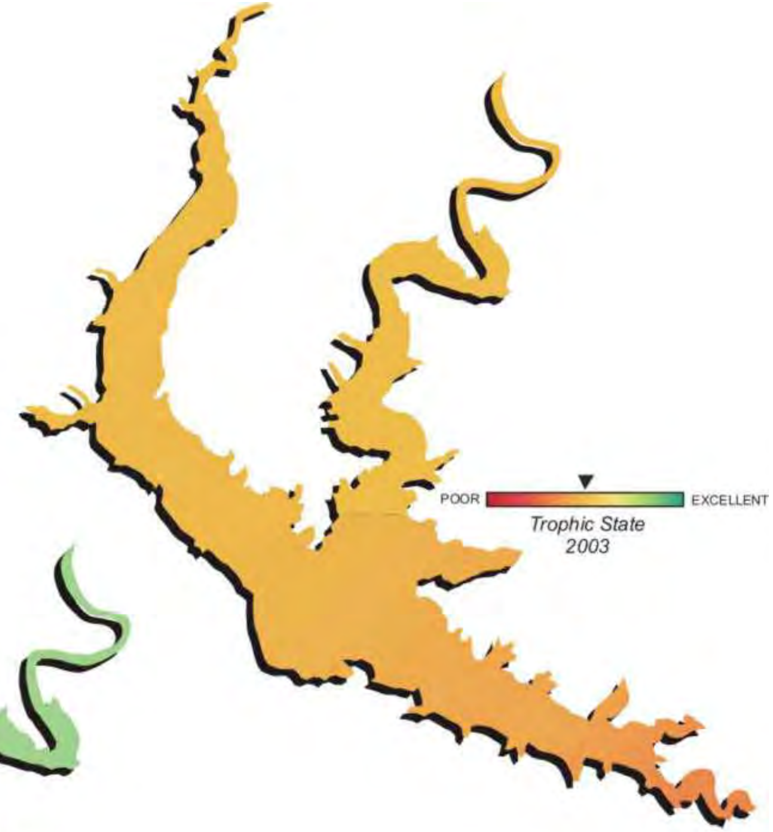


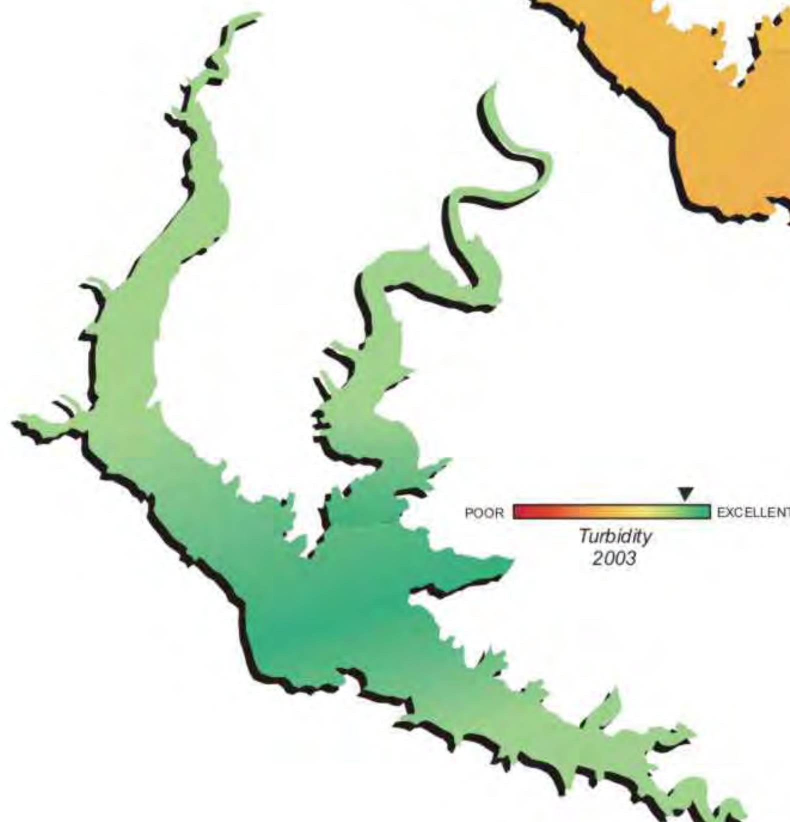
Figure 13a13-f. Graphical representation of data results for Arbuckle Reservoir.

Arbuckle Reservoir and Watershed



Arbuckle Reservoir Location





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

Arcadia Lake

Arcadia Lake was sampled for four quarters, from October 2002 through July 2003. 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 20 NTU (Plate 3), true color was 27 units, and average secchi disk depth was 58 centimeters in sample year 2002-2003. 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 2000. 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 59 (Plate 3), indicating the lake was eutrophic, with high levels of productivity and nutrient conditions for sample year 2003. This value is similar to that calculated in 2000 (TSI=58) indicating no significant change in productivity has occurred. The TSI for all sites varied seasonally and ranged from mesotrophic in the spring to meso-eutrophic in the winter and hypereutrophic in both summer and fall (Figure 14). Seasonal turbidity values by site are displayed in Figure. Although the lake-wide average for turbidity was 20 NTU, below the OWQS of 25 NTU, there are instances when some values were near or above the standard. These spikes in turbidity occurred at sites 4 and 5 in the upper portions of the lake during the fall and spring quarters (Figure 15a). 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 (OWQS) 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 FWP beneficial use is partially supported at Arcadia Lake with 15% of the values above the turbidity standard of 25 NTU. Seasonal true color values are displayed in Figure 15b. All color values are well below the aesthetics OWQS of 70 units.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.19 parts per thousand (ppt) to 0.25 ppt. This is within the average range of values seen in Oklahoma reservoirs. Specific conductance ranged from 333.6 mS/cm to 497.3 mS/cm, indicative of moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 7.07

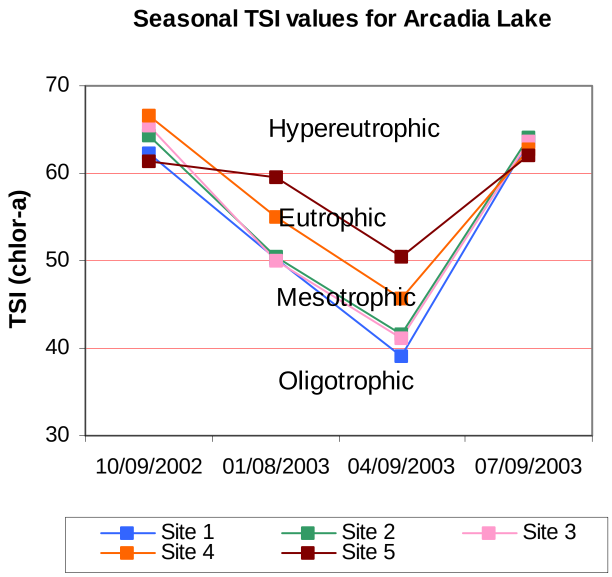


Figure 14. TSI values for Arcadia Lake

in the summer to 8.15 in the fall representing a neutral to slightly alkaline lake system. Oxidation-reduction potentials (ORP) ranged from 215mV in the hypolimnion in the summer to 660 mV in the winter. Reducing conditions were not present at this reservoir during the 2002-2003-sample year. Arcadia Lake was not thermally stratified the in first three sampling quarters (Figure 15c-15e). The lake was stratified and anoxic conditions were present in the hypolimnion during the summer. Stratification occurred at two 1-meter intervals, the first at the 7 to 8 meter depth and again between 8 and 9 meters at which point dissolved oxygen (D.O.) levels dropped below 2 mg/L for the rest of the water column (Figure 15f). 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 35% of the water column experiencing anoxic conditions in the summer months Arcadia Lake is listed as partially 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 2002-2003 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 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.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.73 mg/L at the surface and 0.83 mg/L at the lake bottom. Surface TN ranged from 0.41 mg/L to 0.96 mg/L with the highest values recorded in the spring quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.049 mg/L at the surface and 0.122 mg/L at the lake bottom. Surface TP ranged from 0.016 mg/L to 0.110 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 15:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Arcadia Lake was classified as eutrophic indicative of high primary productivity and nutrient rich conditions. These results are similar to those seen is 2000 indicating no significant increase or decrease in productivity has occurred. Water clarity was average with values for turbidity, true color and secchi disk depth being similar to those recorded in sample year 2000. The lake is currently supporting the FWP beneficial use based on pH, and turbidity, but is partially supporting the beneficial use based on low dissolved oxygen levels in the summer months. The Aesthetics beneficial use is supported based on trophic state and true color values. 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.

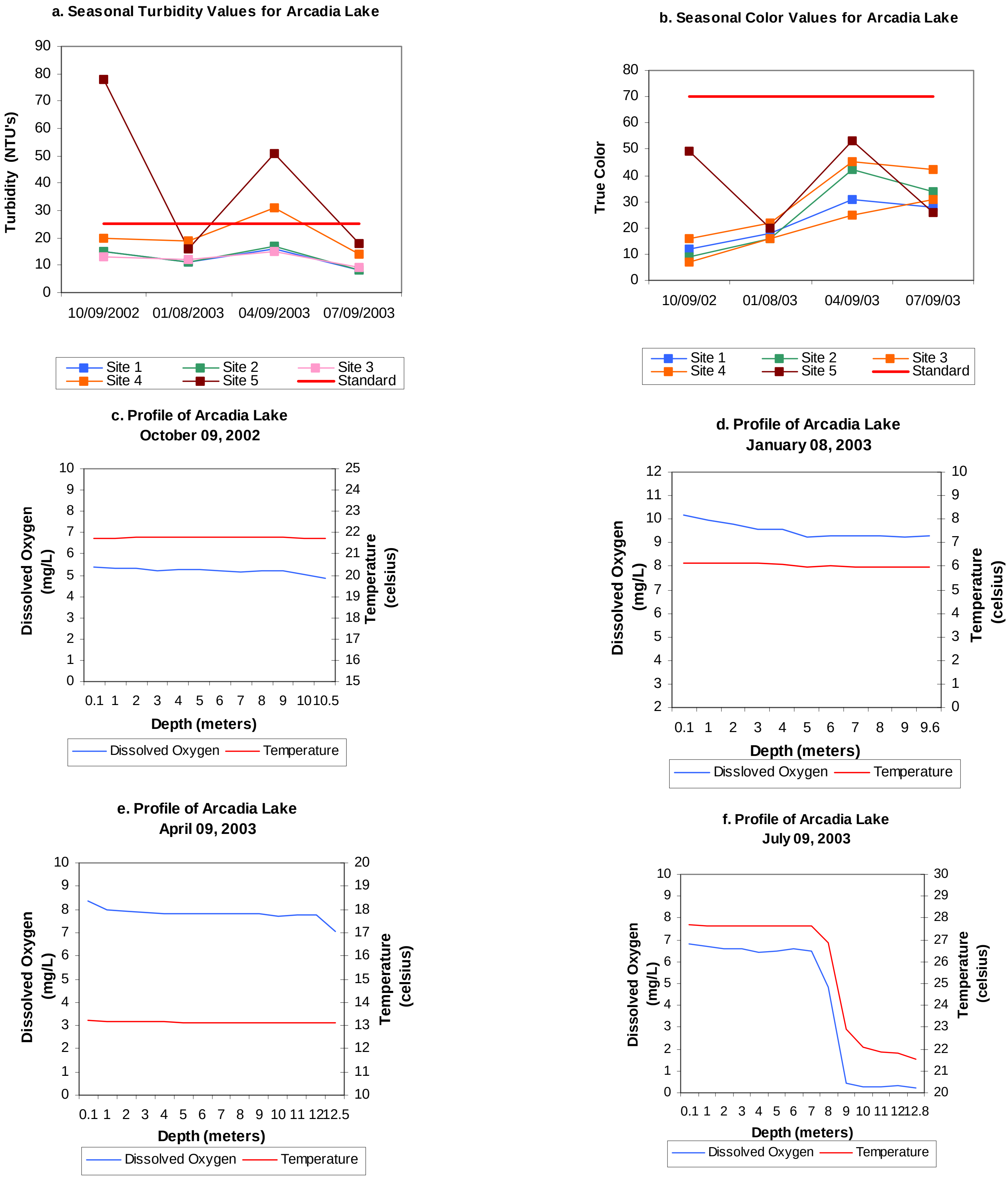
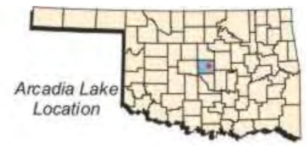
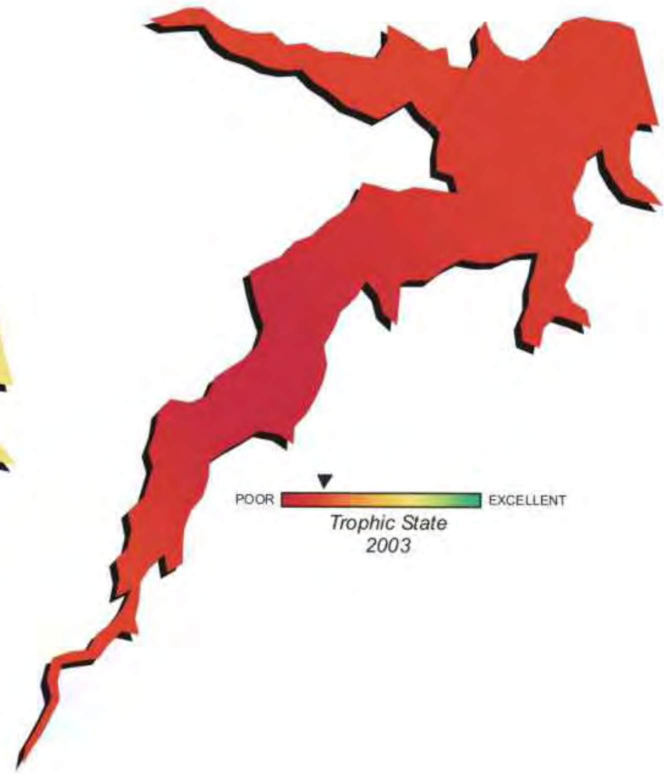
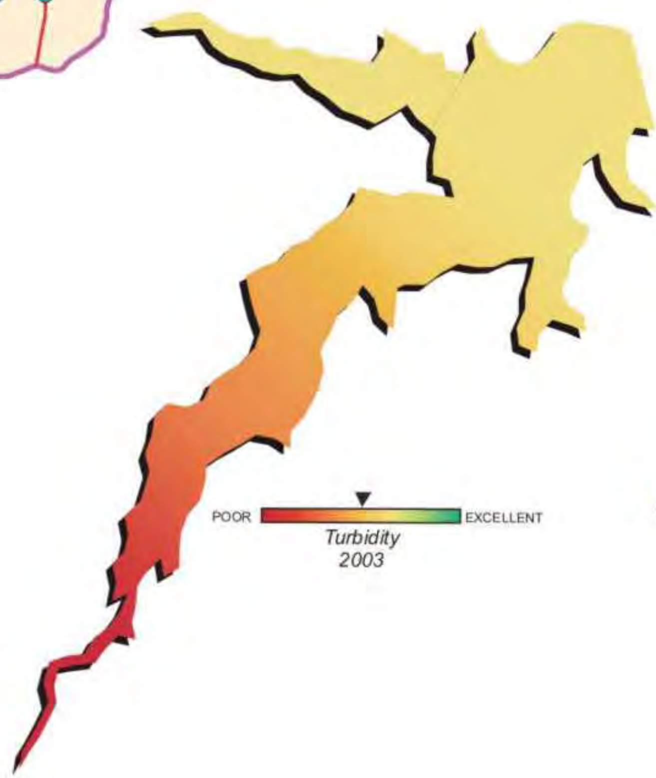


Figure 15a-15f. Graphical representation of data results designed for Arcadia Lake.







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

Ardmore City Lake

Ardmore City Lake was sampled for three quarters, from March 2003 through August of 2003. 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 5 NTU (Plate 4), true color was 19 units, and average secchi disk depth was 128 centimeters in sample year 2001. 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 2001 evaluation. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=9). The TSI was 45 (Plate 4), indicating the lake was mesotrophic in sample year 2003. The TSI values for all sites throughout the sample year varied seasonally ranging from oligotrophic to upper mesotrophic to lower eutrophic (Figure 16). In 2001, the calculated TSI value was also mesotrophic (TSI=49) indicating no significant change in productivity has occurred. All turbidity values were well below the turbidity standard of 25 NTU (Figure 17a) and all color values were well below the aesthetics OWQS for color (70 units). The minimum data requirements were not met for these parameters and attainment of the beneficial uses cannot be assessed at this time, however upon reviewing current and historical data it is likely that the applicable beneficial uses would be fully supported.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.12 parts per thousand (ppt) to 0.19 ppt, which is within the average range of values seen in Oklahoma reservoirs. Specific conductance ranged from 261.2 mS/cm to 372.8 mS/cm, indicative of moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.97 to 8.29 representing a neutral to slightly alkaline lake system. Oxidation-reduction potentials (ORP) ranged from 363mV in the hypolimnion in the spring to 497 mV in the summer. In general, reducing conditions were not present at this reservoir during the 2002-2003-sample year. Thermal stratification was evident and anoxic condition present in both spring and summer sampling quarters. In the spring stratification occurred at several 1-meter intervals with dissolved oxygen concentrations (D.O.) falling below 2.0 mg/L from 6 meters in depth to the lake bottom of 9.8 meters accounting for approximately 45 % of the water column to be experiencing anoxic conditions (Figure 17d). In the summer quarter similar conditions were found, with dissolved oxygen levels less than 2.0 mg/L for greater than 50% of the water column at sites 1 and 2 (Figure 17e). If D.O. values are less than 2.0

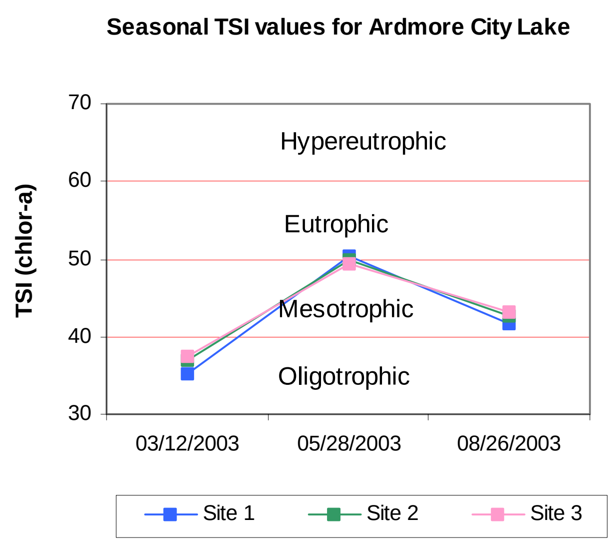


Figure 16. TSI values for Ardmore City Lake

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 partially supporting the FWP beneficial use based on low dissolved oxygen concentrations in the spring and summer.

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.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.44 mg/L at the surface and 1.13 mg/L at the lake bottom. Surface TN ranged from 0.37 mg/L to 0.51 mg/L with the highest values recorded in the summer quarter and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.016 mg/L at the surface and 0.0.046 mg/L at the lake bottom. Surface TP ranged from 0.014 mg/L to 0.022 mg/L was highest in the fall months and the lowest during the summer sampling quarter. The nitrogen to phosphorus ratio (TN:TP) was 27:1 for sample year 2003. 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 2003. These results are similar to those seen in 2001 indicating no significant increase or decrease in productivity has occurred. 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 and partially supporting based on dissolved oxygen. An assessment of the FWP beneficial use could not be made in regards to turbidity due to the minimum data requirements not being met. All true color values were well below the OWQS of 70 units however the minimum data requirements were also not met for this parameter. Ardmore City Lake constructed in 1910 is located in Carter County for the purpose of recreation.

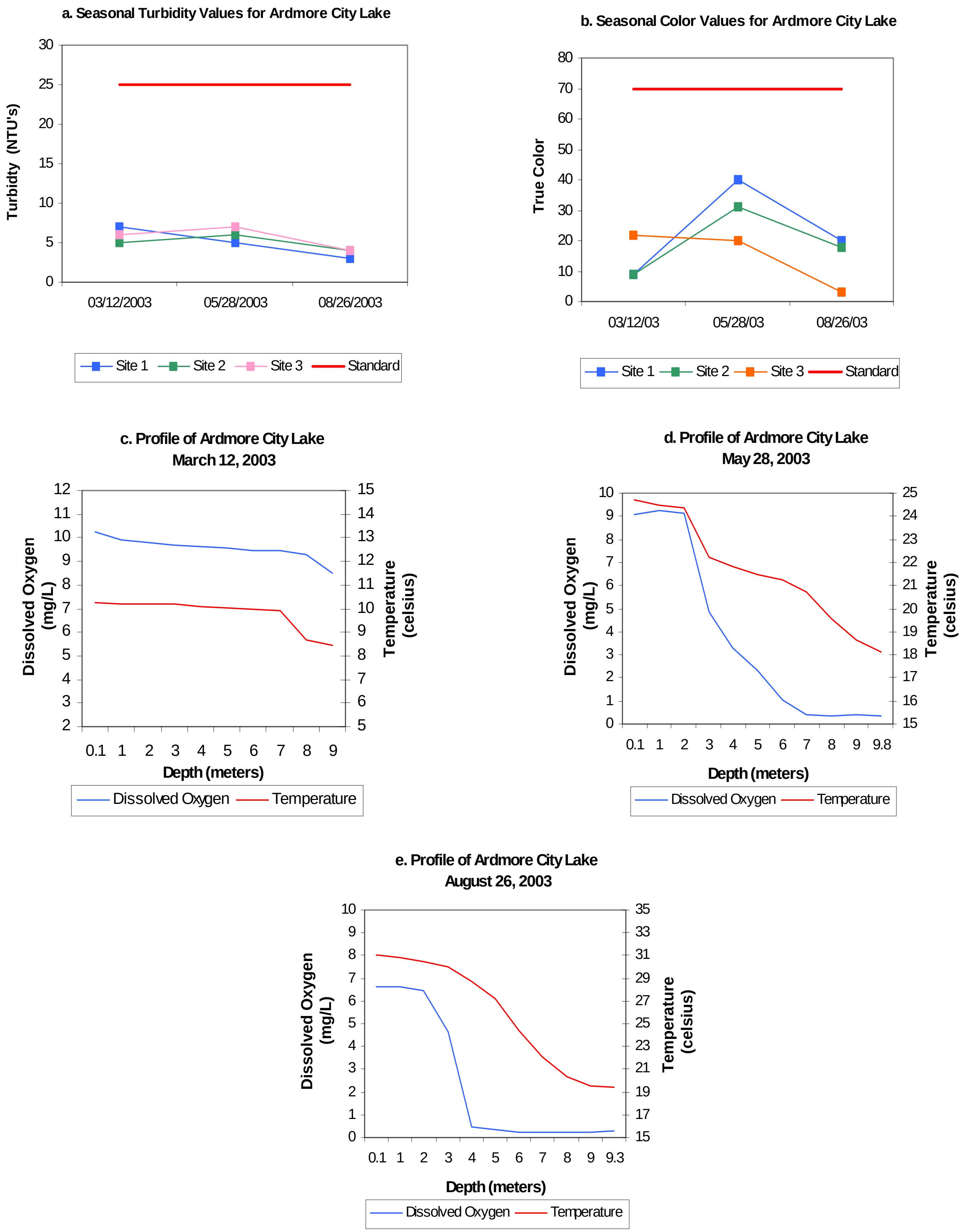


Figure 17a-17e. Graphical representation of data results designed for Ardmore City Lake.

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

Plate 4 - Lake Water Quality for
Ardmore City Lake

Atoka Lake

Atoka Lake was sampled for four quarters, from November 2001 through August of 2002. 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 average lake-wide turbidity was 81 NTU (Plate 5), true color was 243 units, and average secchi disk depth was 21 centimeters in sample year 2001-2002. 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 48 (Plate 5), indicating the lake was mesotrophic in sample year 2001-2002. The TSI values for all sites throughout the sample year were fairly consistent and ranged from upper oligotrophic near the lake dam to lower eutrophic in the upper lake (Figure 19). Seasonal turbidity values per site for sample year 2001-2002 are displayed in Figure 20a. All turbidity values were well above the turbidity standard of 25 NTU with the lowest recorded value being 57 NTU and the maximum value seen being 238 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 (OWQS) 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 there is evidence to suggest that the high turbidity readings are natural based on the local soil conditions. Seasonal true color values are also displayed in Figure 20b. The average lake-wide color was calculated at 243 units, which greatly exceeded the Aesthetics OWQS for color (70 units). The minimum value recorded was 59 units and the maximum value recorded was 405 units. In general color values ranged from 250-300.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites. The salinity values for Atoka Lake ranged from 0.00 parts per thousand (ppt) to 0.03 ppt for this sample year. Specific conductivity ranged from 35.8 to 92.2 mS/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 6.45 units at the lake bottom in the summer to 7.96 at the lake surface in the summer quarter, representing a neutral to slightly acidic system. Oxidation-reduction potentials ranged from 205mV in the hypolimnion in the winter to 451mV in the summer. Reducing conditions were not present at this reservoir in the 2001-2002-sample year. During the fall, winter and spring quarters stratification was not present, the lake

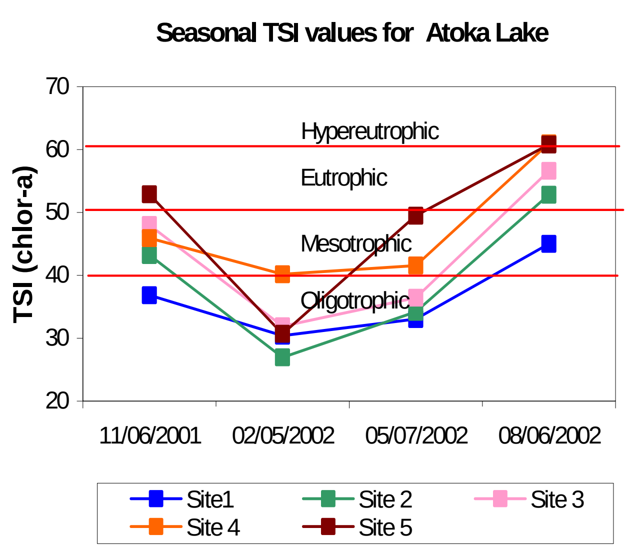


Figure 19. TSI values for Atoka Lake.

was well mixed, and dissolved oxygen values were generally above 7 mg/L see Figure 20a-20f. Thermal stratification was evident in the summer quarter and anoxic conditions were present. Dissolved oxygen (D.O.) was less than 2 mg/L in the hypolimnion, below the thermocline in the summer. The lake was stratified between 10 and 11 meters at which point dissolved oxygen dropped to <2mg/L for the rest of the water column at sites 1 and 2 (see Figure 20a-20f). 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. concentration is less than 2.0 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. Only 44% of the water column was less than 2.0mg/L, therefore the lake is supporting its FWP beneficial use. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.71 mg/L. The TN at the surface ranged from 0.33 mg/L to 1.17mg/L in the upper portion of the lake. Surface TN was highest in the winter and spring quarters and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.096 mg/L. The TP at the surface ranged from 0.038 mg/L to 0.149mg/L. Similar to nitrogen, surface TP was highest in the spring quarter and lowest in the summer. The nitrogen to phosphorus ratio (TN:TP) was approximately 7:1 for sample year 2001-2002. This value is consistent with the 7:1 ratio generally used to determine the limiting nutrient, characterizing the lake as potentially phosphorus-limited to co-limited (Wetzel, 1983).

Atoka Lake was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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, Atoka Lake was classified as mesotrophic with moderate productivity and nutrient levels, in 2001-2002, indicating no significant increase or decrease in lake productivity or nutrient levels has occurred since 1999. 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, but is supporting based on D.O. and 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 21) was generated to determine current storage capacity and identify areas of extreme sedimentaion. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

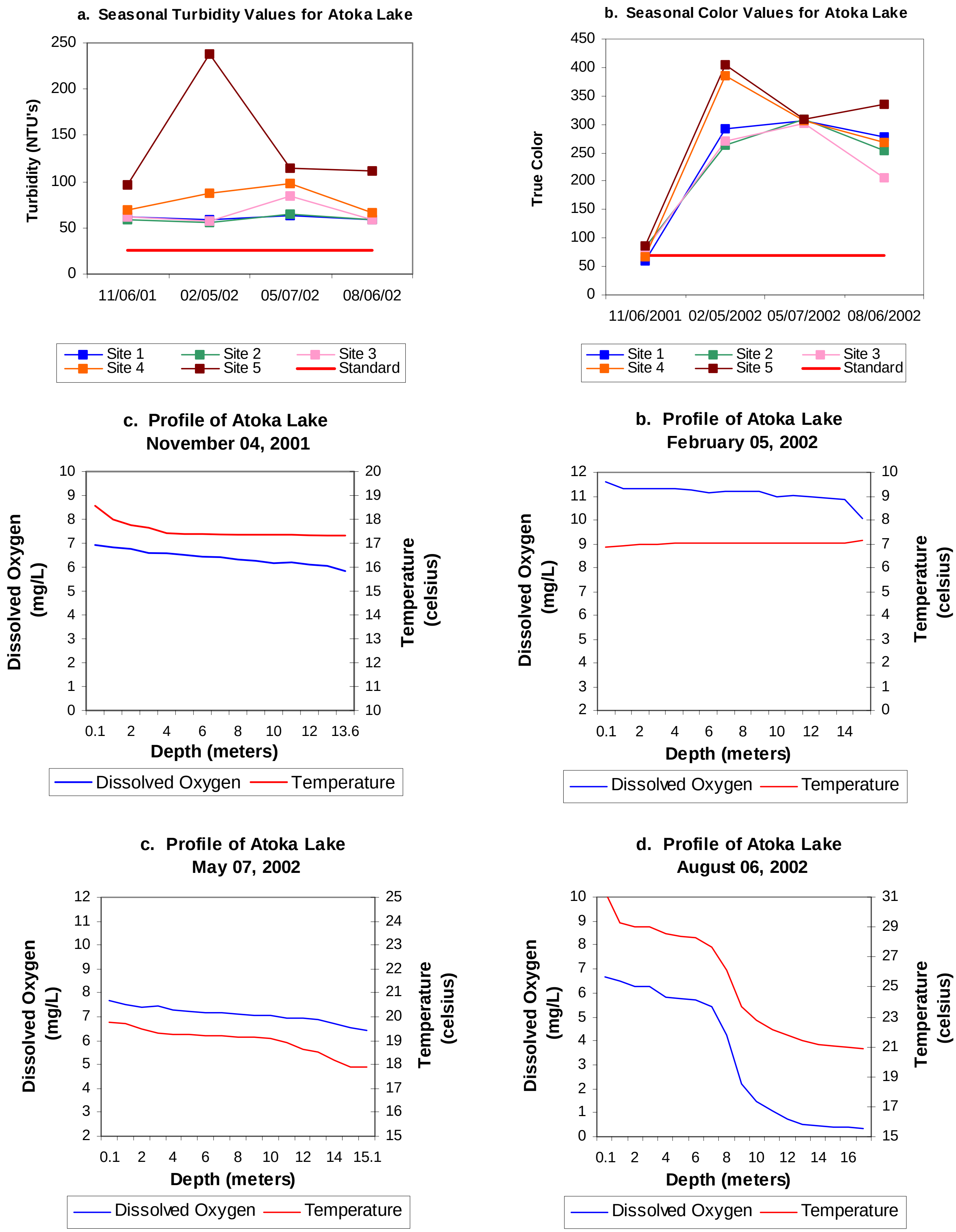
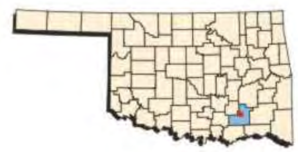


Figure 20a-20f. Graphical representation of data results for Atoka Lake.

Atoka Lake and Watershed



Atoka Lake Location

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

Turbidity 2002

Trophic State 2002

Plate 5 - Lake Water Quality for
Atoka Lake

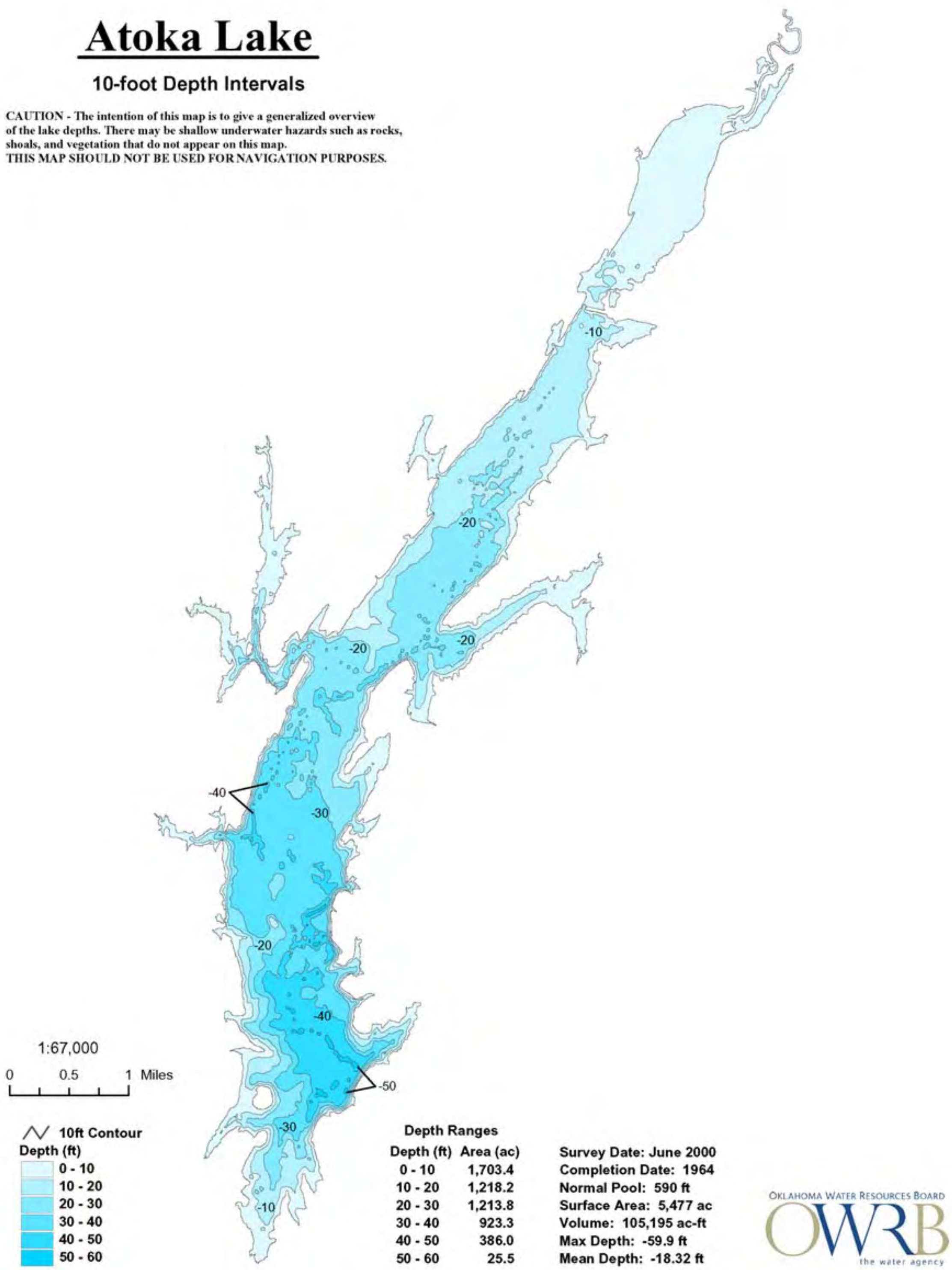


Figure 21. Bathymetric Map of Atoka Lake.

Bellcow Lake

Bellcow Lake was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 at the lake surface for turbidity and chlorophyll-a analysis to meet minimum data requirements. 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 17 NTU (Plate 6), true color was 28 units, and average secchi disk depth was 63 centimeters in sample year 2001-2002. Water clarity was average based on the secchi disk depth, and relatively high turbidity values. True color values were excellent throughout the reservoir. Results for these parameters are similar to results found in previous sampling events although in historical values were based on summer sampling only. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites plus two additional sites which were sampled solely for chlorophyll-a. Sampling occurred for four quarters (n=20). The TSI was 52 (Plate 6), indicating the lake was slightly eutrophic in sample year 2001-2002. The TSI values for all sites throughout the sample year varied from lower mesotrophy to upper eutrophy (Figure 22). According to seasonal observations, Bellcow Lake is typically upper mesotrophic to lower eutrophic in the fall, winter and spring and is at the high end of eutrophy during the warmer summer months. Turbidity values for sample year 2001-2002 are displayed in Figure 23a. For the fall, winter, spring, and summer quarters, turbidity values were well below the Oklahoma Water Quality Standards (OWQS) of 25 NTU with the exception of the sites located in the upper end of the lake which exceeded the OWQS in the spring and 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 the OWQS (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 partially supporting its Fish & Wildlife Propagation (FWP) beneficial use for turbidity with 10% of the collected values exceeding 25 NTU. Seasonal true color values are displayed in Figure 23b. All true color values were well below the Aesthetics OWQS of 70 units; therefore the beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity readings ranged from 0.15 parts per thousand (ppt) to 0.17 ppt throughout sample year 2001-2002 at all sites. Specific conductivity values were moderate in nature, ranging from 305.5 mS/cm at the lake surface in the winter to 354.9 mS/cm at the lake bottom in the fall. These values are comparable to levels seen in most Oklahoma reservoirs, indicating there is moderate to slightly elevated amounts of salts or ions in Bellcow Lake. Values for pH ranged from 7.16 in the hypolimnion in the summer quarter to 9.5 units seen throughout the water column in the winter quarter. Generally, most of the water column throughout the year ranged from 7.5 to 8.0 units, indicating the lake was neutral to slightly alkaline in nature. Of the pH values collected, 25% exceeded the numerical pH

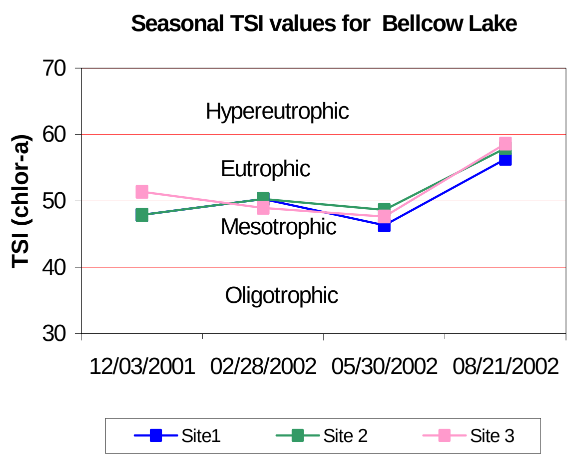


Figure 22. TSI values for Bellcow Lake.

criteria for FWP specified in OAC 785:45-5-12. According to Use Support Assessment Protocols (USAP) in OAC 785:46-15-5, pH values that fall outside the 6.5 to 9.0 numerical criteria range for 25% of the values the FWP beneficial use is not being met. As the lake has not been impounded for very long, high pH conditions may be due to natural processes occurring; therefore, Bellcow Lake will be listed as "provisionally not supporting"*****. Oxidation-reduction potentials (redox) ranged from 139 mV to 473 mV, indicating the absence of reducing conditions. In the summer, a thermocline was present between 5 and 6 meters, at which point the dissolved oxygen (D.O.) values dropped below 1.0mg/L to the lake bottom (Figure 23c-22f). A thermocline was not present in the fall or winter quarters and the water was well mixed, with dissolved oxygen values above 8.0 mg/L throughout the water column. In the spring, a weak thermocline was present near the lake bottom. 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 40% of the water column experiencing anoxic conditions the lake is considered fully supporting its FWP beneficial use. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.88 mg/L. The epilimnetic (surface) TN ranged from 0.85 mg/L to 1.00 mg/L. TN was highest in the spring quarter and lowest in the winter though there wasn't a significant spread in the data collected. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.077 mg/L. The TP ranged from 0.024 mg/L to 0.138 mg/L. TP was highest in the fall and lowest in the winter. The nitrogen to phosphorus ratio (TN:TP) was 11:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Bellcow was sampled for metals at three sites during the spring of 2002. Support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Bellcow Lake was slightly eutrophic, exhibiting moderate to high primary productivity and nutrient levels, consistent with results from historical data collection efforts. The lake was fully supporting its Aesthetics beneficial use based on true color and trophic state findings (for nutrients). The lake was fully supporting its FWP beneficial use based on turbidity and D.O. concentrations, but will be listed as partially supporting based on pH 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.

***** Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

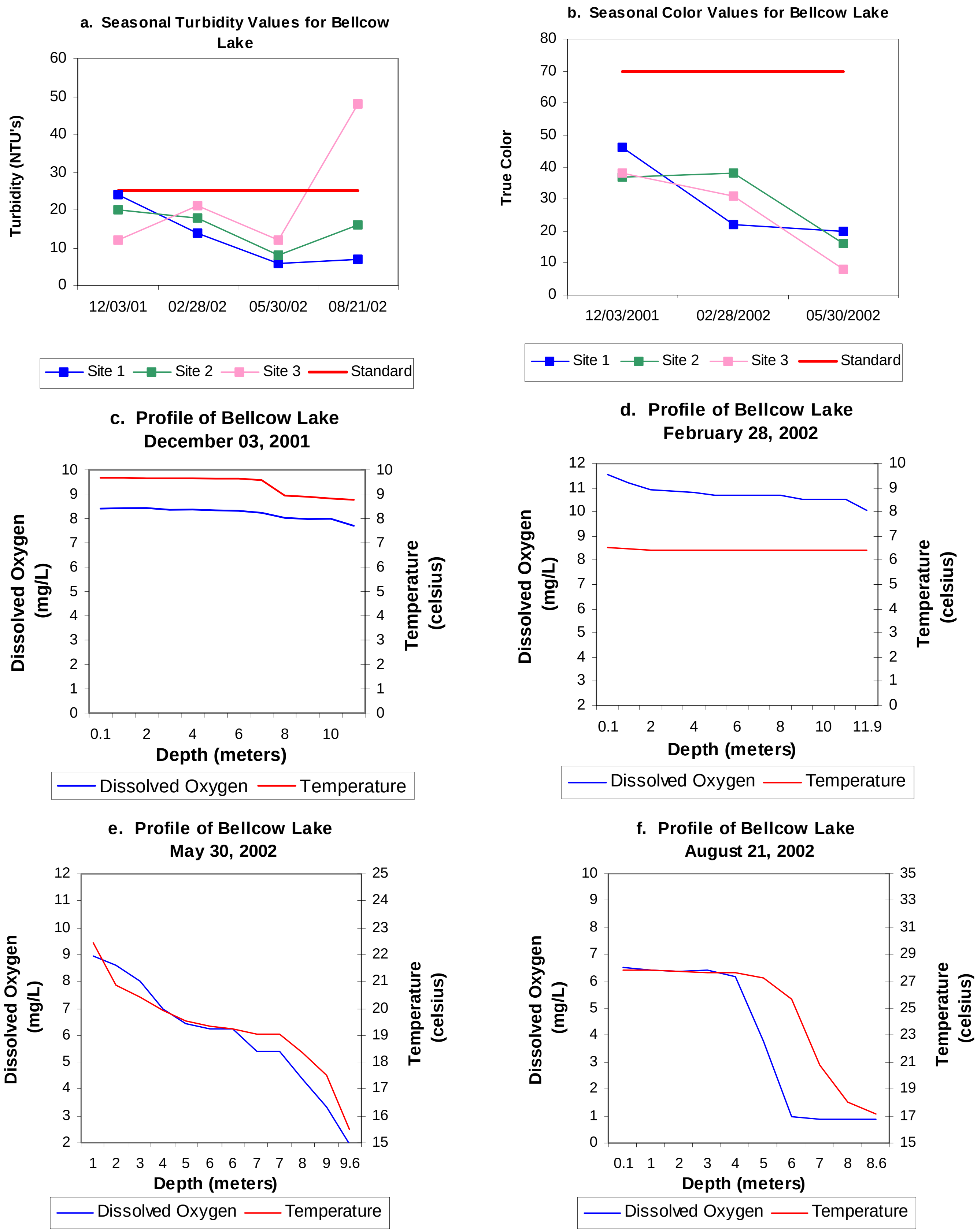


Figure 23a-22f. Graphical representation of data results for Bellcow Lake.

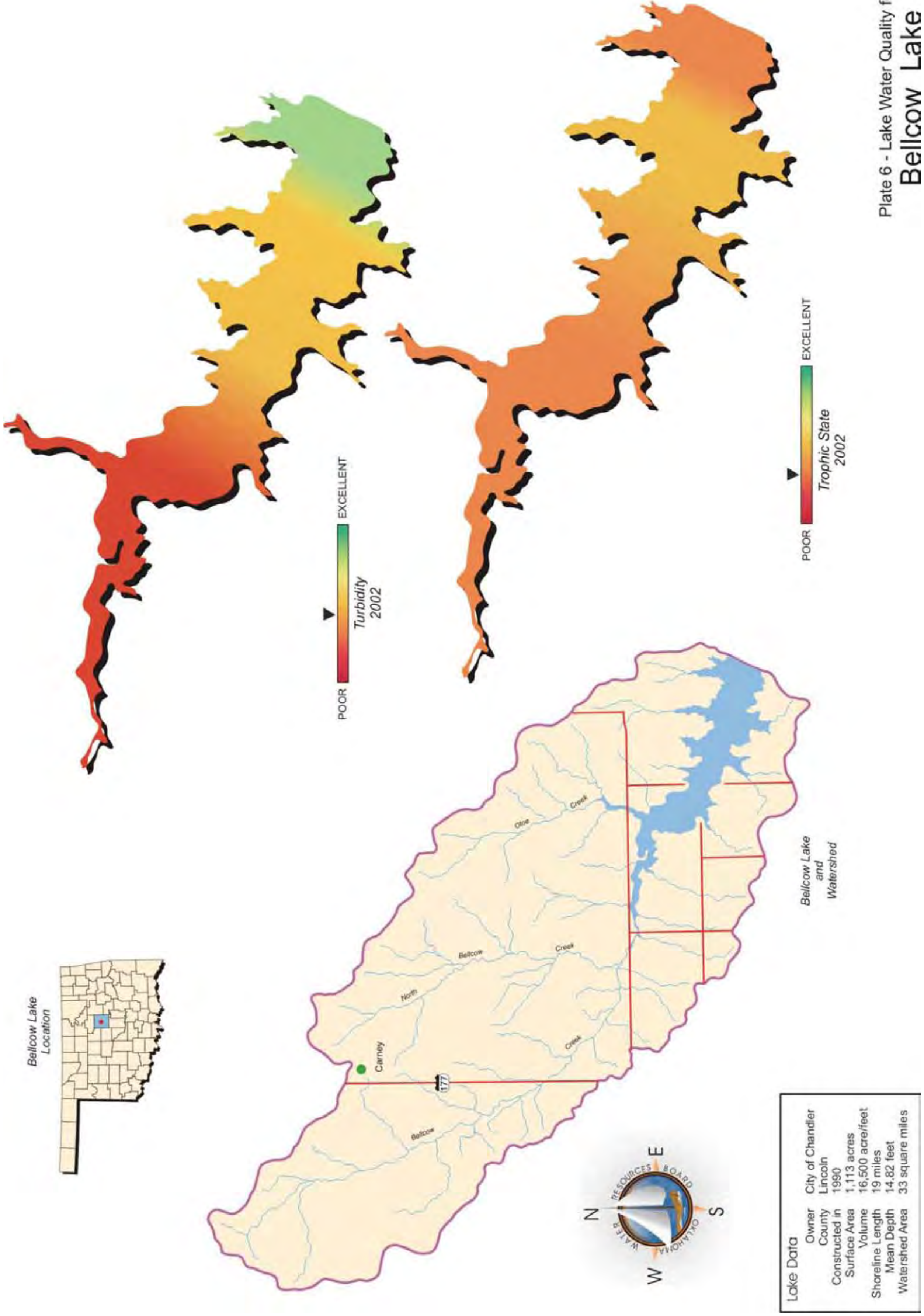


Plate 6 - Lake Water Quality for
Bellcow Lake
Bellcow Lake Location
POOR
EXCELLENT
Turbidity
2002
POOR
EXCELLENT
Trophic State
2002
Bellcow Lake and Watershed
Carney
177
Bellcow
North
Bellcow
Creek
Creek
Otoe
Creek
W
N
E
S
WATER RESOURCES BOARD
OKLAHOMA
Lake Data
Owner City of Chandler
County Lincoln
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

Birch Lake

Birch Lake was sampled for four quarters, from October 2002 through July 2003. 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 17 NTU, true color was 56 units and average secchi disk depth was 85 centimeters in sample year 2002-2003. 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 47 (Plate 7), indicating the lake was mesotrophic in sample year 2002-2003. The TSI values for all sites throughout the sample year were fairly consistent and ranged from upper oligotrophic to eutrophic (Figure 24). Seasonal turbidity values per site are displayed in Figure 25a. 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 (OWQS) 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 samples collected, 25% of the turbidity values were above the turbidity standard of 25 NTU therefore the Fish and Wildlife Propagation (FWP) beneficial use is considered partially supported based on turbidity. Seasonal true color values are also displayed in Figure 25b. Of the 20 samples collected at Birch Lake 28% of the true color values exceeded the OWQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is partially supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation- reduction potential and salinity were recorded at all five sample sites during the sample year. Salinity values ranged from 0.05 parts per thousand (ppt) in the spring to 0.10 ppt in the fall. Specific conductance ranged from 125.5 mS/cm to 217.1 mS/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 6.42 units to 7.84 units. Oxidation-reduction potentials ranged from 56 mV in the fall to 609 mV in the summer. In general, reducing conditions were not present with all recorded values above 100 mV with the exception of two values recorded at the

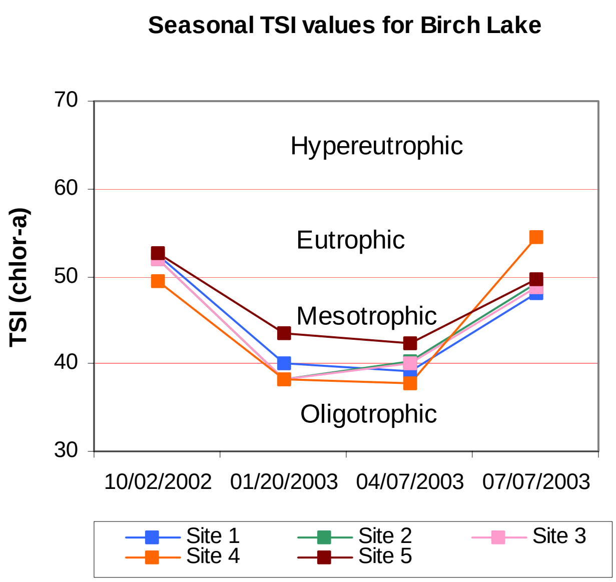


Figure 24. TSI values for Birch Lake.

lake bottom at the dam. Dissolved oxygen (D.O.) levels remained above 7.0 mg/L during the winter and spring sampling quarters (see Figure 25d-23e) 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 several 1-meter intervals but dissolved oxygen concentrations fell below 2.0 mg/L between 10 and 11 meters in depth, accounting for 27% of the water column at site 1 to be anoxic. During the summer sampling interval stratification occurred between 4 and 5 meters at sites 1, 2, and 4. At these sites anoxic conditions were present for 45 to 55% of the water column (see Figure 25f). 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 2002-2003 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.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.55 mg/L at the surface and 0.65 mg/L at the lake bottom. Surface TN ranged from 0.29 mg/L to 0.80 mg/L with the highest values recorded in the summer quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.025 mg/L at the surface and 0.033 mg/L at the lake bottom. Surface TP ranged from 0.007 mg/L to 0.059 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 22:1 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. 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 on turbidity and dissolved oxygen and supporting based on pH values. Birch Lake is supporting the Aesthetics beneficial use based on its trophic status, but only partially supporting the use with 28% of the true color values exceeding the OWQS of 70 color units. 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.

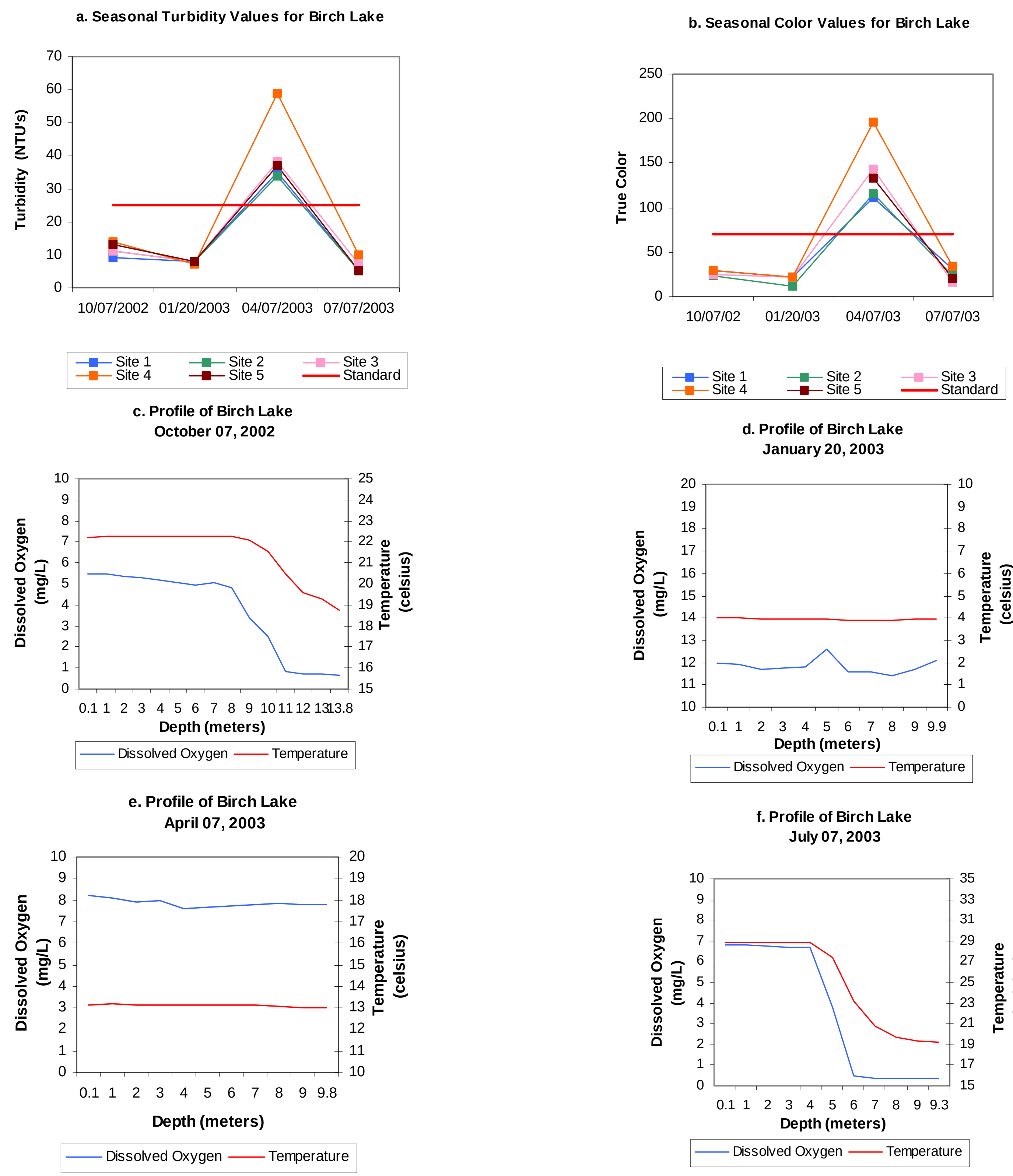
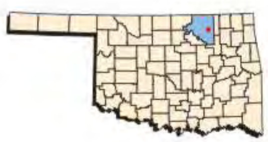
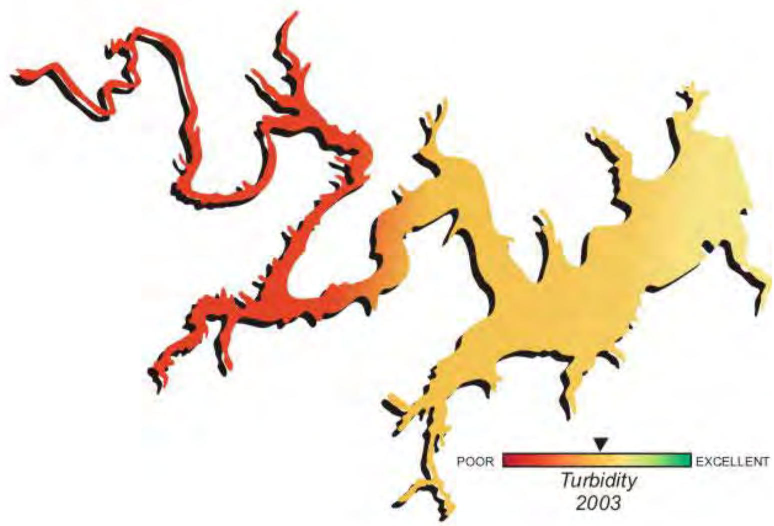


Figure 25a-23f. Graphical representation of data results for Birch Lake.





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

Lake Bixhoma

Lake Bixhoma was sampled for four quarters, from October 2002 through July 2002. Water quality samples were collected at three (3) 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 8), true color was 34 units, and average secchi disk depth was 117 centimeters in sample year 2001-2002. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. 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 47 (Plate 8), indicating the lake was mesotrophic in sample year 2001-2002. The TSI values throughout the sample year were mesotrophic with only one eutrophic spike occurring in the winter (see Figure 26). Based on three summer values in 1997, the calculated TSI value was oligotrophic (TSI=39), much lower than the 2001-2002 evaluation. The higher trophic value in 2001-2002 was probably a more accurate depiction since it was based on data collected year-round as opposed to one season. All turbidity values per site for sample year 2001-2002 were all 11 NTU or less, well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 27a). 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 OWQS (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 also displayed in Figure 27b. All true color values were below the Aesthetics OWQS of 70 units and were consistent throughout all four-sample quarters. The lake was fully supporting its Aesthetics beneficial use as it relates to true color.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, 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 0.03 ppt, which is lower than most of the salinity values recorded in Oklahoma lakes. Specific conductance values ranged from 14.6 to 91.2 mS/cm, also indicating the salt content and ion level in the system is negligible. Values for pH were generally neutral, ranging from 6.14 in the summer to 7.41 in the fall. According to the Use Support Assessment Protocols (USAP) outlined in 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 should be listed as not supporting beneficial uses. 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 beneficial uses. The low pH values recorded primarily in the fall and summer at Lake Bixhoma may be due to natural conditions, and will be listed as "provisionally partially supporting"* the FWP beneficial use. Oxidation-reduction potentials (ORP) were positive at all sample sites and ranged from 194mV in the spring up to 592mV in the fall. Other than one value at site 2 in the spring quarter, all other ORP values were above 200mV. In general, reducing conditions were not

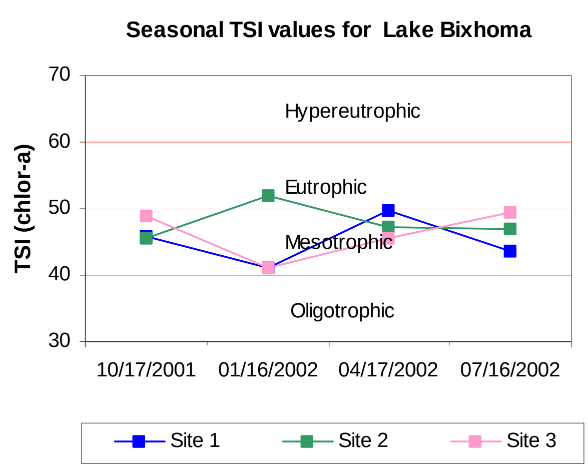


Figure 26. TSI values for Lake Bixhoma.

present in the reservoir. Bixhoma was thermally stratified in the fall of 2001 with 65% of the water column having a dissolved oxygen (D.O.) concentration below 2.0 mg/L (see Figure 27c). The lake was also thermally stratified in the summer between 2 and 3 meters from the lake surface with dissolved oxygen concentrations less than 1.0mg/L from that point to the lake bottom at 17.3 meters. D.O. values ranged from 5.65 mg/L at the surface in the summer down to 0.70 mg/L at the lake bottom. 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. The D.O. values in the winter and spring were above 9 mg/L and 6.3 mg/L, respectively (see Figure 27d-26e). During the summer, the D.O. values dropped to <1.0 mg/L at the 3-meter depth extending to the lake bottom at all sites. Therefore, the FWP beneficial use is considered not supported with 83% of the water column anoxic at site 1. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these variables. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.44 mg/L. The TN at the surface ranged from 0.14 mg/L to 0.74 mg/L. The highest surface TN was in the spring quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.034 mg/L. The TP ranged from 0.009 mg/L to 0.200 mg/L. Surface TP was highest in the summer and lowest in the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 13:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Bixhoma was sampled for metals at three sites during the spring of 2002. Use support assessment for metals is made in the same fashion as turbidity. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Lake Bixhoma was classified as mesotrophic in 2001-2002, indicative of moderate primary productivity and moderate nutrient conditions (Plate 8). Water clarity was excellent and the FWP beneficial use was fully supported as it relates to turbidity. The lake was only partially supporting the FWP use related to pH and it was not supporting its FWP based on D.O. values (OAC 785:46). The lake is fully supporting its Aesthetics beneficial use based on true color data and trophic status. Lake Bixhoma is owned by the City of Bixby and was constructed in 1965 to serve as a water supply and recreational outlet for the public to use.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

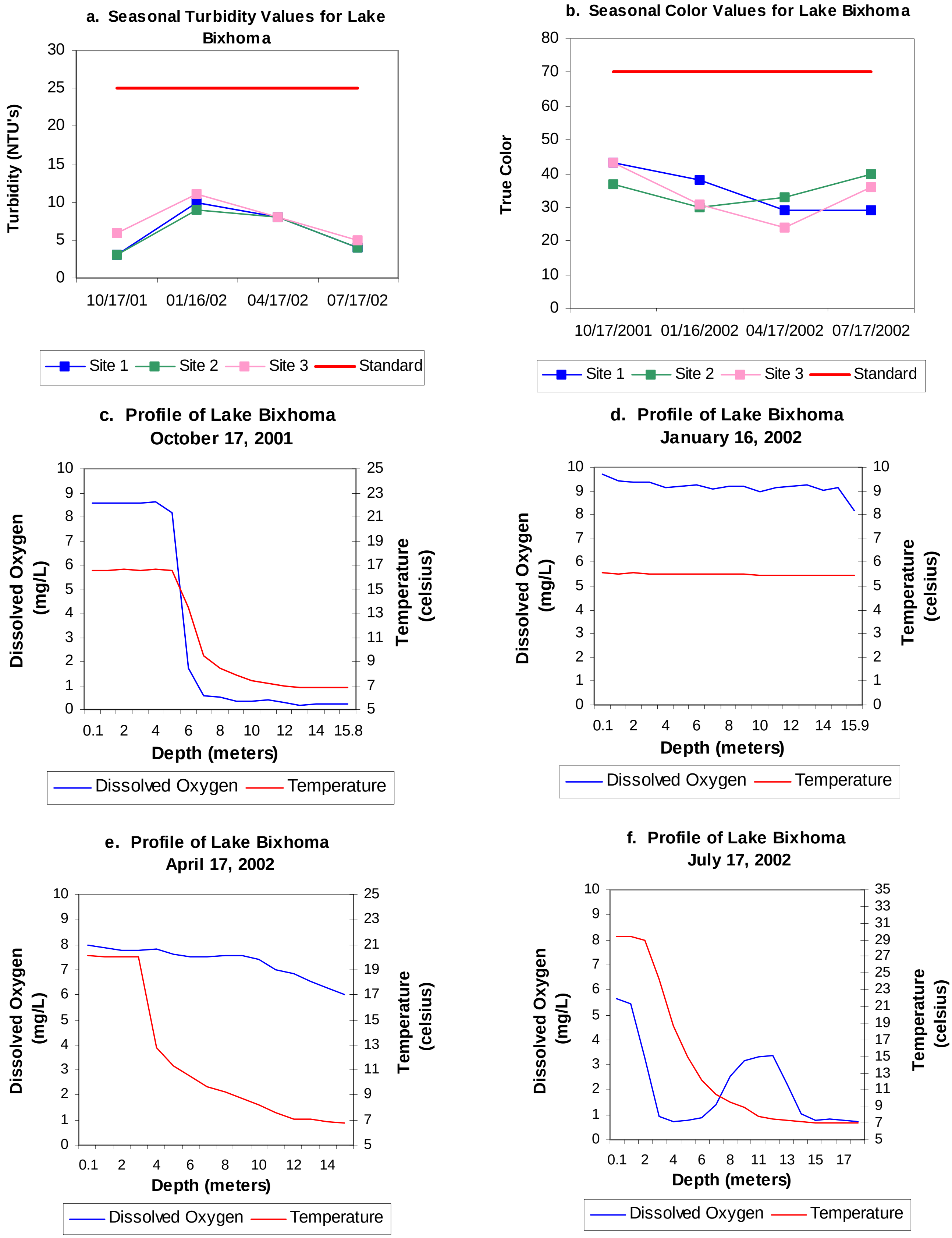


Figure 27a-26f. Graphical representation of data results for Lake Bixhoma.

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

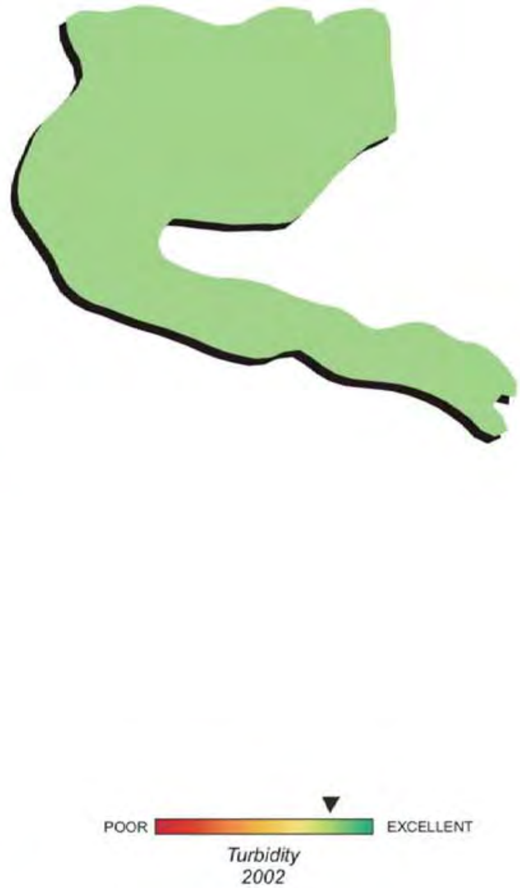


Plate 8 - Lake Water Quality for
Bixhoma Lake

Bluestem Lake

Bluestem Lake was sampled for four quarters, from October 2001 through August 2002. Water quality samples were collected at four sites to represent the riverine, transitional, and lacustrine zones. Additional samples were collected at site 5 for chlorophyll-a and turbidity analysis to meet minimum data requirements. Water quality samples were collected from the lake surface at all sites (with the exception of site 5) and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity was 26 NTU (Plate 9), true color was 36 units, and average secchi disk depth was 52 centimeters in 2001-2002. Water clarity was average based on secchi disk depth and turbidity. Results for these parameters were similar to historical lake sampling results. A trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=25). The TSI was 45 (Plate 9), indicating the lake was mesotrophic, bordering oligotrophic, in sample year 2001-2002. The TSI values throughout the sample year were primarily mesotrophic with oligotrophic values at all sites in the spring of 2002 (see Figure 28). Turbidity values fluctuated greatly throughout the year with the lowest values recorded in the winter quarter and the highest values recorded in the spring quarter (see Figure 29a). Approximately 65% of the turbidity values for 2001-2002 were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, with 35% of the values exceeding the numerical criteria. Although there was an evident increase in the fall and spring quarters, when storm events resulting in runoff are more common (see Figure 29). 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 OWQS (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. Bluestem Lake is considered not supporting its Fish & Wildlife Propagation (FWP) beneficial use due to high turbidity concentrations. Seasonal true color values are displayed in Figure 29b. All true color values were below the aesthetics OWQS of 70 units with the exception of the spring sampling results where values slightly exceeding the criteria were detected. The Aesthetics use support for true color could not be assessed however due to insufficient data. Available data suggests the lake would fully support its Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values were consistent throughout the water column for each quarter, ranging from 0.07 parts per thousand (ppt) to 0.14 ppt. Readings for specific conductance were relatively consistent throughout the water column for each quarter, ranging from 151.7 mS/cm (spring) to 283.9 mS/cm (winter). Both salinity and conductivity values were consistent with values seen in other Oklahoma reservoirs, indicating very low to moderate levels of current conducting compounds or salts were present. The pH values ranged from 6.98 units in the spring to 8.08 units in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if >25% of the recorded values fall outside the 6.5

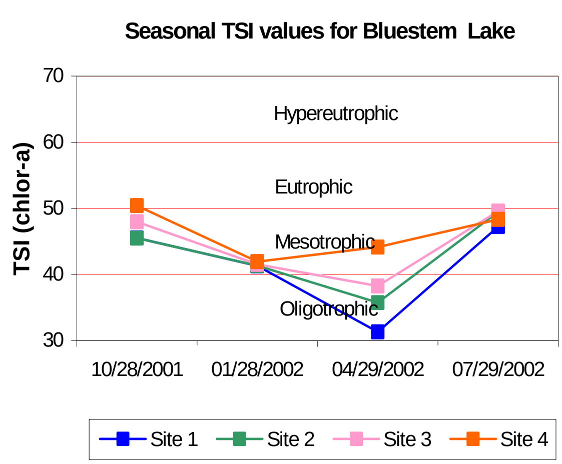


Figure 28. TSI values for Bluestem Lake.

to 9.0 and the lake should be listed as not supporting beneficial uses. 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 beneficial uses. All pH values recorded were within the range therefore meeting the FWP beneficial use. The oxidation-reduction potential (redox) was fairly constant during each sampling interval, ranging from 84 mV to 527 mV, indicating an absence of reducing conditions. Bluestem Lake was well mixed in the fall, winter and spring quarters with thermal stratification absent and dissolved oxygen (D.O.) concentrations above 3.5 mg/L in all instances with most of the values recorded in the 7.0 - 8.5-mg/L range (see Figure 29a-28f). The lake was thermally stratified in the summer between 5 and 6 meters below the surface. D.O. levels were below 2.0 mg/L from 6 meters to the lake bottom at 17.8 meters. The lake was anoxic (<2.0 mg/L) for approximately 68% of the water column at site 1, the dam (see Figure 29c-28f). 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 Bluestem Lake. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these variables. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.53 mg/L at the surface. The TN at the surface ranged from 0.33 mg/L to 0.73 mg/L. Surface TN was highest in the winter and lowest in the summer quarter. The lake-wide total phosphorus (TP) average was 0.035 mg/L at the surface. The total phosphorus ranged from 0.015 mg/L to 0.075 mg/L at the surface. Surface TP was highest in the spring and lowest in the winter. The nitrogen to phosphorus ratio (TN:TP) was approximately 15:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Bluestem Lake was also sampled for metals at four sites during the spring of 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) 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). Water clarity was average and the standard for true color was being met. With 35% of the values exceeding the numerical criteria Bluestem Lake is not supporting its FWP beneficial use due to high turbidity concentrations and is partially supporting its FWP beneficial use based on D.O. values (OAC 785:46). The lake is fully supporting its FWP based on pH concentrations in the water column. Bluestem is fully supporting its Aesthetics beneficial use based on trophic status and true color support cannot be assessed. Bluestem Lake is the municipal water supply reservoir for the City of Pawhuska and is also utilized for flood control and recreational purposes.

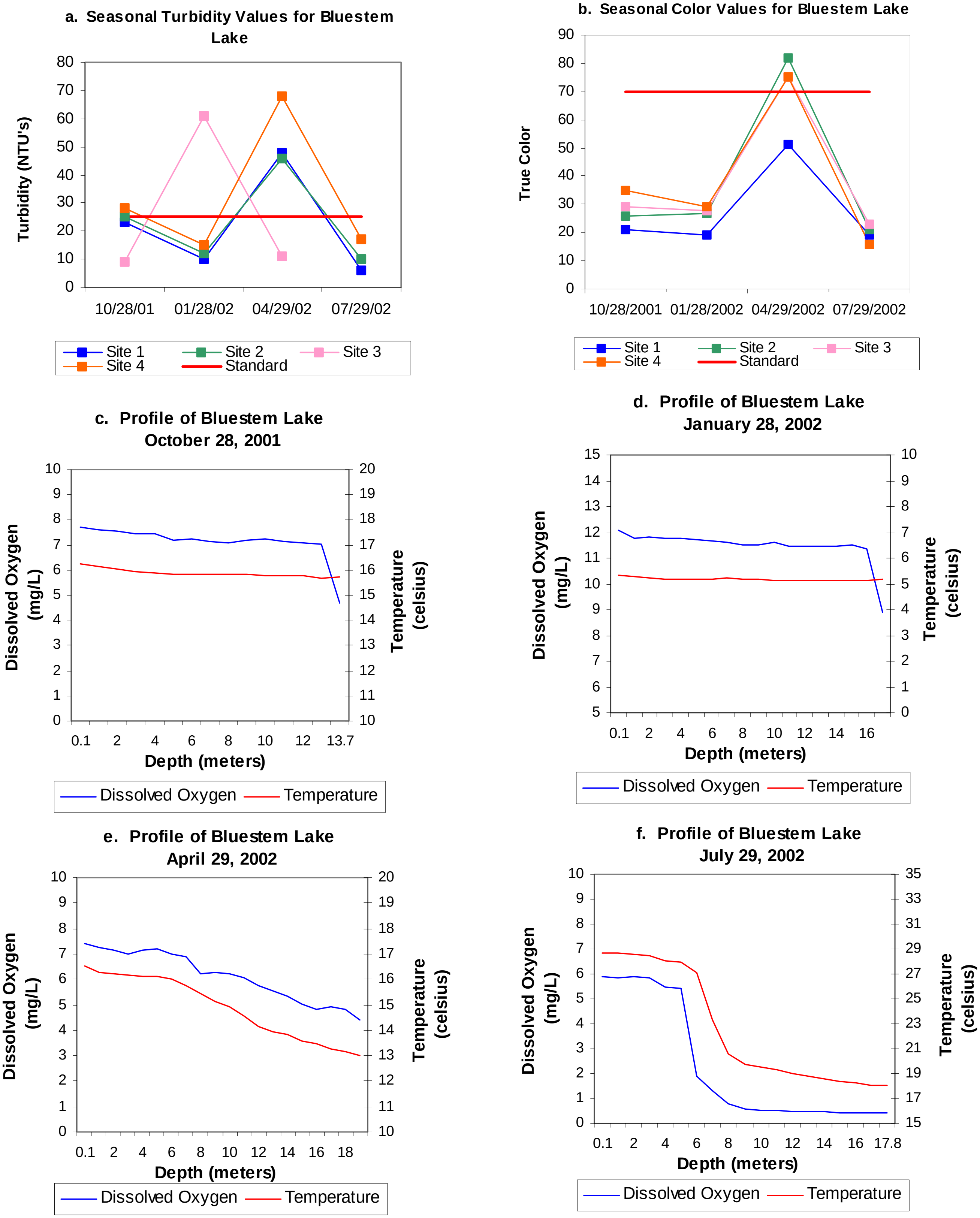


Figure 29a-28f. Graphical representation of data results for Bluestem Lake.

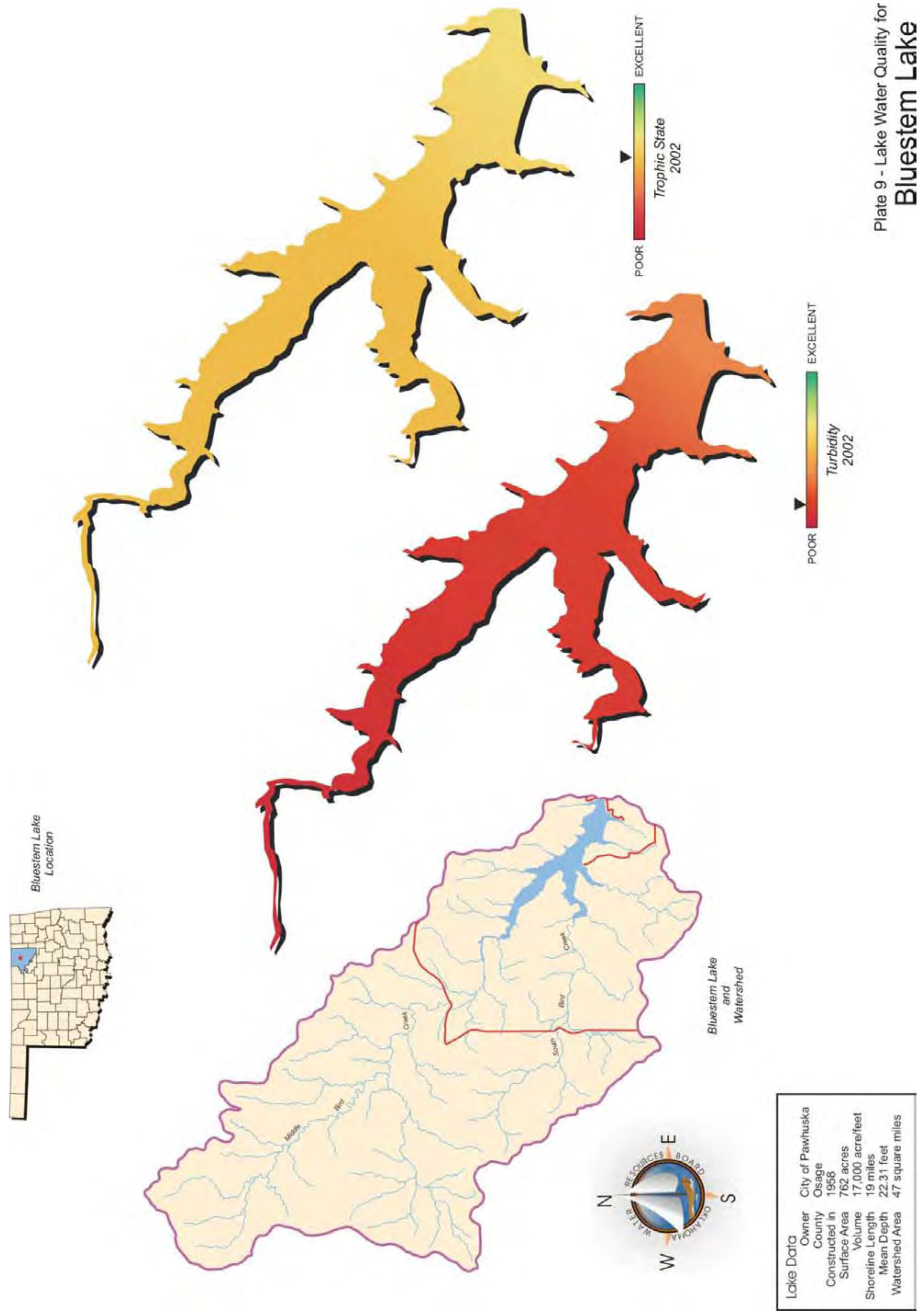


Plate 9 - Lake Water Quality for Bluestem Lake

Boomer Lake

Boomer Lake was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 for chlorophyll-a and turbidity analysis to meet minimum data requirements. 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 20 NTU (Plate 10), true color was 37 units, and average secchi disk depth was 50 centimeters in 2001-2002. Water clarity was average to slightly poor based on these three parameters. 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 49 (Plate 10), indicating the lake was mesotrophic in sample year 2001-2002. The TSI values throughout the sample year varied from upper oligotrophy to lower eutrophy. Not surprisingly, during the winter months the lake was oligotrophic and during the summer months the lake was at the lower end of eutrophy (Figure 30). For sample year 2001-2002, 75% of the turbidity values collected were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and 25% were above (see Figure 31a). 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 OWQS (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 31b. All true color values, with one exception recorded at site 3 in the winter, were well below the Aesthetics OWQS of 70 units therefore the Aesthetics beneficial use is being supported based on true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.12 parts per thousand (ppt) to 0.15 ppt, which was within the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Readings for specific conductivity ranged from 259.6 mS/cm in the winter to 330.6 mS/cm in the summer. Specific conductance 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 59 mV to 550 mV, indicating that reducing conditions were not present in the water column during any time of the year. Low redox potentials were recorded near the lake bottom on two occasions, but not at a level indicating problems with reducing conditions in the lake. The pH values in Boomer Lake were neutral, ranging from 7.15 in the spring to 8.39 units in the summer. 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 should be listed as not supporting beneficial uses. 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

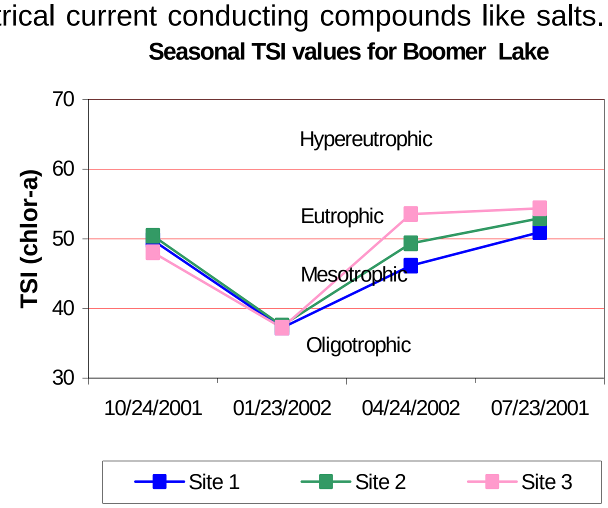


Figure 30. TSI values for Boomer Lake.

beneficial uses. Boomer is currently supporting its FWP beneficial use based on pH concentrations. The lake was well mixed during the fall and winter quarters with dissolved oxygen (D.O.) values above 7.25 mg/L throughout the water column (see Figure 31c-30f). In the spring, the lake was stratified between 4 and 5 meters, at which point the D.O. concentration dropped to 4.04 mg/L, still well above the criteria of 2.0 mg/L. In the summer, the lake was thermally stratified with a thermocline present between 3 and 4 meters below the lake surface at which point the D.O. fell below 1.0 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 (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% of the water column at the dam site was anoxic, and the FWP beneficial use was fully supported. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.60 mg/L at the surface. The epilimnetic TN ranged from 0.49 mg/L to 0.76 mg/L. Surface TN was highest in the summer and fall quarters and lowest in the winter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.036 mg/L for the surface. The TP ranged from 0.038 mg/L to 0.077 mg/L at the surface. Surface TP was highest in the fall and spring quarters and lowest in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 17:1 for sample year 2001-2002. This value is much greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Boomer Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use based on metal (toxic) compounds in the water column. 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, Boomer Lake was classified as mesotrophic, indicative of moderate productivity and nutrients (Plate 10). Water clarity was average to slightly poor, however the Aesthetics beneficial use for true color was fully supported based on currently collected data. The Aesthetics use was also fully supported based upon lake trophic status. The lake is partially supporting its FWP beneficial use based on high turbidity concentrations. Boomer was fully supporting its FWP use based upon D.O. and pH values collected in the water column (OAC 785:46). 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.

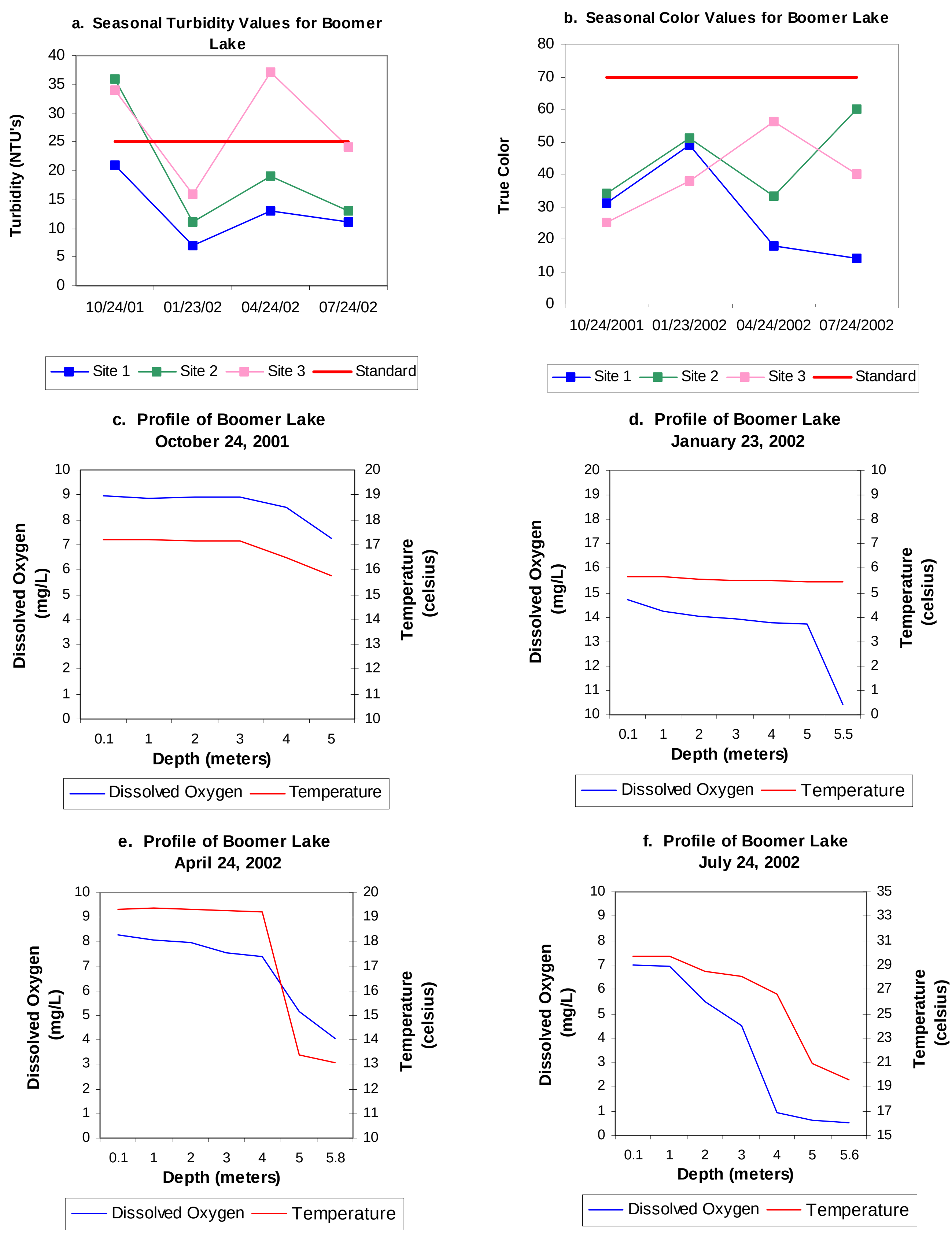


Figure 31a-30f. Graphical representation of data results for Boomer Lake.

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

N W E S

Plate 10 - Lake Water Quality for
Boomer Lake

Broken Bow Lake

Broken Bow Lake was sampled for four quarters, from November 2000 through August 2001. Water quality samples were collected at 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 and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 6 NTU, true color was 20 units, and average secchi disk depth was 204 centimeters in sample year 2001. Water clarity was excellent based on the high secchi disk depth, low turbidity and true color values. Results for these parameters are similar to results found in 1995 and 1997, although previous values were based on summer samples only. The 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 40, indicating the lake was oligotrophic in sample year 2001. The TSI values for all sites throughout the sample year varied from oligotrophic to mesotrophic. In the summer of 1997, the calculated TSI value was also oligotrophic (TSI=24) although only two samples were used to calculate the trophic status. According to seasonal observation, Broken Bow Lake is typically considered oligotrophic with mesotrophic conditions in the summer. For the fall, spring, and summer quarters, turbidity values were well below the OWQS of 25 NTU. During the winter quarter, the two upper end sites were above 25 NTU, although the remaining sites were well below the standard. All true color values were well below the aesthetics OWQS of 70 units. The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1997 and detected mercury in fish tissue that was a cause for concern. The lake was again sampled 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.

Please refer to the “Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report” for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency’s web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Brushy Creek Reservoir

Brushy Creek Reservoir was sampled for four quarters, from October 2000 through July 2001. Water quality samples were collected at three 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 4 NTU, true color was 51 units, and average secchi disk depth was 126 centimeters in sample year 2001. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. Results for these parameters were similar to the results found in 1997, although previous values were based on summer samples only. 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 51, indicating the lake was eutrophic, bordering mesotrophic, in sample year 2001. The TSI values throughout the sample year were primarily mesotrophic with the eutrophic spike at all sites in the fall. Based on three summer values in 1997, the calculated TSI value was oligotrophic (TSI=39), much lower than the 2001 evaluation. The higher trophic value in 2001 was probably a more accurate depiction since it was based on data collected year-round as opposed to one season. Turbidity values per site for sample year 2001 were all 5 NTU or less, well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. The lake-wide annual turbidity of 4 NTU was representative of conditions at Brushy Creek Reservoir in 2001. All true color values were below the aesthetics OWQS of 70 units, although there was evident seasonal variability. In sample year 2001, the fall values were the highest and the winter values were the lowest at all sites.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Lake Burtschi

Lake Burtschi was sampled for four quarters, from November 2001 through August 2002. 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 turbidity value was 9 NTU (Plate 11), true color was 31 units, and average secchi disk depth was 75 centimeters in 2001-2002 sampling. Water clarity was good based on secchi disk depth, turbidity, and true color values. Results for these parameters were similar to historical data collections efforts in 1997. 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 calculated was 61 (Plate 11), indicating the lake was eutrophic to hypereutrophic in sample year 2001-2002. The TSI values throughout the sample year varied seasonally from lower eutrophy in the spring to borderline hypereutrophic to true hypereutrophy in the other three sample quarters (Figure 32). Turbidity values per site for sample year 2001-2002 were all well below the OWQS of 25 NTU for all seasons (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 OWQS (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 nephelometric turbidity concentrations Lake Burtschi was meeting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 33b. All true color values were below the Aesthetics Oklahoma Water Quality Standard (OWQS) of 70 units. Lake Burtschi was meeting its Aesthetics beneficial use related to true color. Although the lake water clarity is very good, the availability of light coupled with the shallow morphometry of the lake could be contributing greatly to the high primary productivity readily apparent in the lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.46 part per thousand (ppt) at all sites in the fall to 0.51 ppt recorded in the spring. Moderate salinity values in the water column indicate chlorides or salts were present in large concentrations in the lake. 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 890.3 mS/cm in the fall of 2001 to 994.7 mS/cm in the summer spring of 2002. Lake pH values were neutral to slightly alkaline, ranging from 7.32 in the spring and summer to 8.78 units in the winter. According to the USAP outlined in (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 should be listed as not supporting beneficial uses. 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 beneficial uses. With all values recorded within the acceptable range

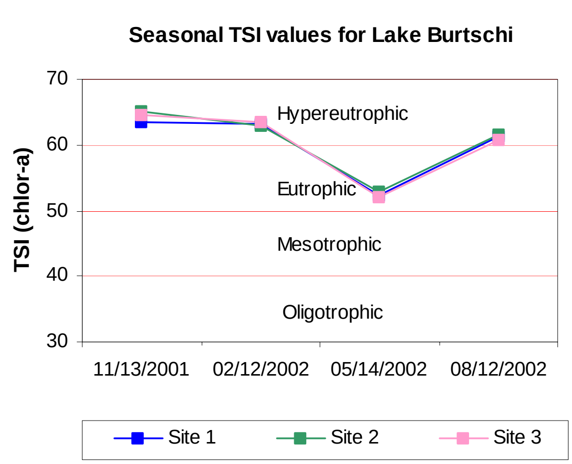


Figure 32. TSI values for Lake Burtschi.

the lake is meeting the FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from –160 mV in the summer quarter to 370 mV recorded in the fall of 2001. Reducing conditions were present in the summer time near the lake bottom, which could result in the release of nutrients into the water column, which can then become available for biotic uptake. Low redox values in the hypolimnion are not uncommon when a lake is strongly thermally stratified and anoxic conditions are present. The lake was not thermally stratified in the fall or winter and the lake was well mixed with dissolved oxygen values at or above 6.0 mg/L throughout most of the water column (see Figure 33c-32d). The lake was very weakly thermally stratified in the spring and strongly thermally stratified in the summer between 5 and 6 meters at which point dissolved oxygen (D.O.) concentrations fell below 1.0 mg/L (see Figure 33e-32f). Although D.O. concentrations were less than 1.0 mg/L below 5 meters to the lake bottom at 8 meters (about 33% of the water column), at site 1, this was not sufficient to result in listing the lake as not supporting it's FWP beneficial use. 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. According to USAP, the FWP beneficial use is considered fully supported at Lake Burtschi. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 1.12 mg/L at the surface, which is a relatively high value when compared to other lakes across the state. The TN at the surface ranged from 0.88 mg/L to 1.21 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 for sample year 2001-2002 was 0.056 mg/L at the surface. The TP ranged from 0.038 mg/L to 0.077 mg/L at the surface. Surface TP was highest in the winter and spring and lowest in the summer. The nitrogen to phosphorus ratio (TN:TP) was approximately 21:1 for 2001-2002. This value is much greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Burtschi was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use based on metal (toxic) compounds in the water column.

In summary, Lake Burtschi was classified as eutrophic to hypereutrophic in nature, indicative of high to excessive primary productivity and nutrient rich conditions (Plate 11). The lake is fully supporting its Aesthetics beneficial use for true color and trophic state. Lake Burtschi is fully supporting its FWP beneficial use based on D.O., pH and nephelometric turbidity. 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.

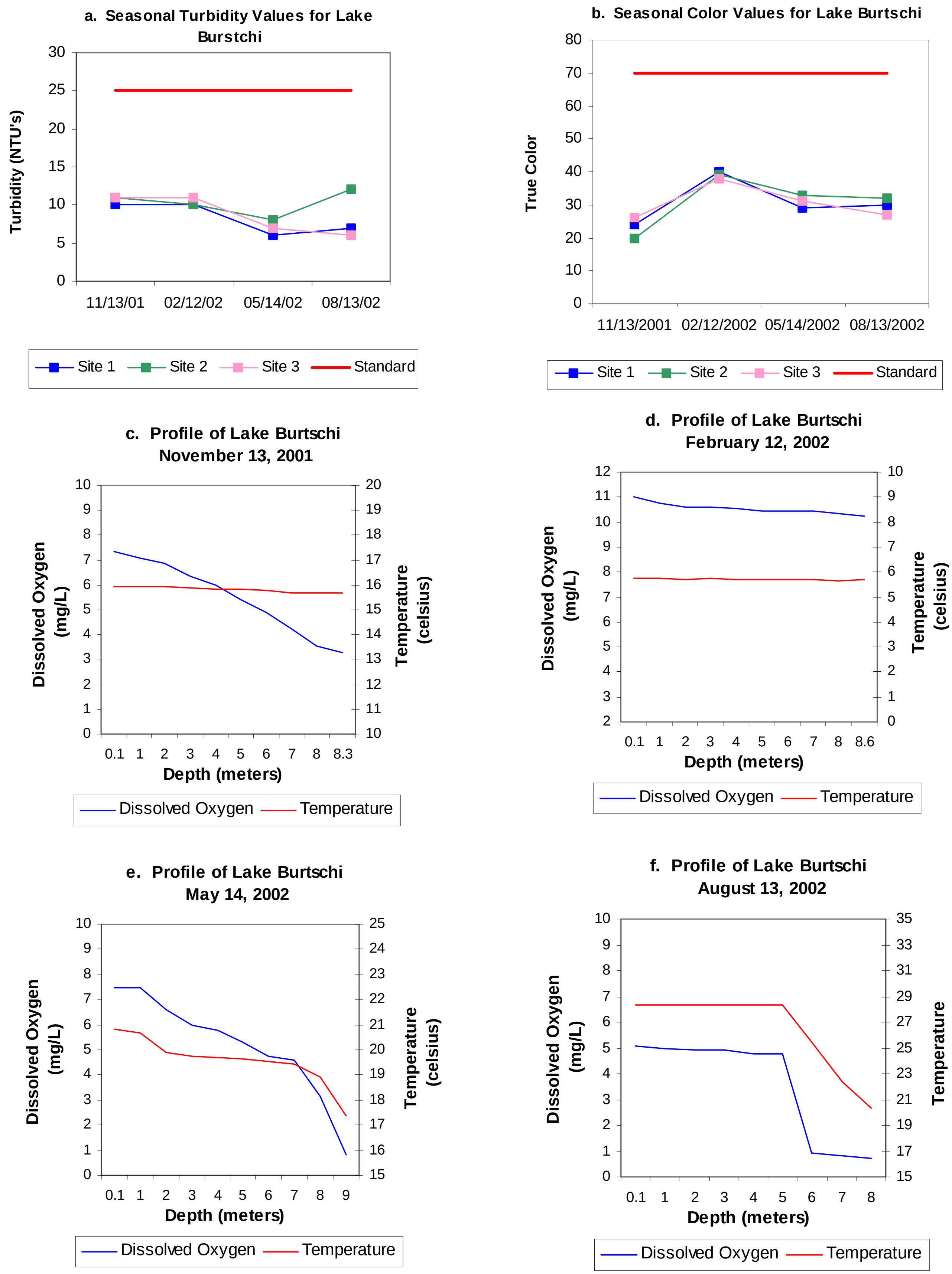
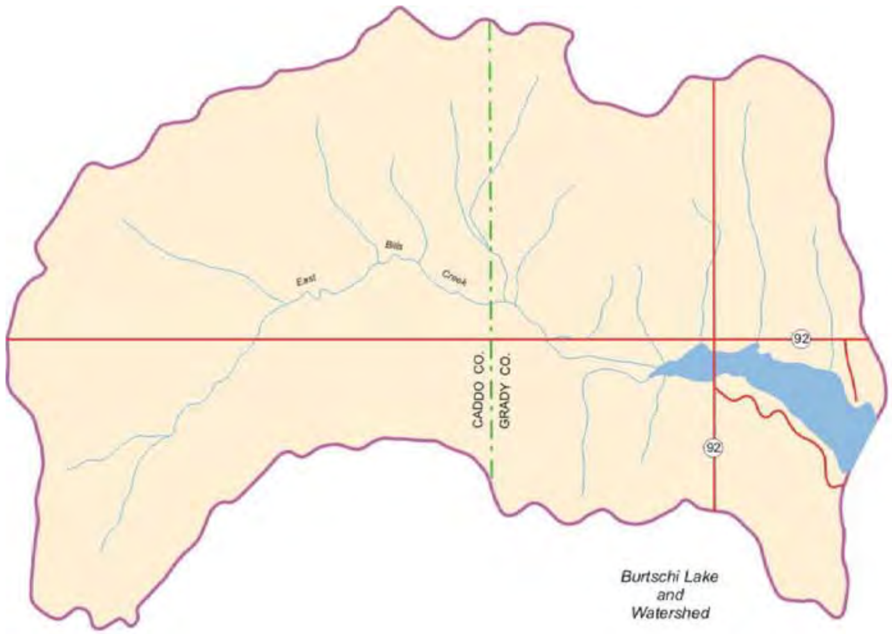
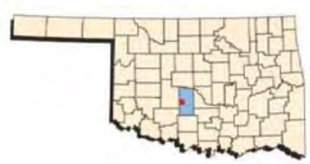


Figure 33a-32f. Graphical representation of data results for Lake Burtschi.

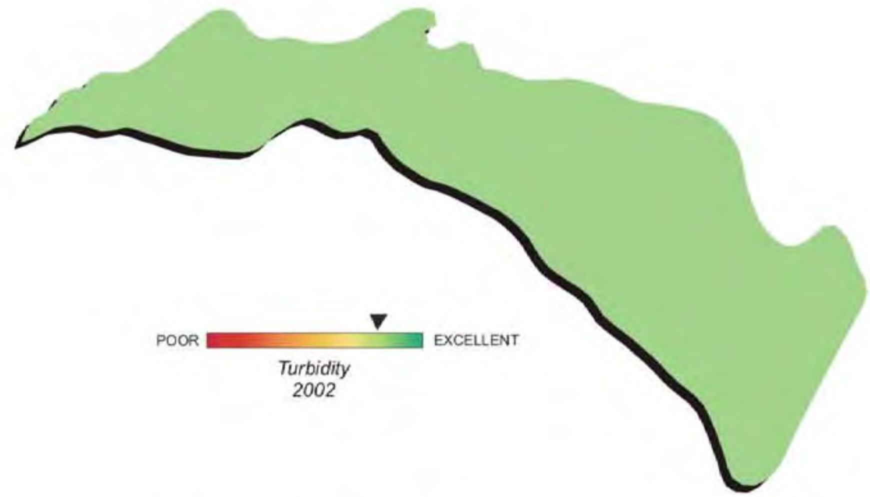


Burtschi Lake
and
Watershed



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



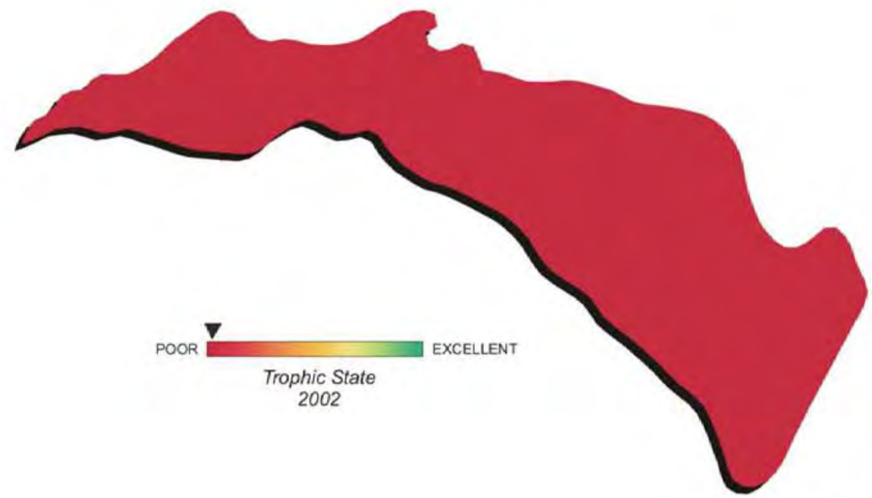


Plate 11 - Lake Water Quality for
Burtschi Lake

Canton Lake

Canton Lake was sampled for four quarters, from December 2001 through August 2002. Water quality samples were collected at four (4) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Additional samples were collected at site 5 for chlorophyll-a and turbidity analysis to meet minimum data requirements. Water chemistry 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 32 NTU (Plate 12), true color was 35 units, and secchi disk depth was 30 centimeters in 2001-2002. Water clarity was fair to poor based on secchi disk depth, turbidity, and true color values. 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 55 (Plate 12), indicating the lake was eutrophic in sample year 2001-2002. The TSI values throughout the sample year varied seasonally from oligotrophic in the fall to eutrophic or hypereutrophic in the summer (Figure 34). Turbidity values per site for sample year 2001-2002 were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons with 65% of the values recorded exceeding the OWQS (see Figure 35a). 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 OWQS (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 currently not supporting is Fish & Wildlife Propagation (FWP) beneficial use based on high turbidity values recorded for the reservoir. Seasonal true color values are displayed in Figure 35b. All true color values were below the Aesthetics OWQS of 70 units, with the exception of site 3 in the winter. 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 conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.78 parts per thousand (ppt) in the summer to 0.85ppt in the winter. Salinity concentrations were consistently elevated above the range of expected values for Oklahoma lakes, reflecting the moderate to high presence of chlorides or other salts in the lake. Specific conductance 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 1468 mS/cm in the summer to 1599 mS/cm in the winter. Lake pH values were neutral to moderately alkaline, ranging from 7.04 to 9.68 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 should be listed as not supporting beneficial uses. 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 beneficial uses. Canton Lake is "provisionally not supporting"* its FWP beneficial use as it relates to pH with 25% of the collected values falling outside the acceptable range. Oxidation-reduction potentials ranged from 146 mV in the winter to 534 mV in the summer, indicating reducing conditions were not present throughout the year. The lake was not stratified at any point

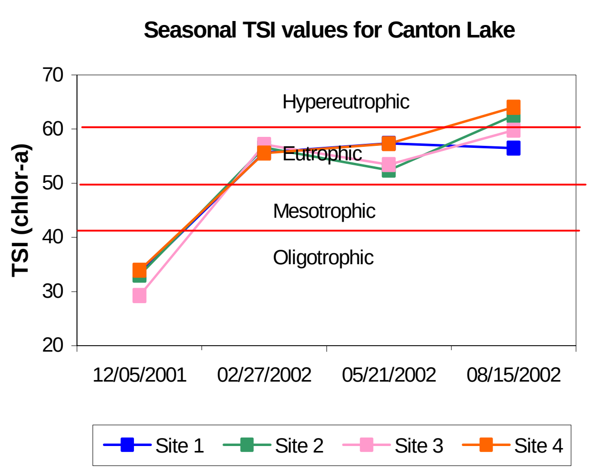


Figure 34. TSI values for Canton Lake.

during the sample year indicating the lake was well mixed. Dissolved oxygen (D.O.) concentrations were above 4.0 mg/L throughout the water column and were generally above 6.0 mg/L for most of the sample year (see Figure 35c-34f). 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. The FWP beneficial use is fully supported at Canton Lake based on D.O. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.72 mg/L at the lake surface. The epilimnetic (surface) TN ranged from 0.88 mg/L to 1.21 mg/L. TN was highest at site 1 in the summer and lowest in the spring at site 1. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.151 mg/L at the lake surface. The TP ranged from 0.061 mg/L to 0.700 mg/L at the surface. TP was highest in the fall and summer and lowest in the winter at the surface. The nitrogen to phosphorus ratio (TN:TP) was approximately 7:1 for sample year 2001-2002. This value is equal to the 7:1, characterizing the lake as potentially co-limited with nitrogen and phosphorus (Wetzel, 1983).

Canton Lake was also sampled for metals at four sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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, Canton Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 12). The trophic status of the reservoir fluctuated greatly depending on the quarter sampled, varying from oligotrophy in the fall quarter to upper eutrophy to hypereutrophy in the other three quarters. Water clarity was poor and the lake was not supporting its FWP beneficial use based upon collected turbidity values. The lake is also listed as provisionally not supporting its FWP beneficial use based on pH. The lake was fully supporting its FWP based on D.O. concentrations. The Lake was fully supporting its Aesthetics beneficial use for both trophic state and true color. 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.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

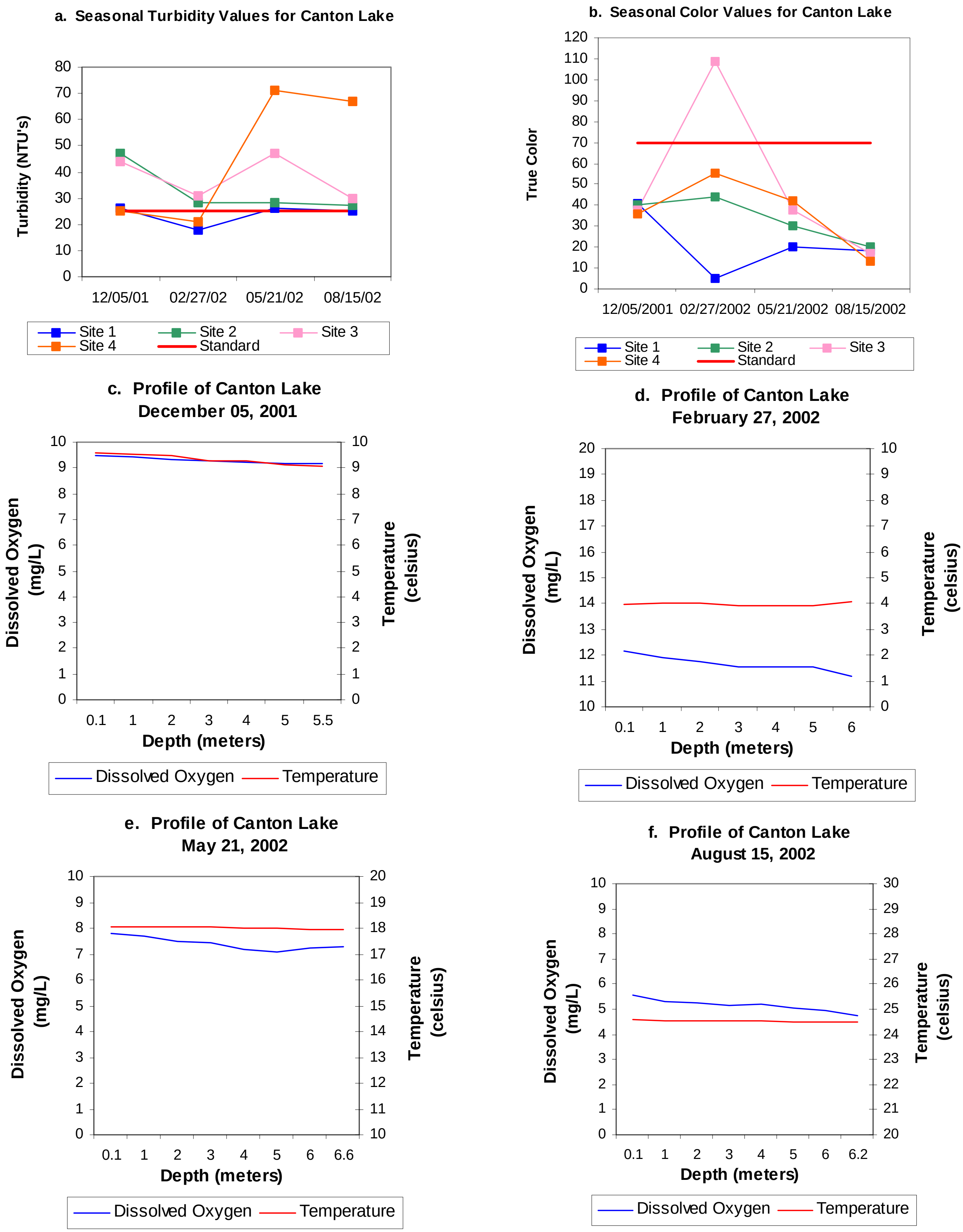
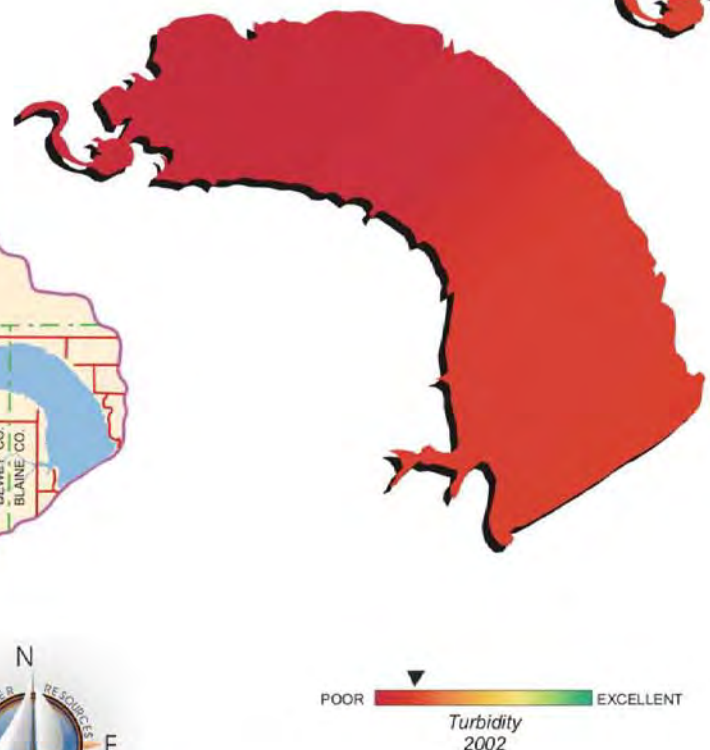
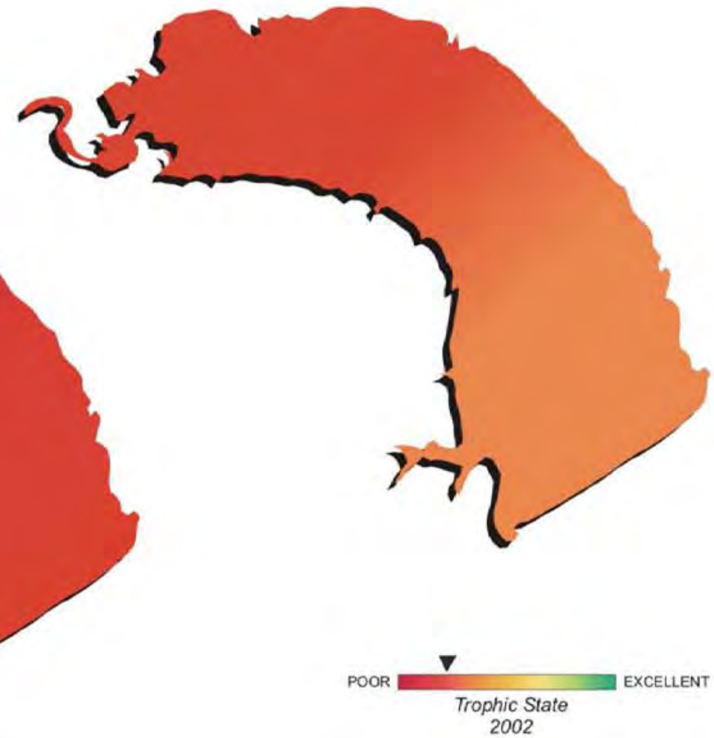


Figure 35a-34f. Graphical representation of data results for Canton Lake.





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 12 - Lake Water Quality for
Canton Lake

Carl Albert Lake

Carl Albert Lake was sampled for four quarters, from November 2000 through August 2001. 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 12 NTU, true color was 35 units, and average secchi disk depth was 85 centimeters in 2001. Water clarity was good based on secchi disk depth, turbidity, and true color values. Results for these parameters were similar to the results found in 1997, although previous values were based on summer samples only. 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, indicating the lake was mesotrophic, bordering oligotrophic, in sample year 2001. The TSI values throughout the sample year were primarily mesotrophic with oligotrophic values at all sites in the fall and site 3 in the winter. Based on three summer values in 1997, the calculated TSI value was also mesotrophic (TSI=48), but a much higher value than the 2001 evaluation, probably due to the high productivity common during the summer growing season. Turbidity values were consistent among sites but varied according to season. All turbidity values for 2001 were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, although there was an evident increase in the spring quarter, when storm events resulting in runoff are more common. The lake-wide annual turbidity of 12 NTU was representative of conditions at Carl Albert Lake in 2001. All true color values were below the aesthetics OWQS of 70 units, although the summer values approached the standard.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Lake Carl Blackwell

Lake Carl Blackwell was sampled for four quarters, from October 2001 through July 2002. 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 20 NTU (Plate 13), true color was 29 units, and secchi disk depth was 61 centimeters in 2001-2002. Based on these three parameters, Lake Carl Blackwell had good to fair water clarity. 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 55 (Plate 13), indicating the lake was eutrophic in sample year 2001-2002. The TSI values throughout the sample year didn't vary seasonally with almost all calculations in the eutrophic range with just a couple of instances where the lake was mesotrophic or at the border of hypereutrophy (Figure 36). Of the turbidity values collected, 75% were below the turbidity standard of 25 NTU and 25% exceeded the turbidity standard for lakes (see Figure 37a). 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 (OWQS) 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 not supporting its Fish & Wildlife Propagation (FWP) beneficial use based on 25% of the collected turbidity data exceeding the criteria. Seasonal true color values are displayed in Figure 37b. All true color values were below the aesthetics OWQS of 70 units. Applying the same default protocol to determine the average for true color the Aesthetics beneficial use is supported.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all three sample sites during the study period. Salinity ranged from 0.16 to 0.20 parts per thousand (ppt), which was consistent with values, recorded most Oklahoma reservoirs. Specific conductance ranged from 334.2 mS/cm to 413.0 mS/cm, which was also consistent with numbers seen for most Oklahoma lakes, 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 slightly alkaline ranging from 8.18 to 8.74 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 should be listed as not supporting beneficial uses. 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 beneficial uses. Lake Carl Blackwell is fully supporting its FWP beneficial use based on pH concentrations recorded during the study period. Oxidation-reduction potentials (redox) ranged from –15 mV in the summer to 457 mV in the fall, which indicated an absence of reducing conditions with the exception of sites 1 and 5 in the summer quarter. The lake was not thermally stratified in the fall, winter or spring and dissolved oxygen (D.O.) concentrations were well above 6.0

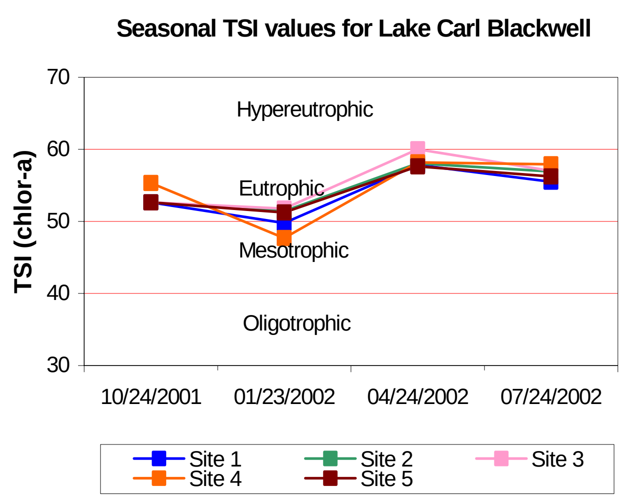


Figure 36. TSI values for Lake Carl Blackwell.

mg/L throughout the water column except at the lake bottom (see Figure 37c-36e). In the summer, the lake was strongly thermally stratified between 6 and 7 meters, where the D.O. concentration fell to 1.0 mg/L or less as you moved down the water column (see Figure 37f). Anoxic conditions were not present at sites 2, 3, or 4 during the summer probably because they were all 5 meters or less in depth. 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 lake is partially supporting its FWP beneficial use with 57% of the water column in the summer less than the proscribed 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 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.60 mg/L at the lake surface. The epilimnetic (surface) TN ranged from 0.32 mg/L to 0.74 mg/L. TN was highest at site 4 in the summer and lowest in the fall at site 2. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.034 mg/L for the lake surface. The TP ranged from 0.022 mg/L to 0.069 mg/L at the lake surface. TP was highest in the fall at site 4 and lowest in the winter at site 2. The nitrogen to phosphorus ratio (TN:TP) was approximately 18:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Carl Blackwell was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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 Carl Blackwell was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 13). Water clarity was average to fair and the Aesthetics beneficial use was fully supported based on current true color data. The lake is also supporting its Aesthetics use based on its trophic status. The FWP beneficial use is fully supported based on current turbidity and pH data. D.O. conditions in the summer were sufficient to cause the FWP beneficial use to only be partially supporting. 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.

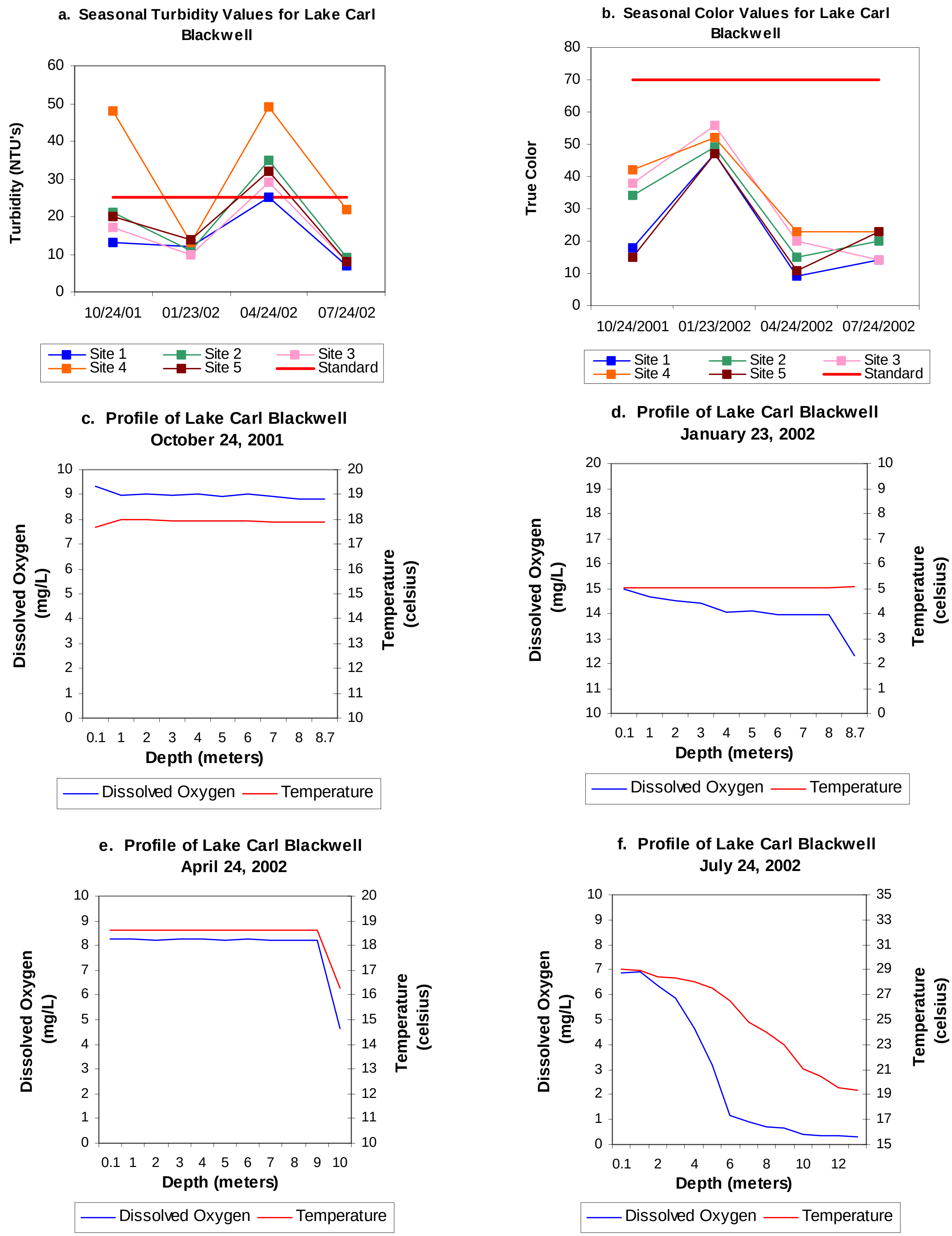
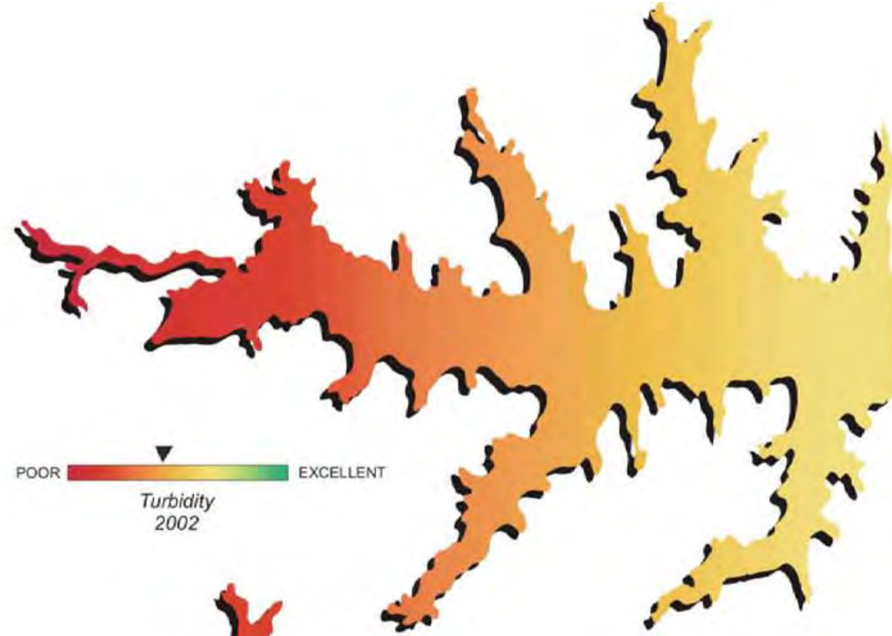


Figure 37a-36f. Graphical representation of data results for Lake Carl Blackwell.

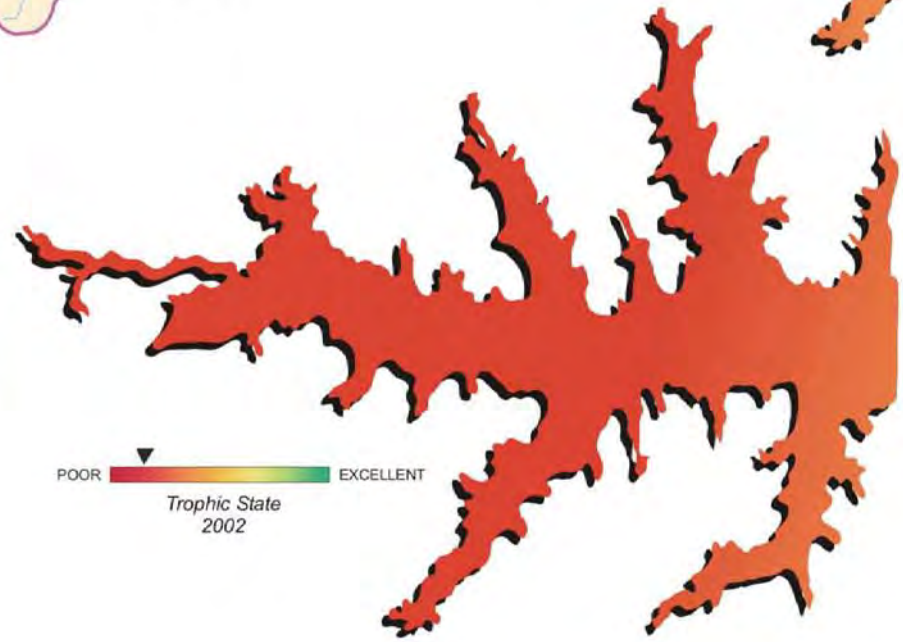
Lake Carl Blackwell and Watershed

Lake Carl Blackwell Location

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



Turbidity 2002



Trophic State 2002

Plate 13 - Lake Water Quality for
Lake Carl Blackwell

[Carter Lake]

Carter Lake was sampled for three seasons, from February 2001 through August 2001. Several attempts were made in the fall quarter to sample the lake; however, due to drought conditions, the lake level was too low to launch a boat until the winter quarter. 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 and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide turbidity value was 8 NTU, true color was 27 units, and average secchi disk depth was 131 centimeters in 2001. Water clarity was excellent based on secchi disk depth, turbidity, and true color values. Turbidity values were similar to the averages calculated in the summer of 1995 and 1998, but secchi disk depth was much higher in 2001 than in previous years. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=10). The TSI was 44, indicating the lake was mesotrophic in sample year 2001. The TSI values throughout the sample year were primarily mesotrophic with oligotrophic values at all sites in the summer. Although there are only 3 sites designated for Carter Lake, an extra sample was collected in the winter to meet the minimum data requirements (n=10) listed in the Use Support Assessment Protocols (USAP) for lakes under 250 surface acres (785:46-15-3). Based on three summer values in 1998, the calculated TSI value was also mesotrophic (TSI=46), indicating little or no significant change in trophic status. Turbidity values per site for sample year 2001 were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons. All true color values were well below the aesthetics OWQS of 70 units.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Cedar Lake

Cedar Lake was sampled for four quarters, from November 2000 through August 2001. 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 and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide turbidity value was 8 NTU, true color was 46 units, and average secchi disk depth was 82 centimeters in 2001. Water clarity was good based on secchi disk depth, turbidity, and true color values. Results for these parameters were similar to the results found in 1997, although previous values were based on summer samples only. 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 51, indicating the lake was eutrophic in sample year 2001. The TSI values throughout the sample year varied seasonally from oligotrophic at all sites in the winter to primarily hypereutrophic in the summer. Based on three summer values in 1997, the calculated TSI value was mesotrophic (TSI=46), indicating an increase in trophic status. The higher trophic value in 2001 was probably a more accurate depiction since it was based on data collected year-round as opposed to one season. Turbidity values per site for sample year 2001 were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons. The lake-wide annual turbidity of 8 NTU was representative of conditions at Cedar Lake in 2001. All true color values were below the aesthetics OWQS of 70 units, with the exception of site 1 in the summer. Although the winter values do not necessarily stand out as unusual, there was an ice storm that resulted in the contribution of trees and debris to the lakes in Southeastern Oklahoma.

Please refer to the “Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report” for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency’s web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Chandler Lake

Chandler Lake was sampled for four quarters, from November 2002 through August 2003. 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 8 NTU (Plate 14), true color was 18 units, and secchi disk depth was 115 centimeters in 2003. Water clarity was good based on secchi disk depth, turbidity, and true color values. Compared to values recorded in 2001, results for these parameters are very similar, although secchi disk depth was a little higher 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 52 (Plate 14), indicating the lake was eutrophic with high primary productivity and nutrient conditions in sample year 2003. The TSI values throughout the sample year varied seasonally from oligotrophic in the winter to eutrophic in the summer (Figure 38). Turbidity values per site for sample year 2003 were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons (Figure 39a). The lake-wide annual turbidity of 8 NTU was representative of conditions at Chandler Lake in 2003. All true color values were below the aesthetics OWQS of 70 units, meeting the Aesthetic beneficial use.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity ranged from 0.12 parts per thousand (ppt) to 0.18 ppt for this sample year. Specific conductance ranged from 259.2 mS/cm to 373.1 mS/cm, which falls within the range of 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 Chandler Lake ranged from 6.81 to 8.42, representing a neutral to slightly alkaline system. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 95 mV in the spring to 470 mV in the fall, however, this low value was the only value indicative of reducing conditions and most likely resulted because it was recorded at the lake bottom at the dam site. In general, reducing conditions were not present in this reservoir. The lake was not stratified during the fall, winter and spring quarters (see Figure 39c-38e). During the summer quarter the lake exhibited thermal stratification between 4 and 5 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

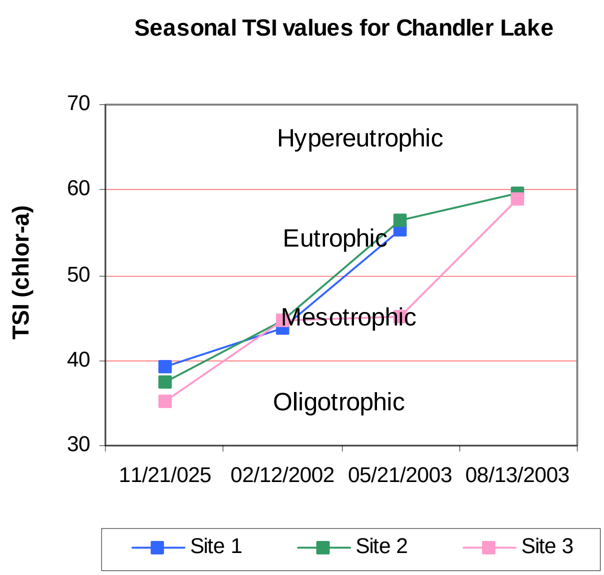


Figure 38. TSI values for Chandler Lake

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 44% of the water column falling below 2.0 mg/L, the FWP Benicia use is partially supported at Chandler Lake. The lake was also sampled for total dissolved solids, chlorides, and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported bases 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.63mg/L at the surface and 0.85 mg/L at the lake bottom. The TN at the surface ranged from 0.38 mg/L in the winter to 0.87 mg/L in the summer. The lake-wide total phosphorus (TP) average was 0.021 mg/L at the surface and 0.090 mg/L at the lake bottom. The total phosphorus at the surfaced ranged from 0.011 mg/L to 0.027 mg/L with lower values occurring in the fall quarter. The nitrogen to phosphorus ration (TN:TP) was 30:1 for sample year 2003. This value is much higher than 7:I, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Chandler Lake was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions. This classification differs from that in 2001 when the TSI of 48 resulted in a mesotrophic classification. The lake should be monitored closely in the future to determine if a change in productivity has actually occurred. Water clarity was good based on turbidity, true color and secchi disk depth and results were similar to those observed in 2001. The lake is supporting the FWP beneficial use based on pH and turbidity, but is listed as partially supporting based on dissolved oxygen levels. The Aesthetics beneficial use is also being met by both the trophic status and true color concentrations. 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.

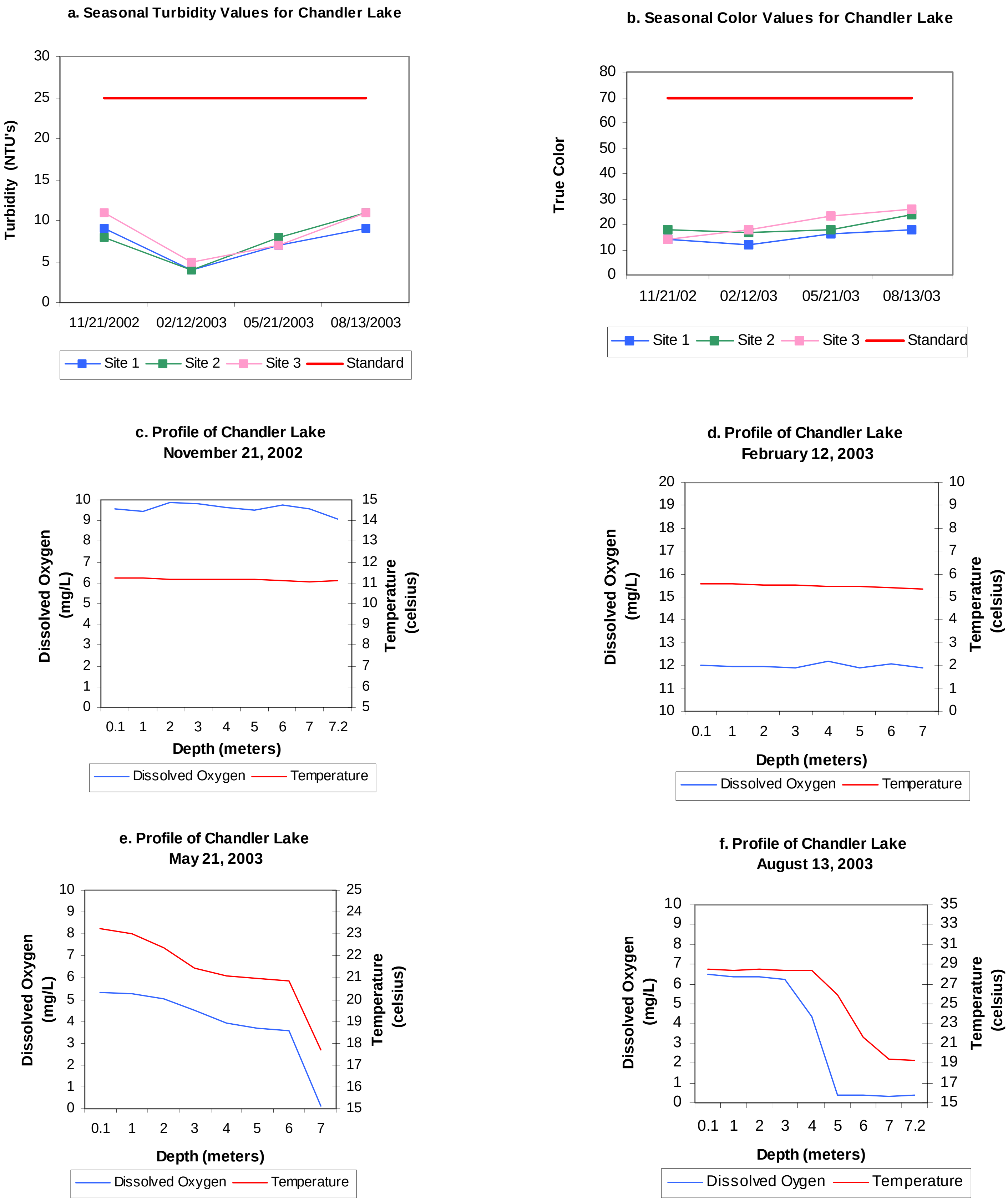
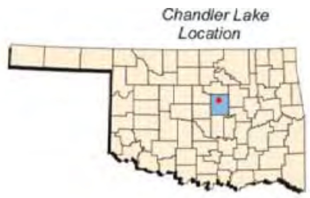


Figure 39a-38f. Graphical representation of data results for Chandler Lake.



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

Plate 14 - Lake Water Quality for
Chandler Lake

Lake Chickasha

Lake Chickasha was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at three (3) sites in the fall and winter and at five (5) sites in the spring and summer sampling quarters. Additional sample sites were added to ensure that an adequate amount of data was being collected as this reservoir is greater than 250 surface acres in size. 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 9 NTU (Plate 15), true color was 11 units, and annual average secchi disk depth was 69 centimeters. Based on these three parameters water clarity was good at Lake Chickasha 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=16). The result was a TSI of 59 (Plate 15), indicating the lake was eutrophic with high primary productivity and nutrient levels in sample year 2002-2003. This value is lower than that calculated in 2000 (TSI=66), however the current calculation is based on the entire dataset and not just data collected during the summer months so it is likely a more accurate depiction of productivity within the lake system. The TSI values for all sites were fairly consistent throughout the year and ranged from hypereutrophic in the fall to mesotrophic in the winter and eutrophic in both spring and summer quarters (see Figure 40). Seasonal turbidity values are displayed in Figure 41a. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and ranged from a low of 4 NTU to a maximum of 15 NTU. 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 OWQS of 70 units and are displayed in Figure 41b. Due to the minimum data requirements not being met assessment of the Aesthetics beneficial use based on true color could not be made.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 1.14 parts per thousand (ppt) to 1.36 ppt for this sample year. Specific conductance ranged from 2137 mS/cm to 2530 mS/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 6.92 to 8.13, representing a neutral to slightly alkaline system. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 92 mV in the spring to 470 mV in the fall, however this low value was the only value indicative of reducing conditions and most likely resulted

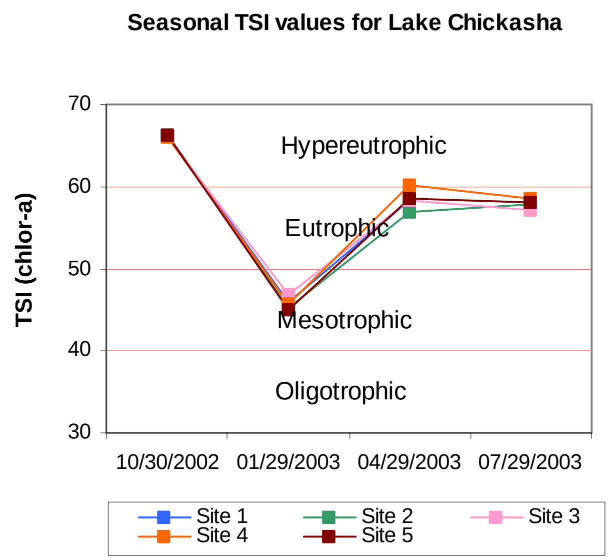


Figure 40. TSI values for Lake Chickasha

because it was recorded at the lake bottom at the dam site. In general, reducing conditions were not present in this reservoir. The lake was not stratified during any of the sampling quarters (see Figure 41c-40f). Dissolved oxygen (D.O.) levels were generally above 4.0 mg/L throughout the 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 water column above 2.0 mg/L the FWP Benicia 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 2002-2003 found the Agriculture beneficial use to be fully supported bases 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.21mg/L at the surface and 1.21 mg/L at the lake bottom. The TN at the surface ranged from 0.68 mg/L in the fall to 1.48 mg/L in the winter. The lake-wide total phosphorus (TP) average was 0.021 mg/L at the surface and 0.090 at the lake bottom. The total phosphorus at the surfaced ranged from 0.033 mg/L to 0.035 mg/L with lower values occurring in the winter quarter. The nitrogen to phosphorus ration (TN:TP) was 37:1 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 eutrophic, indicative of high primary productivity and nutrient rich conditions. This classification differs from that in 2000 when the TSI of 66 resulted in a hypereutrophic classification. The current calculation is based on a larger dataset and not just data collected during warmer summer months so it is likely a more accurate depiction of productivity within the lake system. The lake should be monitored closely in the future to determine if a change in productivity has actually occurred. 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, and dissolved oxygen levels. The Aesthetics beneficial use is being met by the trophic status, however the minimum data requirement of 20 samples for lakes greater than 250 surface acres was not met for true color. Lake Chickasha is located in Caddo County serves as a municipal water supply as well as a recreational reservoir.

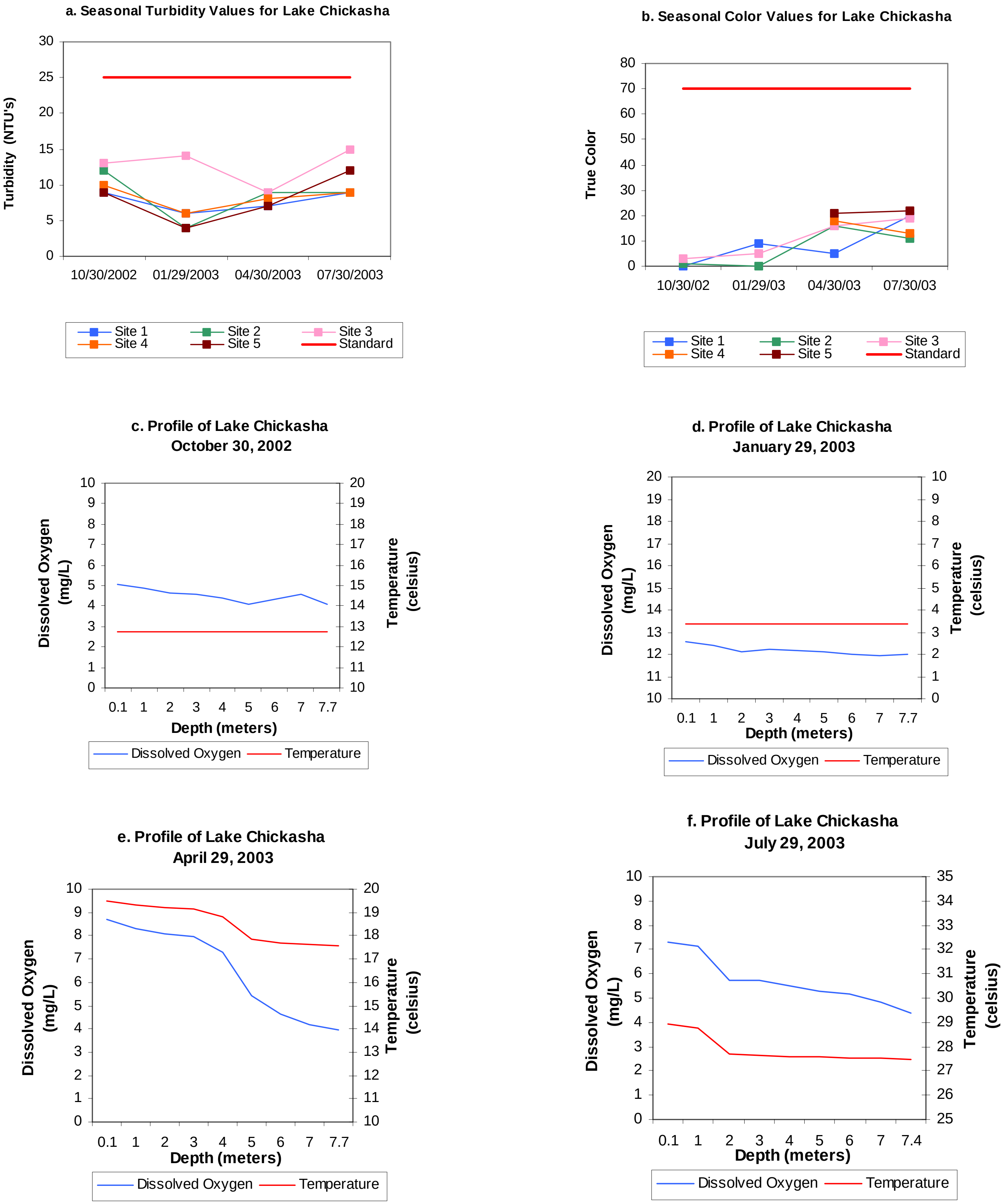
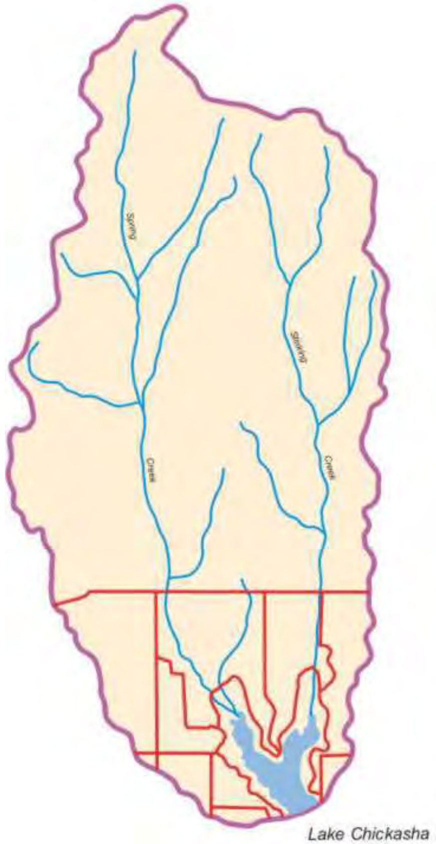
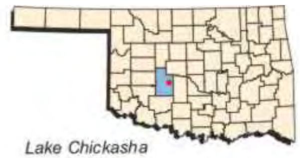


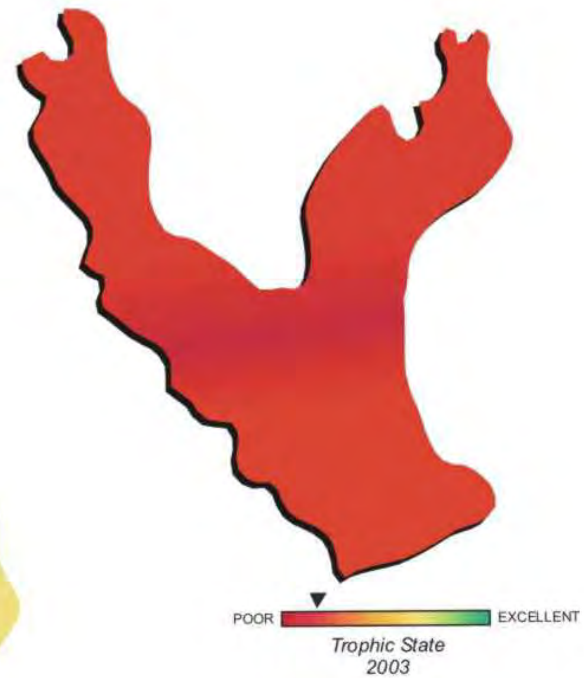
Figure 41a-40f. Graphical representation of data results for Lake Chickasha.



Lake Chickasha and Watershed



Lake Chickasha Location



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 15 - Lake Water Quality for
Lake Chickasha

Claremore Lake

Claremore Lake was sampled for four quarters from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 for the analysis of chlorophyll-a and turbidity in order to meet minimum data requirements. All water 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 13 NTU (Plate 16), true color was 39 units, and secchi disk depth was 54 centimeters in 2001-2002. Based on these three parameters, Claremore Lake had average to slightly above 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=22). Two additional samples were collected in the spring quarter only for chlorophyll-a analysis for quality control purposes and these values were also used in the TSI calculation. The calculated TSI was 63 (Plate 15), indicating the lake was hypereutrophic in sample year 2001-2002. The TSI values throughout the sample year varied very little from season to season with almost all values falling in the hypereutrophic range (Figure 42). These results are consistent with historical data collection efforts on the lake, which also found the lake to be hypereutrophic. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient threatened. All turbidity values, with the exception of site 3 in the fall quarter were below the turbidity water quality standard of 25 NTU (see Figure 43a). 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 OWQS (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 was fully supporting its Fish & Wildlife Propagation (FWP) beneficial use for turbidity. Seasonal true color values are displayed in Figure 43b. None of samples collected had true color values exceeding the 70 units criteria, however the Aesthetics use could not be definitively assessed due to insufficient data. Collected data supports the supposition that the use was fully supported for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. The salinity concentrations at Claremore Lake ranged from 0.09 part per thousand (ppt) to 0.10ppt, well within the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Specific conductance values were also well within the expected range for Oklahoma reservoirs, indicating minimal presence of electrical current conducting compounds like salts. Specific conductance values ranged from 172.0 mS/cm in the summer quarter to 249.7 mS/cm recorded in the winter quarter. The pH values at Claremore Lake were neutral to slightly alkaline ranging from 6.79 to 8.30 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 should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9.0 range, the lake

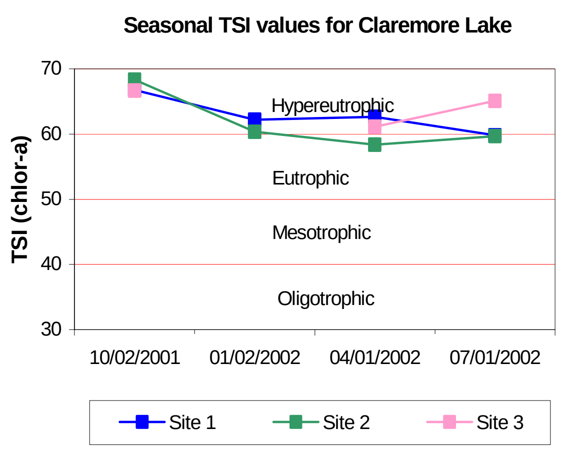


Figure 42. TSI values for Claremore Lake.

should be listed as partially supporting beneficial uses. 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 45 mV in the summer (only four values in any of the quarters were less than 200 mV) to 568 mV recorded in the fall, which indicated an absence of reducing conditions. The lake was not thermally stratified in the fall, winter, or spring quarters and dissolved oxygen (D.O.) concentrations were above 3.0 mg/L throughout the water column during these three seasons and were generally above 6.0 mg/L (see Figure 43c-42e). In the summer quarter, the lake showed thermal stratification between 4 and 5 meters with D.O. concentrations less than 1.5 mg/L from 4 meters to the lake bottom at 6.6 meters at the dam site (see Figure 43f). Anoxic conditions were not present at the other two sites in the summer, as both sites are less than 4 meters in depth. 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, Claremore Lake is partially supporting its FWP beneficial use because 50% of the water column was less than 2.0 mg/L. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.78 mg/L at the lake surface. The TN at the surface ranged from 0.60 mg/L to 0.96 mg/L. The highest surface TN value was reported in the fall and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.052 mg/L at the lake surface. The TP ranged from 0.006 mg/L to 0.107 mg/L at the lake surface. The highest surface TP values were reported in the fall and winter quarters and the lowest were in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was 15:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Claremore Lake was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Claremore Lake was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels. This finding is consistent with historical data collection efforts, which resulted in the lake being listed as NLW water with nutrient threats present. Claremore Lake was partially supporting the FWP beneficial use based on low D.O. concentrations but was fully supporting the beneficial use based pH. The lake Aesthetics beneficial use for true color could not be definitively assessed due to insufficient data, but collected information strongly supports the supposition that it would be fully supporting. Claremore Lake 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 is also utilized for recreation purposes.

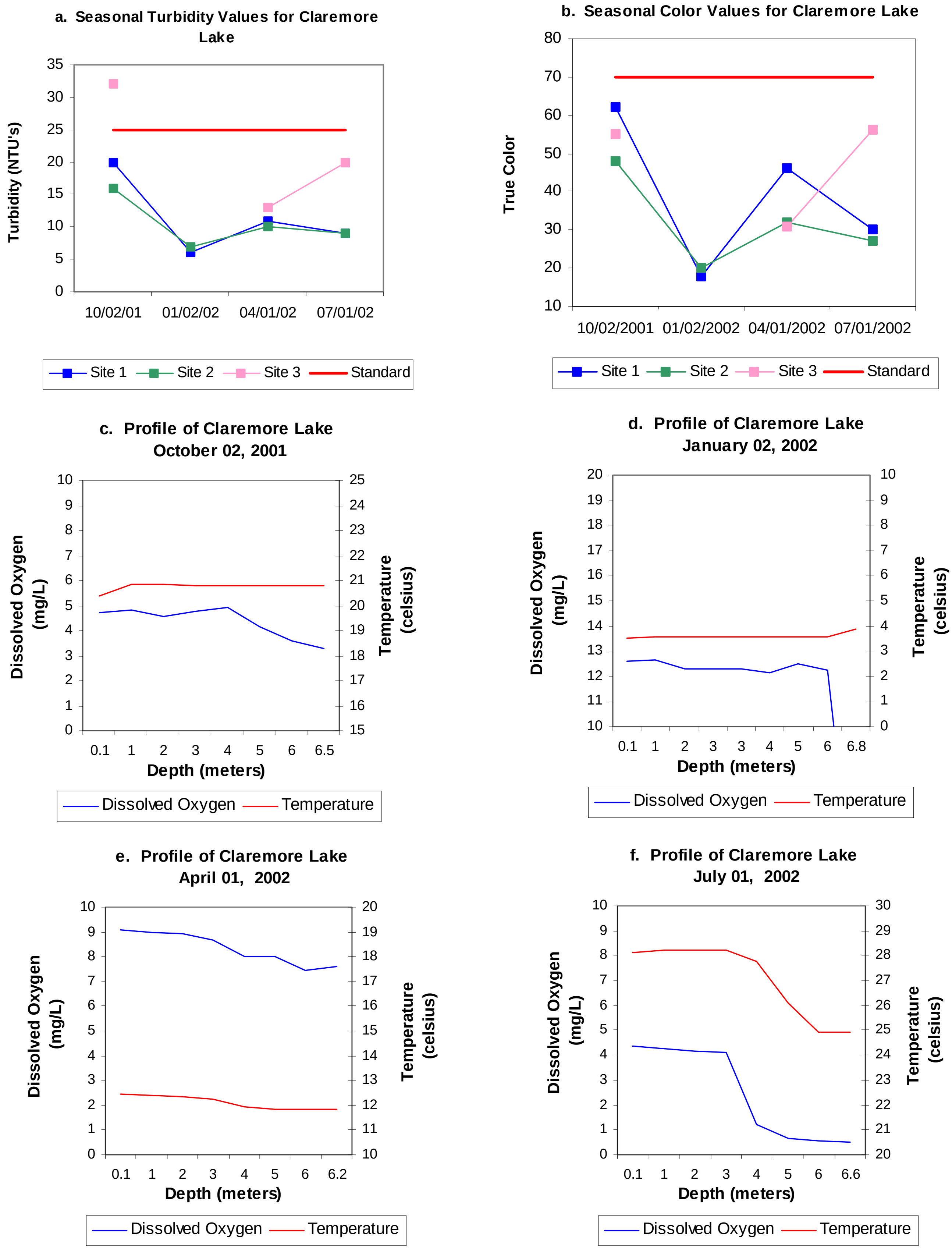


Figure 43a-42f. Graphical Representation of data results for Claremore Lake.

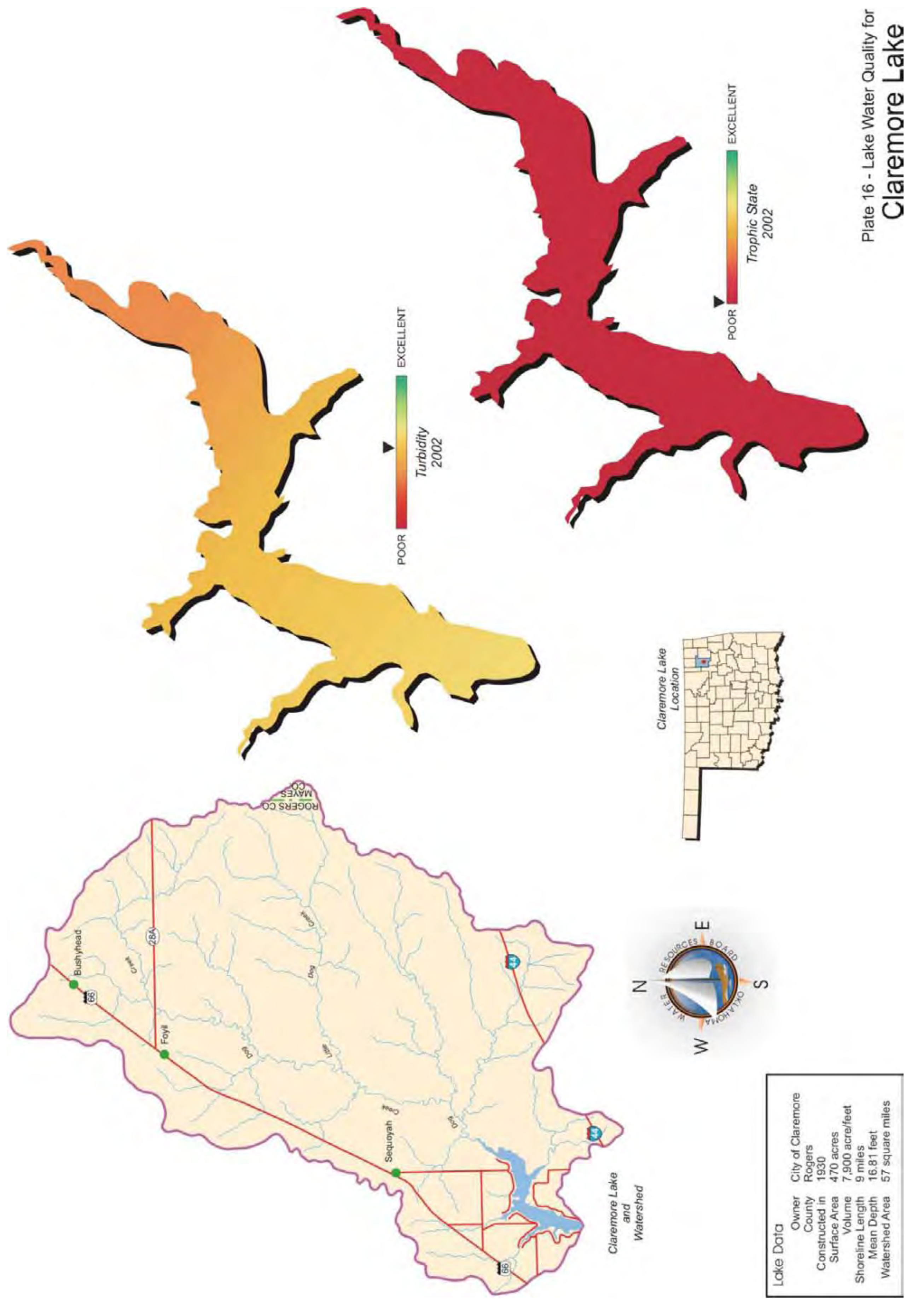


Plate 16 - Lake Water Quality for
Claremore Lake

Clear Creek Lake

Clear Creek Lake was sampled for four quarters, from November 2002 through July 2003. Water quality samples were collected at 3 sites in the fall and winter and from five (5) sites in the spring and summer quarters to represent the riverine, transition, and lacustrine zones of the reservoir. Additional sample sites were added half way in to the sample year to ensure that an adequate amount of data was being collected, as this reservoir is greater than 250 surface acres in size. 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 17), true color was 14 units, and secchi disk depth was 100 centimeters in 2003. Based on these three parameters, Clear Creek Lake had good water clarity. These values are very similar to those calculated in 2001, indicating no significant increase or decrease 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=16). The TSI was 48 (Plate 17), indicating the lake was mesotrophic in sample year 2003. The TSI values throughout the sample year were fairly consistent and ranged from mid-mesotrophic to eutrophic (see Figure 44). The TSI in 2001 was 52 indicative of eutrophic conditions. The lower trophic value in 2003 is probably a more accurate depiction since it was based on a larger dataset. Seasonal turbidity values are displayed in Figure 45a. 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 $\geq$ 25% of the samples exceed the OWQS 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 5% of the values exceeding 25 NTU, the Fish and Wildlife Propagation (FWP) beneficial use is supported based on turbidity. The lake-wide annual turbidity of 12 NTU was representative of conditions at Clear Creek Lake in 2001. Seasonal true color values were all well below the OWQS of 70 units and are displayed in Figure 45b. Due to the minimum data requirements not being met assessment of the Aesthetics beneficial use based on true color could not be made.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 0.27 parts per thousand (ppt) to 0.34 ppt for this sample year. Specific conductance ranged from 530.9 mS/cm to 655.9 mS/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,

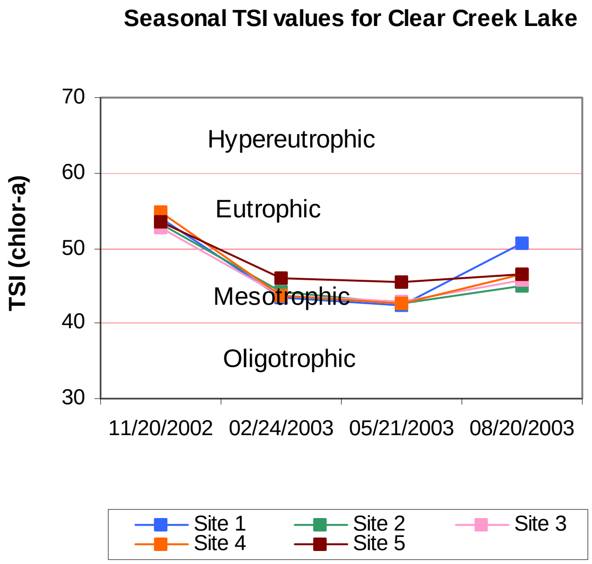


Figure 44. TSI values for Clear Creek Lake.

consistent with recorded salinity concentrations. The pH values at Clear Creek Lake ranged from 7.08 to 8.16, 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 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range Clear Creek Lake is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 311 mV in the hypolimnion during the summer to 467 mV in the fall. In general, reducing conditions were not present in this reservoir. The lake was not stratified during the fall, winter or spring sampling quarters (see Figure 45c-44e) and dissolved oxygen (D.O.) levels were generally above 5.0 mg/L. Thermal stratification and anoxic conditions were present in the summer sampling interval with dissolved oxygen levels fall below 2.0 mg/L below the thermocline. 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 the FWP beneficial use is partially supported at Clear Creek Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 found the Agriculture beneficial use to be fully supported bases 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 five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (37.8 cfu/ml) exceed the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.69 mg/L at the surface and 0.90 mg/L at the lake bottom. The TN at the surface ranged from 0.80 mg/L in the spring to 0.98 mg/L in the summer. The lake-wide total phosphorus (TP) average was 0.021 mg/L at the surface and 0.027 at the lake bottom. The total phosphorus at the surfaced ranged from 0.012 mg/L to 0.027 mg/L with lower values occurring in the fall quarter. The nitrogen to phosphorus ration (TN:TP) was 33:1 for sample year 2003. 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. This classification differs from that in 2001 when the TSI of 53 resulted in a eutrophic classification. The current calculation is based on a larger dataset and is likely a more accurate depiction of productivity within the lake system. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use for pH and turbidity, but partially supporting based on dissolved oxygen levels. The Aesthetics beneficial use is being met by the trophic status, however the minimum data requirement of 20 samples for lakes greater than 250 surface acres was not met for true color. Clear Creek Lake, located in Stephens County, serves as a municipal water supply as well as a recreational reservoir for the city of Duncan.

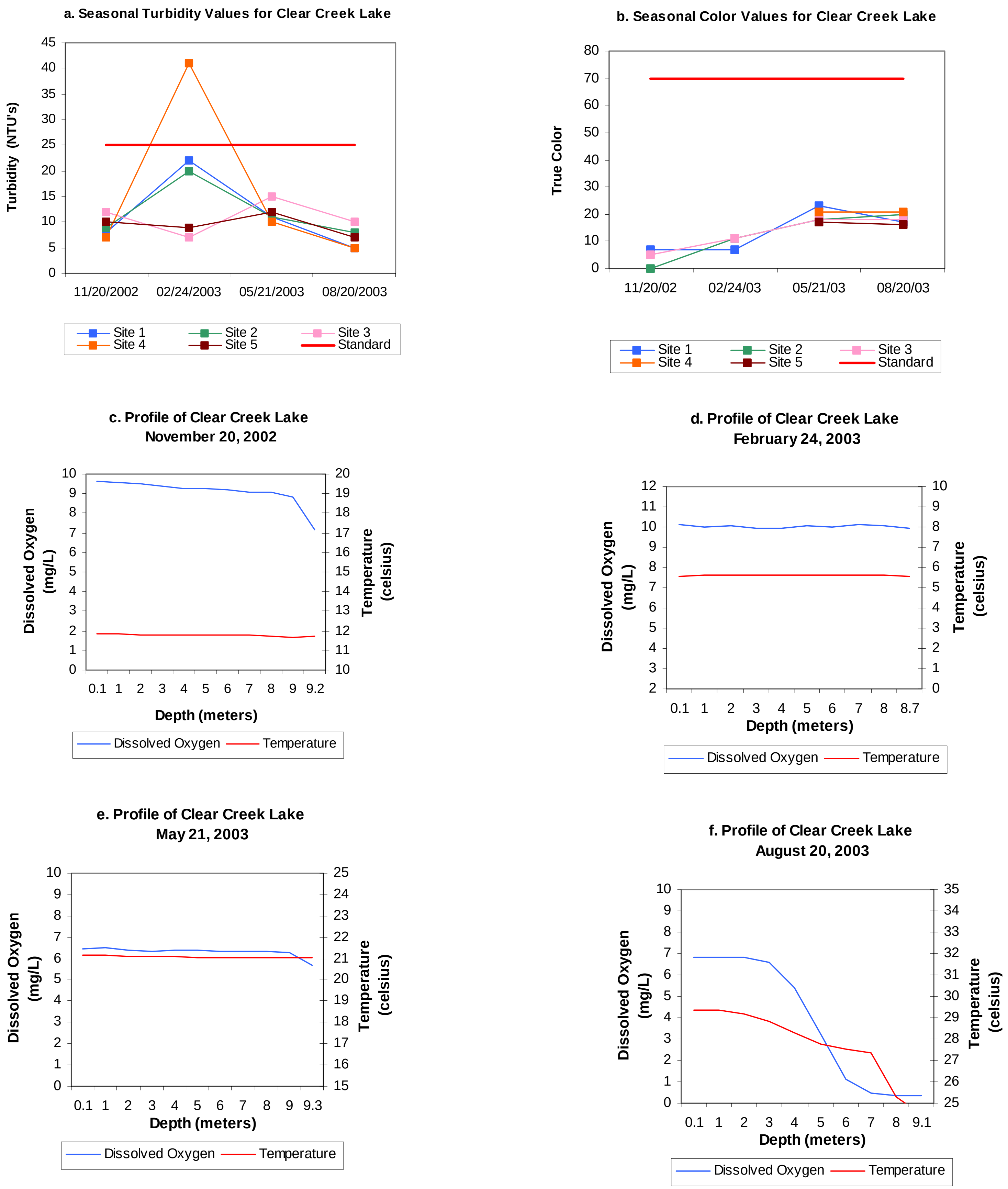


Figure 45a-44f. Graphical representation of data results for Clear Creek Lake.

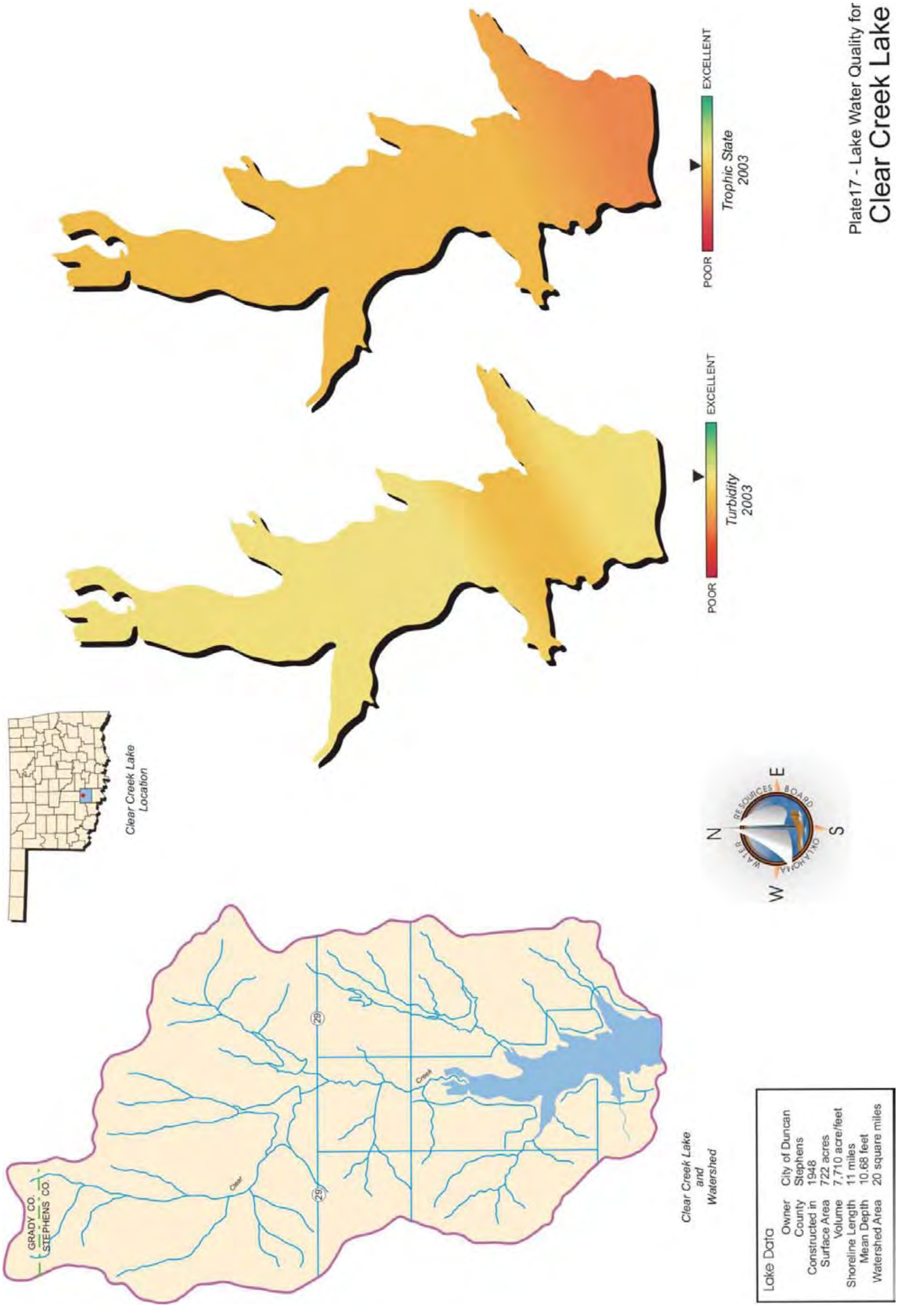


Plate17 - Lake Water Quality for
Clear Creek Lake

Cleveland City Lake

Cleveland City Lake was sampled for four quarters, from October 2001 through July 2002. 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 21 NTU (Plate 18), true color was 45 units, and secchi disk depth was 42 centimeters in 2001-2002 sampling. Based on these three parameters, Cleveland City Lake had moderate to fair 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=12). The average calculated TSI was 55 (Plate 18), indicating the lake was eutrophic, with high levels of primary productivity and nutrients. The TSI values throughout the sample year varied seasonally from mesotrophic in the winter to hypereutrophic at site 3 in the spring (Figure 46). Of the turbidity values collected, 25% were above the turbidity standard of 25 NTU and 75% were below, resulting in Cleveland City Lake to be listed as not supporting its Fish & Wildlife Propagation (FWP) beneficial use (see Figure 47a). 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 OWQS (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 47b. Of the 12 samples collected at Cleveland City Lake in 2001-2002, 8% of the true color values exceeded the 70 units criteria listed in OWQS. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.08 parts per thousand (ppt) to 0.12 ppt, well within the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Specific conductance values were also well within the expected range for Oklahoma reservoirs, coinciding with the low salinity concentrations. Specific Conductance values ranged from 171.2 mS/cm in the spring to 293.2 mS/cm in the summer. Oxidation-reduction potentials (redox) ranged from –17 mV in the summer quarter to 504 mV in the winter season, indicating reducing conditions were present in the lake in the warmer summer season but not at a level to cause concern. The pH values indicated that the lake was neutral to slightly alkaline with values ranging from 6.87 to 8.25 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 should be listed as not supporting beneficial uses. 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 beneficial uses. Cleveland Lake is fully supporting its FWP as it relates to pH. The lake was not thermally stratified and the water column appeared to be well mixed during the fall

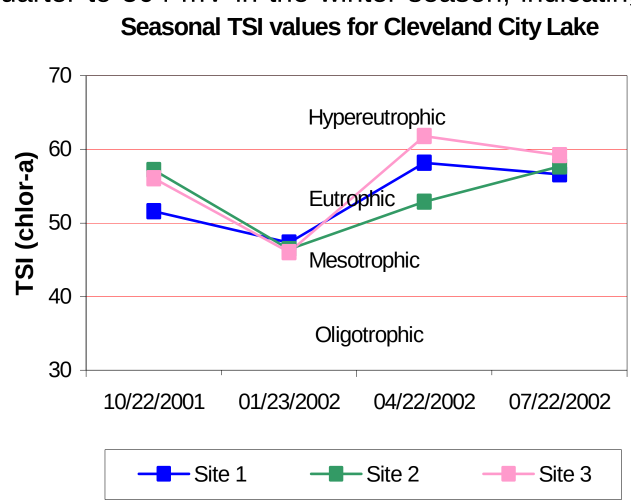


Figure 46. TSI values for Cleveland City Lake.

and winter months (see Figure 47c-46d). However, the lake was weakly thermally stratified in the spring quarter and strongly thermally stratified in the summer quarter (see Figure 47e-46f). Dissolved oxygen (D.O.) values remained above or near 6.0 mg/L in the fall and winter, but were less than 2.0 mg/L at the lake bottom in the spring. In the summer, the lake was strongly thermally stratified between 3 and 4 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 6.1 meters (see Figure 47f). 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 50% 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 total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.98 mg/L at the lake surface. The TN at the surface ranged from 0.73 mg/L to 1.33 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 for sample year 2001-2002 was 0.046 mg/L at the lake surface. The TP ranged from 0.033 mg/L at site 2 in the winter to 0.077 mg/L at the lake surface at site 3 in the fall quarter. Similar to the TN values, the highest surface TP values were reported in the fall quarter and the lowest were seen in the winter and spring quarters. The nitrogen to phosphorus ratio (TN:TP) was 21:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Cleveland Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Cleveland City Lake was classified as eutrophic, indicative of 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 true color and trophic state (for nutrients). The lake is also partially supporting in FWP beneficial use based on low D.O. concentrations in the water column based on the Use Support Assessment protocols outlined in OAC 785:46. Cleveland City Lake is fully supporting its FWP beneficial use base on turbidity and pH. 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.

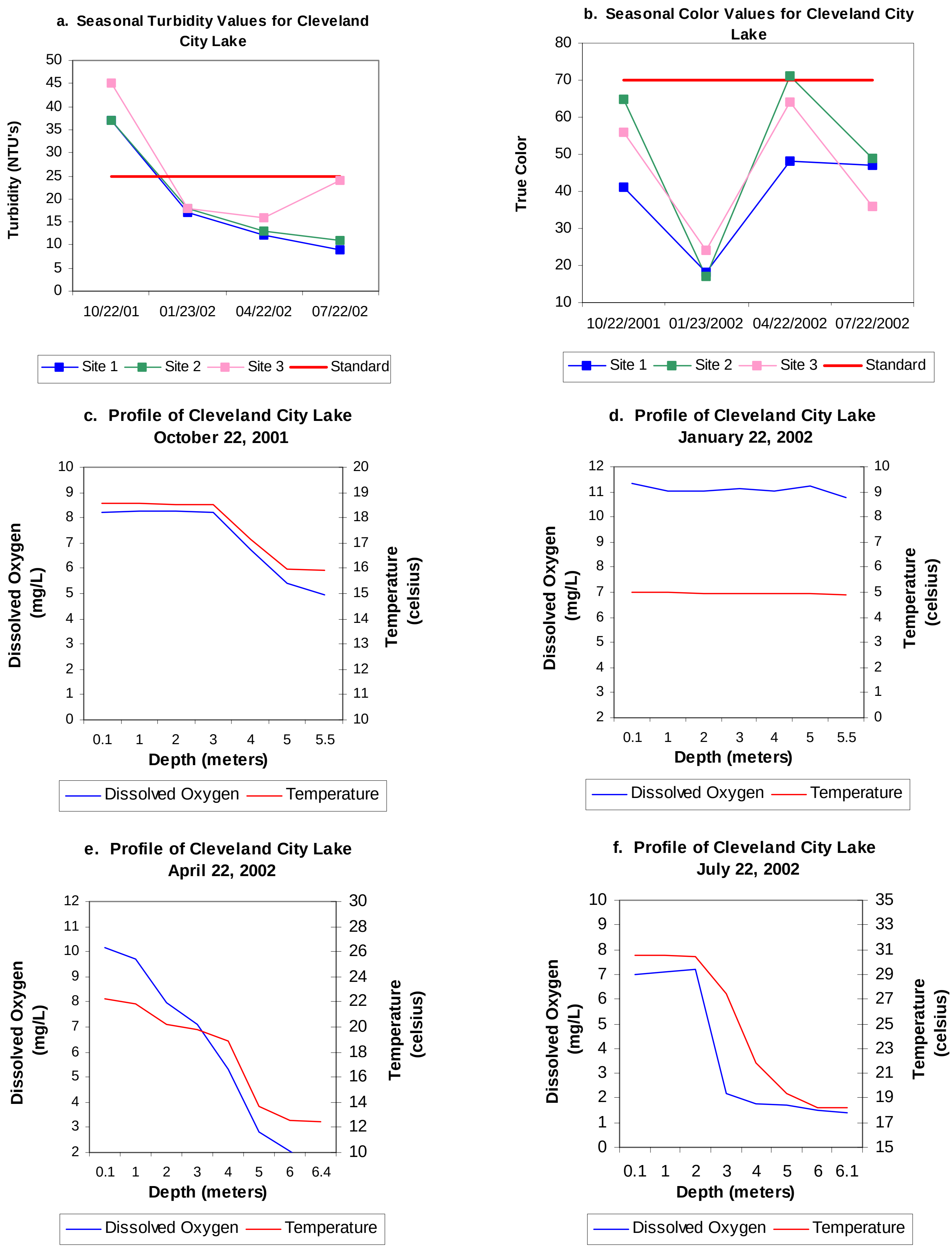
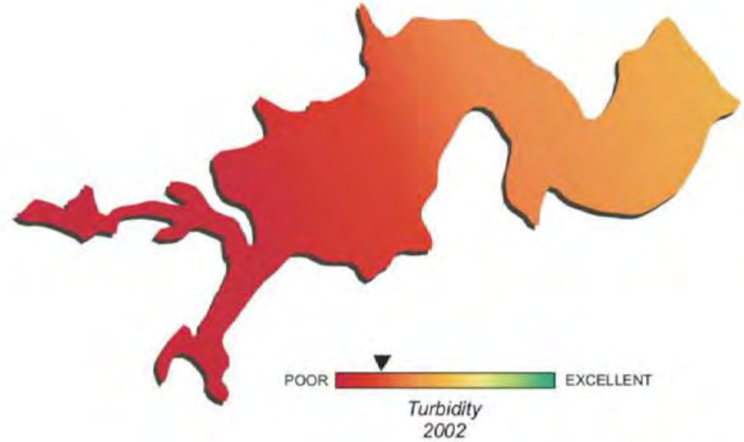
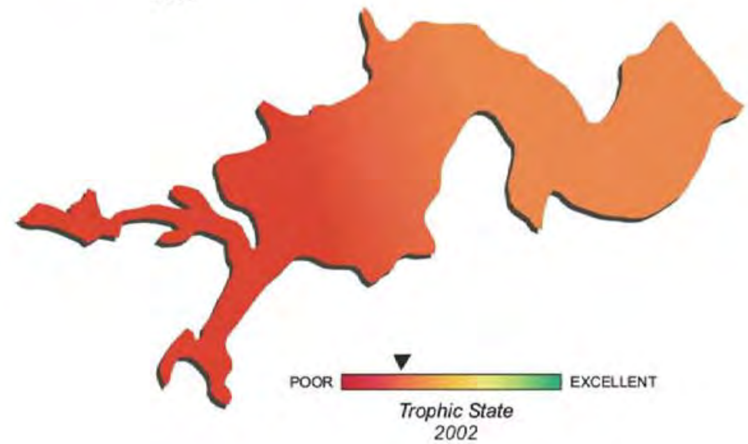


Figure 47a-46f. Graphical representation of data results for Cleveland City Lake.

Cleveland Lake
Location

Cleveland Lake
and
Watershed





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 18 - Lake Water Quality for
Cleveland Lake

Clinton Lake

Clinton Lake was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. In addition, samples were also collected at the lake surface at sites 4 and 5 for chlorophyll-a and turbidity analysis in order to meet minimum data requirements. 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 52 NTU (Plate 19), true color was 44 units, and secchi disk depth was 22 centimeters in 2001-2002. Based on these three parameters, Clinton Lake 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 61 (Plate 19), indicating the lake was eutrophic to 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 (see Figure 48). Turbidity values per site for sample year 2001-2002 were generally above the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons with 75% of the collected data exceeding the OWQS (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 OWQS (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 52 NTU is representative of conditions at Clinton Lake in 2001-2002 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. All true color values were below the Aesthetics OWQS of 70 units (see Figure 49b), but the Aesthetics beneficial use could not be assessed due to insufficient data. Collected information supports the supposition that the use would be supported for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.27 parts per thousand (ppt) to 0.28ppt, which slightly higher than the expected range for most Oklahoma lakes, reflecting minimal to moderate levels of chlorides or other salts in the lake. Specific conductance values were slightly higher than most Oklahoma reservoirs, with values ranging from 530.0 mS/cm in the summer to 551.9 mS/cm in the winter. Oxidation-reduction potentials ranged from 39 mV to 432 mV, indicating reducing conditions were not present in the lake. The pH was neutral to slightly alkaline with values ranging from 7.0 to 8.51 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

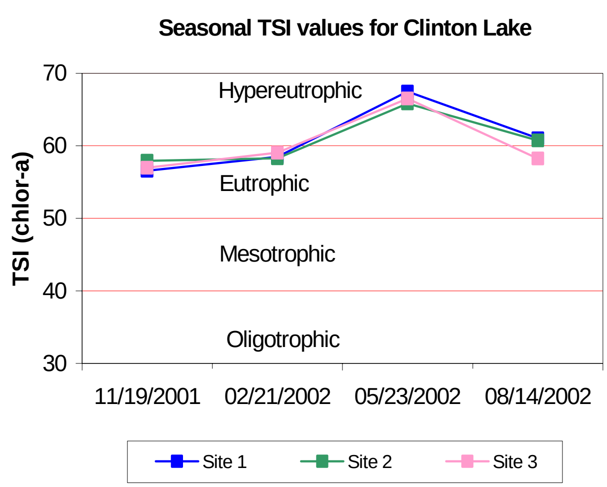


Figure 48. TSI values for Clinton Lake.

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. 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 49c-48e). Dissolved oxygen (D.O.) values remained above 6.0 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 (see Figure 49c-48e). The FWP beneficial use is fully supported based on D.O. concentrations. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 1.18 mg/L at the surface. The TN at the surface ranged from 0.75 mg/L to 1.71 mg/L, which is higher than generally seen in Oklahoma lakes. 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 for sample year 2001-2002 was 0.193 mg/L at the surface. The TP ranged from 0.077 mg/L to 0.458 mg/L at the lake surface. The highest surface TP values were reported in the fall quarter and the lowest were in the winter quarter. Nitrogen values in Clinton Lake were also higher than normally seen in most Oklahoma Lakes. The nitrogen to phosphorus ratio (TN:TP) was approximately 6:1 for sample year 2001-2002. This value is less than 7:1, characterizing the lake as potentially nitrogen-limited (Wetzel, 1983).

Clinton Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Clinton Lake was classified as eutrophic to borderline hypereutrophic, indicative of high to excessive primary productivity and nutrient levels (Plate 19). The trophic status of the reservoir would be much higher if the inorganic turbidity of the lake were not limiting the level of productivity that would normally be seen in a lake with such high nutrient concentrations. The lake was supporting its Aesthetics beneficial use based on trophic status and insufficient data was available to definitively assess use support for true color, though collected data suggests it would be fully supporting. D.O. and pH values were fully supporting the FWP beneficial use. Clinton Lake was not meeting its FWP beneficial use due to high turbidity values. 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.

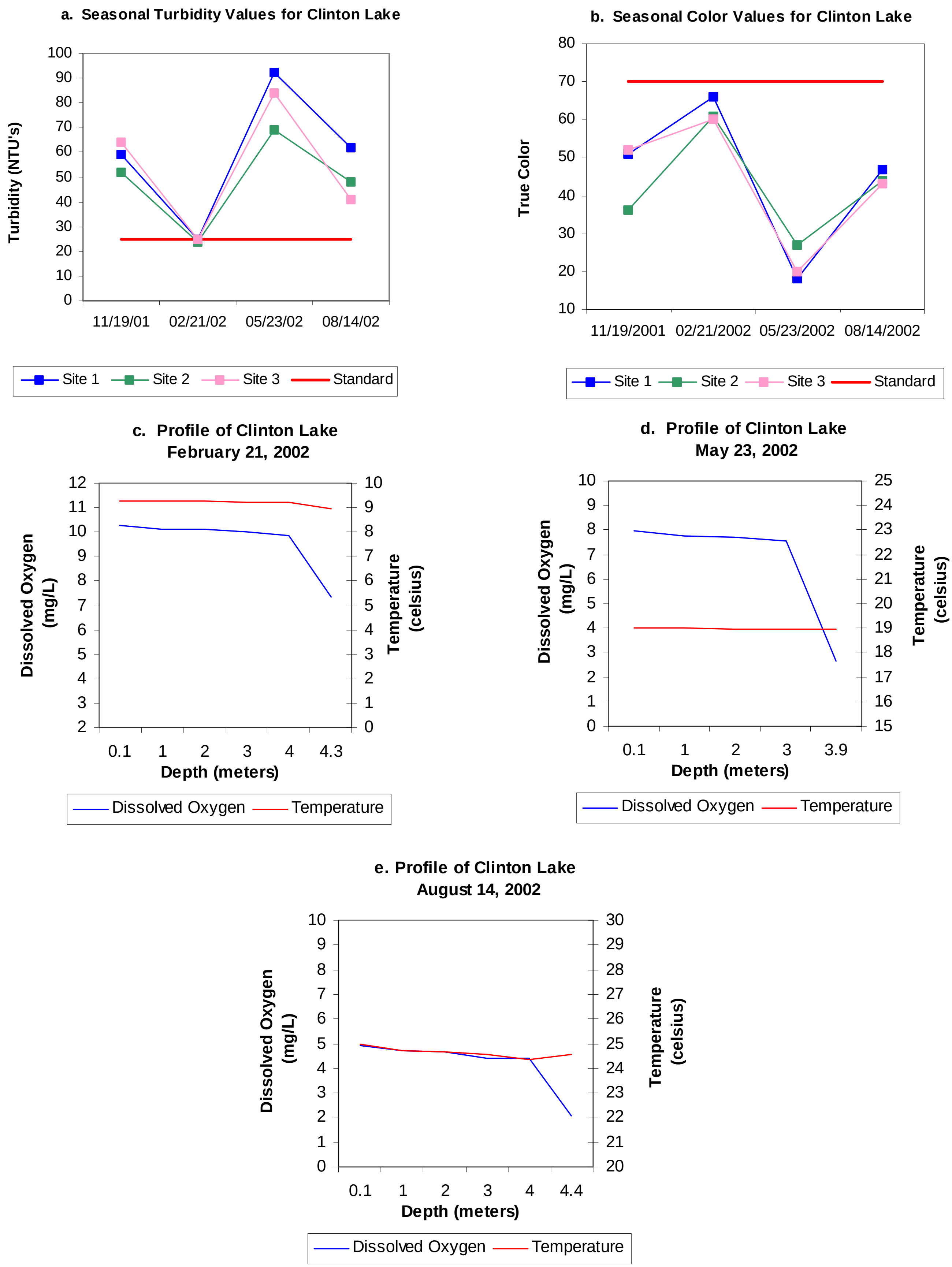


Figure 49a-48e. Graphical representation of data results for Clinton Lake.

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 19- Lake Water Quality for
Clinton Lake

Coalgate City Lake

Coalgate City Lake was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional samples were collected at the lake surface at sites 4 and 5 for chlorophyll-a and turbidity analysis in order to meet minimum data requirements. All other 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 86 NTU (Plate 20), true color was 310 units, and secchi disk depth was 17 centimeters in 2001-2002. 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 45 (Plate 20), indicating the lake was mesotrophic, with moderate levels of productivity and nutrients. The TSI values were varied based on site location and season with oligotrophic values present in the winter quarter and lower eutrophic conditions present in the summer season (see Figure 50). Turbidity values per site for sample year 2001-2002 were all above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 51a). 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 OWQS (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 86 NTU is representative of conditions at Coalgate City Lake in 2001-2002 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 85% of the true color values were above the aesthetics OWQS of 70 units, (see Figure 51b). Although 85% of the samples were above the standard, a beneficial use determination cannot be made because the minimum data requirements were not met (See OAC 785:46).

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, 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 expected range for most Oklahoma lakes if not less than what is normally seen. Values reflect a minimal presence of chlorides or other salts in the lake. Specific conductance values followed a similar pattern and were much lower than most Oklahoma reservoirs, with values ranging from 20.6 mS/cm in the spring to 120.5 mS/cm in the summer, which indicates a very low content of electrical current conducting compounds or salts. Oxidation-reduction potentials ranged from 164 mV to 494 mV, indicating reducing conditions were not present in the reservoir at the time data collection occurred. The pH was neutral to very slightly acidic with values ranging from 6.52 to 7.27 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

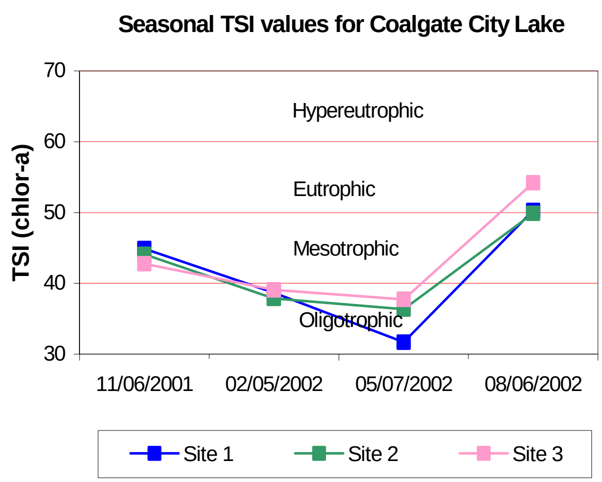


Figure 50. TSI values for Coalgate City Lake.

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. Coalgate Lake was fully supporting its FWP beneficial use for pH. The lake was not thermally stratified in the fall and winter and the water column was well mixed (see Figure 51c-50d). 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 60% in the fall and winter. In the spring the lake was showed weak thermal stratification, but the OWQS were met. In the summer quarter, the lake was strongly stratified between 2 and 3 meters and the D.O. concentration dropped from 4.57 mg/L to less than 2.0 mg/L from that point to the lake bottom at 6.9 meters. The readings at the lake bottom were anoxic at all three sites (see Figure 51f). 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 63% 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 total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.86 mg/L at the lake surface. The TN at the surface ranged from 0.38 mg/L to 1.28 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.090 mg/L at the lake surface. The TP ranged from 0.050 to 0.134 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 nitrogen to phosphorus ratio (TN:TP) was approximately 9:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Coalgate Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Coalgate City Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 20). 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 insufficient data was available to definitively assess the use for true color, though collected data strongly suggests that the lake would be not supporting. 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. 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.

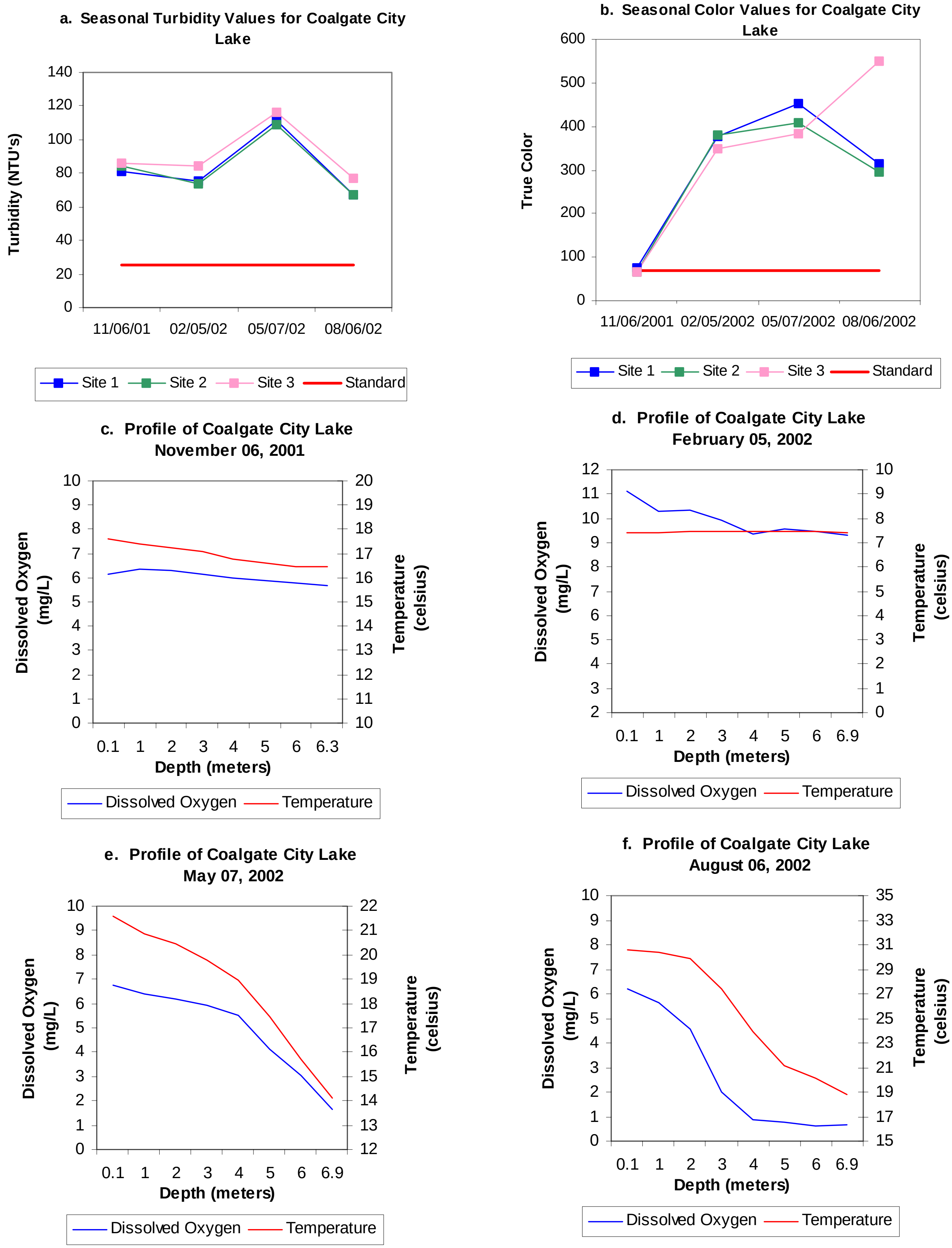
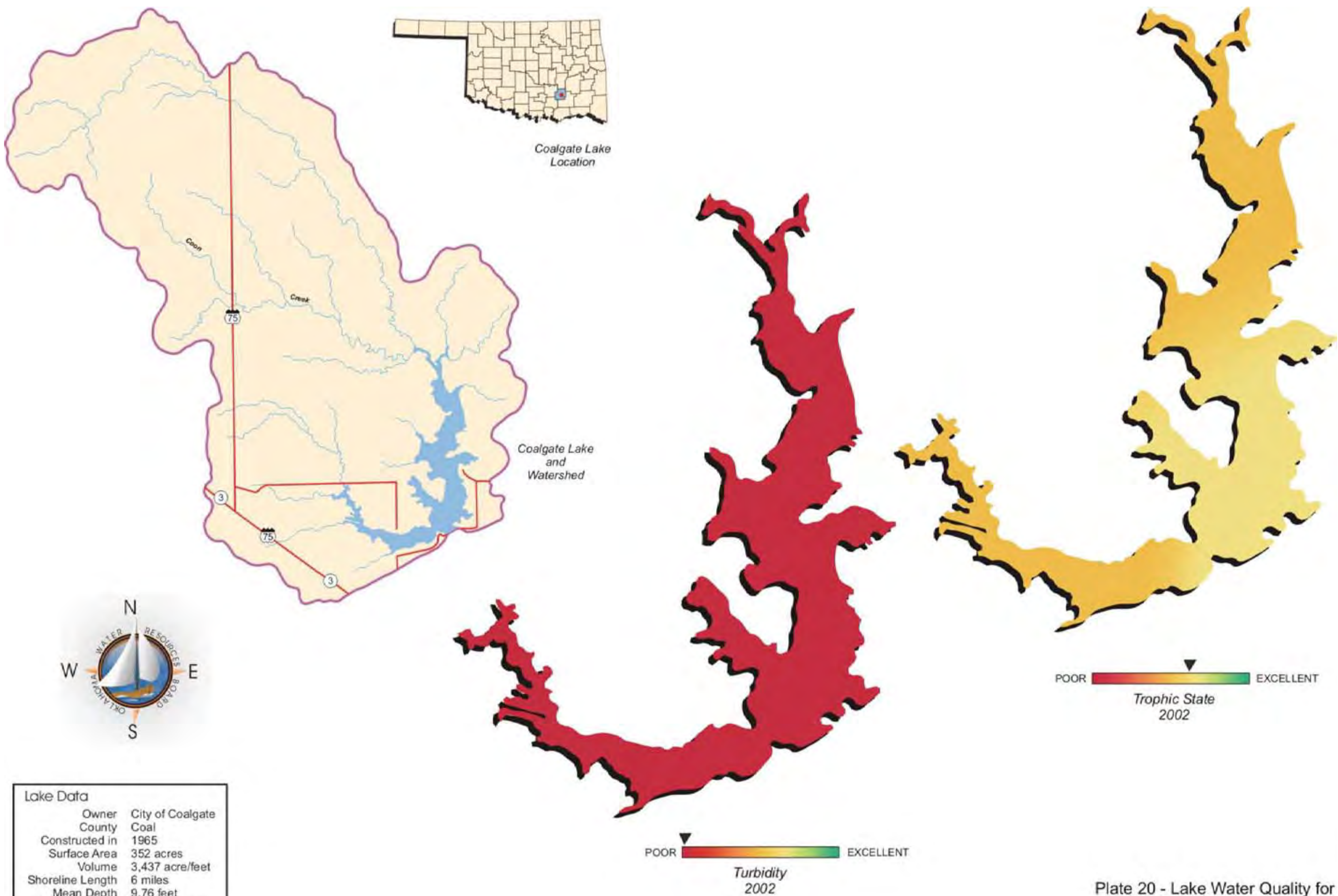


Figure 51a-50f. Graphical representation of data results for Coalgate City Lake.



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

Plate 20 - Lake Water Quality for
Coalgate Lake

Comanche Lake

Comanche Lake was sampled for four quarters from November 2002 through July 2003. 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 12 NTU (Plate 21), true color was 16 units, and secchi disk depth was 86 centimeters in 2003. Based on these three parameters, Comanche Lake had good 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=12). The TSI was 45 (Plate 21), indicating the lake was mesotrophic in sample year 2003. Although this value is slightly lower than that in 2001(TSI=50), the lake is still classified as mesotrophic, indicating little or no change in productivity has occurred. The TSI values throughout the sample year were fairly consistent and ranged from oligotrophic in the winter, to mesotrophic the remainder of the sample year (see Figure 52). The one exception to this was a spike in chlorophyll concentration at site 2 in the spring quarter. Seasonal turbidity values are displayed in Figure. 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 (OWQS) 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 OWQS (Figure 53b). Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is supported based on the high true color values.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation-reduction potential and salinity were recorded at all three sample sites. The salinity ranged from 0.11 parts per thousand (ppt) to 0.16 ppt for this sample year. Specific conductance ranged from 216.6 mS/cm to 321.2 mS/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 6.84 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

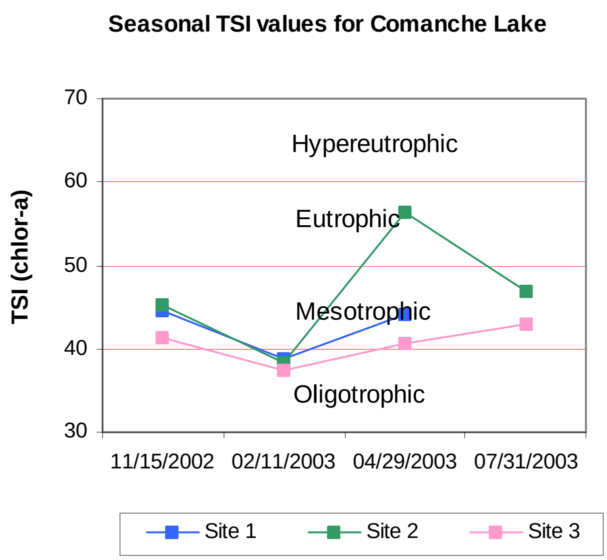


Figure 52. TSI values for Comanche Lake

fall outside the 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range Comanche Lake is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) were positive at all sites and ranged from 229 mV in the spring to 493 mV in the winter. In general, reducing conditions were not present in this reservoir. During the fall, winter and spring quarters stratification was not present and the lake was well mixed. Thermal stratification was evident and anoxic conditions were present during the summer. Stratification occurred between 5 and 6 meters in depth at which the dissolved oxygen (D.O.) fell below 1.0 mg/L for the rest of the water column. 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 50% of the water column in the summer less than 2.0mg/L, Comanche Lake is considered partially supporting its FWP. The lake was sampled for total dissolved solids, chlorides, and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the surface and 0.78 mg/L at the lake bottom. The TN at the surface ranged from 0.21 mg/L in the winter to 0.51 mg/L in the fall. The lake-wide total phosphorus (TP) average was 0.017 mg/L at the surface and 0.104 at the lake bottom. The total phosphorus at the surfaced ranged from 0.008 mg/L to 0.023 mg/L with lower values occurring in the fall quarter. The nitrogen to phosphorus ration (TN:TP) was 24:1 for sample year 2003. This value is much higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Comanche was classified as mesotrophic with moderate primary productivity and nutrient conditions in 2002-2003, indicating no significant change has occurred since 2001. Water clarity was good based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use for pH and turbidity, but partially supporting based on dissolved oxygen levels. The Aesthetics beneficial use is also being met for both the trophic status and true color parameters. 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.

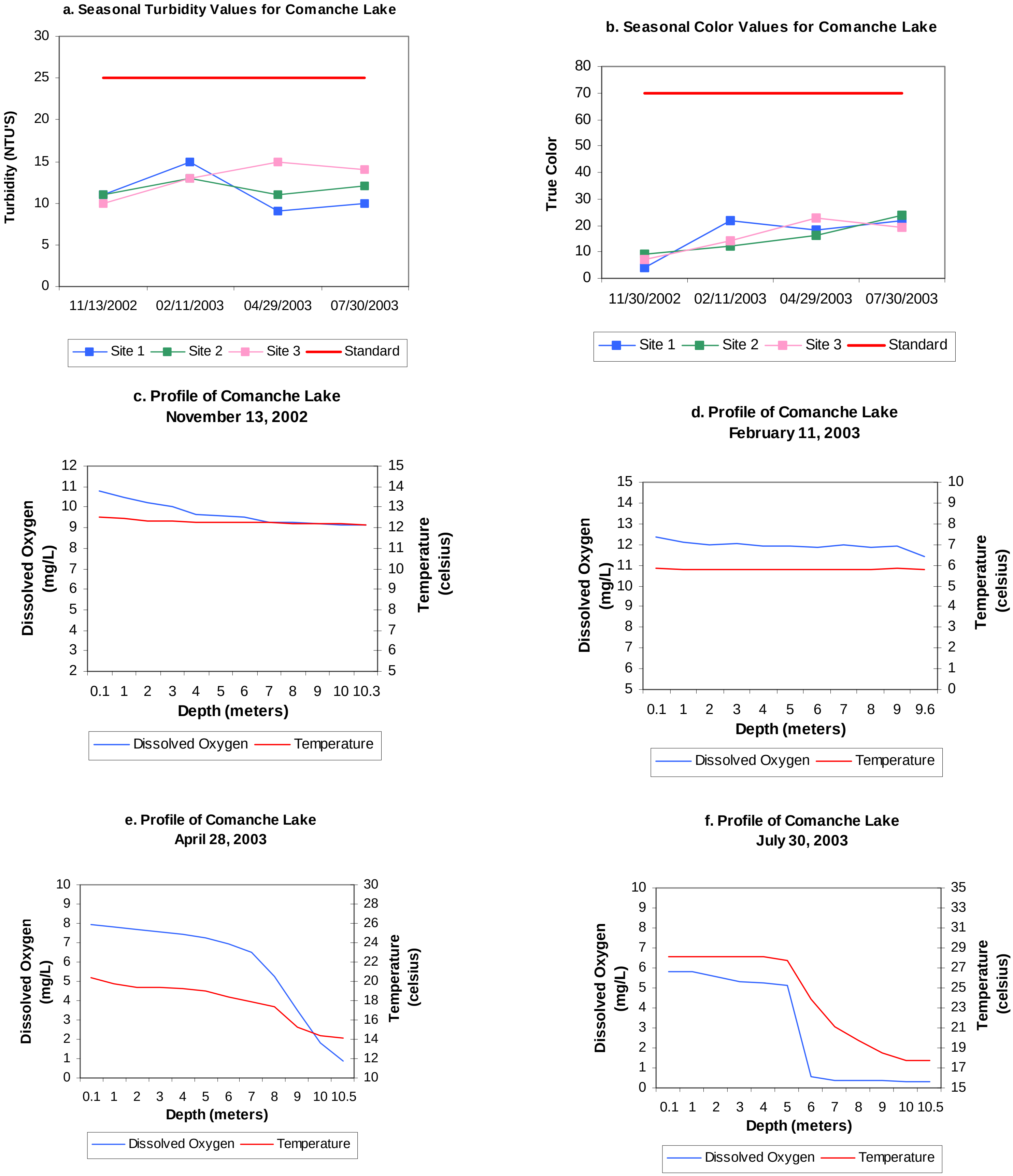


Figure 53a-52f. Graphical representation of data results for Comanche Lake.

Comanche Lake
Location

Comanche Lake
and
Watershed

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

Turbidity
2003

Trophic State
2003

Plate 21 - Lake Water Quality for
Comanche Lake

Copan Lake

Copan Lake was sampled for four quarters, from October 2002 through July 2003. 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 46 NTU (Plate 22), true color was 50 units, and average secchi disk depth was 36 centimeters in sample year 2002-2003. Water clarity was poor at Copan Lake based on these three parameters. Results for turbidity, true color and secchi disk depth are similar to those recorded in 2000. 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 59 (Plate 22), indicating the lake was eutrophic, with high levels of productivity and nutrient conditions for sample year 2003. This value is similar to that calculated in 2000 (TSI=57) indicating no significant change in productivity has occurred. The TSI values for all sites were fairly consistent and ranged from upper eutrophic to lower hypereutrophic (Figure 54). Seasonal turbidity values by site are displayed in Figure 55a. Although the lake-wide average for turbidity was 46 NTU, above the OWQS of 25 NTU, there are instances when some values were near or below the standard. These lower turbidity values occurred at all sites during the winter quarter (see Figure 55a). 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 (OWQS) 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 70% of the values exceed the turbidity standard of 25 NTU. Seasonal true color values are displayed in Figure 55b. Of the 20 samples collected, 20% exceeded the OWQS 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 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.14 ppt, which is within the range of values seen in Oklahoma reservoirs. Specific conductance ranged from 152.1 mS/cm to 256.3 mS/cm, indicative of minimal levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.81 in the summer to 8.18 in the spring, representing a neutral to slightly alkaline lake system. According to USAP (OAC 785:46-15-

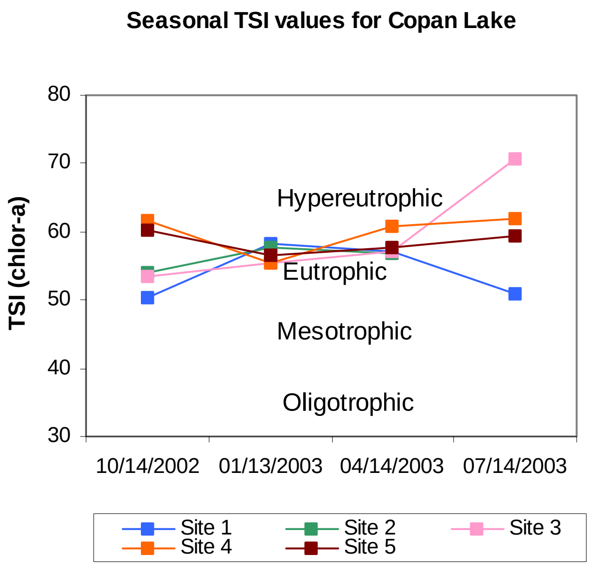


Figure 54. TSI values for Copan Lake

5), pH values are exceeding standards if they fall outside the 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range, Copan Lake is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from 407mV in the hypolimnion in the spring to 594 mV in the fall. In general, reducing conditions were not present at this reservoir during the 2002-2003-sample year. Copan Lake was not thermally stratified during any of the sampling quarters (see Figure 55c-54f). Dissolved oxygen (D.O.) levels were generally above 4.0 mg/L throughout the sample year. The relatively shallow nature of the lake is likely responsible for keeping 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 Benicia use is fully supported at Copan Lake. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.55mg/L at the surface and 0.36 mg/L at the lake bottom. Surface TN ranged from 0.25 mg/L to 1.38 mg/L, with the highest values recorded in the summer quarter, and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.080 mg/L at the surface and 0.057 mg/L at the lake bottom. Similar to total nitrogen surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.023 mg/L to 0.184 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 7:1 for sample year 2003 characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Copan Lake was classified as eutrophic with high primary productivity and nutrient levels in 2002-2003. This value is similar to that calculated in 2000 (TSI=57), indicating no significant change in productivity has occurred. Water clarity was poor based on turbidity, true color and secchi disk depth. The lake is not supporting the FWP beneficial use based on turbidity, but is supporting based on pH and dissolved oxygen values. The Aesthetics beneficial use is supported based on the trophic status, and is partially supported for true color, as 20% of the collected values exceed the OWQS 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.

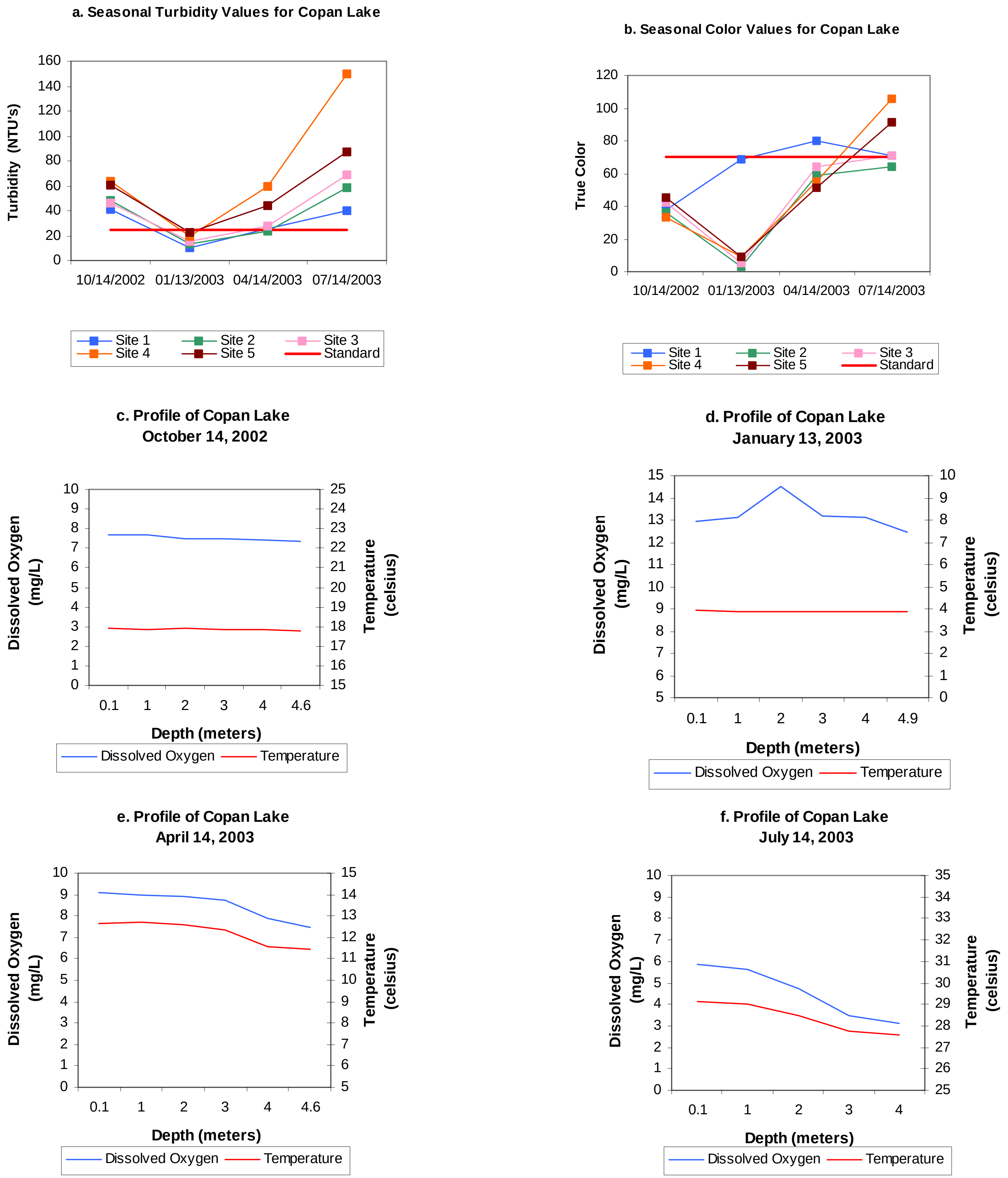
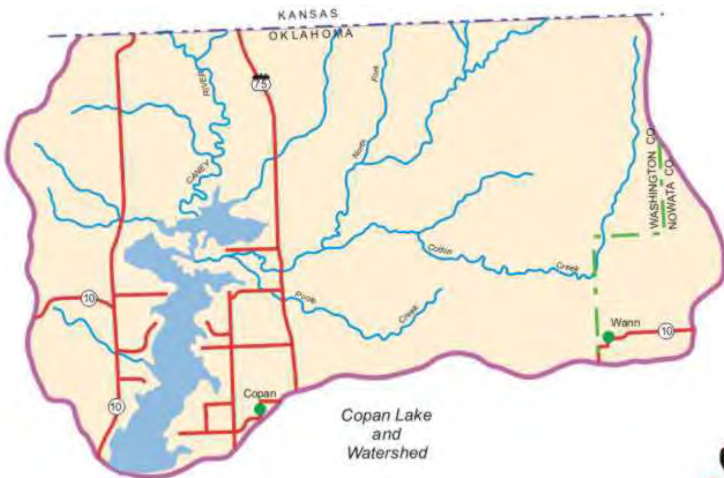
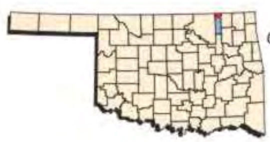


Figure 55a-54f. Graphical representation of data results for Copan Lake.





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

Plate 22 - Lake Water Quality for
Copan Lake

Crowder Lake

Crowder Lake was sampled for four quarters, from October 2001 through July 2002. 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 17 NTU (Plate 23), true color was 27 units, and secchi disk depth was 60 centimeters in 2001-2002. Based on these three parameters, Crowder 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=12). The average TSI was 60 (Plate 23), indicating the lake was eutrophic, with high levels of productivity and nutrients. The TSI values were primarily eutrophic in the spring and summer with upper eutrophic to hypereutrophic values seen in the fall and winter (see Figure 56). This isn't a pattern you generally see in Oklahoma where the highest trophic status of the year was recorded in the early fall of the year. Crowder Lake is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW) indicating that its Aesthetics use is threatened due to nutrients (based on trophic status). An intensive study should be conducted to assist in understanding the dynamics of the system to determine if the Aesthetics use is not supported. Turbidity values per site for sample year 2001-2002 were below the OWQS of 25 NTU for all seasons except for one event in the fall and one in the summer, which exceeded the standard (see Figure 57a). With only 16% of the turbidity values exceeding the criteria, the Fish & Wildlife Propagation (FWP) is considered fully supported. 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 OWQS (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 OWQS of 70 units (see Figure 57b). 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 conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.29 parts per thousand (ppt) to 0.61 ppt, which is higher than the expected range for most Oklahoma lakes. Salinity values indicated a moderate to high presence of chlorides or other salts in the lake. Specific conductance values exhibited a similar pattern and were somewhat higher than most Oklahoma reservoirs, with values ranging from 574.3 mS/cm in the fall to 1233 mS/cm in the spring, which is indicative of a high content of electrical current conducting compounds or salts. Oxidation-reduction potentials (redox) ranged from –59 mV to 538 mV, indicating reducing conditions were present in the summer quarter when the lake was thermally stratified. The presence of reducing conditions increases the possibility of getting release of compounds (i.e. nutrients) from the sediments back into the water column. The pH was neutral to slightly alkaline with values ranging from 7.06 to 8.36 units.

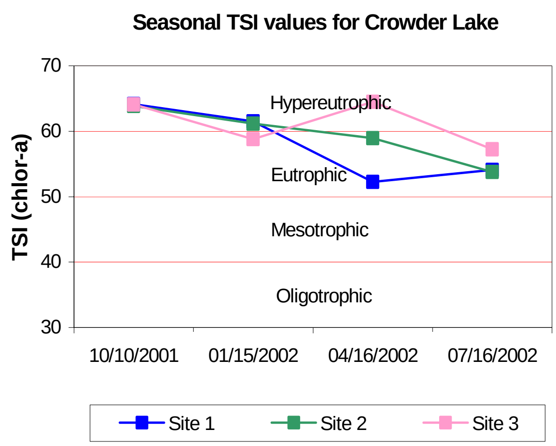


Figure 56. TSI values for Crowder Lake.

According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 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. Crowder Lake is fully supporting its FWP for pH. The lake was not thermally stratified and the water column appeared to be well mixed throughout the fall, winter and spring quarters at all sites (see Figure 57c-56e). Dissolved oxygen (D.O.) values remained above 2.0 mg/L throughout the water column and were generally above 5.0 mg/L and the dissolved oxygen percent saturation was never less than 45% in the first three seasons (see Figure 57c-56e). In the summer, the lake was stratified between 4 and 5 meters and the D.O. concentration dropped from 3.86 mg/L at 3 meters below the surface to 0.56 mg/L at the lake bottom (see Figure 57f). The readings at the lake bottom were anoxic at two of the three sites monitored. Site 3 was not anoxic due to the shallow depth of the site. 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 55% of the water column < 2.0 mg/L, Crowder Lake is partially supporting its FWP beneficial use based on D.O. concentrations. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.76 mg/L at the lake surface. The TN at the surface ranged from 0.42 mg/L to 1.32 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 for sample year 2001-2002 was 0.053 mg/L at the lake surface. The TP ranged from 0.030 mg/L to 0.082 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 14:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Crowder Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) 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 23). Anoxic conditions were a cause of concern and the lake is only partially supporting its FWP beneficial use due to low D.O. concentrations in the water column. The FWP beneficial use was fully supported based on pH and nephelometric turbidity. Although some true color values were above the OWQS criteria, the lake was fully supporting its Aesthetics beneficial use. The Aesthetics beneficial use is threatened due to nutrients and the lake is listed in the OWQS as a NLW Waterbody. Crowder Lake 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.

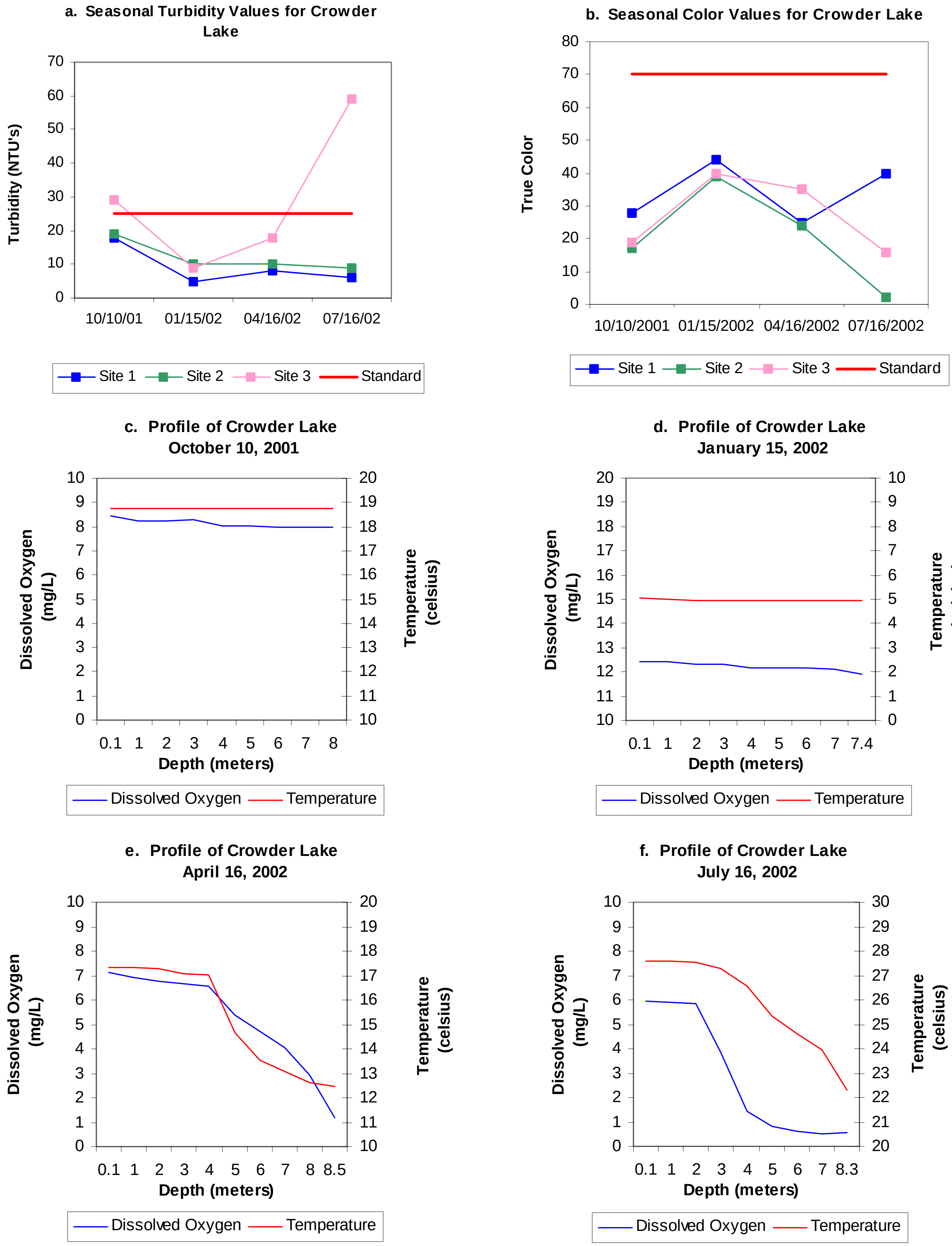


Figure 57a-56f. Graphical representation of data results for Crowder Lake.

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

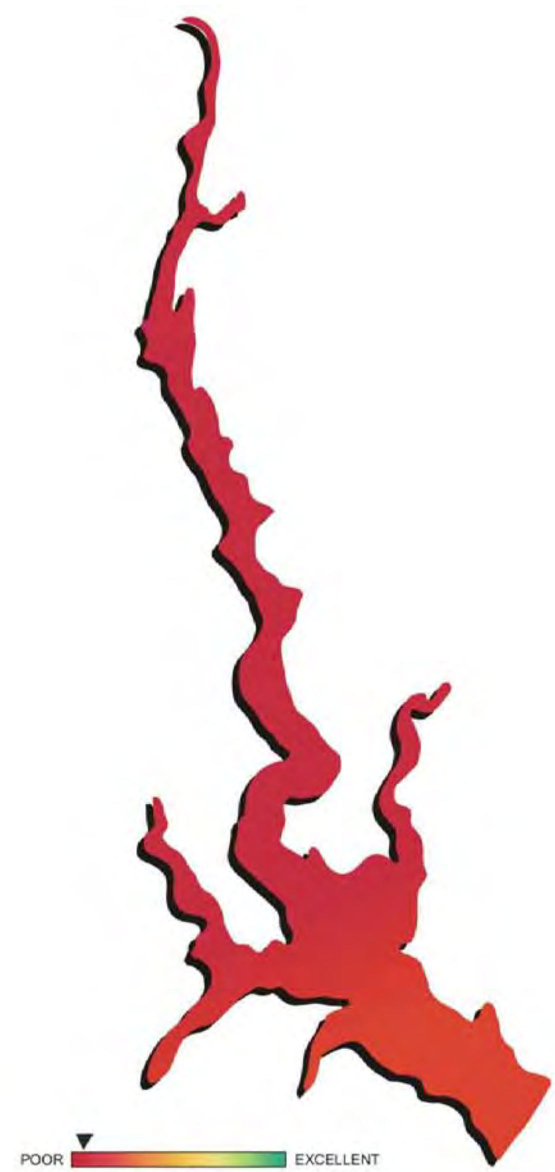


Plate 23 - Lake Water Quality for
Crowder Lake

Cushing Municipal Lake

Cushing Municipal Lake was sampled for three quarters, from February 2002 through August 2002. The lake was scheduled for sampling in the fall of 2003, however the lake was closed for the waterfowl season preventing Water Resources Board personnel from getting on the lake. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. In addition, samples were collected at the lake surface at sites 4, 5, 7, and 8 for chlorophyll-a and turbidity analysis to meet minimum data requirements. Water quality 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 77 NTU (Plate 24), true color was 127 units, and secchi disk depth was 18 centimeters in 2002. 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 three quarters (n=21). The average TSI was 52 (Plate 24), indicating the lake was eutrophic, with high levels of productivity and nutrients. 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 (see Figure 58). Turbidity values per site for sample year 2001-2002 were all above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 59a). 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 OWQS (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 2002 above the standard, Cushing Lake is not meeting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. The lake-wide annual turbidity of 77 NTU is in agreement with historical data collection results seen for the lake. All true color values were above the aesthetics OWQS of 70 units (see Figure 59b). Although 100% of the samples were above the standard, a beneficial use determination cannot be made because the minimum data requirements were not met (See OAC 785:46).

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity values ranged from 0.10 parts per thousand (ppt) to 0.12 ppt, which was within the expected range for most Oklahoma lakes and reflecting minimal presence of chlorides or other salts in the lake. Specific conductance values were also consistent with values that would normally be seen in Oklahoma reservoirs, with values ranging from 220.9 mS/cm in the spring to 260 mS/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 239 mV to 551 mV, indicating reducing conditions were not present at any time during the sampling regime. The pH was neutral with values ranging from 6.99 to 7.93 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the

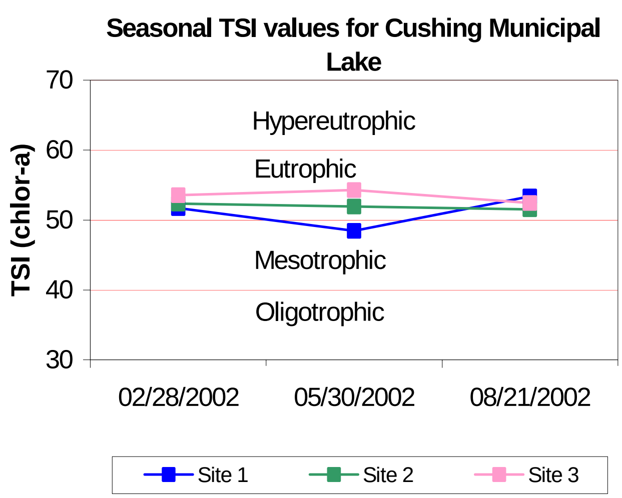


Figure 58. TSI values for Cushing Municipal Lake.

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. 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 winter and summer sampling seasons at all sites (see Figure 59c-58e). Dissolved oxygen (D.O.) values remained above 5.4 mg/L and the D.O. percent saturation was never less than 50% in the winter and summer (see Figure 59c-, 58e). In the spring the lake was stratified at site 1 between 5 and 6 meters and the D.O. concentration dropped from 4.42 mg/L to 0.86 mg/L at the lake bottom of 6.3 meters (Figure 59d). 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 25% of D.O. readings collected at site 1 in the spring less than 2.0 mg/L, the lake is partially supporting its FWP beneficial use. It does appear that the sampling methodology employed contributed to the lake not meeting the FWP beneficial use for D.O. and the lake should be further examined to confirm the presence of a partial support. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2002 was 1.07 mg/L at the lake surface. The TN at the surface ranged from 0.93 mg/L to 1.23 mg/L. The highest surface TN value was reported in the spring and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average for sample year 2002 was 0.120 mg/L at the lake surface. The TP ranged from 0.116 mg/L to 0.123 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 9:1 for sample year 2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Cushing Municipal Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Cushing Municipal Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 24). 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 insufficient data was available to assess the use for true color. The FWP beneficial use was fully supported based on pH. The lake was not meeting its FWP beneficial use due to high turbidity and was partially supporting its FWP beneficial use based on D.O. values. Cushing Municipal Lake is the municipal water supply for the City of Cushing and was constructed for that purpose in 1950. The lake is also utilized for recreational pursuits.

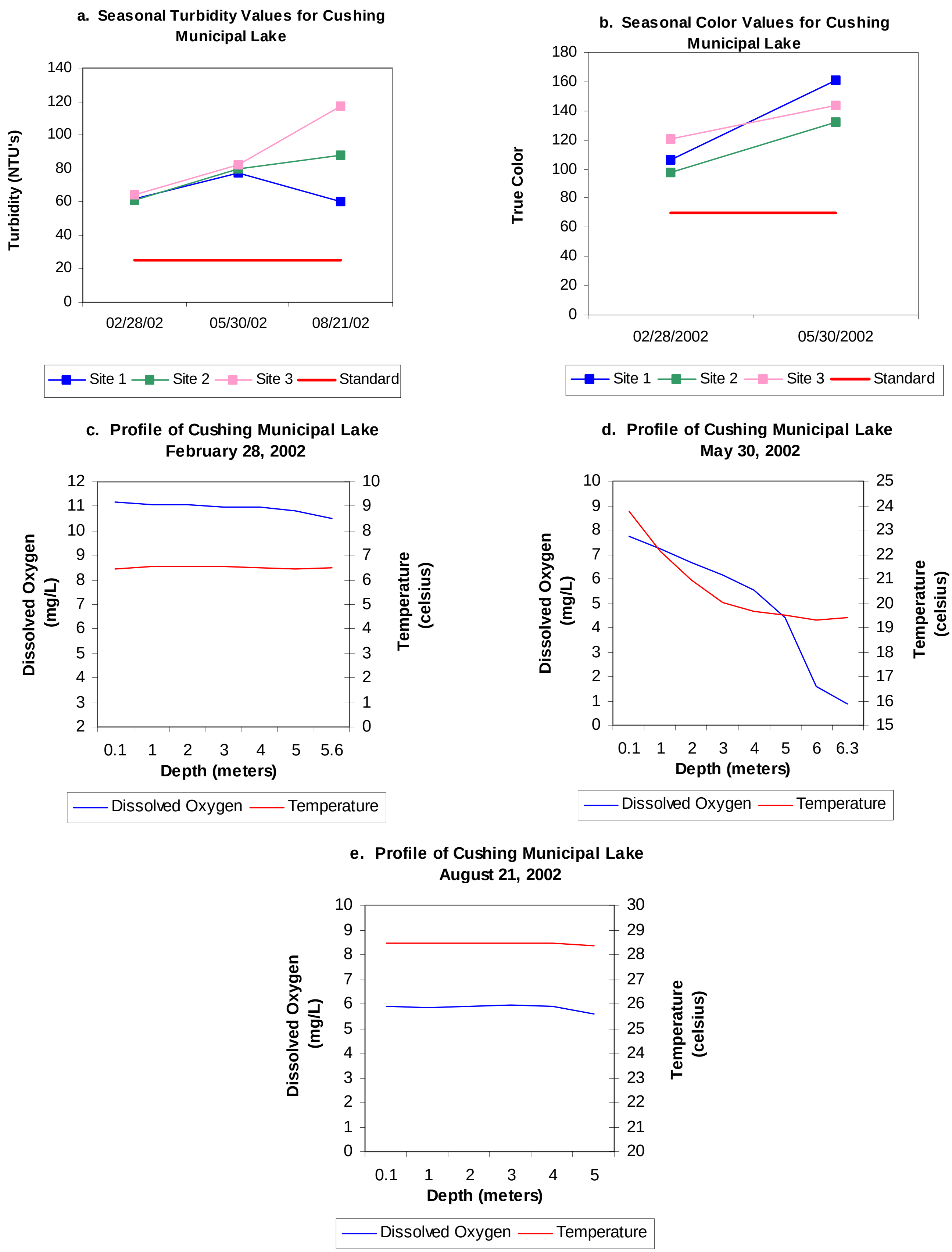
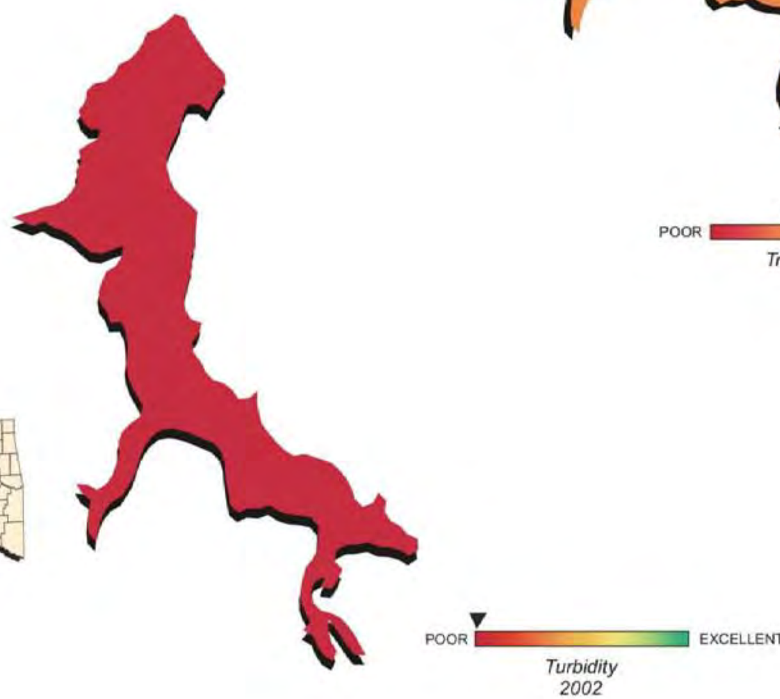


Figure 59a-58e. Graphical representation of data results for Cushing Municipal Lake.



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 24 - Lake Water Quality for
Cushing Lake

Dave Boyer (Walters) Lake

Dave Boyer (Walters) Lake was sampled for four quarters, from November 2000 through July 2001. 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 120 NTU, true color was 242 units, and secchi disk depth was 12 centimeters in 2001. Based on these three parameters, Dave Boyer Lake had poor water clarity in comparison to other Oklahoma reservoirs. Water clarity was similar in the summer of 1998, and is likely always poor based on the soil composition and nature of this lake. For sample year 2001, this lake had the highest turbidity and color values and lowest secchi disk depths. 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 51, indicating the lake was eutrophic, high levels of productivity and nutrients. This value is slightly higher than the TSI in 1998, based on three summer values. The TSI values throughout the sample year varied seasonally from oligotrophic in the fall to eutrophic in the spring and summer. In October 2000, Dave Boyer Lake was so low that a boat could to be launched from the boat ramp. Southwestern Oklahoma received significant amounts of rainfall in October and early November and the lake quickly filled to normal pool levels, resulting in the low productivity in the fall quarter. All turbidity values were well above the turbidity standard of 25 NTU at all sites throughout the year, resulting in Dave Boyer Lake listed as not supporting the Fish & Wildlife Propagation (FWP) beneficial use. According to the Use Support Assessment Protocols (USAP) outlined in Oklahoma Demonstrative 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 Standard (OWQS) 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. Of the 12 samples collected at Dave Boyer Lake in 2001, 75% of the true color values exceeded the 70 units criteria listed in OWQS. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is not supported based on the high true color values.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Dripping Springs Lake

Dripping Springs Lake was sampled for four quarters, from October 2001 through July 2002. 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. 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 25), true color was 27 units, and secchi disk depth was 88 centimeters in 2001-2002. Based on these three parameters, Dripping Springs 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=20). The average TSI was 46 (Plate 25), indicating the lake was mesotrophic, with moderate levels of productivity and nutrients. The TSI values were mesotrophic in the first three seasons, but some sites were oligotrophic during the summer season (see Figure 60). Turbidity values per site for sample year 2001-2002 were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 61a). 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 OWQS (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 11 NTU seemed representative of conditions at Dripping Springs Lake in 2001-2002 and the lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity concentrations. All true color values were below the aesthetics OWQS of 70 units. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use supported based on the true color values (see Figure 61b).

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, 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 0.04 ppt, which was well within the expected range for most Oklahoma lakes if not lower than the normally seen values. The low salinity concentrations recorded reflected minimal presence of chlorides or other salts in the lake. Specific conductance values were also very low when compared to most Oklahoma reservoirs, with values ranging from 53.0 mS/cm in the fall quarter to 99.0 mS/cm in the winter quarter, which indicated that a very low content of electrical current conducting compounds or salts in the water column. Oxidation-reduction potentials ranged from 130 mV to 514 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 6.43 to 8.9 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

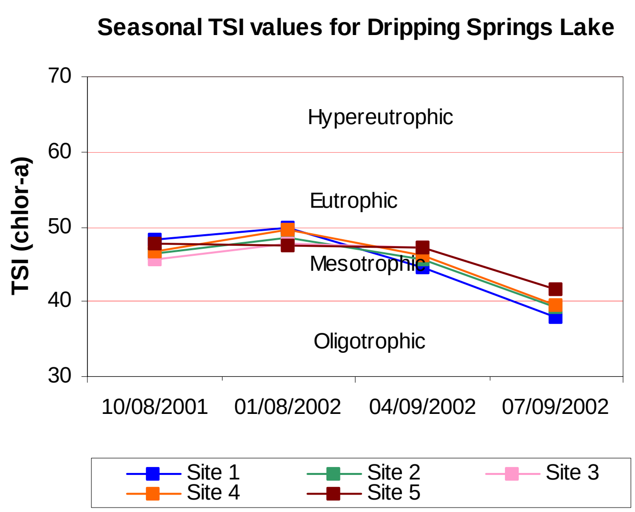


Figure 60. TSI values for Dripping Springs Lake.

supporting beneficial uses. Dripping Springs Lake had 4% of the pH values collected fall outside the prescribed range, which indicated that the lake was meeting its FWP beneficial use based on pH. The lake was not thermally stratified and the water column appeared to be well mixed throughout in the fall, winter and spring at all sites (see Figure 61c-60e). Dissolved oxygen (D.O.) values generally remained above 6.0 mg/L except at the very bottom of the lake and the dissolved oxygen percent saturation was never less than 50% in the first three seasons with the exception of the actual lake bottom in the fall quarter (see Figure 61c-60e). In the summer, the lake was strongly thermally stratified between 4 and 5 meters and the D.O. concentration dropped from 2.4 mg/L 4 meters from the lake surface to 0.37 mg/L at the lake bottom of 14 meters (see Figure 61f). The readings in the lake hypolimnion were anoxic at all five sites and approximately 67% 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 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. 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 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.49 mg/L at the lake surface. The TN at the surface ranged from 0.32 mg/L to 0.70 mg/L. The highest and lowest surface TN values were both reported in fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.020 mg/L at the lake surface. The TP ranged from 0.009 mg/L to 0.032 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 nitrogen to phosphorus ratio (TN:TP) was approximately 24:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Dripping Springs Lake was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Dripping Springs Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 25). The Aesthetics beneficial use was fully supporting for true color and trophic state. Turbidity and pH values were not a cause for concern in meeting the FWP beneficial use and they were fully supporting. Dripping Springs is partially supporting its FWP beneficial use based on D.O. concentrations. In general, the water quality of Dripping Springs is very good. 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.

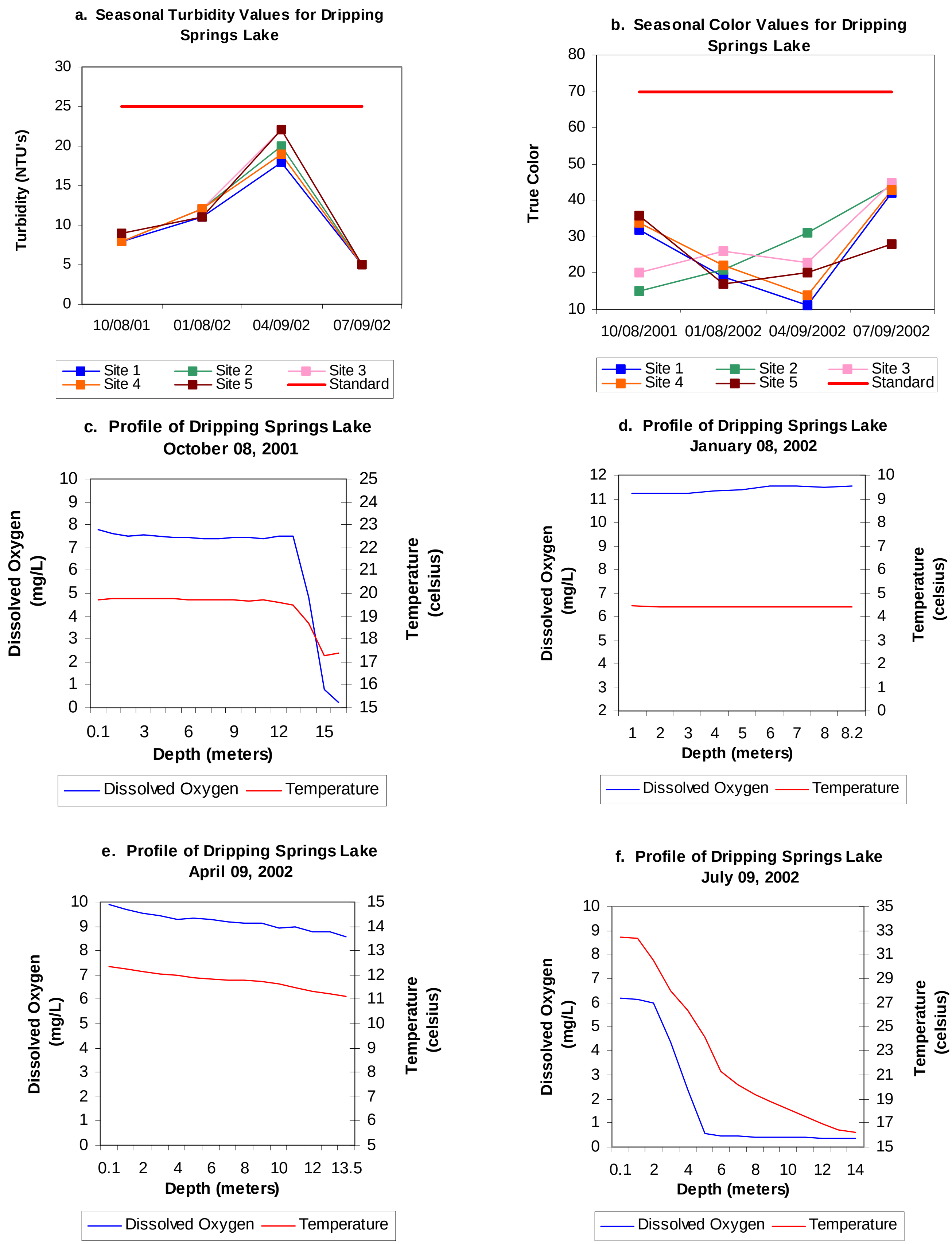
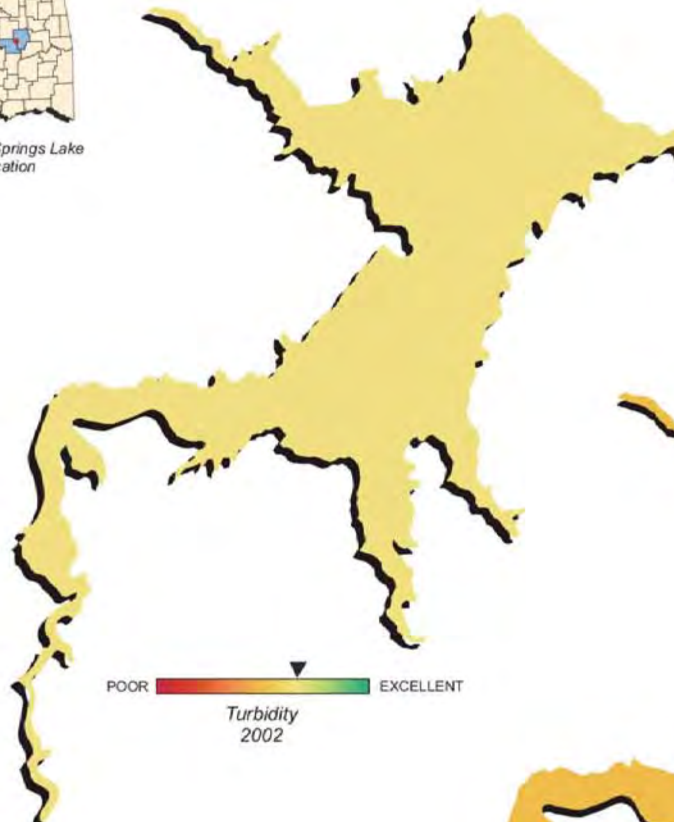


Figure 61a-60f. Graphical representation of data results for Dripping Springs Lake.

Dripping Springs Lake and Watershed

Dripping Springs Lake Location

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



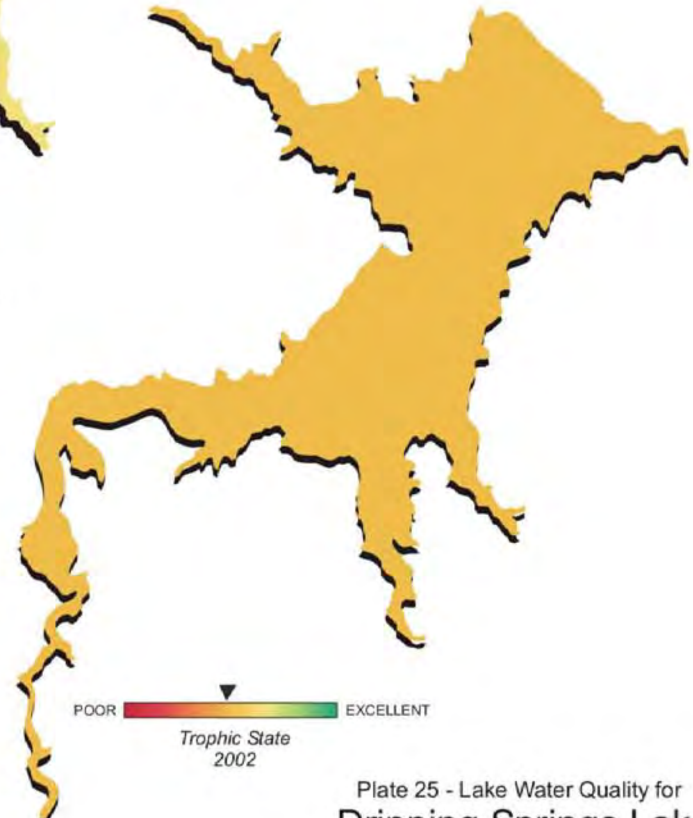


Plate 25 - Lake Water Quality for

Dripping Springs Lake

Duncan Lake

Duncan Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in both the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure minimum data requirements for lakes of this size were met. 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 14 NTU (Plate 26), true color was 15 units, and secchi disk depth was 84 centimeters in 2003. Based on these three parameters, Duncan Lake had average water clarity comparable to other Oklahoma reservoirs. Water clarity was slightly better than 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=16). The average TSI was 47 (Plate 26), indicating the lake was mesotrophic, with moderate levels of productivity and nutrients. This value is similar to the TSI in 2001 (TSI=49), indicating no significant increase or decrease over time. The TSI values were fairly consistent with all values mesotrophic to upper mesotrophic (see Figure 62). Seasonal turbidity values are displayed in Figure 63a. Turbidity values per site for sample year 2003 were generally below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons except for the winter when values were near or above the standard. 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 (OWQS) 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 5% of the turbidity values above the standard, the Fish and Wildlife Propagation (FWP) beneficial use is fully supported based on turbidity. Seasonal true colors are displayed in Figure 63b. All true color values were below the Aesthetics OWQS of 70 units, however a beneficial use determination cannot be made because the minimum data requirements were not met.

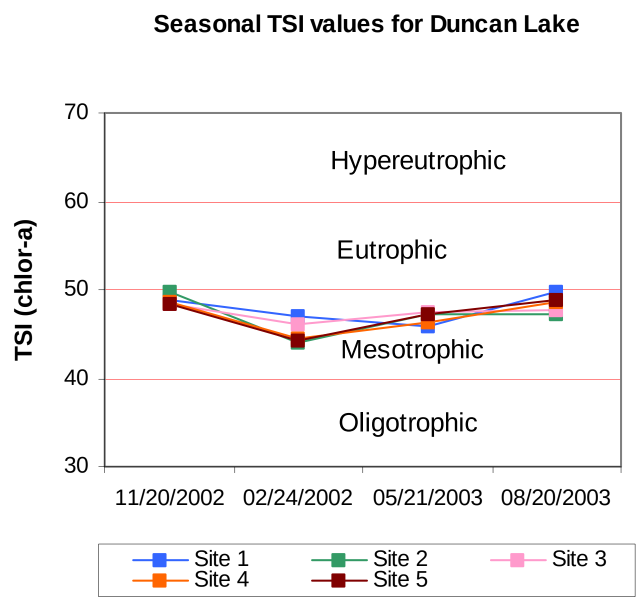


Figure 62. TSI values for Duncan Lake

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance; oxidation-reduction potential and salinity were recorded at all five sample sites in 2002-2003. Salinity values ranged from 0.19 parts per thousand (ppt) to 0.21 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 385.3 mS/cm to

423.7 mS/cm, indicative of moderate levels of current conducting ions (chlorides and salts) in the lake system. The recorded values for pH ranged from 7.09 in the summer to 8.26 in the fall 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 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range Duncan Lake is meeting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from 389mV in the spring to 627 mV in the summer. In general, reducing conditions were not present at this reservoir during the 2002-2003-sample year. Duncan Lake was not thermally stratified during the fall, winter and spring quarters (see Figure 63c-62e). Dissolved oxygen (D.O.) levels were generally above 4.0 mg/L throughout the sample year. The lake was stratified and anoxic conditions were present in the hypolimnion during the summer. Stratification occurred between 4 and 5 meters (Figure 63f) at which point dissolved oxygen (D.O.) levels dropped below 1 mg/L for the rest 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 37% of the water column below 2.0 mg/L the FWP beneficial use is partially supported at Duncan Lake. The lake was also sampled for chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.50mg/L at the surface and 0.50 mg/L at the lake bottom. Surface TN ranged from 0.22 mg/L to 0.72 mg/L with the highest values recorded in the spring quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.022 mg/L at the surface and 0.025 mg/L at the lake bottom. Similar to total nitrogen surface TP was highest in the summer quarter and lowest in the fall with values ranging from 0.011 mg/L to 0.027 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 23:1 for sample year 2003. 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 in 2002-2003. This value is similar to the TSI in 2001 (TSI=49), indicating no significant increase or decrease over time. 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 partially supporting based dissolved oxygen values. The Aesthetics beneficial use is supported based on the trophic status however a beneficial use determination cannot be made for true color because the minimum data requirements were not met. Duncan Lake is located in Stephens County serves as a water supply and recreation reservoir for the city of Duncan.

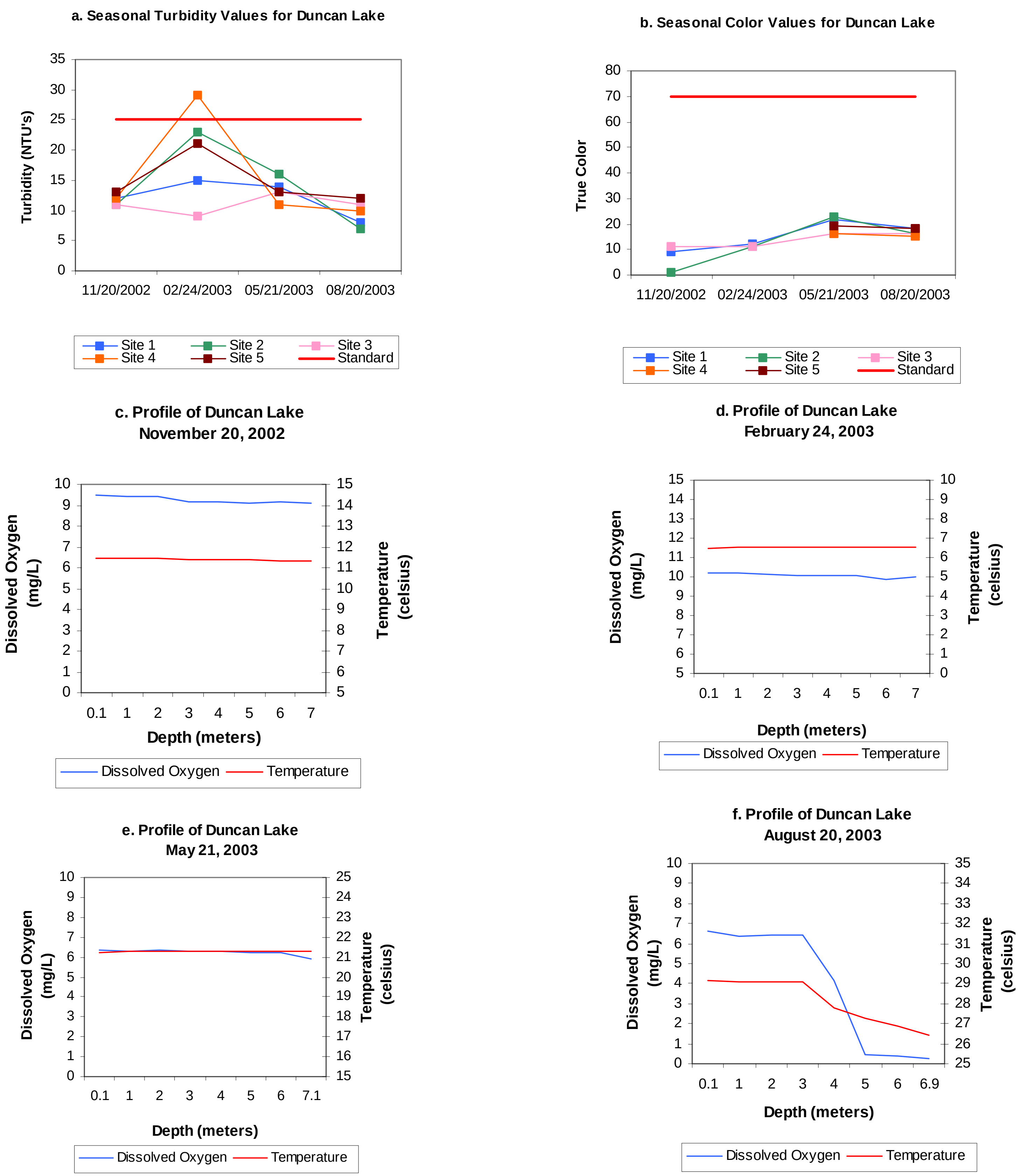
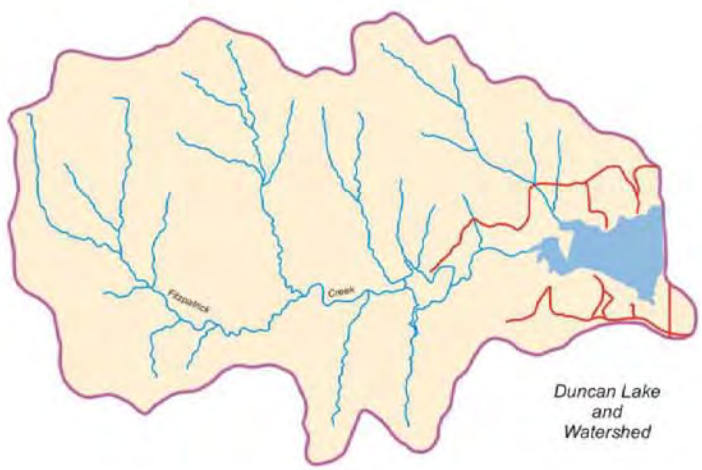
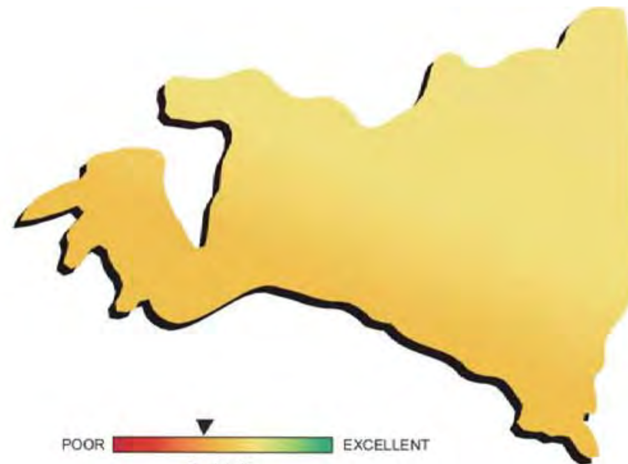
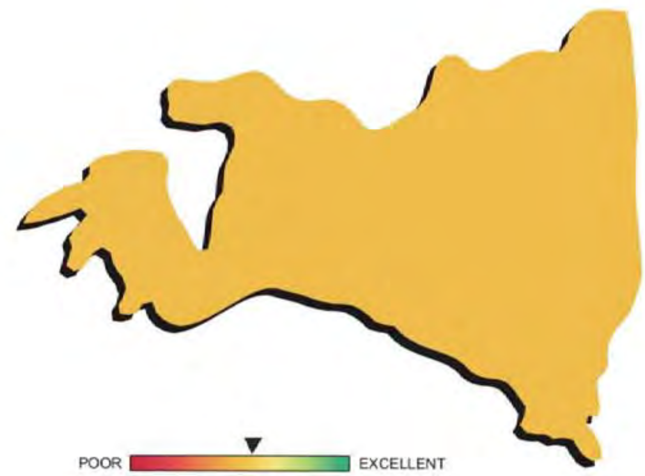


Figure 63a-62f. Graphical representation of data results for Duncan Lake.







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 26 - Lake Water Quality for
Duncan Lake

Lake El Reno

Lake El Reno was sampled for four quarters, from October 2002 through July 2003. 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 26 NTU (Plate 27), true color was 21 units, and secchi disk depth was 45 centimeters in 2003. Based on these three parameters, Lake El Reno had fair water clarity in comparison to other Oklahoma reservoirs. Water clarity was very similar 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 average TSI was 59 (Plate 27), indicating the lake was 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, indicating no significant increases or decreases over time. The TSI values were primarily eutrophic throughout the year, with hypereutrophic values in the fall and summer quarters (Figure 64). Seasonal turbidity values are displayed in Figure 65a. Turbidity ranged from a low of 8 NTU to a maximum of 55 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 (OWQS) 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 considered partially supported at Lake El Reno with 42% values recorded exceeding the OWQS of 25 NTU. Seasonal true color values are displayed in Figure 65b. All true color values were below the aesthetics OWQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is supported based on true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity ranged from 0.71 parts per thousand (ppt) to 0.90 ppt for this sample year. Specific conductance ranged from 1340 mS/cm to 1693 mS/cm, which is higher than most Oklahoma reservoirs. These values indicate the presence of current conducting compounds (salts) in the lake, consistent with higher recorded salinity concentrations. The pH values at Lake El Reno ranged from 7.70 to 8.32, 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 6.5 to 9.0 range for 25% of the values and should

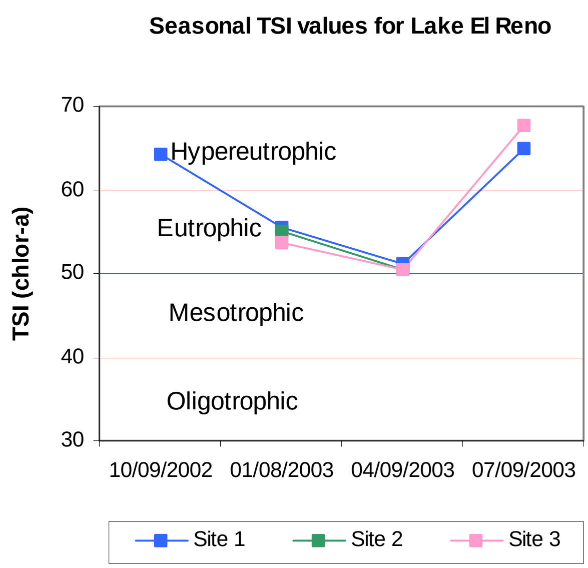


Figure 64. TSI values for Lake El Reno

be listed as not supporting beneficial uses. 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 beneficial uses. 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 208 mV in the hypolimnion during the spring to 585 mV in the winter. In general, reducing conditions were not present in this reservoir. The lake was not stratified during any of the sampling quarters (see Figure 65a-64f) 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.98 mg/L at the surface and 1.15 mg/L at the lake bottom. The TN at the surface ranged from 0.68 mg/L in the winter to 1.47 mg/L in the summer. The lake-wide total phosphorus (TP) average was 0.204 mg/L at the surface and 0.202 at the lake bottom. The total phosphorus at the surface ranged from 0.119 mg/L in the spring to 0.295 mg/L in the fall quarter. These values are very similar to those seen in 2001. The nitrogen to phosphorus ration (TN:TP) was 5:1 for sample year 2003. This value is much lower than 7:I, characterizing the lake as nitrogen limited (Wetzel, 1983).

In summary, Lake El Reno was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. This classification is the same as 2001 indicating no change in productivity has occurred. Water clarity was fair based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use for pH and dissolved oxygen levels, but only partially supporting based on turbidity. The Aesthetics beneficial use is being met based on both trophic status and true color. Lake El Reno, located in Canadian County, is owned by the city of El Reno and serves as a flood control and recreation reservoir.

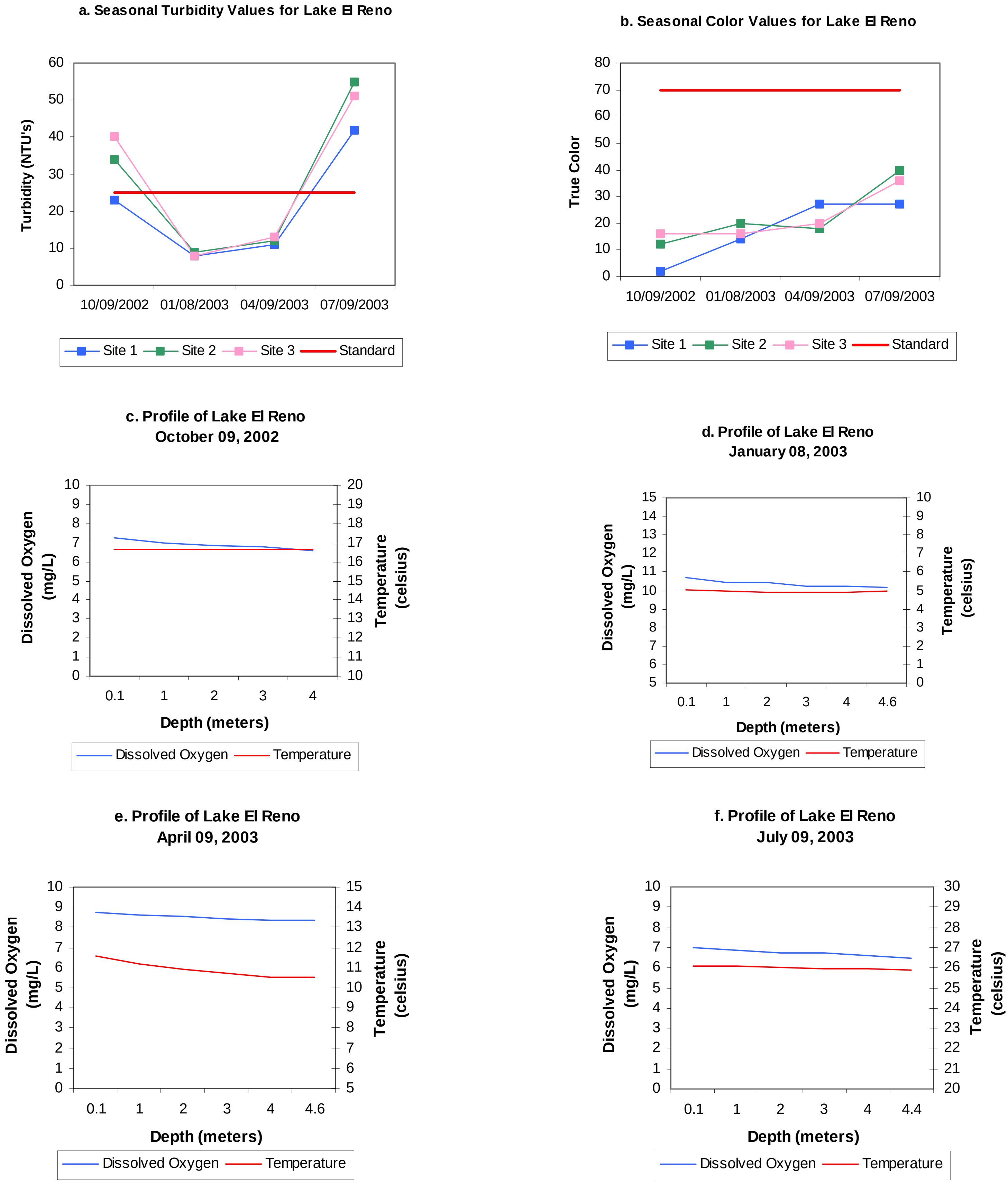


Figure 65a-64f. Graphical representation of data results for Lake El Reno.


El Reno Lake Location

El Reno Lake and Watershed

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


POOR EXCELLENT
Turbidity 2003

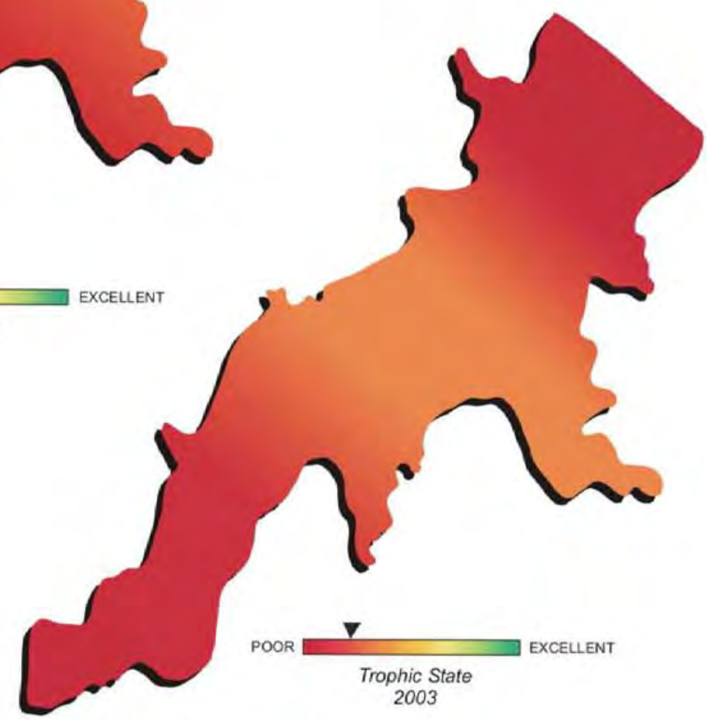

POOR EXCELLENT
Trophic State 2003

Plate 27 - Lake Water Quality for
Lake El Reno

Lake Elk City

Lake Elk City was sampled for four quarters, from November 2001 through August 2002. 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 56 NTU (Plate 28), true color was 33 units, and secchi disk depth was 30 centimeters in 2001-2002. 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 57 (Plate 28), indicating the lake was eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values were eutrophic at all sites throughout sampling year, with one mesotrophic value present at site 1 in the fall quarter (see Figure 66). Lake Elk City is listed in the Oklahoma Water Quality Standards (OWQS) at a Nutrient Limited Watershed (NLW), which means that the Aesthetics beneficial use is threatened due to nutrients. The lake should be further studied to understand the nutrient dynamics involved. Turbidity values were above OWQS of 25 NTU approximately 58% of the time (see Figure 67a). 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 OWQS (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 not supporting its Fish & Wildlife Propagation (FWP) beneficial use based on OAC 785:46. All true color values were below the Aesthetics OWQS 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 high true color values.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all sample sites and yielded the following results. Salinity readings ranged from 0.29 parts per thousand (ppt) to 0.31ppt, slightly higher than most values recorded in Oklahoma reservoirs. Readings for specific conductance were consistent with values normally seen in most Oklahoma reservoirs if perhaps only slightly higher. Specific Conductance ranged from 559.5 mS/cm in the fall quarter to 599.7 mS/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 160 mV to 482 mV, indicating reducing conditions were not present during the 2001-2002 sampling events. Lake pH values were neutral to slightly alkaline, ranging from 7.83 to 8.59 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

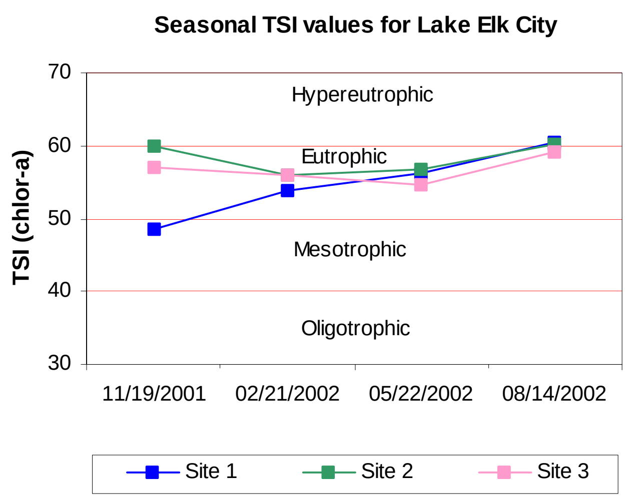


Figure 66. TSI values for Lake Elk City.

partially supporting beneficial uses. 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 any of the four quarters sampled in 2001-2002 (see Figure 67c-66f). The water column was evenly mixed and oxygenated during the entire study period and may be attributed to the shallow nature of the lake (see Figure 67c-66e). Dissolved oxygen (D.O.) concentrations never fell below 4.6 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 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. Per OAC 785:46 the FWP beneficial use is supported based and dissolved oxygen concentrations. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 1.05 mg/L at the lake surface. The TN at the surface ranged from 0.84 mg/L to 1.41 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 for sample year 2001-2002 was 0.138 mg/L at the lake surface. The TP ranged from 0.053 mg/L to 0.351 mg/L at the lake surface. The highest surface TP values were reported in the fall quarter and the lowest were in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2001-2002. This value is very close to 7:1, characterizing the lake as potentially co-limited with nitrogen and phosphorus (Wetzel, 1983).

Lake Elk City was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use based on metal (toxic) compounds in the water column.

In summary, Lake Elk City was as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 28). The lake is listed in the OWQS as an NLW and it should be more intensively studied to understand the nutrient dynamics at play in the system. The lake is not supporting its FWP beneficial based on high turbidity concentrations. The FWP beneficial use is fully supported for pH and D.O. based on collected data. Elk City Lake is fully supporting its Aesthetics beneficial use based on true color readings and based on its listing as an NLW the use is considered nutrient threatened. Lake Elk City 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.

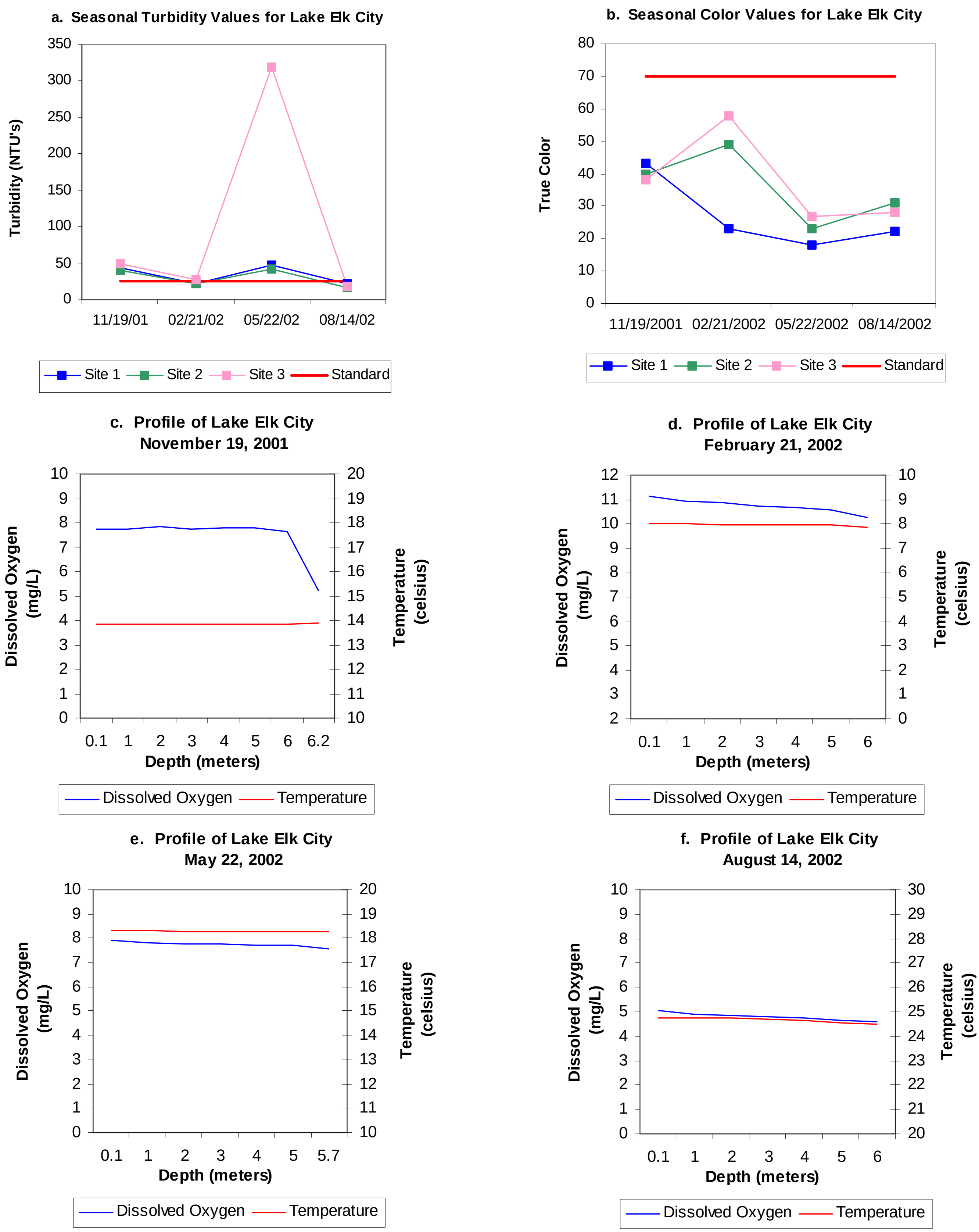


Figure 67a-66f. Graphical representation of data results for Lake Elk City.

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 28 - Lake Water Quality for
Elk City Lake

Lake Ellsworth

Lake Ellsworth was sampled for four quarters, from November 2001 through August 2002. 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 28 NTU (Plate 29), true color was 34 units, and secchi disk depth was 36 centimeters in 2001-2002. 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 52 (Plate 29), indicating the lake was eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values varied seasonally with mesotrophic values present in the fall and spring and upper-mesotrophic to lower eutrophic values present in the winter and summer quarters (see Figure 68). Turbidity values for site 1 for sample year 2001-2002 were all below the Oklahoma Water Quality Standard (OWQS) of 25 NTU; however, at site 2 one-half of the collected values exceeded the criteria and the vast majority of the data collected at sites 3-5 exceeded the criteria (see Figure 69a). 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 OWQS (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 55% of the sample values exceeding the criteria. Almost all true color values were below the aesthetics OWQS of 70 units, with only 5% of the recorded values greater than 70 units (see Figure 69b). The Aesthetics beneficial use is supported based on true color values collected in 2001-2002 (See OAC 785:46 for detailed assessment protocols used).

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all sample sites and yielded the following results. Salinity readings ranged from 0.26 parts per thousand (ppt) to 0.27 ppt, which was slightly higher than the expected range of values recorded for Oklahoma reservoirs. Readings for specific conductance were within the range of expected values recorded for most Oklahoma reservoirs. Specific conductance ranged from 510.0 mS/cm in the fall quarter to 580.2 mS/cm in the summer quarter, indicating moderate to slightly elevated concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials ranged from 26 mV to 463 mV, indicating reducing conditions were not present during 2001-2002 sampling. Lake pH values were neutral to slightly alkaline, ranging from 6.71 to 8.62 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. The FWP

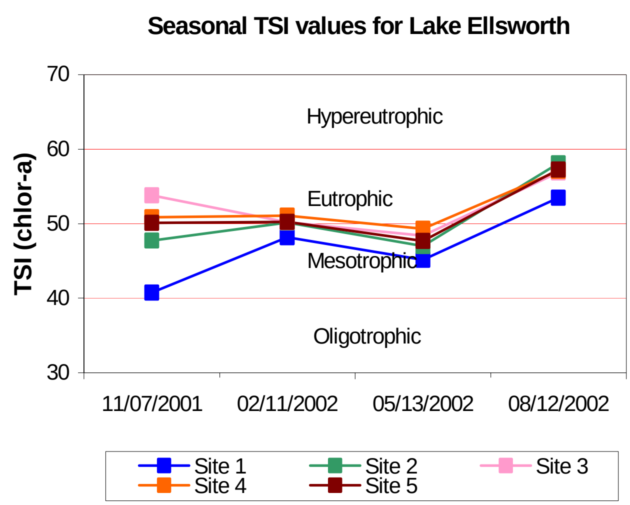


Figure 68. TSI values for Lake Ellsworth.

beneficial use is fully supported based on pH with all values within the acceptable range. The lake was not thermally stratified during the fall, winter or spring quarters (see Figure 69c-68e). The water column was evenly mixed and oxygenated in the fall, winter and spring quarters (see Figure 69c-68e). In the summer quarter the lake was thermally stratified between the 7 to 8 meter depths, at which point dissolved oxygen (D.O.) concentrations fell below 1.0 mg/L all the way to the lake bottom at 13.5 meters (see Figure 69f). 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 approximately 47% of the water column having D.O. values less than 2.0 mg/L, the FWP beneficial use according to USAP (OAC 785:46-15-5) is fully supported. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.50 mg/L at the lake surface. The TN at the surface ranged from 0.28 mg/L to 0.89 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 for sample year 2001-2002 was 0.051 mg/L at the lake surface. The TP ranged from 0.033 mg/L to 0.76 mg/L at the lake surface. The highest surface TP values were reported in the summer quarter and the lowest were in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Ellsworth was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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 29). The FWP beneficial use is considered not supported for turbidity at Lake Ellsworth with 55% of the sample values exceeding the criteria. Almost all true color values were below the aesthetics OWQS of 70 units, with only 5% of the recorded values greater than 70 units (see Figure 69b). The Aesthetics beneficial use is supported based on true color and trophic status values collected in 2001-2002. The FWP beneficial use is supported for both pH and dissolved oxygen. 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.

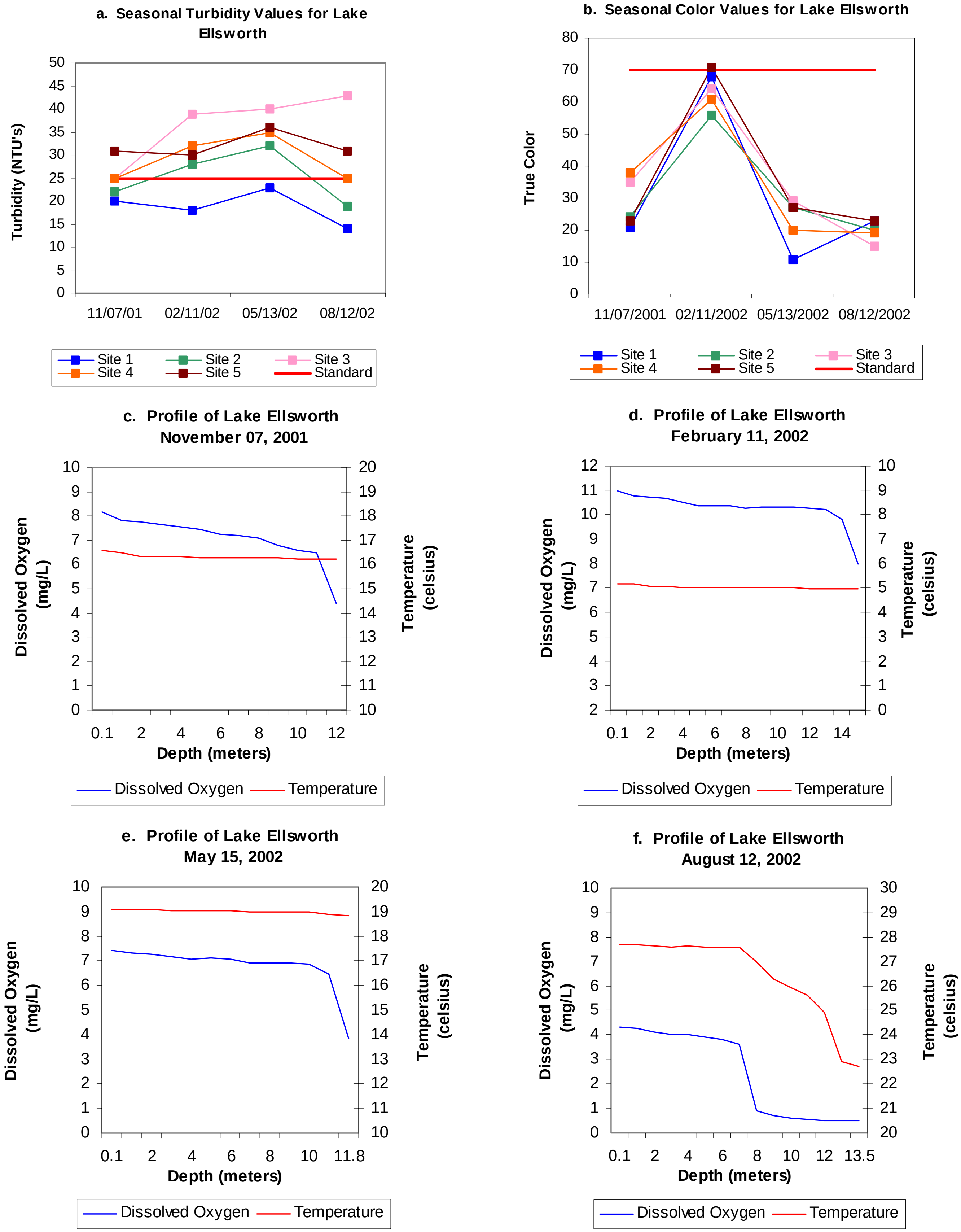


Figure 69a-68f. Graphical representation of data results for Lake Ellsworth.

Lake Ellsworth
and
Watershed

Lake Ellsworth
Location

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

Turbidity
2002

Trophic State
2002

Plate 29 - Lake Water Quality for
Lake Ellsworth

Elmer Thomas Lake

Elmer Thomas Lake was sampled for three quarters from January 2003 through July 2003. Water quality samples were collected at three (3) sites in the winter and from five (5) sites in the spring and summer quarters. Additional sites were added to ensure sample size was representative for the reservoir as it is greater than 250 surface acres in size. 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 2 NTU (Plate 30), true color was 18 units and secchi disk depth was 290 centimeters. Water clarity was excellent at Elmer Thomas Lake and is similar to results from the 2000 evaluation. 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 34 (Plate 30), indicating the lake was oligotrophic, with low primary productivity and nutrient levels in sample year 2002-2003. The TSI values for all sites were consistent with all values in the oligotrophic category (Figure 70). This value is lower than that in 2000 (TSI=43), however, fewer samples were used to calculate trophic status in 2000. The current value is based on data collected for the entire year versus growing season only, and is likely a more accurate depiction of productivity within the lake system. Seasonal turbidity values are displayed in Figure 71a. Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. Due to the minimum data requirements of 20 samples for lakes greater than 250 surface acres not being met, assessment of the Fish and Wildlife Propagation (FWP) beneficial use cannot be made at this time; however upon reviewing historical data it is likely that the use would be supported. Seasonal true color values were all below the aesthetics standard of 70 units and are displayed in Figure 71b. Like turbidity, minimum data requirements were not met but it is likely that the Aesthetics beneficial use would be supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites in 2002-2003. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.06 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 36.8 mS/cm to 141.5 mS/cm, indicative of minimal levels of current conducting ions (chlorides and salts) in the lake system. The recorded values for pH ranged from 6.24 in the summer to 8.04 in the fall representing a neutral to slightly acidic system. 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 should be listed as not supporting beneficial

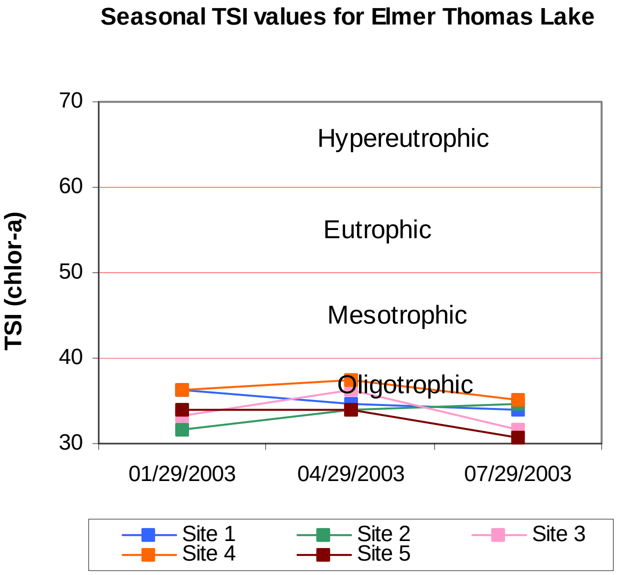


Figure 70. TSI values for Elmer Thomas Lake.

uses. 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 beneficial uses. With 12% of collected values out of the acceptable range Elmer Thomas Lake is partially supporting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from 58mV in the spring to 650 mV in the fall. 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, the dam. Elmer Thomas Lake was not thermally stratified during the winter and spring quarters (see Figure 71c-70d). Dissolved oxygen (D.O.) levels were generally above 4.0 mg/L throughout the sample year. The lake was stratified and anoxic conditions were present in the hypolimnion during the summer. Stratification occurred between 7 and 8 meters at which point dissolved oxygen (D.O.) levels dropped below 1 mg/L for the rest of the water column (Figure 71e). 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 62% of the water column below 2.0 mg/L the FWP beneficial use is partially 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.41mg/L at the surface and 0.46 mg/L at the lake bottom. Surface TN ranged from 0.32 mg/L to 0.54 mg/L with the highest values recorded in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.010 mg/L at the surface and 0.015 mg/L at the lake bottom. Similar to total nitrogen surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.008 mg/L to 0.012 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 39:1 for sample year 2003. 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 2002-2003. This value is lower than that in 2000 (TSI=43), however, fewer samples were used to calculate trophic status in 2000. The current value is based on data collected year round versus growing season only, and is likely a more accurate depiction of productivity within the lake system. Water clarity was excellent based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial use based on pH, but partially supporting based dissolved oxygen values. The minimum data requirements (20 samples) were not met for turbidity; therefore attainment of the FWP based on turbidity cannot be made at this time. Reviewing historical data it is likely that the beneficial use would be supported. The Aesthetics beneficial use is supported based on the trophic status however a beneficial use determination cannot be made for true color because like turbidity, the minimum data requirements were not met. Elmer Thomas Lake, located in Comanche County, was constructed by the U.S. Department of Interior for the purpose of recreation.

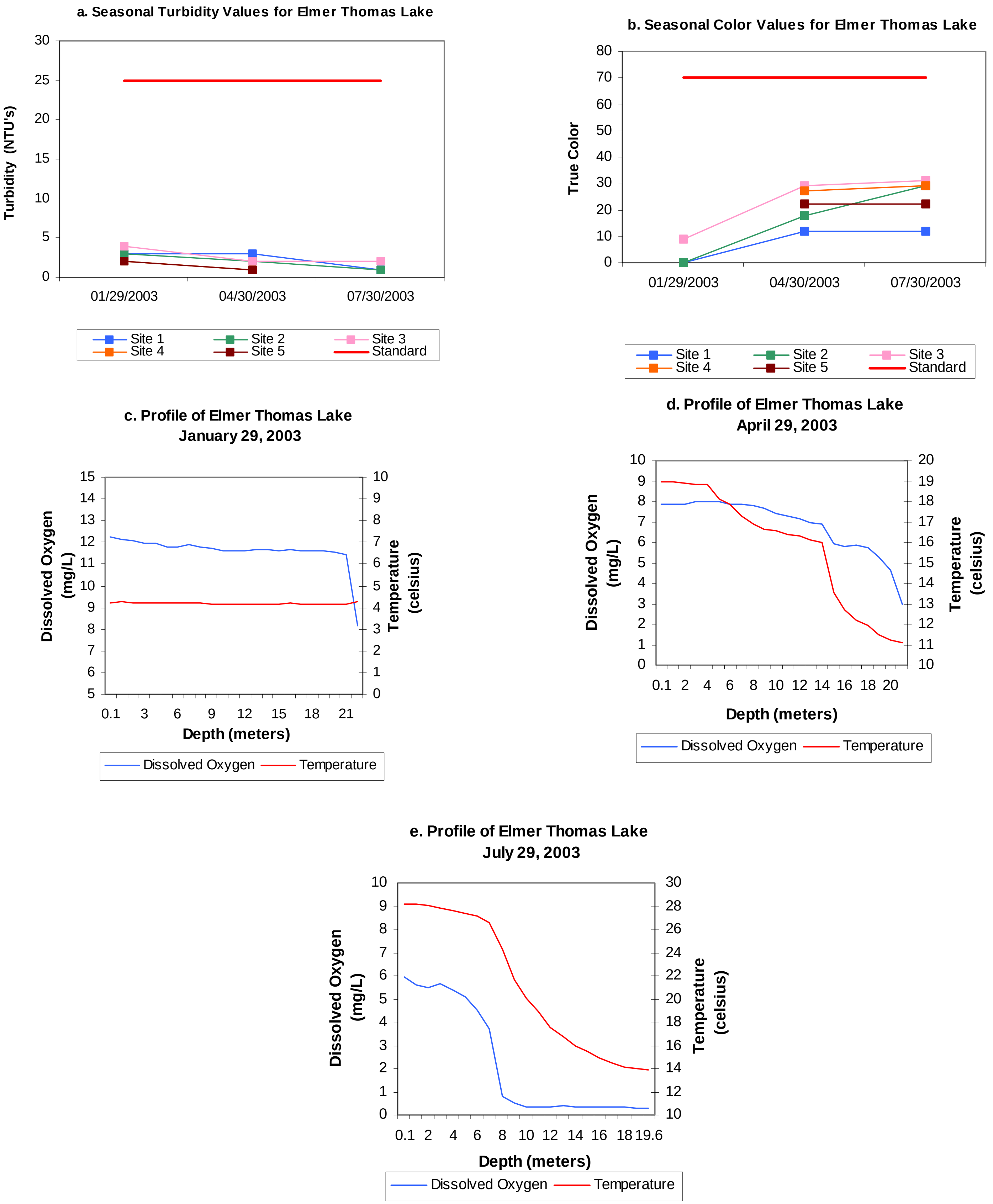
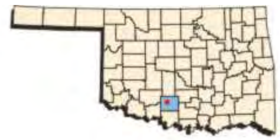
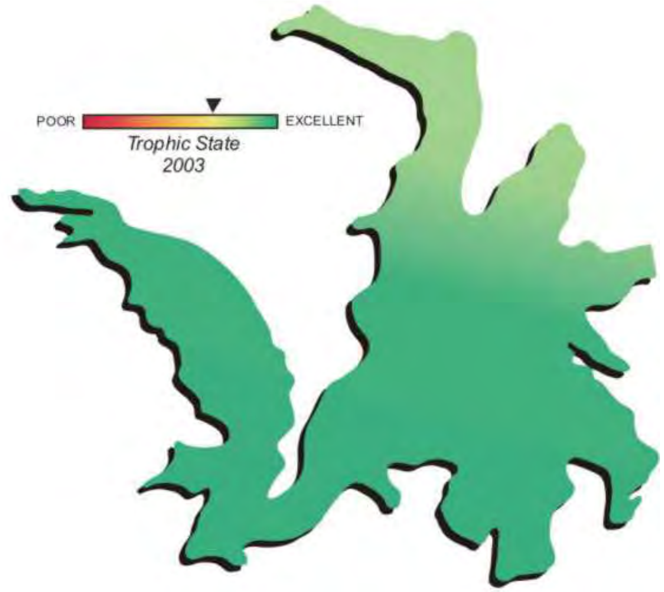


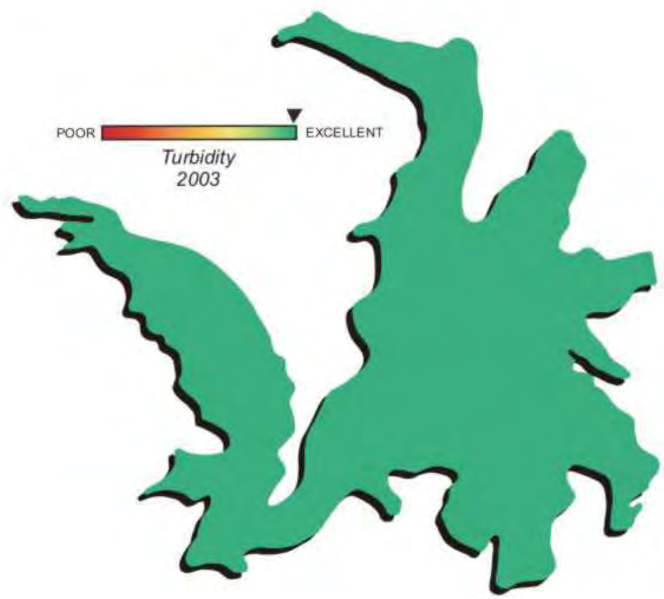
Figure 71a-70e. Graphical representation of data results for Elmer Thomas Lake.

Elmer Thomas Lake
and
Watershed



Elmer Thomas Lake
Location





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 30 - Lake Water Quality for
Elmer Thomas Lake

Lake Etling

Lake Etling was sampled for three seasons, from March 4, 2000 through August 13, 2001. Several attempts were made in the fall quarter to sample the lake; however, due to drought conditions, the lake level was too low to launch a boat until late in the winter quarter. Water quality samples were collected at 3 sites to represent the riverine, transition, and lacustrine zones of the reservoir in the winter and spring; however, samples were taken from the shore at 3 sites in the summer because the lake was too low once again to launch a boat. Although there are only 3 sites designated for Lake Etling, an extra sample was collected in the winter to meet the minimum data requirements (n=10) listed in the Use Support Assessment Protocols (USAP) for lakes under 250 surface acres (785:46-15-3). Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam, in the winter and spring. The lake-wide annual turbidity value was 21 NTU, true color was 28 units, and secchi disk depth was 45 centimeters in 2001. Based on these three parameters, Lake Etling had fair water clarity in comparison to other Oklahoma reservoirs. Water clarity was fairly similar in the summer of 1997, based on only three samples. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=10). The average TSI was 57, indicating the lake was eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is similar to the TSI in 1997 (TSI=56), based on three summer values, indicating no significant increase or decrease in trophic status over time. The TSI values varied seasonally from mesotrophic at all sites in the winter to hypereutrophic in the summer. Only two of the ten turbidity values exceeded the OWQS of 25 NTU; however, this constitutes a listing as partially 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 (OWQS) 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 OWQS of 70 units for all three seasons at all sites.

Please refer to the “Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report” for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency’s web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Eucha Lake

Eucha Lake was sampled for four quarters from October 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer, to represent the riverine, transition, and lacustrine zones of the lake. Additional sites were added to ensure the sample size was representative for lakes greater than 250 surface acres in size. 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 8 NTU (Plate 31), true color was 8 units, and secchi disk depth was 118 centimeters. Based on these three parameters water clarity at Eucha Lake was good in sample year 2002-2003. 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 50 (Plate 31), indicating the lake was mesotrophic bordering eutrophic, indicative of moderate primary productivity and nutrient levels in sample year 2002-2003. The TSI values varied seasonally and generally ranged from mesotrophic to lower eutrophic, with the exception of the spring quarter when values dipped down to oligotrophic (Figure 72). These results differ with historical data collection efforts on the lake, which found the lake to be hypereutrophic in 1999 (TSI=62). The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient impaired and a nutrient impairment study should be conducted to determine if uses are impaired. Seasonal turbidity values are displayed in Figure 73a. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and ranged from a low of 3 NTU to a maximum of 24 NTU. 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 OWQS of 70 units and are displayed in Figure 73b. Due to the minimum data requirements not being met assessment of the Aesthetics beneficial use based on true color could not be made.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, 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, which is within the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 155 mS/cm to 266.1 mS/cm, indicative of minimal levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.88 in the summer to 8.43 in the fall 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 6.5 to

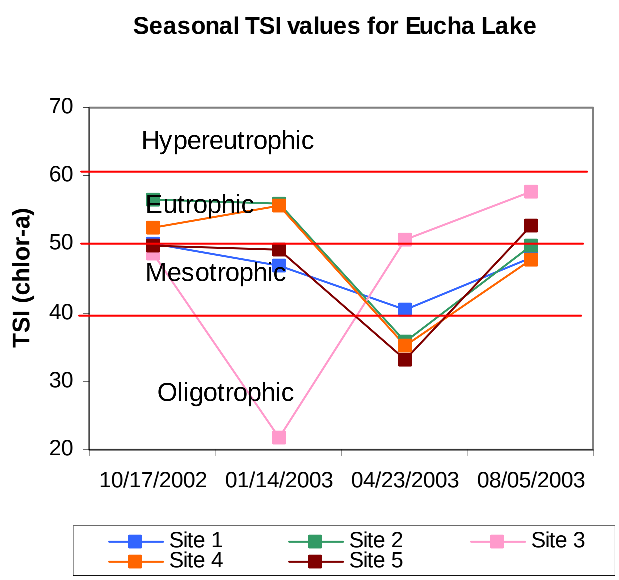


Figure 72. TSI values for Eucha Lake.

9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With all the collected values within the acceptable range Eucha Lake is fully supporting its FWP beneficial use for pH. Oxidation-reduction potentials (ORP) ranged from 25 mV in the hypolimnion in the summer to 522 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 summer quarter when anoxic conditions were present for much of the water column (see Figure 73f). 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 8 and 9 meters at which point dissolved oxygen levels dropped to 1.0 mg/L for the remainder (55%) of the water column at site 1, the dam site. During the summer sampling interval, stratification occurred between 5 and 6 meters at site 1 accounting for 70% 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 40 to 60% 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 70% of the water column in the summer Eucha 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.79 mg/L at the surface and 1.26 mg/L at the lake bottom. Surface TN ranged from 0.33 mg/L to 1.78 mg/L with the highest values recorded in the winter quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.027mg/L at the surface and 0.087 mg/L at the lake bottom. Similar to total nitrogen surface TP was highest in the winter quarter and lowest in the fall with values ranging from 0.013 mg/L to 0.054 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 29:1 for sample year 2003. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Eucha Lake was classified as mesotrophic, bordering eutrophic, with moderate to high primary productivity and nutrient levels in 2002-2003. These results differ with historical data collection efforts on the lake, which found the lake to be hypereutrophic in 1999 (TSI=62). The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) 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, but partially supporting based dissolved oxygen values. The Aesthetics beneficial use is supported based on the trophic status however a beneficial use determination cannot be made for true color because the minimum data requirements were not met. 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 74) 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 Kathy Koon at (405) 530-8800.

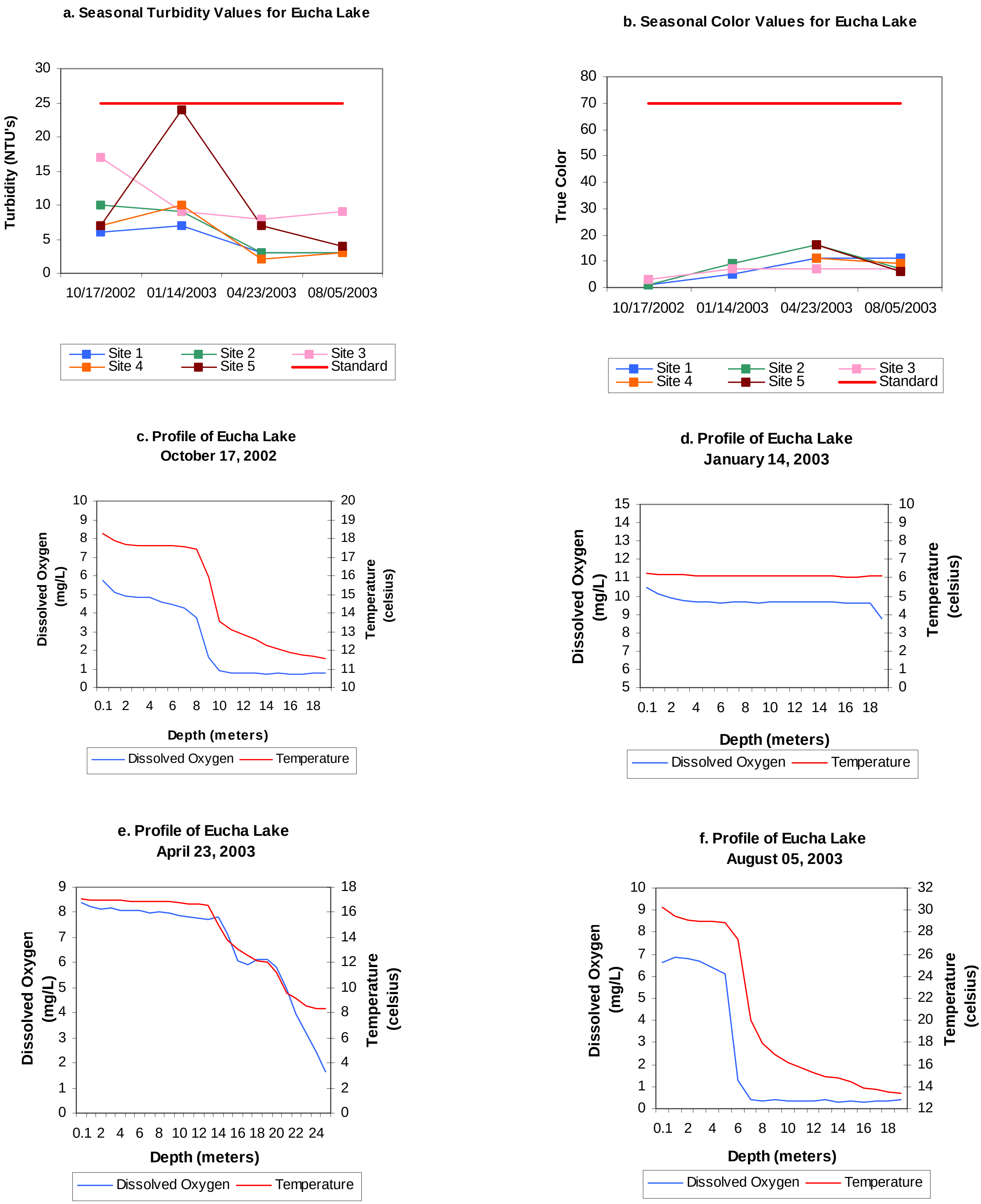
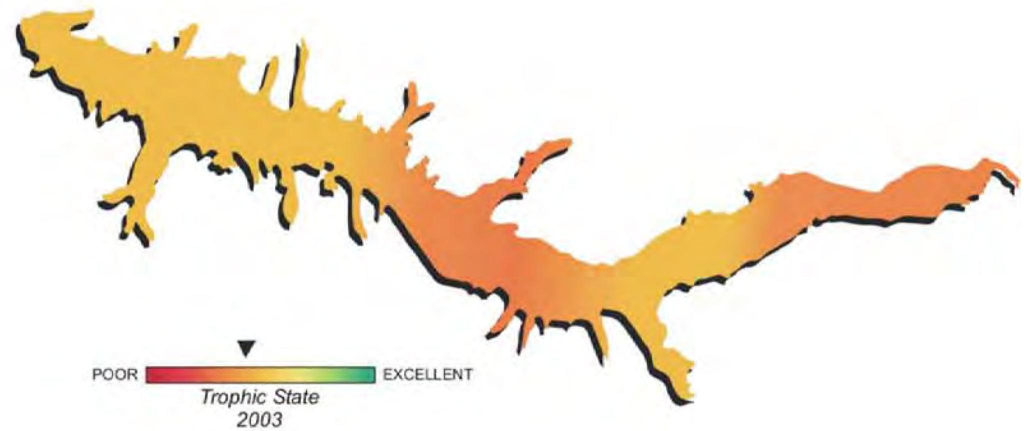


Figure 73a-72f. Graphical representation of data results for Eucha Lake.

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



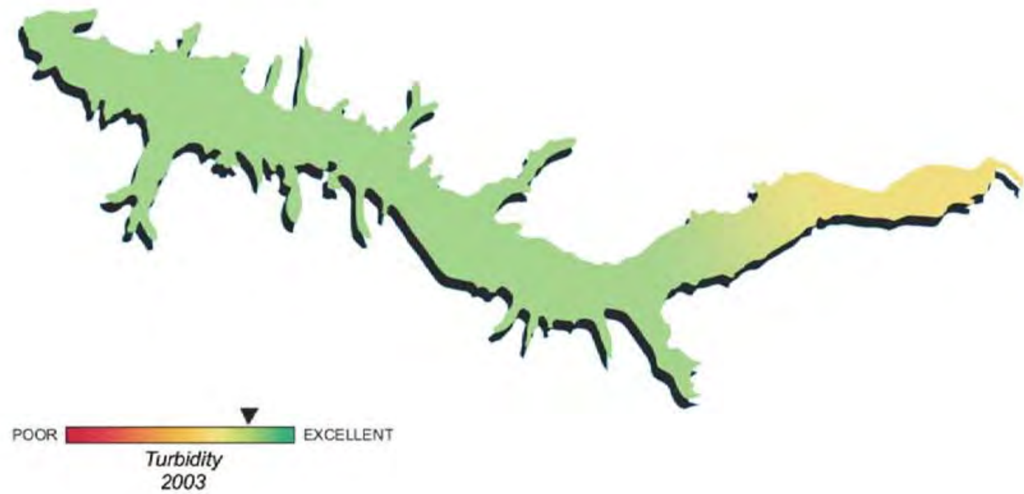


Plate 31- Lake Water Quality for
Lake Eucha

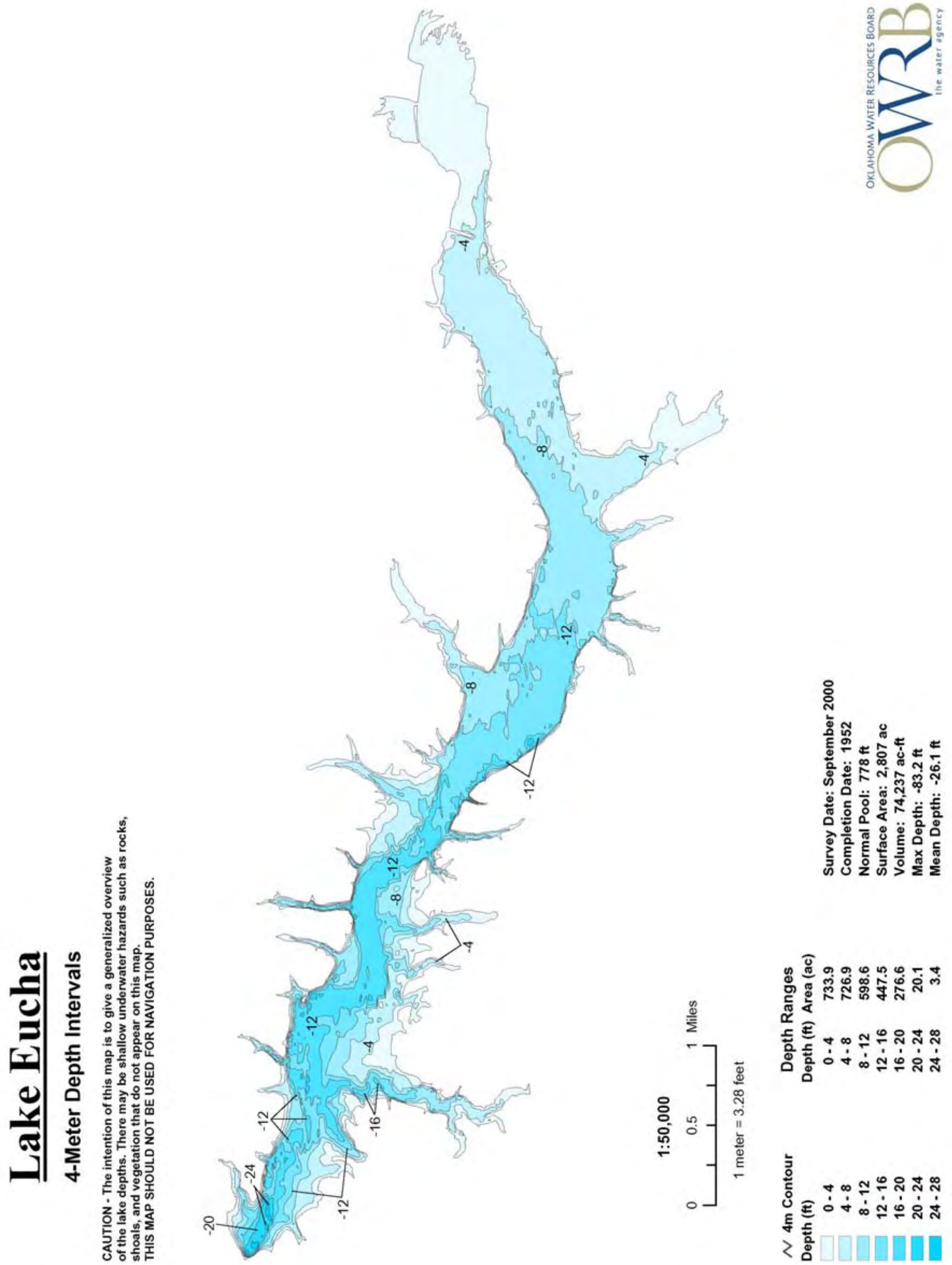


Figure 74. Bathymetric Map of Eucha Lake.

Eufaula Lake

Eufaula Lake was sampled for four quarters from December 2002 through August 2003. 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 21 NTU (Plate 32), true color was 50 units, and secchi disk depth was 85 centimeters. Water clarity was average at Eufaula Lake in comparison to other Oklahoma reservoirs based on these three parameters, and results are similar to those of the 2000 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 32), indicating the lake was eutrophic, indicative of high primary productivity and nutrient levels in sample year 2002-2003. This value is similar to that calculated in 2000, (TSI=53), indicating no significant increase or decrease in productivity has occurred. The TSI values varied seasonally and ranged from oligotrophic to hypereutrophic (Figure 75). Turbidity values varied by site and by season, but were typically above the Oklahoma Water Quality Standard (OWQS) 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 (OWQS) 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 28% of the turbidity values above the standard, the Fish and Wildlife Propagation (FWP) beneficial use is not supported based on turbidity (see Figure 76a). Seasonal true color values are displayed in Figure 76b. True color values followed the same trend as turbidity, with values exceeding the OWQS of 70 units at

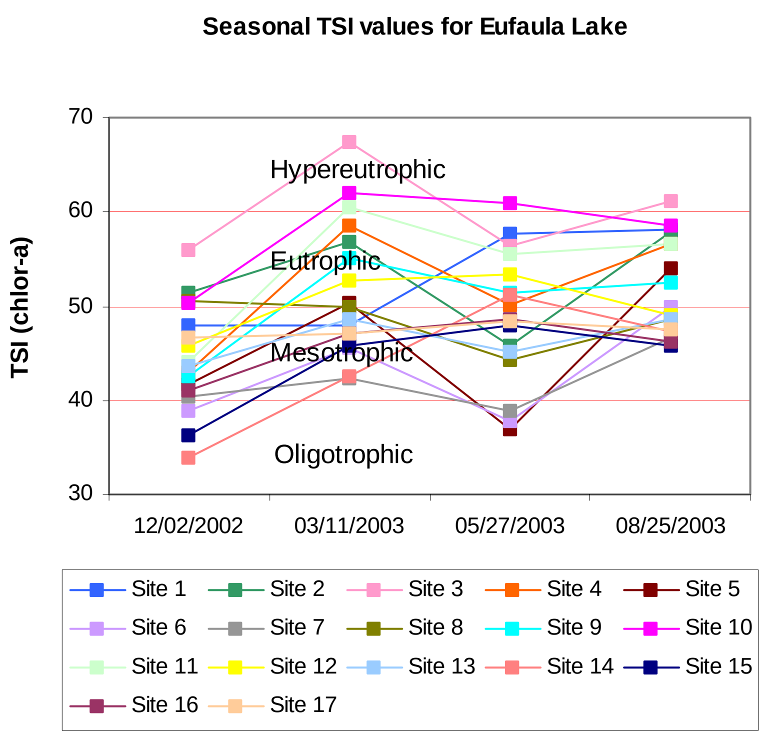


Figure 75. TSI values for Eufaula Lake.

sites 14-17 throughout the year except for the summer quarter. Of the values collected, 17.5% exceeded 70 units. Applying the same default protocol, the Aesthetic beneficial use is partially supported based on true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the 2002-2003-sample year. Salinity values at Eufaula Lake varied by site and season, but generally ranged from 0.04 (winter, site 16) to 0.43 parts per thousand (spring, site 10). The lowest salinity values occurred in the winter (site 16), and throughout the year were 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 conductance ranged from 105 mS/cm to 831.5 mS/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 6.85 to 8.80 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 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With 100% of collected values within the acceptable range, Eufaula Lake is partially 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 76c-75e). Dissolved oxygen (D.O.) was above 4.0 mg/L, with the exception of site 8 (Highway 9 Landing), in the spring. This is the only site to exhibit stratification during the first three quarters. At that time approximately 26% of the water column fell below 2.0 mg/L. In the summer, the lake was stratified throughout between 4 and 6 meters 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 76f). Anoxic conditions were present throughout accounting for 33 to 70% 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 for 26% of the water column in the spring, and up to 70% 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.67 mg/L at the surface and 0.68 mg/L at the lake bottom. Surface TN ranged from 0.25 mg/L to 1.54 mg/L with the highest values recorded in the fall and lowest in the winter quarter. The lake-wide total phosphorus (TP) average was 0.042mg/L at the surface and 0.078 mg/L at the lake bottom. TP values at the surface ranged from 0.011 mg/L to 0.127 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 16:1 for sample year 2003. 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 2000 (TSI=53), 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 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. The Aesthetics baneful use is supported based on trophic status, but partially supported based on true color values as 17.5% of the collected values exceed the OWQS of 70 units. 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.

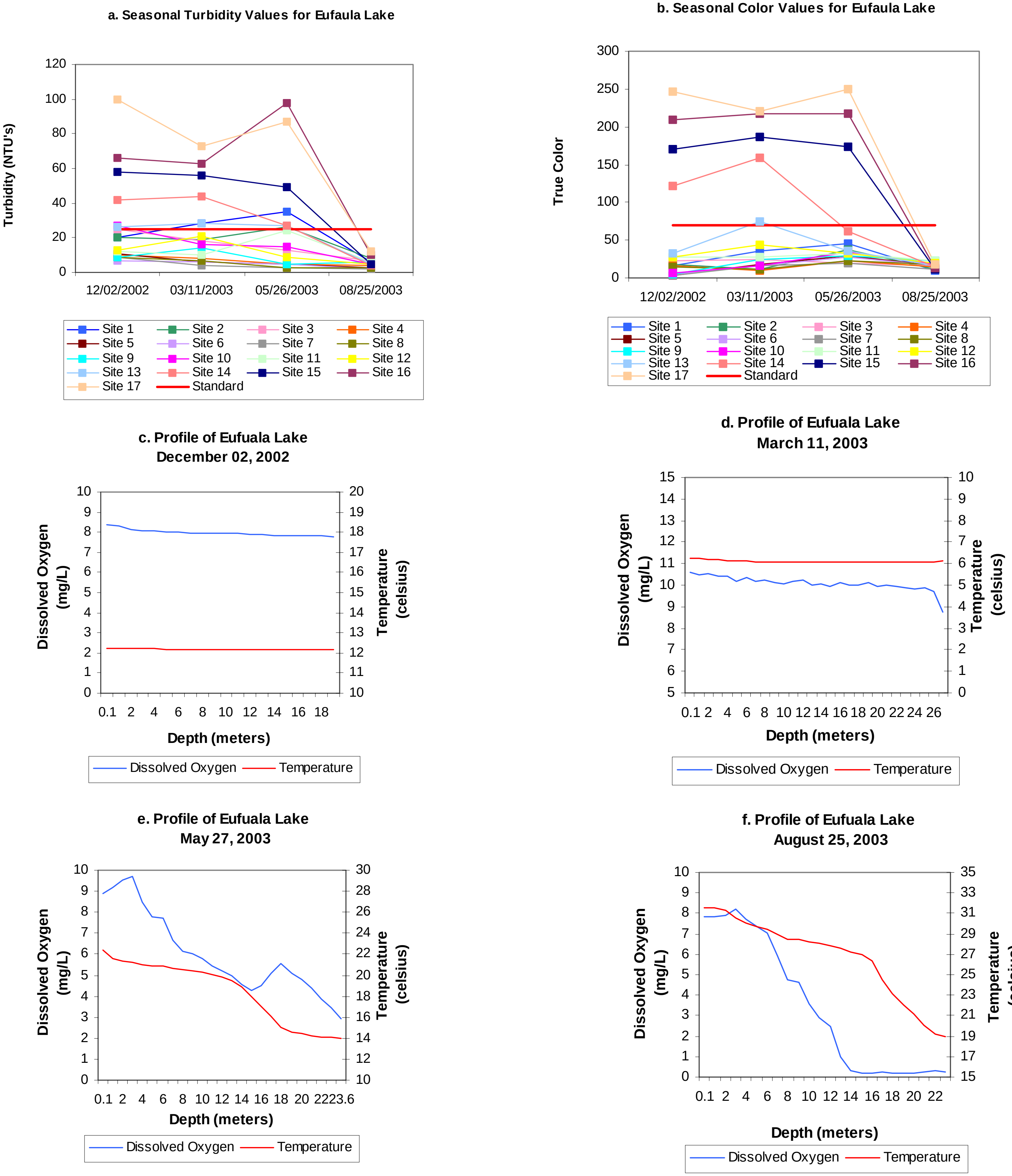
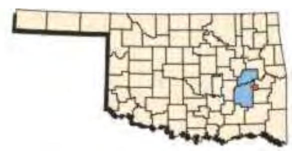


Figure 76a-75f. Graphical representation of data results for Eufaula Lake.

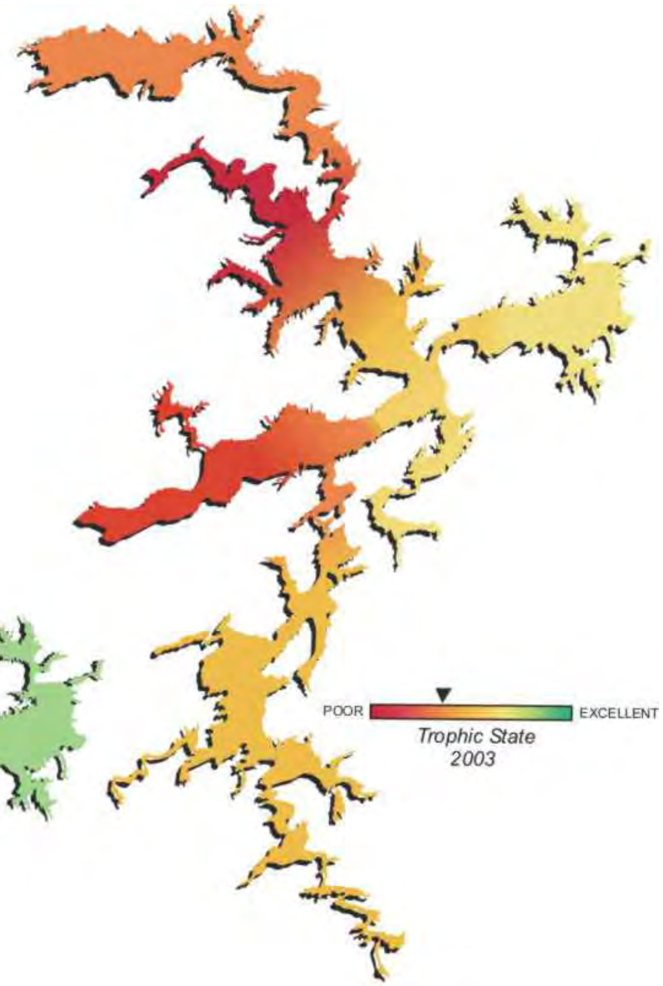


Eufaula Lake Location

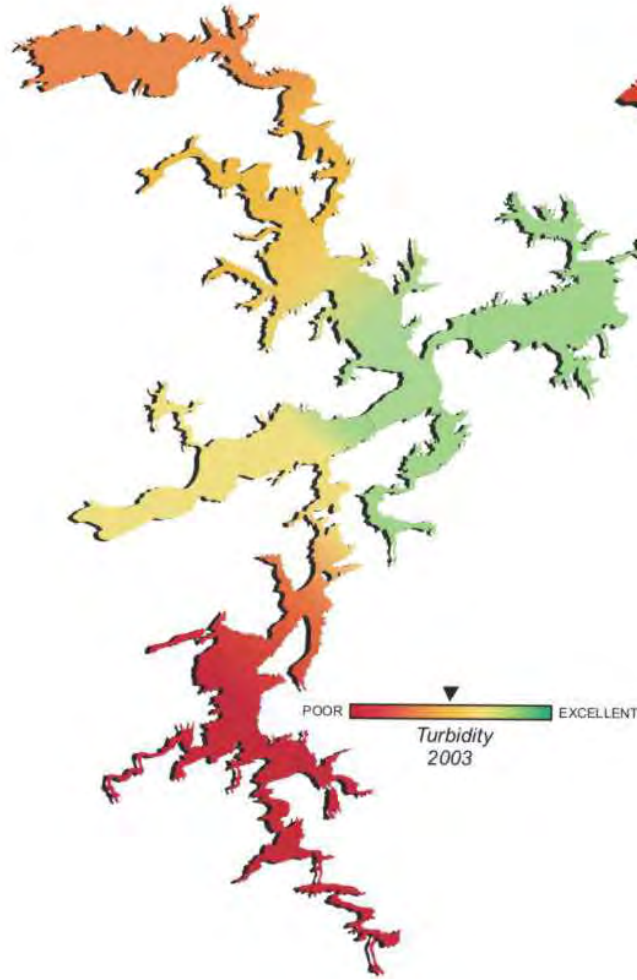
Eufaula Lake and Watershed

N E S W

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



Trophic State 2003



Turbidity 2003

Plate 32 - Lake Water Quality for
Eufaula Lake

Fairfax City Lake

Fairfax City Lake was sampled for four seasons, from October 2001 through July 2002. 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, in the winter and spring. The lake-wide annual turbidity value was 10 NTU (Plate 33), true color was 22 units, and secchi disk depth was 71 centimeters in 2001-2002. Based on these three parameters, Fairfax City Lake had very 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=10). The average TSI was 53 (Plate 33), indicating the lake was eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values varied seasonally from mesotrophic in the winter to eutrophic in the other three seasons (see Figure 77). All of the turbidity values recorded were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and the Fish & Wildlife Propagation (FWP) beneficial use was fully supported (See Figure 78a). 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 OWQS (25 NTU for turbidity). Seasonal true color values are displayed in Figure 78b. All true color values were below the aesthetics OWQS of 70 units for all three seasons 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 high true color values.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity values ranged from 0.12 parts per thousand (ppt) to 0.14 ppt, within the expected range for Oklahoma reservoirs. Readings for specific conductance were also well within the range of expected values for most Oklahoma reservoirs. Conductivity ranged from 247.6 mS/cm recorded in the summer quarter to 306.8 mS/cm recorded in the spring quarter of 2002, indicating moderate concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from 6 mV to 627 mV, indicating reducing conditions were not a concern during 2001-2002 sampling. Lake pH values were neutral to slightly alkaline with values ranging from 6.82 in the summer quarter to 8.35 in the spring quarter. 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. 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 was well mixed and oxygenated, with dissolved oxygen (D.O.) values above 6.9 mg/L in the fall and winter (See Figure 78d-77e). The lake was weakly stratified in the spring with anoxic conditions

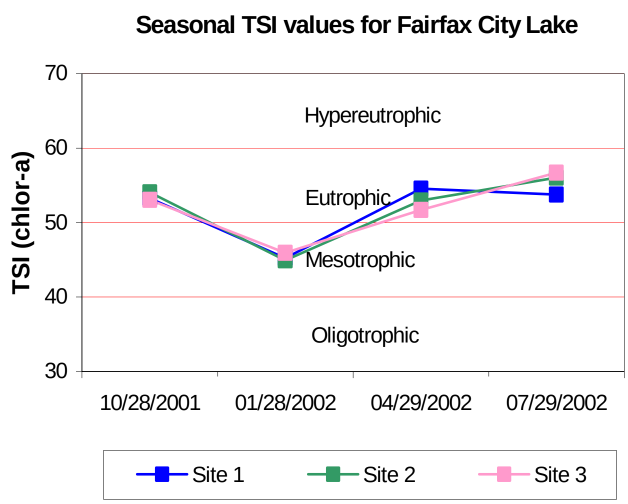


Figure 77. TSI values for Fairfax City Lake.

present only at the lake bottom. Fairfax was strongly thermally stratified in the summer quarter between the 5 and 6 meters depths at which point D.O. values fell below 2.0 mg/L (see Figure 78f). 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 only 40% of the water column less than 2.0mg/L the lake is fully supporting its FWP beneficial use based on D.O. values. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.54 mg/L at the lake surface. The TN at the surface ranged from 0.26 mg/L to 0.76 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 for sample year 2001-2002 was 0.031 mg/L at the lake surface. The TP ranged from 0.024 mg/L to 0.039 mg/L. The highest surface TP values were reported in the summer quarter and the lowest were in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 17:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Fairfax City Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Fairfax City Lake was classified as eutrophic indicative of high primary productivity and nutrient rich conditions (Plate 33). The FWP beneficial use was fully supported based on turbidity data. 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 dissolved oxygen concentrations in the water column. 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.

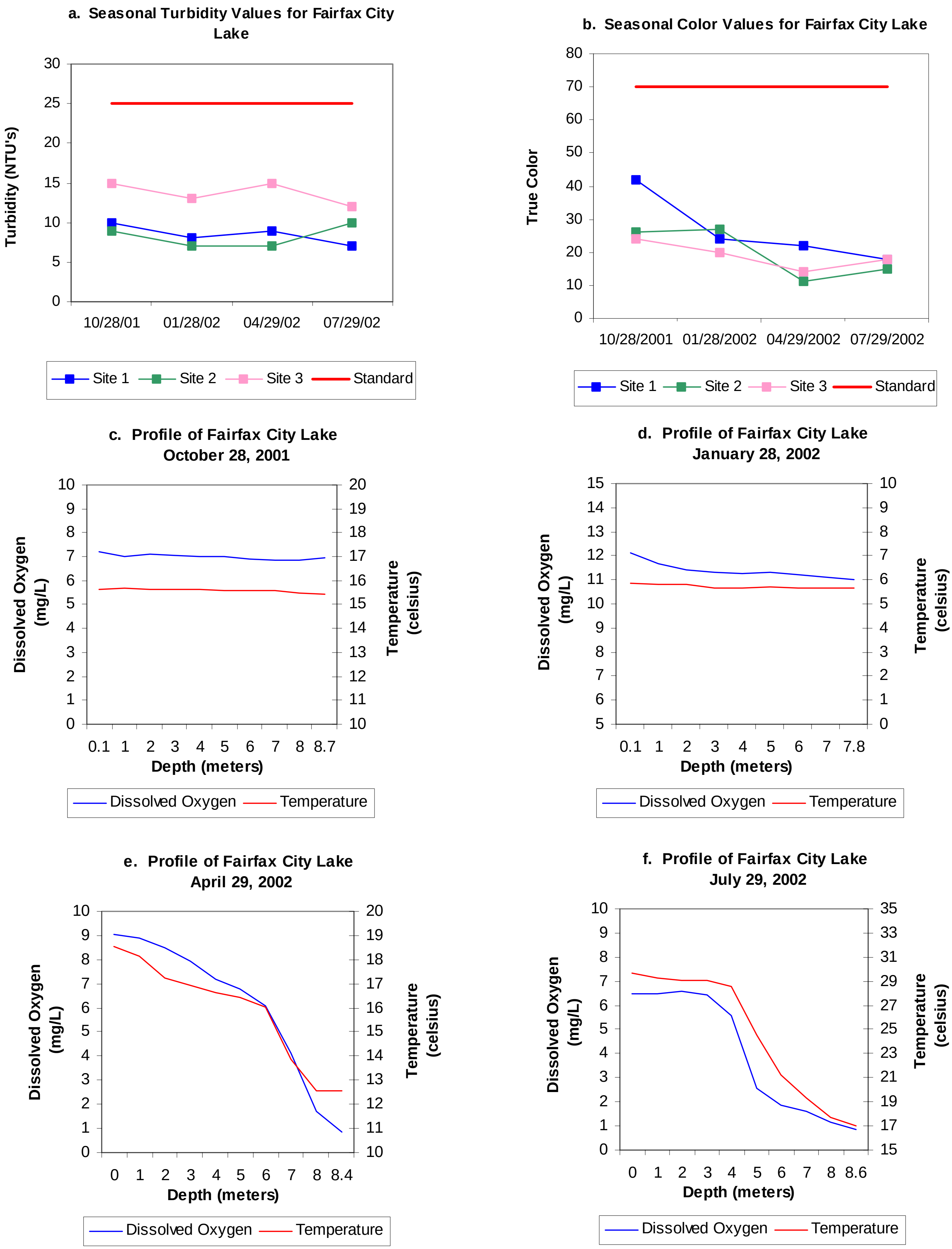
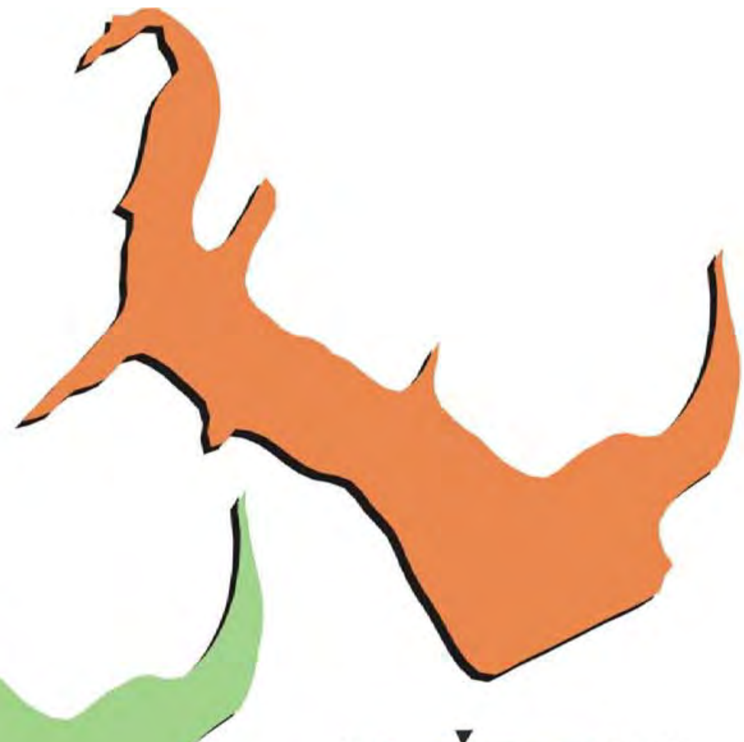


Figure 78a-77f. Graphical representation of data results for Fairfax City Lake.

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 33- Lake Water Quality for
Fairfax Lake

Fort Cobb Reservoir

Fort Cobb Reservoir was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at 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 0.5 meters from the lake bottom at site 1, the dam, in the winter and spring. The lake-wide annual turbidity value was 15 NTU (Plate 34), true color was 26 units, and secchi disk depth was 62 centimeters in 2001-2002. 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 63 (Plate 34), 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 (OWQS). At this time Fort Cobb is considered threatened due to nutrients until a non-support status can be confirmed. The TSI values varied seasonally from the lower end of eutrophy in the winter to the upper end of hypereutrophy in the summer (see Figure 79). Only three of the twenty-four turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) 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 OWQS (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 meeting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Seasonal true color values are displayed in Figure 80b. All true color values were below the Aesthetics OWQS of 70 units for all three seasons at all sites so the Aesthetics beneficial use is being met for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity values ranged from 0.22 parts per thousand (ppt) to 0.26 ppt, slightly elevated above the expected range for most Oklahoma reservoirs. Readings for specific conductance were within the expected range for Oklahoma reservoirs. Specific conductivity ranged from 429.7 mS/cm in the summer to 509.2 mS/cm in the spring quarter, indicating moderate concentrations of electrical current conducting compounds (salts) in the water column. Oxidation-reduction potentials (redox) ranged from -27 mV near the lake bottom in the summer quarter to 555 mV at site 1 also in the summer quarter, indicating reducing conditions were not present to an appreciable degree during 2001-2002 sampling. Lake pH values were neutral to slightly alkaline with values ranging from 6.5 units to 8.91 all within the OWQS range of 6.5-9.0 units, therefore 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

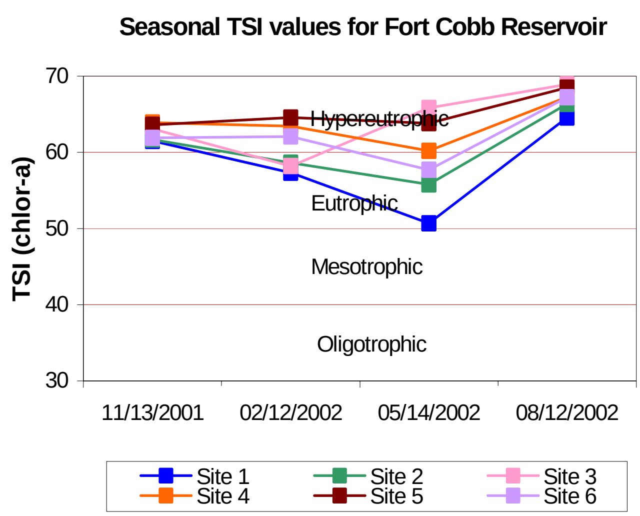


Figure 79. TSI values for Fort Cobb Reservoir.

oxygen values above 5.0 mg/L except at the very bottom of the lake (see Figure 80d-79e). Fort Cobb Reservoir was thermally stratified during the summer quarter between 10 and 11 meters below the surface at which point dissolved oxygen (D.O.) concentrations fell below 1.0 mg/L and remained below 1.0 mg/L all the way to the lake bottom at 12.7 meters (see Figure 80f). 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 only 21% 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 total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 1.15 mg/L at the lake surface. The TN at the surface ranged from 0.73 mg/L in winter quarter at site 6 to 1.49 mg/L recorded in the winter quarter at site 4. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.087 mg/L at the lake surface. The TP ranged from 0.052 mg/L to 0.152 mg/L. The highest surface TP values were reported in the summer and the lowest were in the winter. The nitrogen to phosphorus ratio (TN:TP) was 13:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Fort Cobb Reservoir was also sampled for metals at six sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Fort Cobb Reservoir was classified as hypereutrophic indicative of excessive primary productivity and nutrient rich conditions (Plate 19). This confirms findings from previous data collection efforts and further supports the listing of the lake in the OWQS as NLW water with nutrient threats present. The lake was fully supporting its Aesthetics beneficial use based on true color. With only 8% of the nutrient values above the OWQS criteria for turbidity, the lake is fully supporting its FWP beneficial use for turbidity and with only 31% of the dissolved oxygen concentrations collected exceeding that criteria 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. Fort Cobb 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. The Bureau of Reclamation and its contractors are currently studying the lake intensively to further identify the source of the nutrient problems and to recommend corrective actions in the lake and watershed.

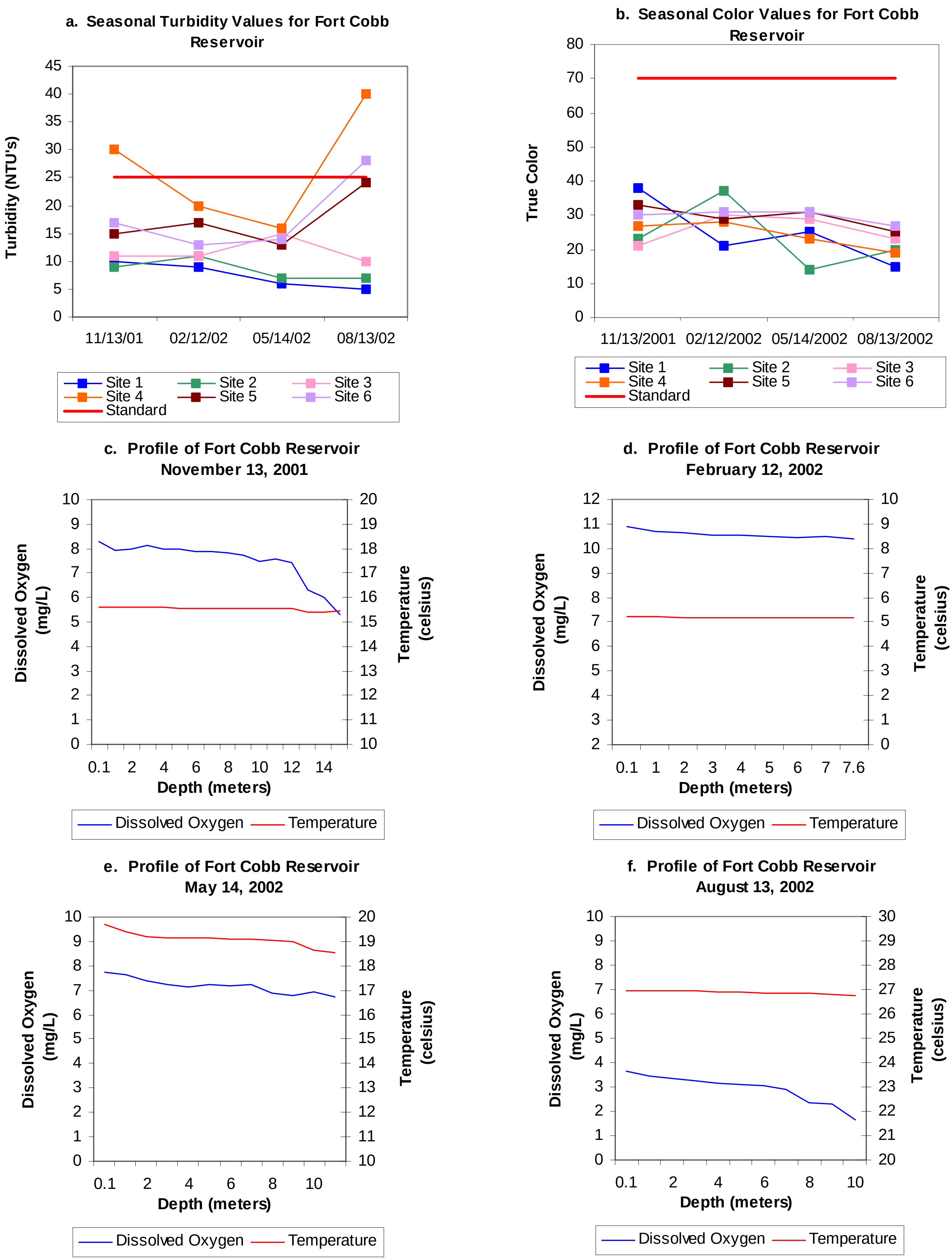
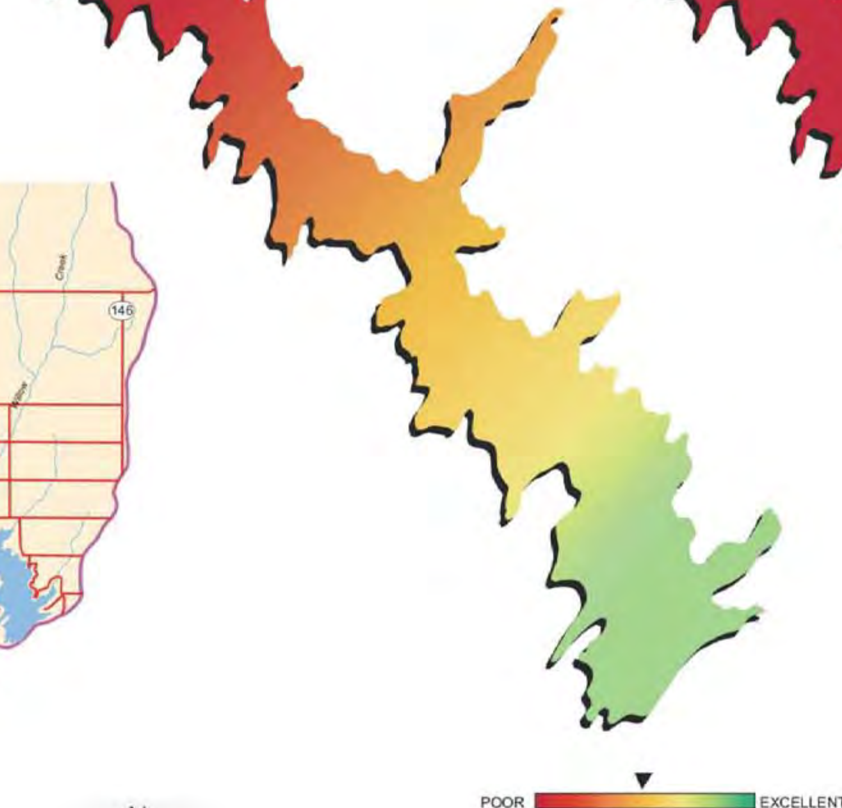


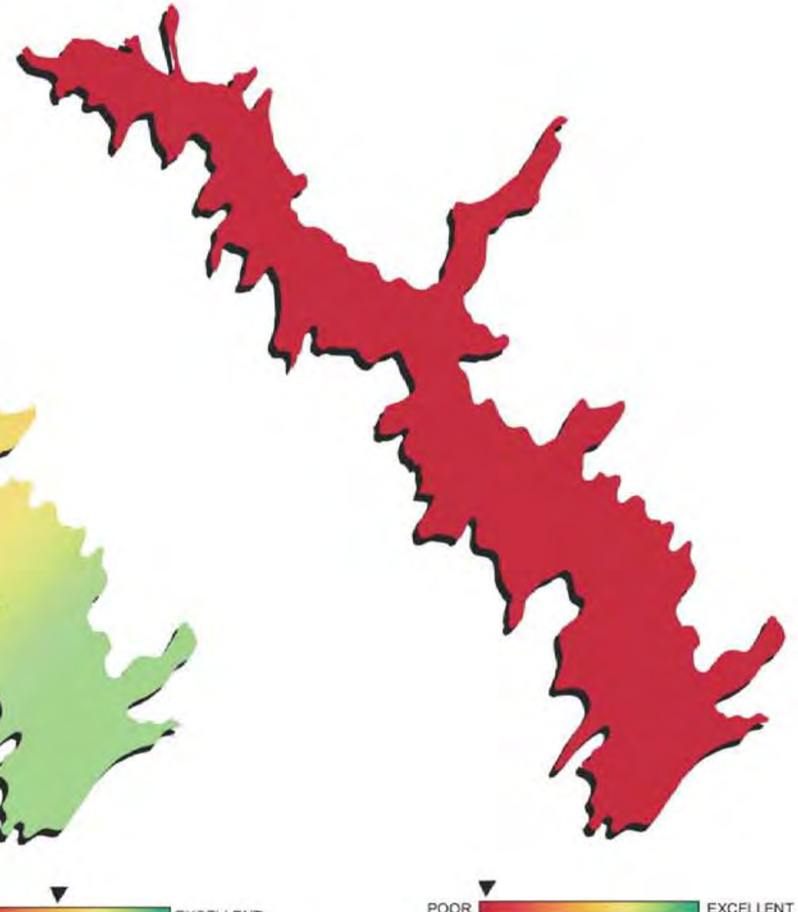
Figure 80a-79f. Graphical representation of data results for Fort Cobb Reservoir.

Fort Cobb Lake
Location

Fort Cobb Lake
and
Watershed



Turbidity
2002



Trophic State
2002

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 34 - Lake Water Quality for
Fort Cobb Lake

Fort Gibson Lake

Fort Gibson Lake was sampled for four quarters, from October 2000 through July 2001. Water quality samples were collected at eight sites to represent the riverine, transitional, and lacustrine zones and 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 14 NTU, true color was 46 units, and secchi disk depth was 82 centimeters in 2001. Based on these three parameters, Fort Gibson Lake had good water clarity in 2001. Water clarity is about the same compared to the summer of 1998, although secchi disk depth has improved while true color and turbidity are higher 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=32). The average TSI was 64, classifying the lake as hypereutrophic, indicative of excessive levels of productivity and excessive nutrient conditions. This value is similar to the TSI in 1998 (TSI=67), based on eight summer values, indicating no significant increase or decrease in trophic status over time. The TSI values were primarily hypereutrophic throughout the year (78% of samples) at all sites although the TSI at several sites in the winter were mesotrophic or eutrophic. Only five of the 31 turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU; however, this constitutes a listing as partially supporting the 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 OWQS (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 standard in the fall and winter, but several in the spring and summer were above the 25 NTU criteria. Similar to the turbidity trend, all true color values were below the aesthetics OWQS of 70 units in the fall and winter; however, several values were above the standard in the spring/summer. Less than 10% of the true color values exceeded the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is still considered fully supported. 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.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Fort Supply Lake

Fort Supply Lake was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional samples were collected at the lake surface at sites 4 and 5 for chlorophyll-a and turbidity analysis in order to meet minimum data requirements. 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 79 NTU (Plate 35), true color was 70 units, and secchi disk depth was 18 centimeters in 2001-2002. Based on these three parameters, Fort Supply Lake had poor water clarity in 2001-2002. 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 60 (Plate 35), classifying the lake in the upper end of eutrophy, indicative of high levels of productivity and high nutrient conditions. Currently Fort Supply Lake is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW) with the Aesthetics beneficial use threatened. The TSI values were primarily hypereutrophic in the fall and summer quarters and at the lower to upper end of eutrophic in the winter and spring quarters respectively (see Figure 81). All of the turbidity values recorded exceeded the OWQS of 25 NTU (See Figure 82a). 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 OWQS (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 based on turbidity. Seasonal true color values are shown in Figure 82b. 33% of the true color values were in violation of the Aesthetics OWQS of 70 units, however, a beneficial use determination cannot be made because the minimum data requirements were not met (See OAC 785:46).

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.50 parts per thousand (ppt) to 0.54 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 conductance values were also above the expected range for Oklahoma reservoirs, coinciding with the high salinity concentrations. Values ranged from 964.5 mS/cm in the spring to 1037 mS/cm recorded at site 2 in the fall. Oxidation-reduction potentials (redox) ranged from 74 mV in the spring quarter to 515 mV in the winter, indicating reducing conditions were not present in an appreciable way. Lake pH values were either slightly alkaline or acidic depending on the season of the year with values ranging from 5.33 in the summer to 8.40 in the winter. 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. Of the pH values recorded approximately 27% were below 6.5 units, so the lake is provisionally

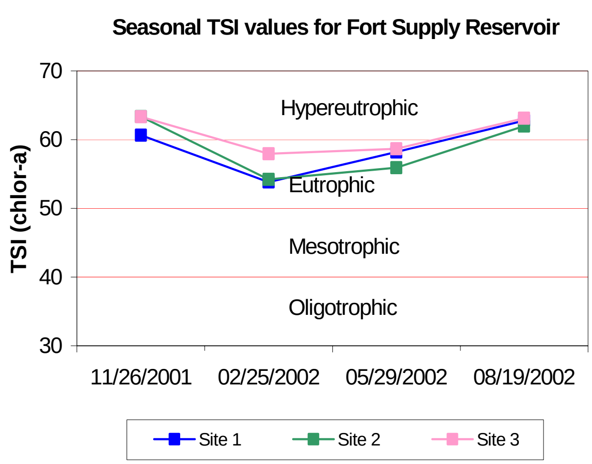


Figure 81. TSI values for Fort Supply Lake.

not supporting* its FWP beneficial use based on low pH values in the water column. 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 82c-81f). Dissolved oxygen (D.O.) values were above 2.5mg/L throughout the water column at all sites in all quarters and generally values were above 6.5 mg/L meaning the water column was well oxygenated and well mixed (see Figure 82c-81f). 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. The FWP beneficial use was fully supported based on D.O. values. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 1.14 mg/L at the lake surface. The TN at the surface ranged from 0.55 mg/L to 1.57 mg/L. The highest surface TN value was reported in the winter and the lowest was in the summer. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.187 mg/L at the lake surface. The TP ranged from 0.058 mg/L to 0.467 mg/L. The highest surface TP value was reported in the fall and the lowest was in the winter. The nitrogen to phosphorus ratio (TN:TP) was 6:1 for sample year 2001-2002. This value is less than 7:1, characterizing the lake as nitrogen-limited (Wetzel, 1983).

Fort Supply Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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, Fort Supply Lake was classified as eutrophic, bordering hypereutrophic, indicative of high primary productivity and high nutrients (Plate 35). Fort Supply Lake should be studied more intensively and the NLW listing should lead to more intensive sampling to confirm if water quality impairment is occurring. The lake has a threatened Aesthetics beneficial use based on its trophic status and a use support determination for true color cannot be made due to insufficient data. The FWP beneficial use is not supporting based on turbidity and pH concentrations in the lake. The FWP use is supported based on D.O. readings. According to ODEQ, the lake was sampled in 1998 and none of the fish tissue samples exceeded the screening level or low consumption advisory level for metals toxicity or organic residues. Fort Supply Lake, constructed by the United States Army Corps of Engineers, was built in 1942 for flood control and hydroelectric power purposes.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

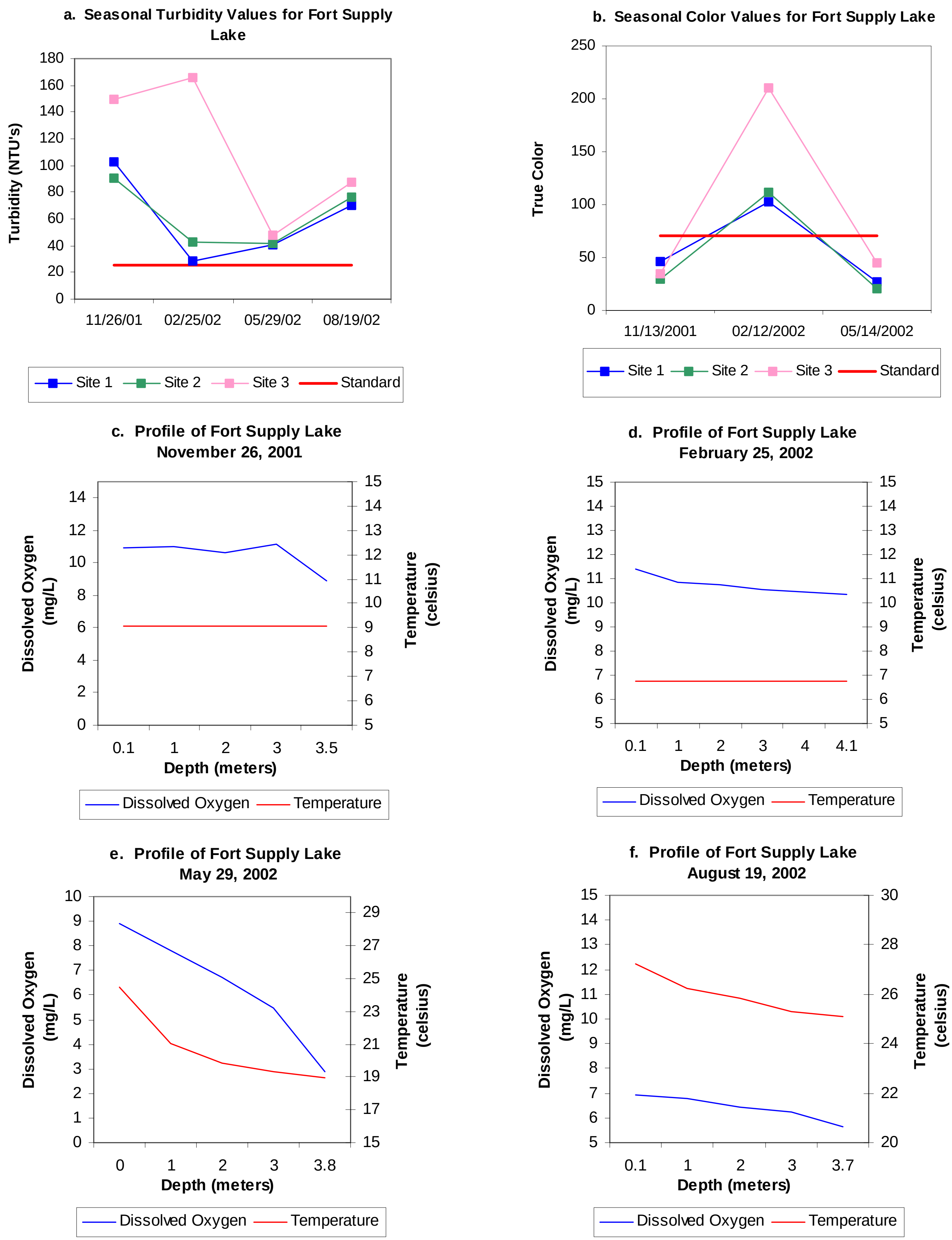


Figure 82a-81f. Graphical representation of data results for Fort Supply Lake.

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 35 - Lake Water Quality for

Fort Supply Lake

Foss Reservoir

Foss Reservoir was sampled for four quarters, from October 2002 through July 2003. 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 12 NTU (Plate 36), true color was 10 units, and average secchi disk depth was 161 centimeters in sample year 2002-2003. 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 2000. 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 36), indicating the lake was mesotrophic, with moderate levels of productivity and nutrient conditions for sample year 2003. This value is similar to that calculated in 2000 (TSI=47) indicating no significant change in productivity has occurred. The TSI for all sites varied seasonally and ranged from oligotrophic in the spring to mesotrophic in the winter and eutrophic in both summer and fall (Figure 83). A similar pattern was seen during the 2000 evaluation. The only exception occurred at site 5, when chlorophyll concentrations spiked in the spring, which made this site hypereutrophic. Seasonal turbidity values by site are displayed in Figure. Although the lake-wide average for turbidity was 12 NTU, below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, there are instances when some values were near or above the standard. These spikes in turbidity occurred at sites 4 (summer) and 5 (fall) in the upper portions of the lake (see Figure 84a). 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 (OWQS) 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 partially supported at Foss Reservoir with 10% of the values above the turbidity standard of 25 NTU. Seasonal true color values are displayed in Figure 84b. All color values are well below the aesthetics OWQS of 70 units.

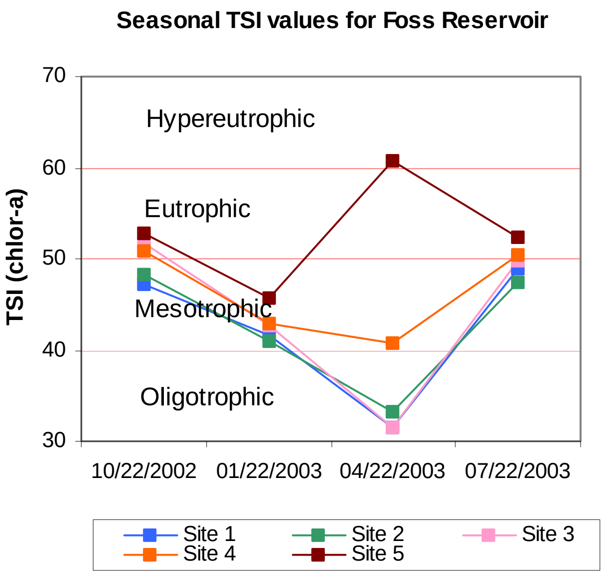


Figure 83. TSI values for Foss Reservoir.

In 2002-2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Foss Reservoir ranged from 0.67 parts per thousand (ppt) to 1.29 ppt, which is higher than most Oklahoma reservoirs. Specific conductivity ranged from 1274 mS/cm to 2409 mS/cm, indicating extremely high concentrations of current conducting compounds (chlorides and salts) in the lake, consistent with higher salinity concentrations. The pH values ranged from 7.31 at the lake bottom in the summer to 8.23 at the surface in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. 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 329 mV in the hypolimnion in the spring to 525 mV during the fall. During the fall, winter, and spring thermal stratification was not present and the lake was well mixed with dissolved oxygen values remaining above 7.0 mg/L (see Figure 84c-83e). The lake was thermally stratified and anoxic conditions were present during the summer sampling interval. Stratification generally occurred between 8 and 10 meters with dissolved oxygen (D.O.) values falling below 2.0 mg/L for the rest of the water column (Figure 84f). 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 39% of the water column in the summer, Foss Reservoir 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.52 mg/L at the surface and 0.48 mg/L at the lake bottom. Surface TN ranged from 0.29 mg/L to 0.82 mg/L with both the highest and lowest values occurring during the summer. The lake-wide total phosphorus (TP) average was 0.024mg/L at the surface and 0.020 mg/L at the lake bottom. Similar to total nitrogen surface TP was highest in the summer quarter, however, the lowest value was seen in the fall. TP values ranged from 0.011 mg/L to 0.091 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 22:1 for sample year 2003. This value is higher than 7:1, characterizing the lake phosphorus limited (Wetzel, 1983).

In summary, Foss Reservoir was classified as mesotrophic with moderate primary productivity and nutrient conditions. The current trophic status is similar that in 2000 (TSI=47), indicating no significant change in productivity has occurred since the last evaluation. Water clarity was good in 2002-2003 based on turbidity, true color and secchi disk depth. The FWP beneficial use is supported based on pH, but is partially supported based on both turbidity and dissolved oxygen levels. The Aesthetics beneficial use is supported at Foss Reservoir based on its trophic status and true color. 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.

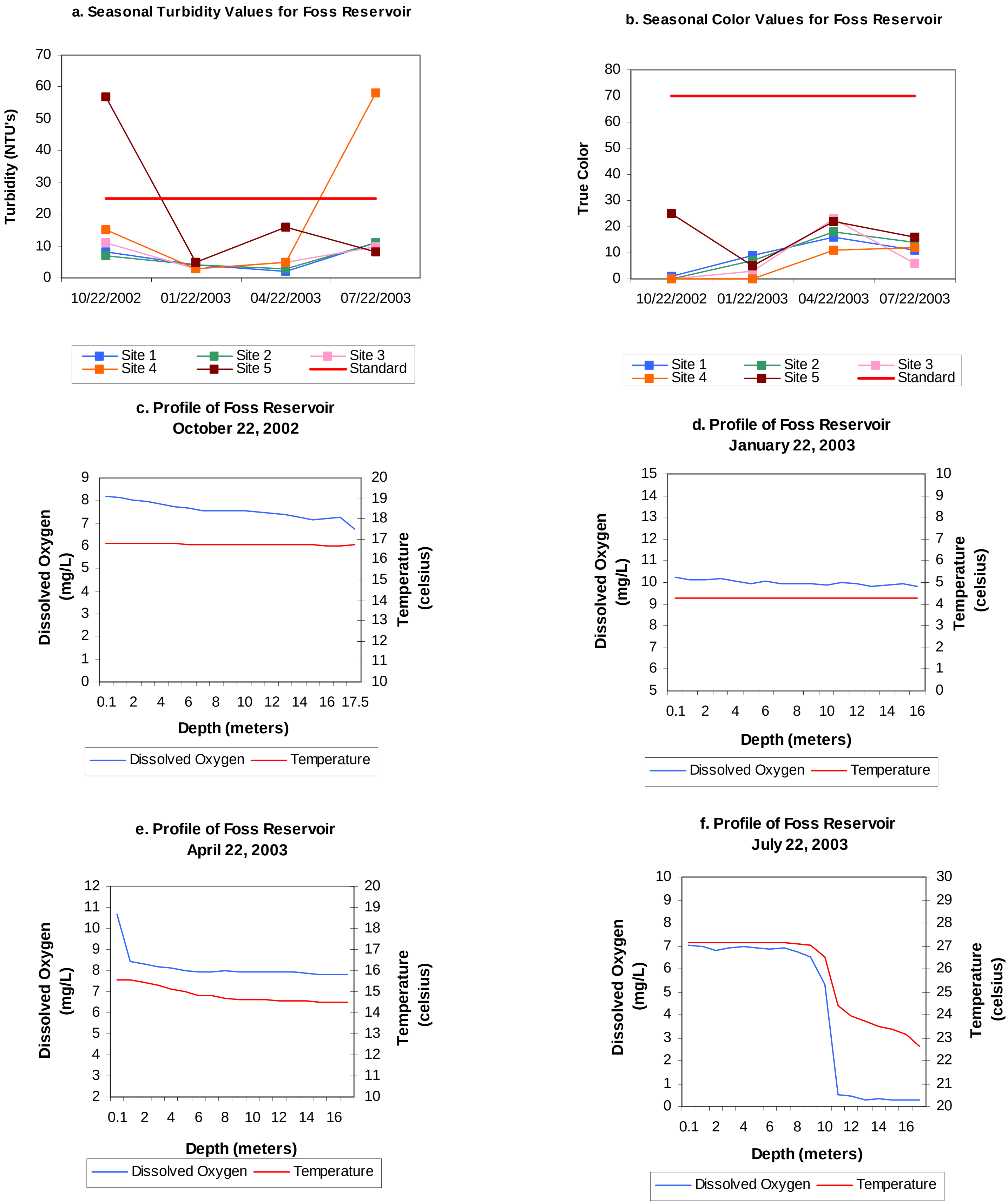
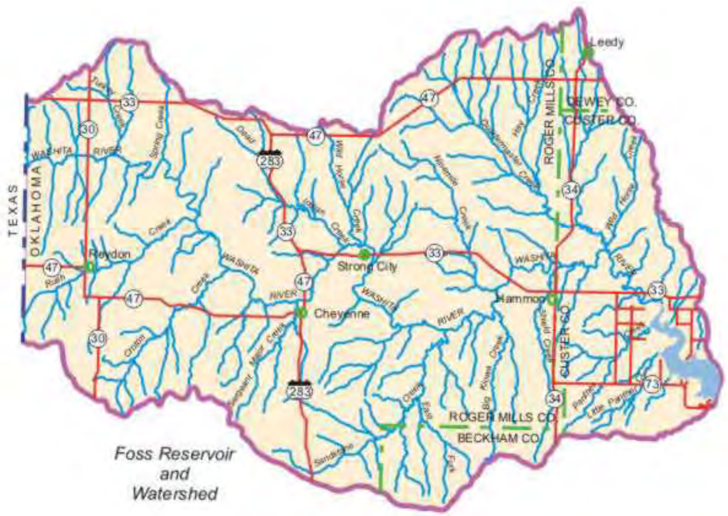
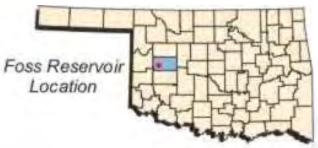


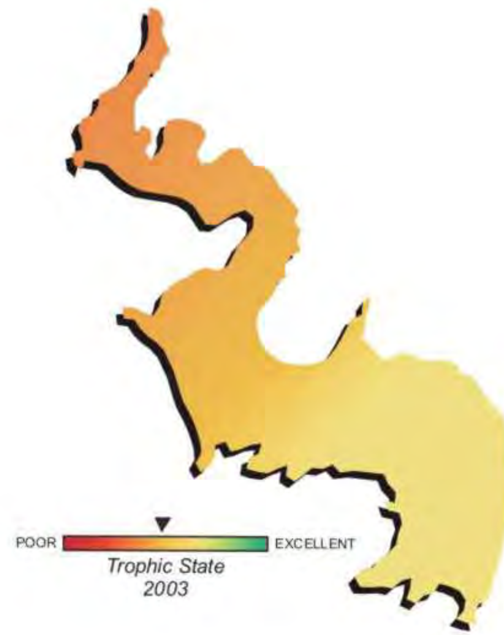
Figure 84a-83f. Graphical representation of data results for Foss Reservoir.

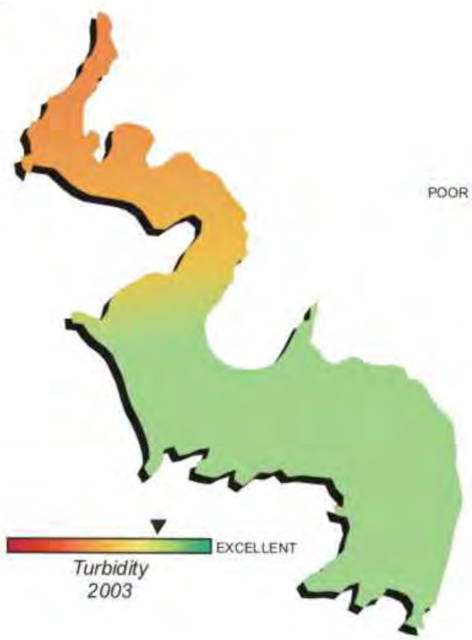


Foss Reservoir and Watershed



Foss Reservoir Location





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 36 - Lake Water Quality for
Foss Reservoir

Lake Frederick

Frederick Lake was sampled for four quarters from October 2002 through July 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for the reservoir as it is greater than 250 surface acres in size. 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 93 NTU (Plate 37), true color was 57 units, and secchi disk depth was 17 centimeters. Based on these three parameters, Frederick Lake had poor water clarity in 2003. 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 37), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. This value is consistent with the TSI in 2000 (TSI=50). The TSI values were eutrophic throughout the year at all sites except for sites 3 and 5 in the summer, which were mesotrophic, and therefore the lake-wide TSI of 51 seems representative of conditions at Lake Frederick (Figure 85). Seasonal turbidity values are displayed in Figure 86a. All turbidity values (100%) in 2003 exceeded the Oklahoma Water Quality Standard (OWQS) 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 Oklahoma Water Quality Standard (OWQS) 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 Lake Frederick based on high turbidity. Seasonal true color values are displayed in Figure 86b. All color values are well below the aesthetics OWQS of 70 units during the first three sampling quarters, but were above the standard in the spring. It is likely that this is due to spring rains and runoff. Additional samples sites were not added until later in the sample year therefore the minimum data requirements of 20 samples for lakes greater than 250 surface acres was not met and a determination for the Aesthetics beneficial use cannot be made.

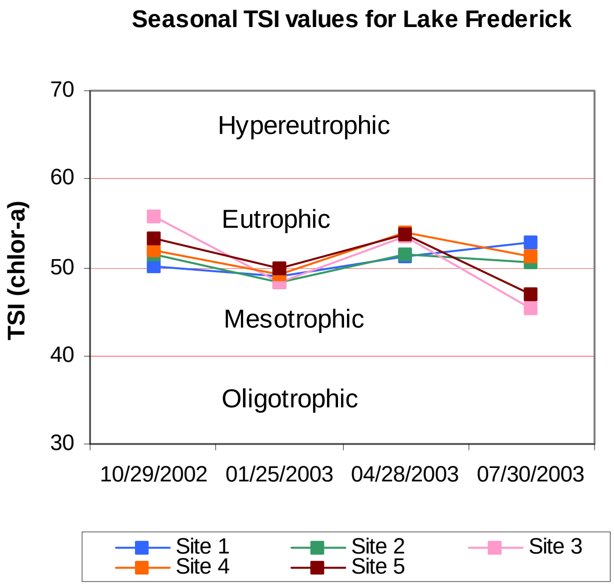


Figure 85. TSI values for Lake Frederick.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values at Lake Frederick ranged from

0.14 parts per thousand (ppt) to 0.26 ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 286.5 mS/cm to 503.7 mS/cm, indicating minimal concentrations of current conducting compounds (chlorides and salts) in the lake system. The pH values ranged from 7.21 at the lake bottom in the summer to 8.29 at the surface in the spring. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. All values recorded within the acceptable range the lake supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 210 mV in the spring to 615 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. 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 86a-85f) throughout the entire sample year. The only time the D.O. fell below 4.0 mg/L was during the summer near the lake bottom. 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 chlorides, sulfates, and total dissolved solids to assess its Agriculture beneficial use. Sampling in 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.59 mg/L at the surface and 0.56 mg/L at the lake bottom. Surface TN ranged from 0.22 mg/L to 0.87 mg/L with the lowest values occurring during the fall and the highest in the spring. The lake-wide total phosphorus (TP) average was 0.065 mg/L at the surface and 0.062 mg/L at the lake bottom. Surface TP was also highest in the spring quarter; however, the lower value recorded in the summer. TP values ranged from 0.041 mg/L to 0.115 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 9:1 for sample year 2003. This value is slightly higher than 7:1, characterizing the lake phosphorus limited to co-limited (Wetzel, 1983).

In summary, Lake Frederick was classified as eutrophic (TSI=51), indicative of high primary productivity and nutrient rich conditions. This value is slightly higher than the TSI in 2001 that classified the lake as mesotrophic bordering eutrophic, however the current value is based on a larger dataset and is likely a more accurate depiction of productivity in the system. Water clarity is poor based on turbidity, true color, and secchi disk depth and is 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 a beneficial use determination cannot be made for true color due to minimum data requirements for lakes greater than 250 surface acres not being met. 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 87) and determine current lake volume. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405)

530-8800. Frederick Lake was constructed in 1974 by the Soil Conservation Service and is located in Tillman County.

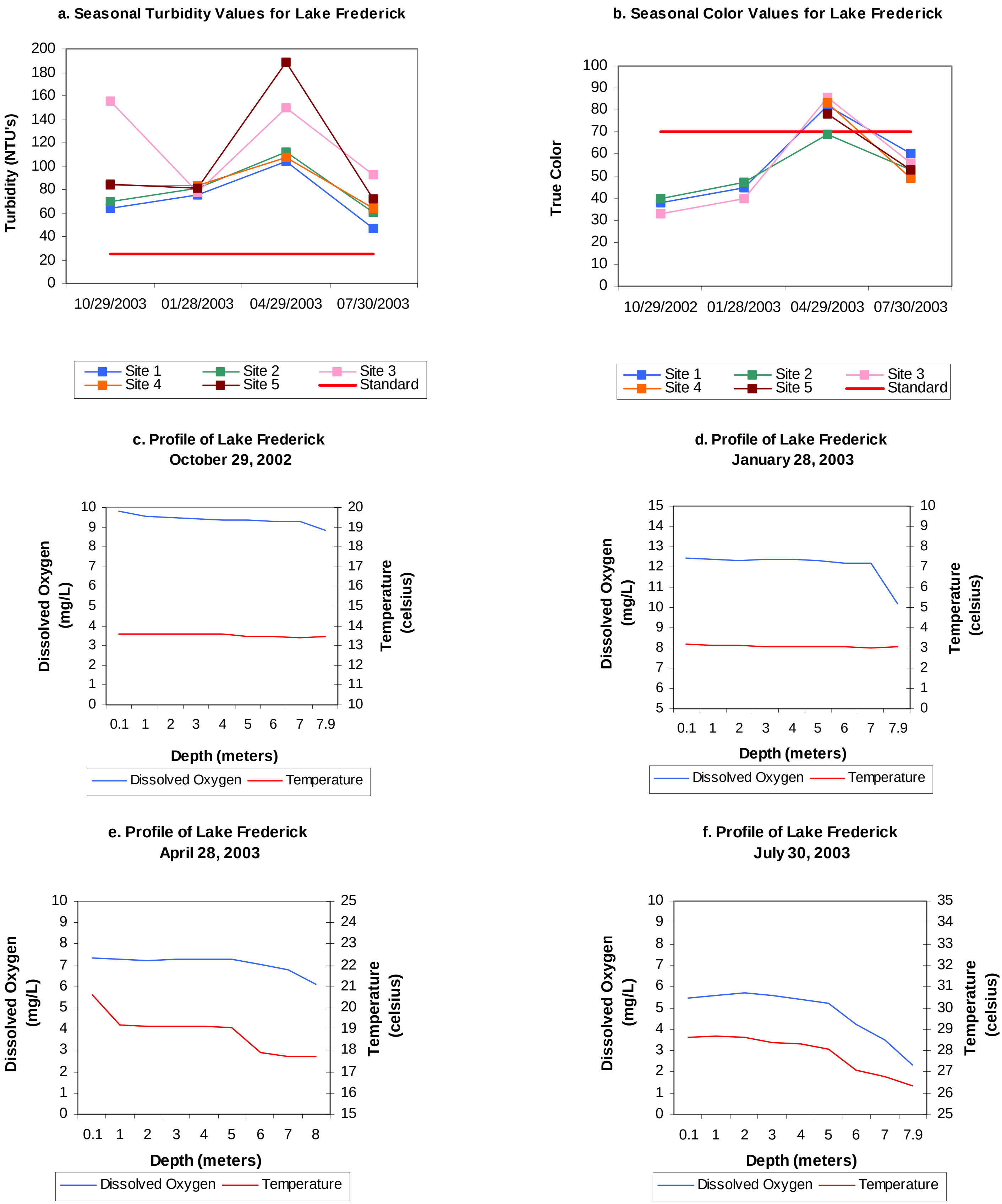


Figure 86a-85f. Graphical representation of data results for Lake Frederick.

Frederick Lake
and
Watershed

Frederick Lake
Location

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

Turbidity
2003

Trophic State
2003

Plate 37 - Lake Water Quality for
Lake Frederick

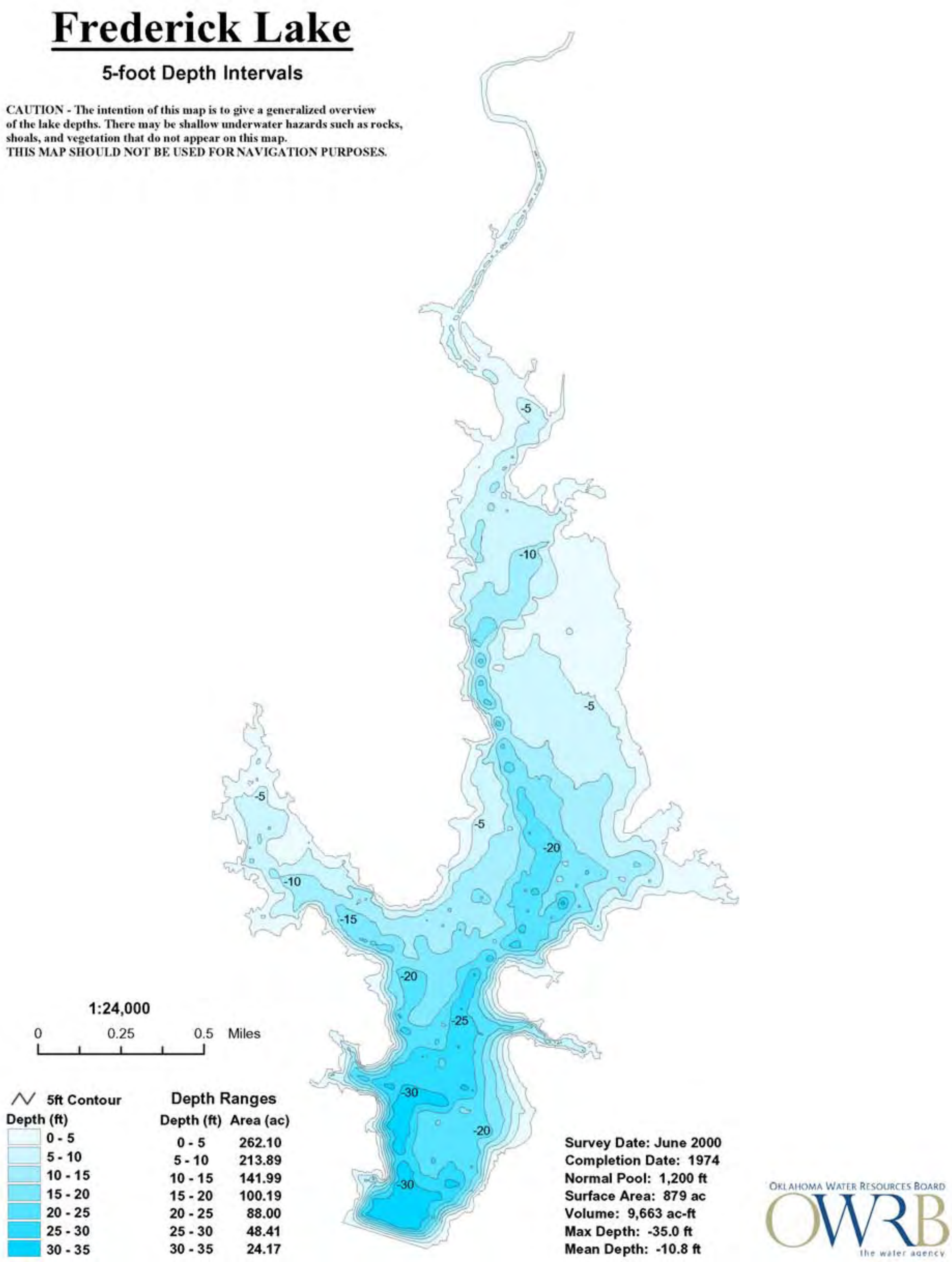


Figure 87. Bathymetric Map of Lake Frederick.

Fuqua Lake

Fuqua Lake was sampled for four quarters, from November 2002 through August 2003. 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 17 NTU (Plate 38), true color was 12 units, and secchi disk depth was 98 centimeters. Based on these three parameters, Fuqua Lake had good water clarity in 2003, better than observed in the 2001 evaluation. The 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 a lab accident the chlorophyll for one of the twenty samples could not be analyzed. The average TSI was 47 (Plate 38), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is similar to the one in 2001 (TSI=48), indicating no significant increase or decrease in productivity has occurred. All of the collected values were in the mesotrophic category (Figure 88). 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 (OWQS) 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 five of the nineteen or 26% of the turbidity values exceeded the OWQS of 25 NTU the minimum data requirements of 20 samples for lakes greater than 250 surface acres was not met and a determination cannot be made at this time. However upon reviewing historical data it is likely that the lake would be listed as partially supporting the Fish and Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 89b. All true color values were well below the OWQS of 70 units. Applying the same default protocol the Aesthetic beneficial use is fully supported based on true color.

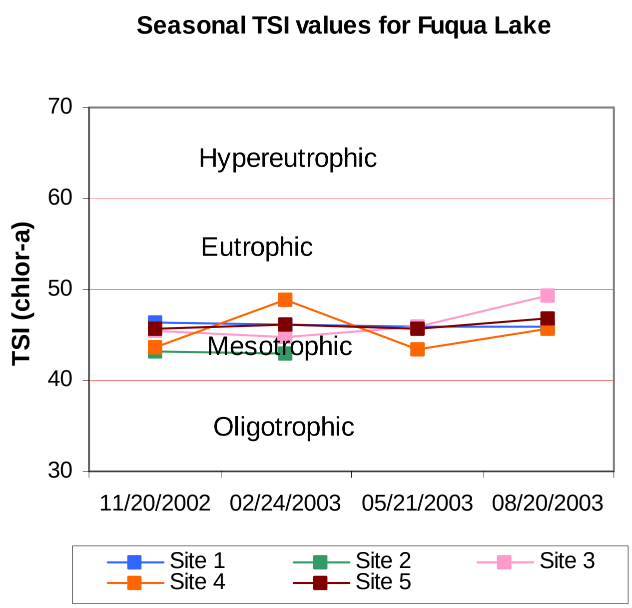


Figure 88. TSI values for Fuqua Lake

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values at Fuqua Lake ranged from 0.25 parts per thousand (ppt) to 0.29ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 490.4 mS/cm to 566.5 mS/cm, indicating moderate concentrations of current conducting compounds or other analogous material (salts) in the lake system. The pH values ranged from 7.16 to 8.29 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 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. All values recorded were within the acceptable range therefore the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 375 mV in the fall to 515 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 4.0 mg/L (see Figure 89c-88e) 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 5 and 6 meters with dissolved oxygen dropping below 2.0 mg/L from the thermocline to the lake bottom (see Figure 89f). 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 water column was less than 2.0 mg/L in the summer Fuqua Lake 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 2002-2003 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 five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (58.8 cfu/ml) exceeds the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.36 mg/L at the surface and 0.43 mg/L at the lake bottom. Surface TN ranged from 0.16 mg/L in the winter to 0.54 mg/L in the spring. The lake-wide total phosphorus (TP) average was 0.018mg/L at the surface and 0.017 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.007 mg/L in the fall to 0.033 mg/L in the spring. The nitrogen to phosphorus ratio (TN:TP) was 20:1 for sample year 2003. This value is 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 2002-2003. The TSI in 2001 was also mesotrophic, indicating no increase or decrease in productivity. Water clarity was good based on turbidity, true color, and secchi disk depth, even better than that observed in 2001. The lake is supporting its FWP beneficial use for pH, but only partially supporting based on dissolved oxygen values. Although there are only nineteen of the twenty required turbidity values, it is likely that the FWP beneficial use would be partially supported. The Aesthetics beneficial use is supported based on its trophic status and true color values. The PBCR beneficial use is not supported as five (5) or 50% enterococci samples exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (58.8 cfu/ml) exceeds the prescribed mean standard of 33 cfu/ml. Fuqua Lake is owned by the city of Duncan and serves as a municipal water supply and recreational reservoir.

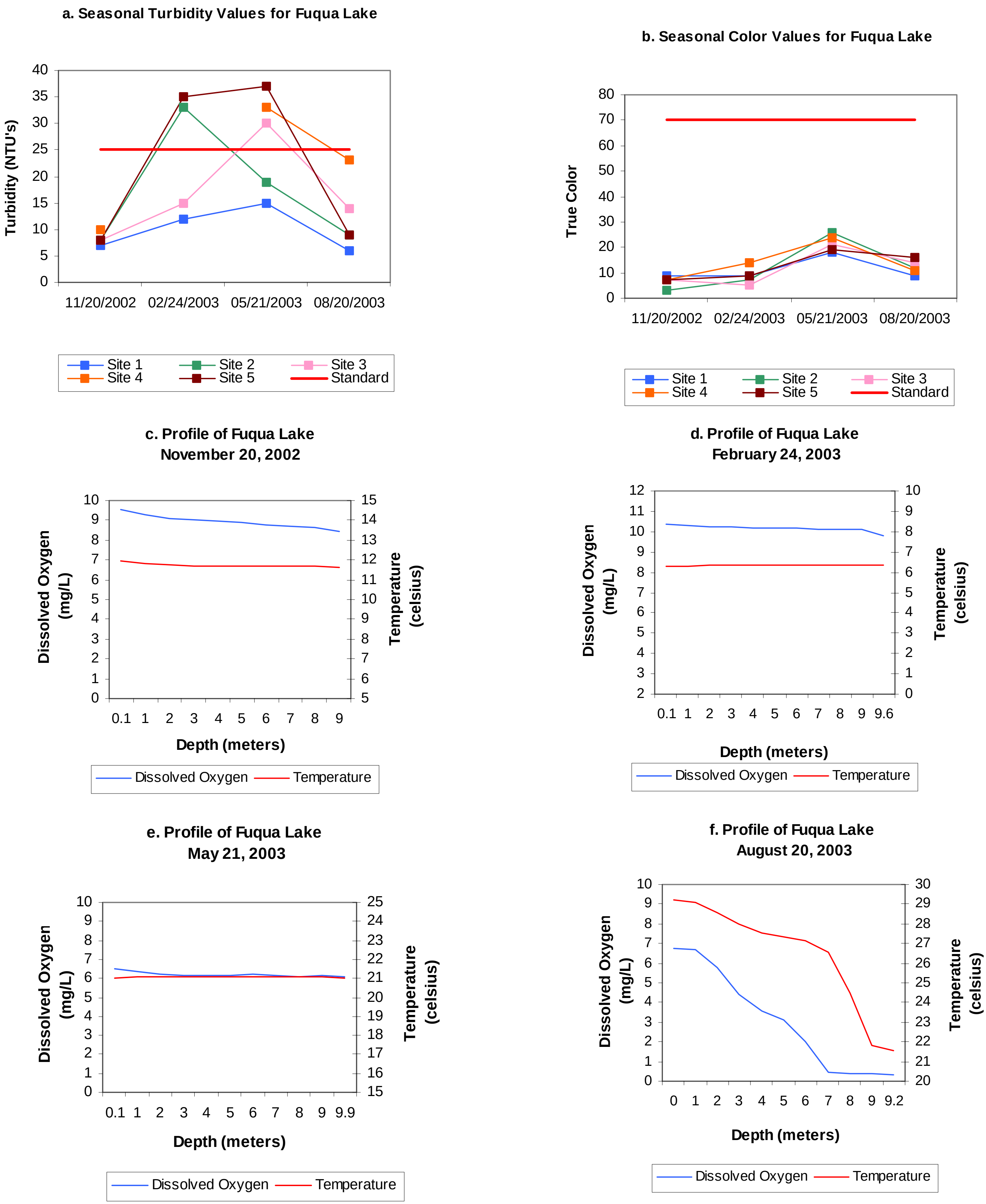
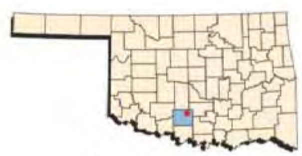


Figure 89a-88f. Graphical representation of data results for Fuqua Lake.

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 2003

Trophic State 2003

Plate 38- Lake Water Quality for

Fuqua Lake

Grand Lake

Grand Lake was sampled for four quarters, from October 2000 through July 2001. Water quality samples were collected at 13 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 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 45 NTU, true color was 41 units, and secchi disk depth was 62 centimeters in 2001. Based on these three parameters, Grand Lake had poor to average water clarity in 2001. In the summer of 1998, based on samples from the 13 designated sites, the water clarity was good, much better than the annual assessment for 2001. The assessment of clarity for 2001 is most likely a more accurate depiction of lake conditions as this was based on four sampling events throughout the year (n=52). The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=51; one outlier chlorophyll-a value was not used in the TSI calculation). The average TSI was 59, classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is slightly lower than the one calculated in the summer of 1998 (TSI=61), although it is more accurate of trophic conditions throughout the year. Chlorophyll-a values were variable at this reservoir, between sites and seasons, and only one sampling event would not be adequate or representative. The TSI values ranged from oligotrophic (8%) to hypereutrophic (31%), although most values were in the eutrophic category (49%). As expected, the lowest TSI average was at the lower end of the lake (sites 1, 2, and 3) as well as site 10, and the most productive sites were in the tributary arms, Honey Creek (site 6) and Spring/Neosho River arm (sites 13 and 12). Turbidity values were also extremely variable between sites and seasonally. Twenty-three of the 52 turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU constituting a listing as “not supporting” the 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 OWQS (25 NTU for turbidity). In the fall and summer very few samples exceeded the criteria; however in the spring, 12 of the 13 sites were above 25 NTU. In the winter, high turbidity values (above 150 NTU) were recorded at sites 9, 12 and 13, increasing the annual lake-wide turbidity average from 23 NTU to 45 NTU. Regardless of the extraordinary values in the winter, Grand Lake would still be considered “not supporting” the FWP beneficial use based on high turbidity. Only 3 of the 52 true color values exceeded the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is considered fully supported. For most sites, true color was highest in the spring and lowest in the winter, which is the common pattern for most lakes.

Please refer to the “Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report” for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency’s web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Great Salt Plains Lake

Great Salt Plains Lake was sampled for four quarters from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional samples were collected at sites 4, 5, 7 and 8 and were used for chlorophyll-a and turbidity analysis in order to meet minimum data requirements. Water samples were collected from the lake surface at all three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 261 NTU (Plate 39), true color was 91 units, and secchi disk depth was 19 centimeters in 2001-2002. Based on these three parameters, Great Salt Plains Lake had poor water clarity in 2001-2002, which is consistent with historical data collection results on this lake. Water clarity is likely to always be poor based on the soil composition and shallow optometry 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=22). The average TSI was 73 (Plate 39), classifying the lake as hypereutrophic, indicative of excessive levels of primary productivity and nutrients. This lake is also listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW), indicating the lake is nutrient threatened and potentially not supporting its Aesthetics beneficial use due to nutrients. The TSI values for Great Salt Plains were hypereutrophic throughout the year with the exception of the spring when oligotrophic values were present, indicating the lake had low productivity and nutrient levels (see Figure 90). All 22 turbidity values (100%) in 2001-2002 exceeded the OWQS 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 OWQS (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 (see Figure 91a). Seasonal true color values are displayed in Figure 91b. Unfortunately, not enough data was available to make a beneficial use determination for the Aesthetics use. The annual lake-wide average of 91 units was well above the Aesthetics OWQS of 70 units and indicates the beneficial use would not be supported had sufficient data been available.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were also recorded at all sample sites during the study period. Salinity ranged from 1.52 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 conductance values ranged from 2798 mS/cm to 10016 mS/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 413 mV, indicating an absence of reducing

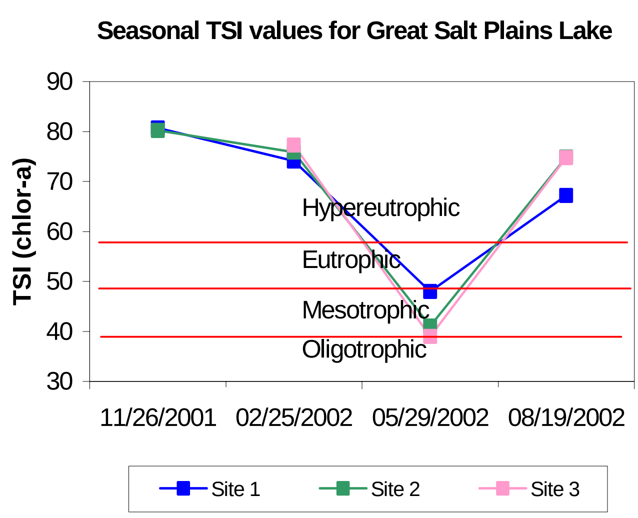


Figure 90. TSI values for Great Salt Plains Lake.

conditions at any time in the water column during the course of lake sampling. The pH values were neutral to acidic, ranging from 5.11 in the summer quarter to 7.98 in the winter. According to the 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 33% of the collected values falling outside the acceptable range the lake is provisionally not supporting* its FWP beneficial use based on pH. Thermal stratification was not present in this reservoir in sample year 2001-2002, due to the shallow nature of the reservoir (see Figure 91c-90f) and dissolved oxygen (D.O.) concentrations were above 2.0 mg/L at all times and were generally above 5.0 mg/L (see Figure 91c-90f). 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. The FWP beneficial use is fully supported at Great Salt Plains Lake. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be not supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 1.37 mg/L at the lake surface. The TN at the surface ranged from 0.075 mg/L to 2.85 mg/L, which is a lot of nitrogen to be present in the water column. The highest surface TN value was reported in the fall and the lowest was in the winter quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.482 mg/L at the lake surface, which was also very high value. The TP ranged from 0.080 mg/L to 1.783. The highest surface TP value was reported in the fall and the lowest was in the spring. The nitrogen to phosphorus ratio (TN:TP) was approximately 3:1. This value is less than 7:1, characterizing the lake as nitrogen-limited (Wetzel, 1983).

Great Salt Plains Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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 or consumption advisory levels. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Great Salt Plains Lake was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels (Plate 39). The lake is currently listed in the OWQS as NLW water and should be studied intensively in the future to verify if beneficial uses are not being supported. At this time the Aesthetics beneficial use is considered threatened due to nutrients. Water clarity is consistently poor at this lake. The lake was not supporting its FWP beneficial use based on turbidity and is provisionally not supporting its FWP beneficial use due to low pH concentrations. The FWP is fully supported based on D.O. concentrations. The United States Army Corps of Engineers constructed Great Salt Plains Lake in 1941 for flood control and other conservation purposes and is a popular spot for birding related activities.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

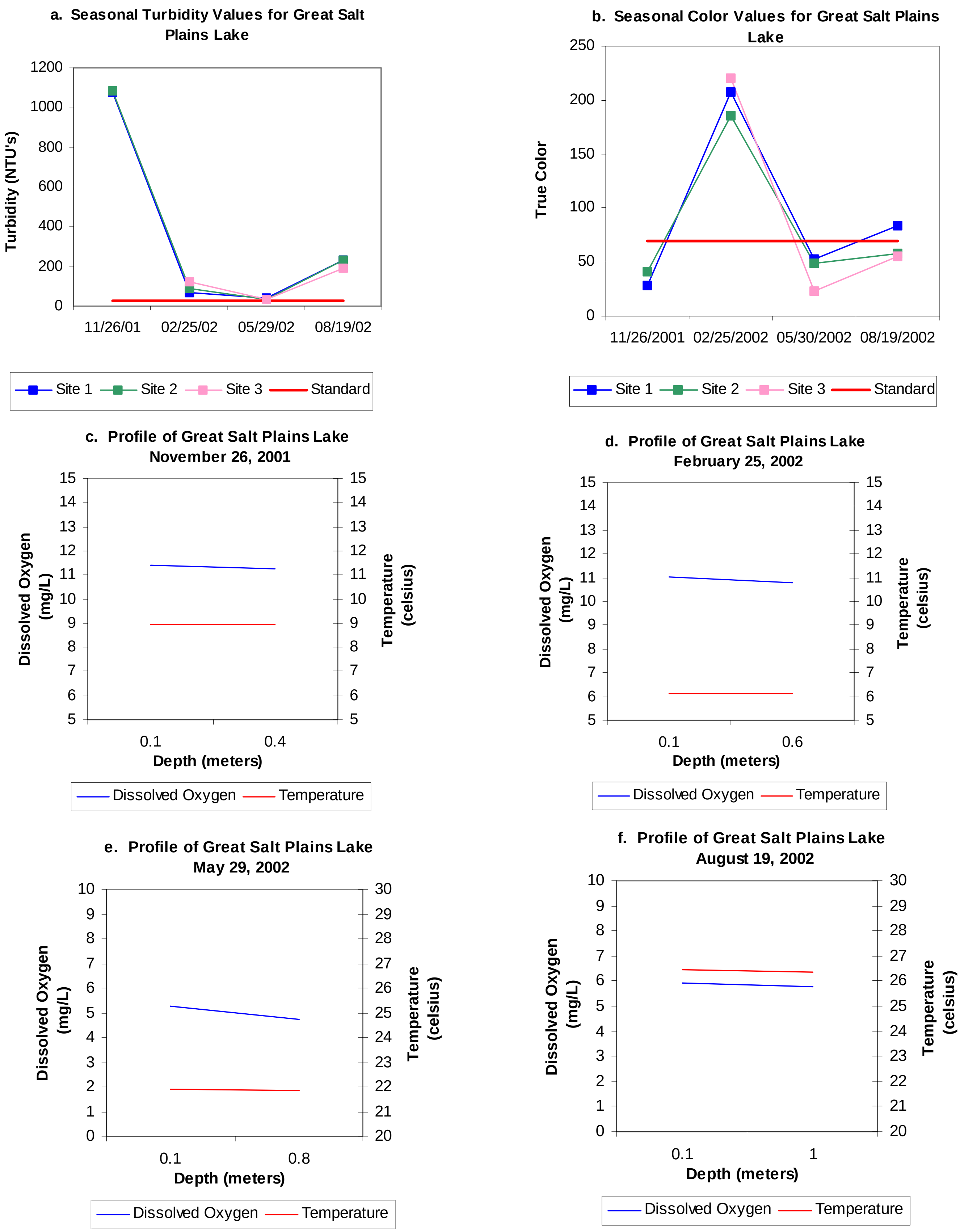
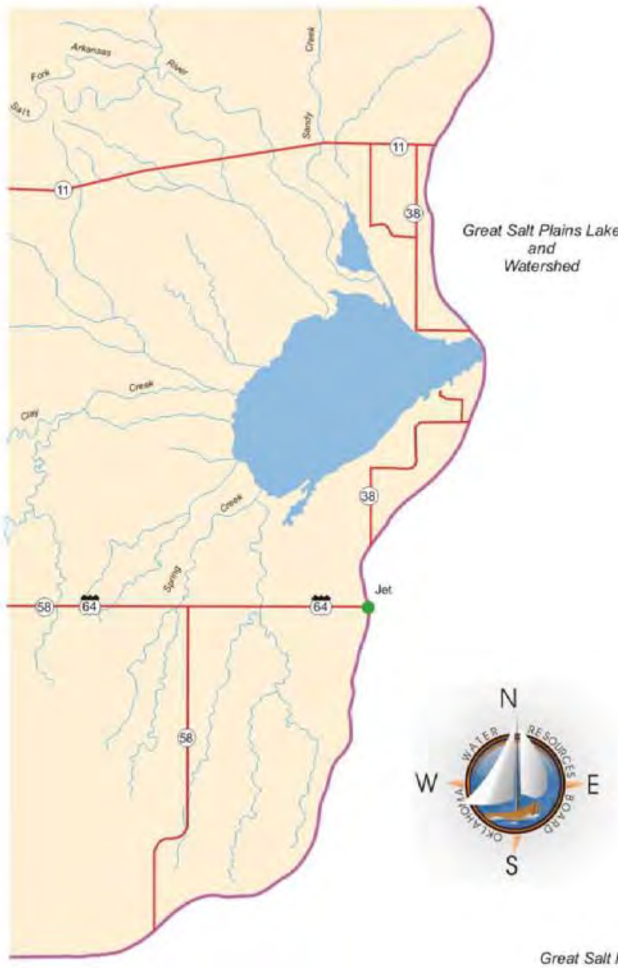
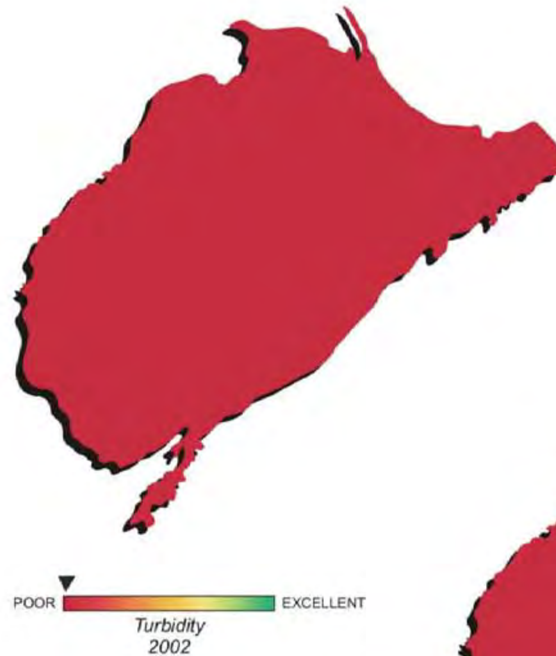


Figure 91a-90f. Graphical representation of data results for Great Salt Plains Lake.



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



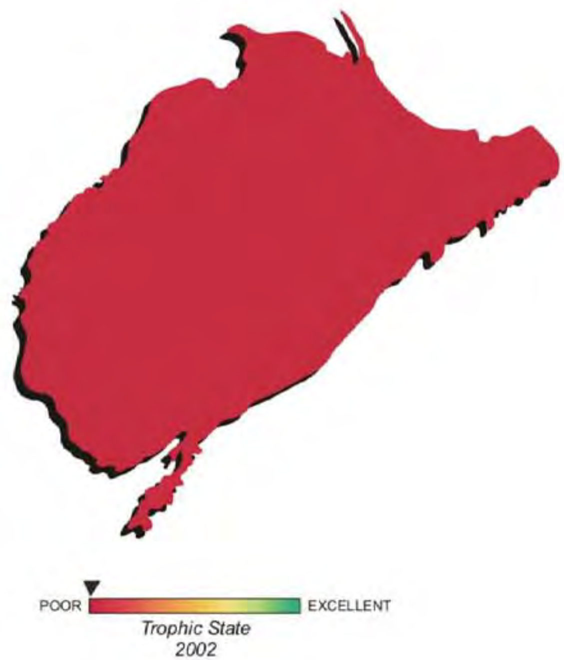


Plate 39 - Lake Water Quality for
Great Salt Plains Lake

Greenleaf Lake

Greenleaf Lake was sampled for four quarters, from October 2000 through July 2001. Water quality samples were collected at three 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, true color was 29 units, and secchi disk depth was 79 centimeters in 2001. Based on these three parameters, Greenleaf Lake had good water clarity in 2001. The water clarity was slightly better in the summer of 1997 although this was based on only three samples collected during one event instead of four sampling events throughout the year (n=12). 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 54, classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is similar to the one calculated in 1997 (TSI=52), indicating no change in trophic status over time. The TSI values were all eutrophic with the exception of site 2 in the winter and site 1 in the summer. The annual TSI of 54 seems representative of conditions at Greenleaf Lake throughout 2001. All turbidity values for in 2001 were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU except in the winter at sites 2 and 3. 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 OWQS (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% of the samples collected in 2001 were above the standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres. All true color values were below the aesthetics OWQS of 70 units; therefore the Aesthetics beneficial use is considered fully supported at Greenleaf Lake. 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.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Guthrie Lake

Guthrie Lake was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 at the lake surface solely for the analysis of chlorophyll-a and turbidity to meet minimum data requirements. 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 40), true color was 32 units, and secchi disk depth was 50 centimeters in 2001-2002. Based on these three parameters, Guthrie Lake had average to fairly good water clarity in 2001-2002. 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 62 (Plate 40), classifying the lake as hypereutrophic, indicative of excessive levels of productivity and nutrients. This value is such that it would result in listing the lake in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW), which classifies the lake as nutrient threatened and not be meeting its Aesthetics beneficial use due to excessive nutrients. It will be recommended that the lake be designated an NLW during the next OWQS revision process. The TSI values ranged from eutrophic to hypereutrophic, with eutrophic conditions prevailing in the winter and spring and hypereutrophic conditions prevalent in the fall and summer quarters (see Figure 92). Only one of the twenty turbidity values exceeded the OWQS of 25 NTU (see Figure 93a). 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 OWQS. 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. Guthrie Lake is meeting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 93b. None of the true color values exceeded the numeric criteria of 70 units, however, there is insufficient data available to determine if the Aesthetics beneficial use is fully supporting for color, though all available data indicates that this is the case.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity ranged from 0.3 to 0.37 parts per thousand (ppt), which is slightly higher than the expected range for Oklahoma lakes. Readings for specific conductance ranged from 611.4 mS/cm to 718.1 mS/cm, indicating moderate to slightly elevated concentrations of electrical current conducting compounds (salts) present in the water column throughout the year. In general, pH values were neutral to alkaline, ranging from 7.43 in the summer to 8.81 units in the winter quarter. 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

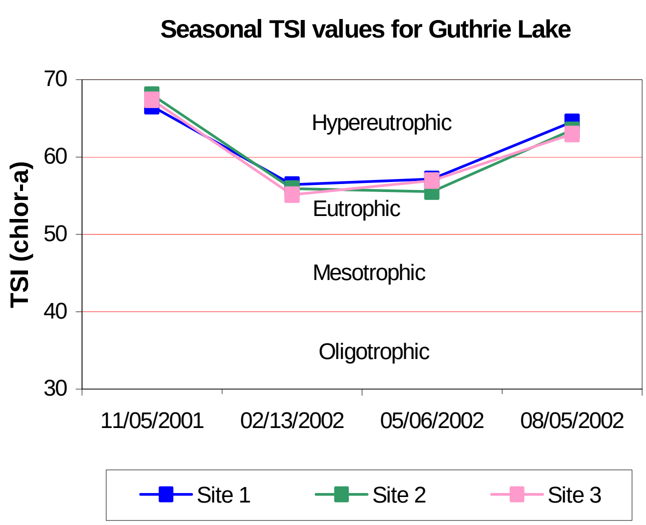


Figure 92. TSI values for Guthrie Lake.

be listed as partially supporting beneficial uses. Guthrie Lake is meeting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 137 mV at the sediment-water interface in the winter to 500 mV in the fall, indicating that reducing conditions were not present in the water column at any time during the course of sampling. The lake was not thermally stratified in the fall, winter, or spring and dissolved oxygen (D.O.) concentrations were generally above 6.0 mg/L throughout the water column, with the exception of the sediment-water interface at the lake bottom (see Figure 93c-92e). The lake was thermally stratified in the summer and anoxic conditions were present below the thermocline at site 1, constituting about 43% of the water column (see Figure 93f). The thermocline was between 3 and 4 meters at the dam site with D.O. concentrations falling below 2.0 mg/L from the 4-meter depth to the lake bottom at 5.9 meters. 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. According to USAP, the FWP beneficial use is fully supported at Guthrie Lake. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002-0 was 1.04 mg/L at the lake surface. The TN at the surface ranged from 0.82 mg/L to 1.35 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 for sample year 2001-2002 was 0.063 mg/L at the lake surface. The TP ranged from 0.051 mg/L to 0.098 mg/L. The highest surface TP value was reported in the fall quarter and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 16:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Guthrie Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Guthrie Lake was classified as hypereutrophic in 2001-2002, indicating excessive primary productivity and nutrient levels (Plate 40). It will be recommended that the lake be designated an NLW during the next OWQS revision process and the Aesthetics beneficial use is threatened due to nutrients. The Aesthetics use for true color could not be assessed due to insufficient information, but collected data strongly suggests that the use would be supported. Guthrie Lake is meeting its FWP beneficial use based on turbidity, pH and dissolved oxygen concentrations. Guthrie Lake was constructed in 1919 and is owned and operated by the City of Guthrie and is utilized for water supply and recreational purposes.

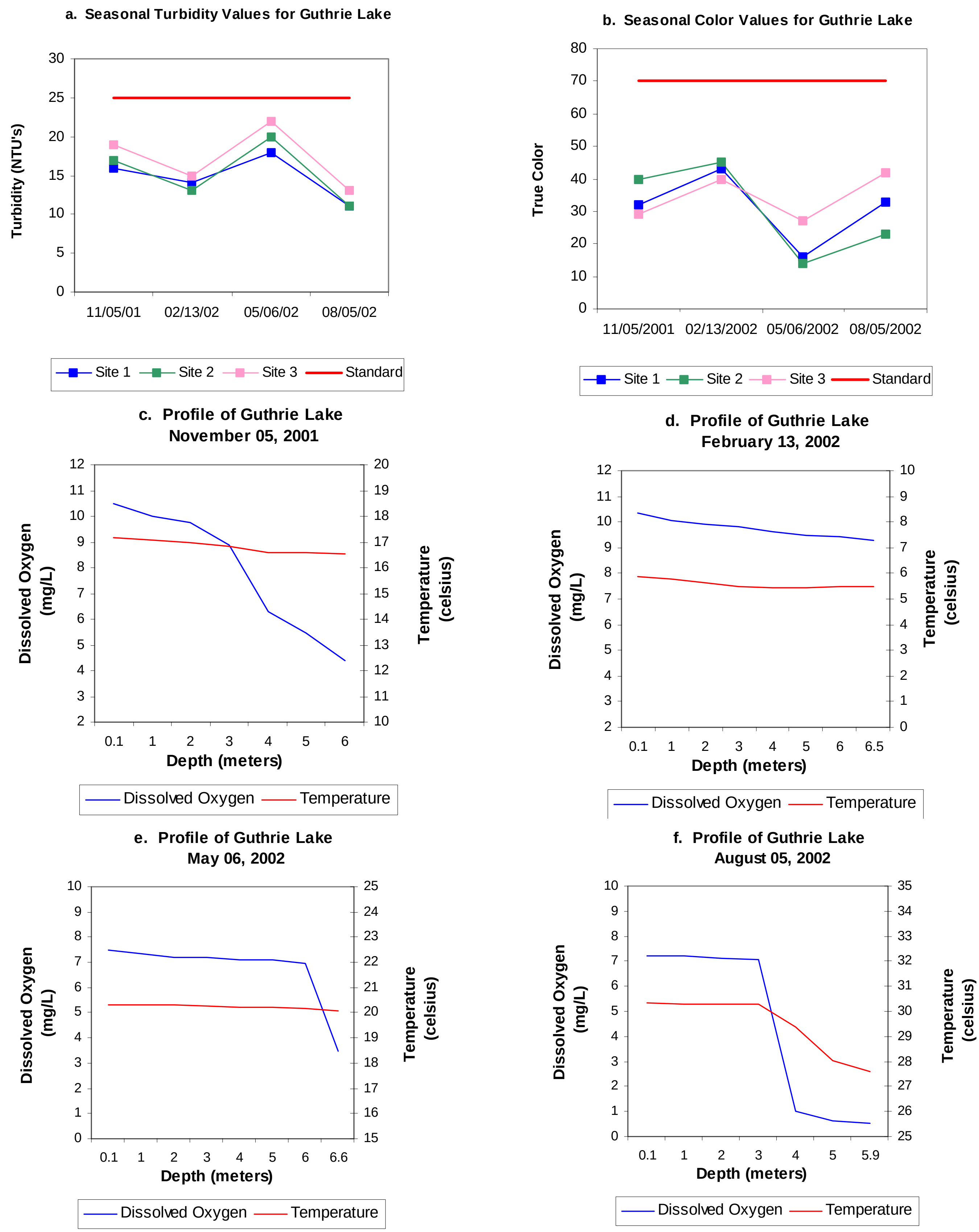
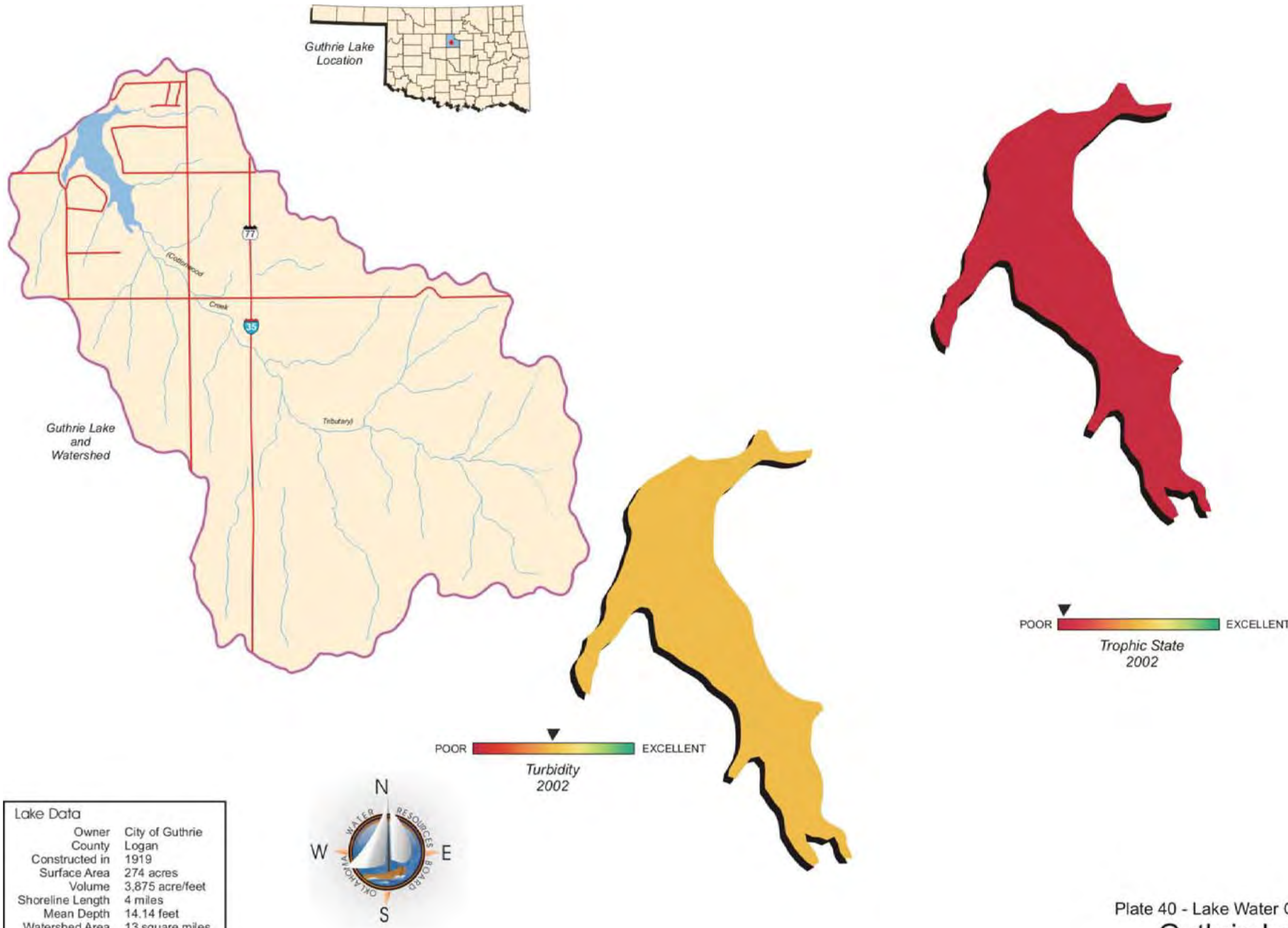


Figure 93a-92f. Graphical representation of data results for Guthrie Lake.



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

Plate 40 - Lake Water Quality for
Guthrie Lake

Healdton City Lake

Healdton City Lake was sampled for four quarters, from November 2000 through August 2001. Water quality samples were collected at three 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 73 NTU, true color was 91 units, and secchi disk depth was 23 centimeters in 2001. Based on these three parameters, Healdton City Lake had poor water clarity in 2001. The water clarity was very similar in the summer of 1997 although this was based on only three samples collected during one event instead of four sampling events throughout the year (n=12). 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 42, classifying the lake as mesotrophic, indicative of low to moderate levels of productivity and nutrients. This value is in the same category, although lower than the one calculated in 1997 (TSI=48). The TSI values varied seasonally at Healdton Lake throughout 2001 from oligotrophic in the fall and spring to mesotrophic/eutrophic in the summer. Although the chlorophyll-a concentrations place this lake in the oligotrophic category, this is probably more a factor of light limiting the system, and not because low levels of nutrients are entering or cycling within the lake. All turbidity values in 2001 were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU except in the summer, when all three sites were below the standard. 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 OWQS (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 75% of the samples collected in 2001 were above the standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres. True color values varied seasonally and were below the Aesthetics OWQS of 70 units at all sites in the winter and summer, but above at all sites in the fall and spring. Although 50% of the samples collected in 2001 were above the standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres, therefore, the Aesthetics beneficial use is considered fully supported.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Lake Hefner

Lake Hefner was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 at the lake surface for chlorophyll-a and turbidity analysis to meet minimum data requirements. 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 9 NTU (Plate 41), true color was 27 units, and secchi disk depth was 84 centimeters in 2001-2002. Based on these three parameters, Lake Hefner had good water clarity in 2001-2002. This was not unexpected at 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 56 (Plate 41), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. Chlorophyll-a values were variable with the lake being eutrophic during the fall and spring, mesotrophic during the winter quarter and hypereutrophic during the summer quarter (see Figure 94). Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 95a). 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 OWQS (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 based on turbidity. Seasonal true color values are displayed in Figure 95b. None of the collected true color values exceeded the numeric criteria of 70 units, however, the Aesthetics beneficial could not be assessed due to insufficient data. The collected data suggests that the Aesthetics beneficial use is being met for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample during the study period. Salinity ranged from 0.31 to 0.54 parts per thousand (ppt), which was greater than the expected range of values reported for Oklahoma lakes. Specific conductivity ranged from 599.9 mS/cm in the fall to 1033 mS/cm in the summer, 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 6.97 units in the summer to 8.54 units in the spring quarter. 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

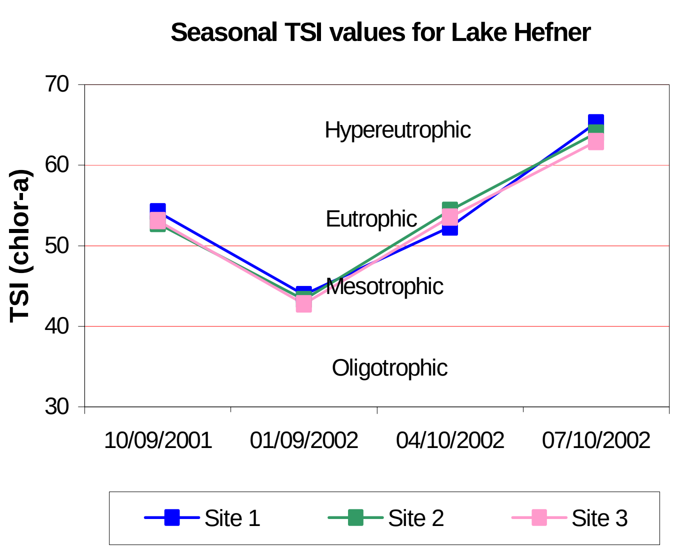


Figure 94. TSI values for Lake Hefner.

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. Lake Hefner is fully supporting its FWP beneficial use based on pH values. Oxidation-reduction potentials (redox) ranged from 12 mV near the sediment-water interface in the summer at site 1 to 524 mV also in the summer quarter at site 1, indicating that reducing conditions were not an appreciable problem in the water column during any season. The lake was not thermally stratified in the fall, winter or spring quarter with dissolved oxygen (D.O.) concentrations well above 7.0 mg/L throughout the water column at all sites (see Figure 95a-94e). In the summer quarter, the lake exhibited stratification between the 2 and 3 meters depth below the surface (see Figure 95f). D.O. concentrations were less than 2.0 mg/L from the 9-meter depth extending to the lake bottom at 21.5 meters where D.O. readings of 0.17 mg/L were recorded. 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 partially supported at Lake Hefner with 61% of the water column having D.O. concentrations less than 2.0 mg/L. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.89 mg/L at the lake surface. The TN at the surface ranged from 0.69 mg/L to 1.24 mg/L. The highest surface TN value was in the summer quarter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.061 mg/L at the lake surface. The TP ranged from 0.044 mg/L to 0.85 mg/L. The highest surface TP value was reported in the fall and the lowest was in the spring and summer. The nitrogen to phosphorus ratio (TN:TP) was approximately 15:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Hefner was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Hefner was classified as eutrophic in 2001-2002, indicative of high primary productivity and nutrient rich conditions (Plate 41). The lake is fully supporting its Aesthetics beneficial use based on its trophic status and collected information strongly supports the supposition that it would be fully supporting for true color if sufficient data were available. Lake Hefner is fully supporting its FWP beneficial use based on turbidity and pH values, however, based on anoxic conditions in the summer quarter, the FWP beneficial use is only partially supported at Lake Hefner based on D.O. readings. 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. 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 96) was generated to determine current storage capacity and identify areas of extreme sedimentaion. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

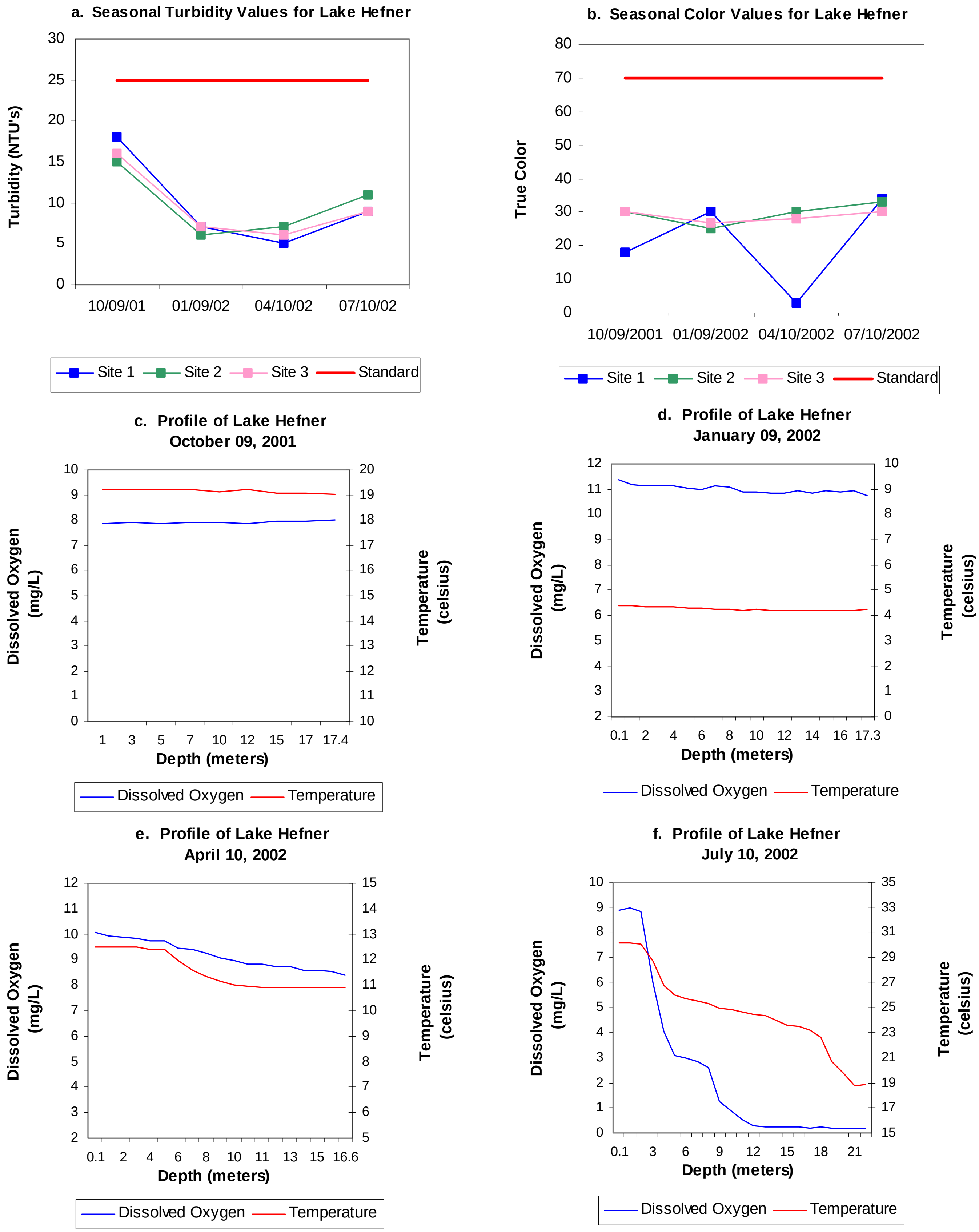


Figure 95a-94f. Graphical representation of data results for Lake Hefner.

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

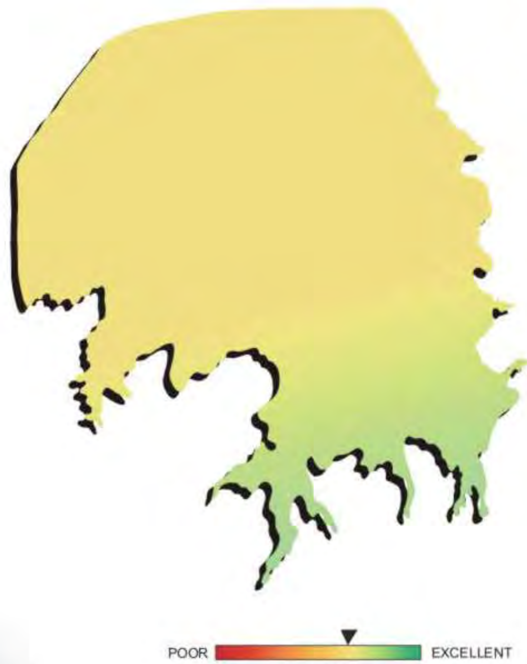


Plate 41 - Lake Water Quality for
Hefner Lake

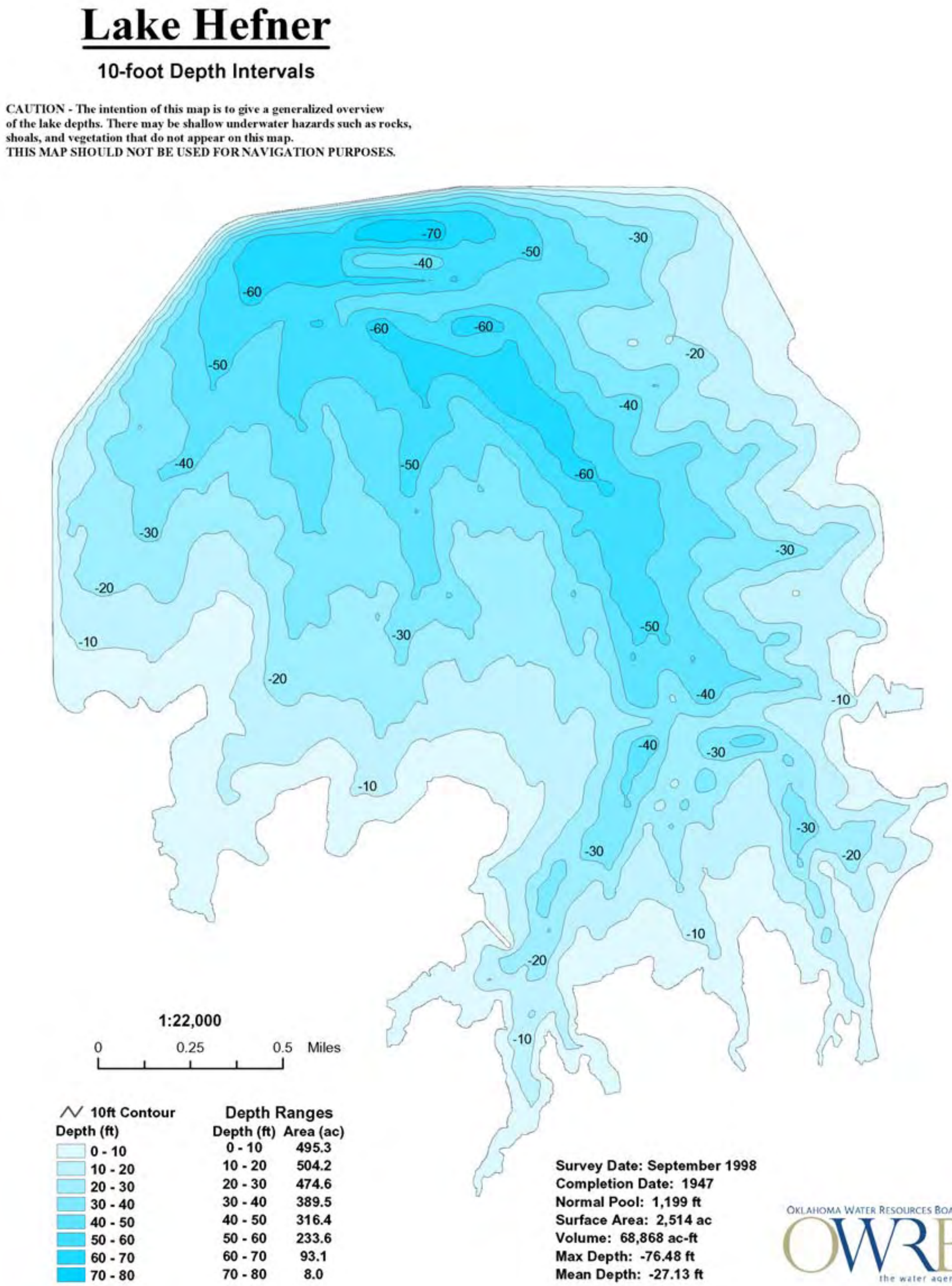


Figure 96. Bathymetric map of Hefner Lake.

Lake Henryetta

Lake Henryetta was sampled for three quarters from October 2002 through July 2003. Due to low water levels we were unable to launch the boat and sample during the winter. Water quality samples were collected at three (3) sites in the fall and at five (5) sites in the spring and summer. The additional sites were added to ensure that sample size was representative for a lake greater than 250 surface acres in size. 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 126 NTU (Plate 42), true color was 250 units and average secchi disk depth was 17 centimeters. Based on these parameters water clarity was poor at Lake Henryetta. These values are similar to those calculated in 2000 indicating no significant increase or decrease over time. The trophic state index (TSI) was calculated using values collected at all sites for three quarters (n=15). The result was a TSI of 43 (Plate 42), indicating the lake was mesotrophic in sample year 2002-2003. This value is higher than that in 2000 (TSI=38), however, fewer samples were used to calculate trophic status in 2000. The current value is based on data collected year round versus growing season only, and is likely a more accurate depiction of productivity within the lake system. The TSI values were fairly consistent and ranged seasonally from oligotrophic in the fall to mesotrophic in the spring and summer (Figure 97). The only exception was a spike in chlorophyll concentration that resulted in a hypereutrophic value at site 1 during the summer. Seasonal turbidity values are displayed in Figure 98a. All turbidity values were well above the turbidity standard of 25 NTU and ranged from a low of 113 NTU to a maximum of 152 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 (OWQS) 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 should be considered not supported based on turbidity; however with data from only three sampling quarters there is not enough data to make beneficial use assessment. Seasonal true color values are displayed in Figure 98b. True color values followed the same trend as turbidity, with all values exceeding the OWQS of 70 units. Reviewing historical data it is likely that both true color and turbidity would not be supporting.

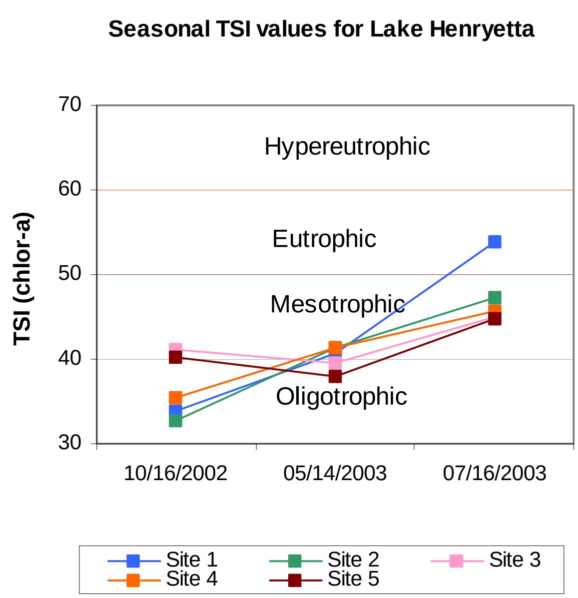


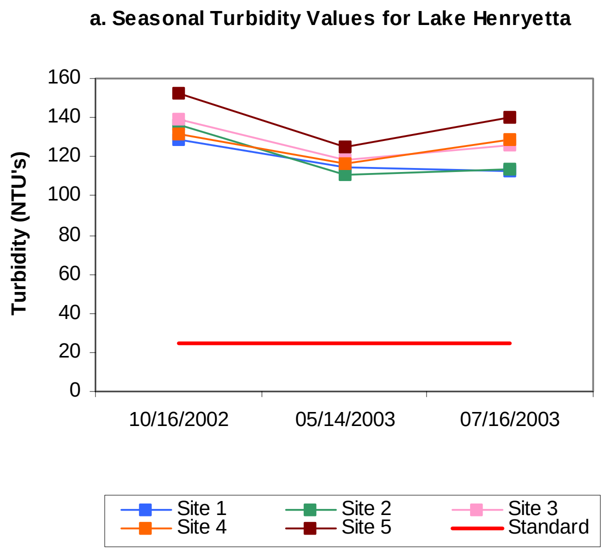
Figure 97. TSI values for Lake Henryetta.

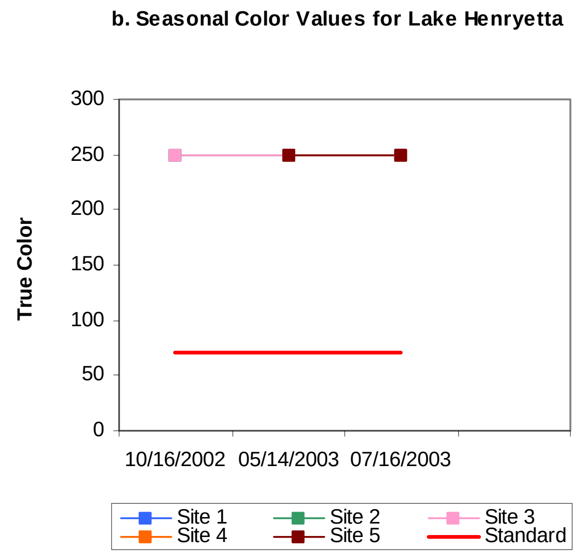
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at sites in 2002-2003. The salinity at Lake Henryetta ranged from 0.01 parts per thousand (ppt) to 0.02 ppt, which is lower than that seen in most Oklahoma reservoirs. Specific conductivity ranged from 52.3 mS/cm in the summer to 82 mS/cm in the spring, indicating the minimal presence of current conducting ions (salts and chlorides) in the lake system. The pH values ranged from 6.44 to 7.37 representing a neutral to slightly acidic system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. Only one value recorded was less than 6.5 and is likely due to the instrument being in the sediment therefore the lake will be listed as supporting the FWP beneficial use for pH. Oxidation-reduction potential ranged from 399 mV at the surface to 519 mV in the hypolimnion in the fall. In general, reducing conditions were not present at any time during the study period. Thermal stratification was not present during the fall or spring quarters and the lake was well mixed with dissolved oxygen (D.O) levels remaining above 5.0 mg/L (Figure 98c-96d). In the summer the lake was between 5 and 6 meters at which point the dissolved oxygen dropped below 2.0 mg/L to bottom of the lake accounting for 26% of the water column to be experiencing anoxic conditions (Figure 98e). 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 partially 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 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

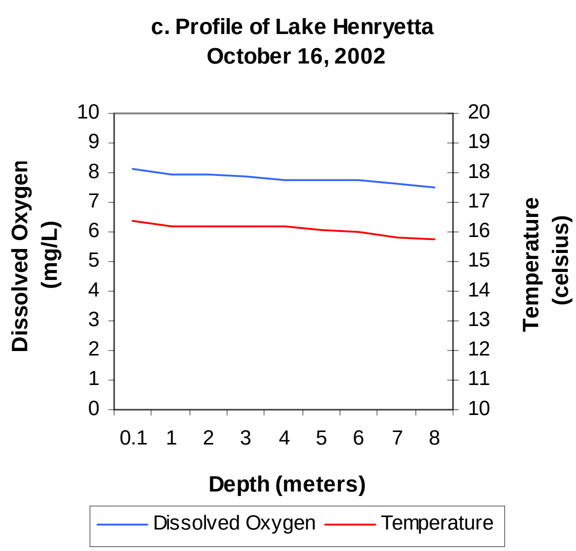
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is therefore considered supported for sample year 2002-2003.

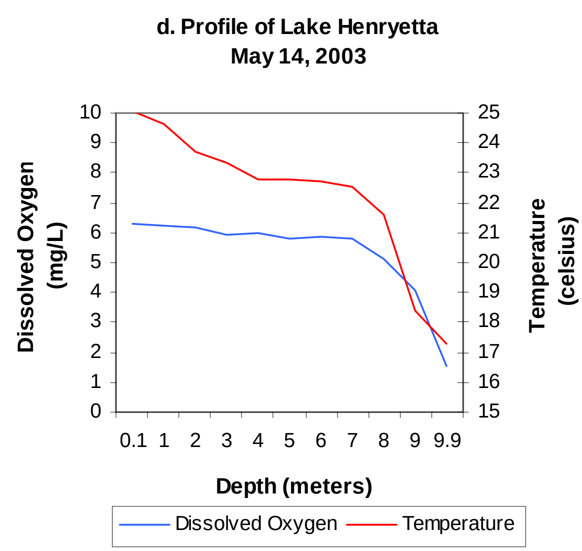
Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 1.05 mg/L at the surface and 0.96 mg/L at the lake bottom. Surface TN ranged from 0.50 mg/L in the fall to 1.31 mg/L in the spring. The lake-wide total phosphorus (TP) average was 0.130mg/L at the surface and 0.148 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.115 mg/L in the summer to 0.147 mg/L in the fall. The nitrogen to phosphorus ratio (TN:TP) was 8:1 for sample year 2003. This value is slightly higher than 7:1, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Lake Henryetta was classified as mesotrophic with moderate primary productivity and nutrient conditions, indicating no significant increase or decrease in productivity has occurred since 2000. Water clarity is poor based on true color; turbidity and low secchi disk depth and is consistent with findings from the 2000 data collection efforts. The FWP beneficial use is supported based on pH, but only partially supporting based on dissolved oxygen levels. The lake is supporting the Aesthetics beneficial use based on its trophic status. Due to low lake levels we were unable to sample during the winter and do not have enough data to meet the minimum data requirements of 20 samples to make a use determinations based on turbidity and true color. Lake Henryetta, located in Okmulgee County, constructed in 1928 serves as municipal water supply and recreation reservoir.









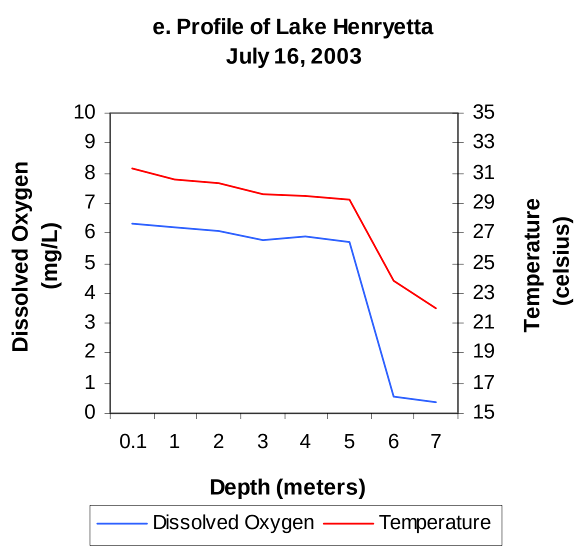
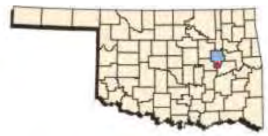


Figure 98a-96e. Graphical representation of data results for Lake Henryetta.



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

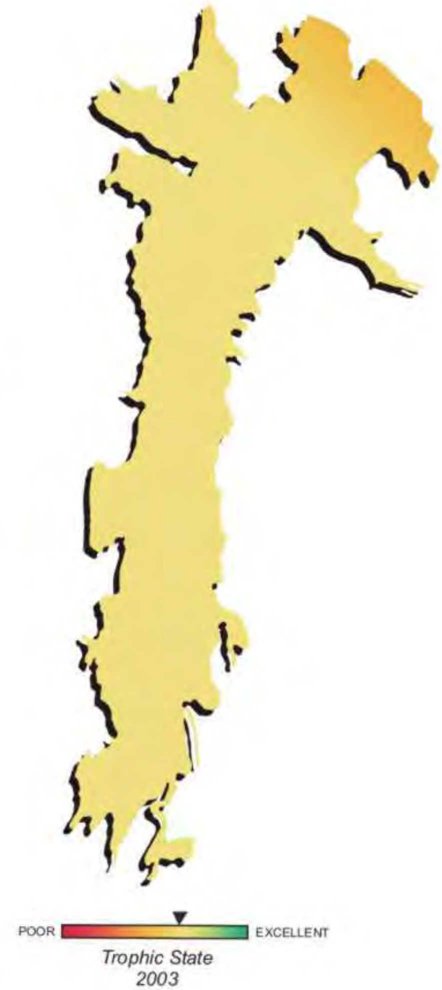


Plate 42 - Lake Water Quality for

Lake Henryetta

Heyburn Lake

Heyburn Lake was sampled for four quarters from October 2002 through July 2003. Water quality samples were collected at three (3) sites in the fall and at five (5) sites in the spring and summer. Additional sites were added to ensure that sample size was representative for a lake greater than 250 surface acres in size. 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 67 NTU (Plate 43), true color was 144 units and average secchi disk depth was 32 centimeters. Based on these parameters Heyburn Lake had poor water clarity in sample year 2002-2003. These values are similar to those calculated in 2000 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 46 (Plate 43), indicating the lake was mesotrophic during the study period. This value is the same as that calculated in 2000 (TSI=46), indicating that no change in productivity has occurred. The TSI values were fairly consistent and varied seasonally from oligotrophic in the winter to upper mesotrophic/eutrophic in the fall, spring, and summer quarters (Figure 99). Seasonal turbidity values are displayed in Figure 100a. Turbidity values ranged from a low of 16 NTU to a maximum of 164 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 (OWQS) 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 70 % of the 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 100b. Although thirteen of the sixteen (81%) values were a above the OWQS of 70 units a beneficial use determination cannot be made at this time due to the minimum data requirements of 20 samples for lakes larger than 250 surface acres not being met.

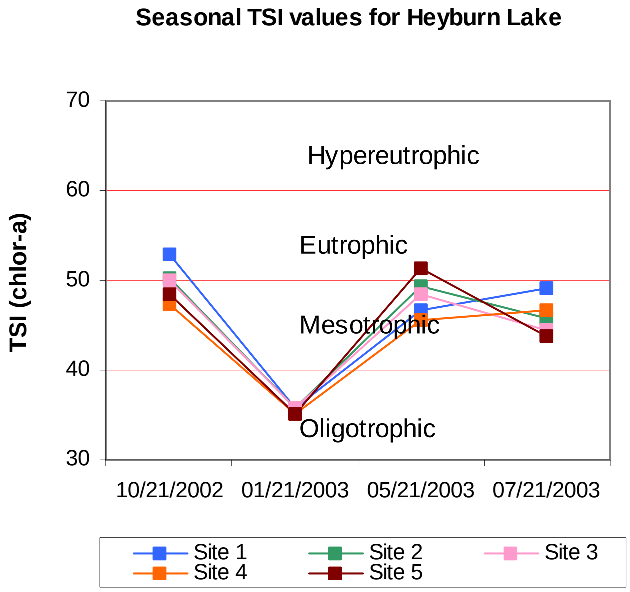


Figure 99. TSI values for Heyburn Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at sites in 2002-2003. The salinity at Heyburn Lake ranged from 0.03 parts per thousand (ppt) to 0.10 ppt. This is within the average recorded for most Oklahoma reservoirs. Specific conductivity ranged from 87.7 mS/cm to 214.1 mS/cm indicating the minimal presence of current conducting ions (salts and chlorides) in the lake system. The pH values ranged from 6.85 to 8.03 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 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all of the recorded values within the acceptable range the lake will be listed as supporting the FWP beneficial use for pH. Oxidation-reduction potential (ORP) ranged from 276 mV to 467 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 100c-98e). In the summer the lake was stratified between 3 and 4 meters at which point the dissolved oxygen dropped below 2.0 mg/L to bottom of the lake accounting for 33% 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. Heyburn Lake is considered partially 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 2002-2003 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 five (5) or 50% exceeded the prescribed screening level of 61 cfu/ml and the geometric mean (142.8 cfu/ml) exceeds the prescribed mean standard of 33 cfu/ml. The PBCR beneficial use is therefore considered not supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.63 mg/L at the surface and 0.59 mg/L at the lake bottom. Surface TN ranged from 0.32 mg/L in the fall to 1.22 mg/L in the summer. The lake-wide total phosphorus (TP) average was 0.062 mg/L at the surface and 0.098 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.0.18 mg/L in the winter to 0.145 mg/L in the spring. The nitrogen to phosphorus ratio (TN:TP) was 10:1 for sample year 2003. This value is slightly higher than 7:1, characterizing the lake as potentially phosphorus limited to co-limited (Wetzel, 1983).

In summary, Heyburn Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels in sample year 2002-2003. This value is the same as that calculated in 2000 (TSI=46), indicating that no change in productivity has occurred. Water clarity was poor based on turbidity, true color, and low secchi disk depth readings. The FWP beneficial use is supported based on pH, partially supported for dissolved oxygen and not supported based on high turbidity values. The Aesthetics beneficial use is supported based on its trophic status. Although minimum data requirements were not met for true color and a beneficial use determination cannot be made, it is likely that it would not be supported based on true color. 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.

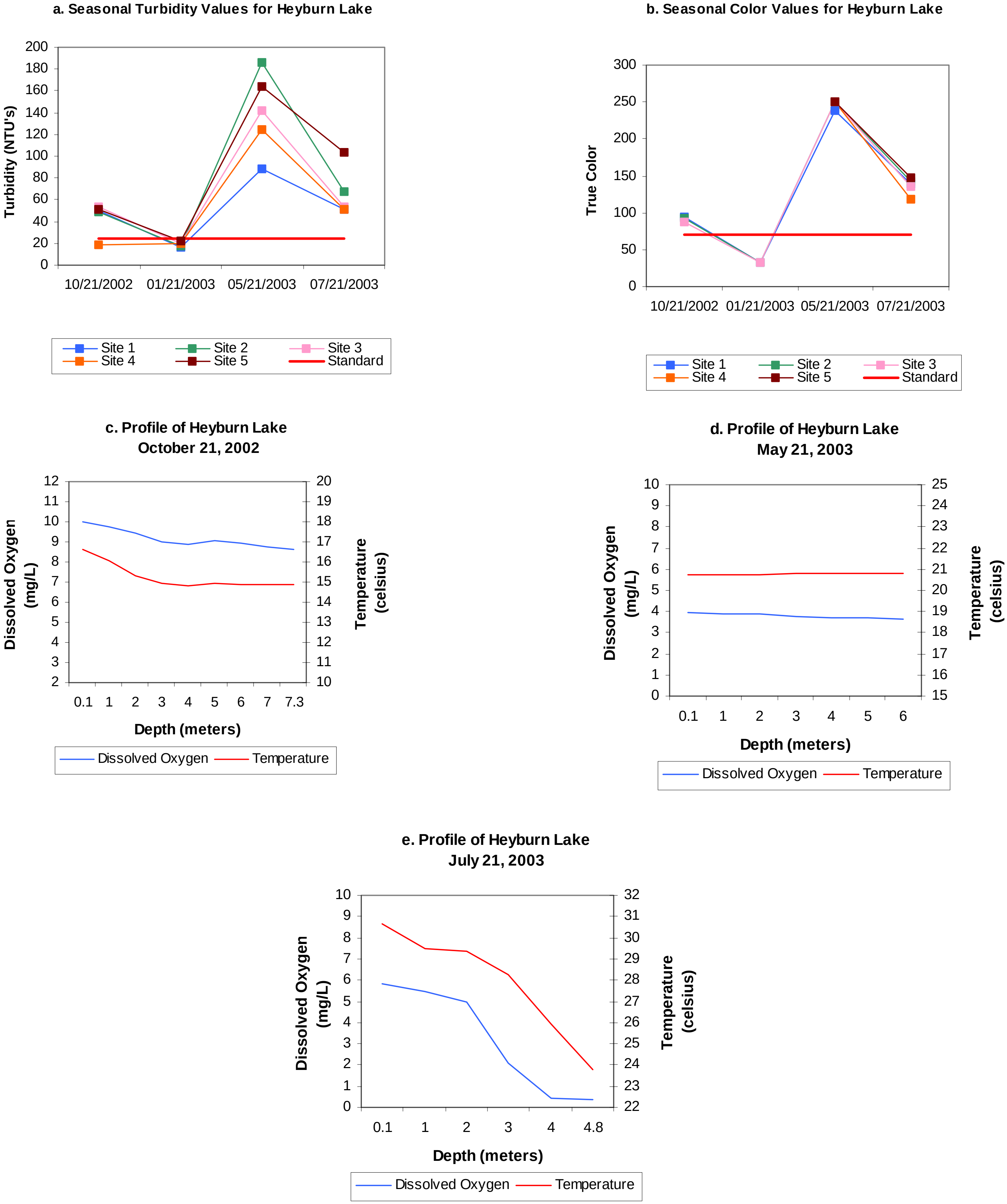
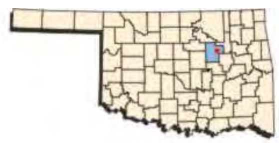
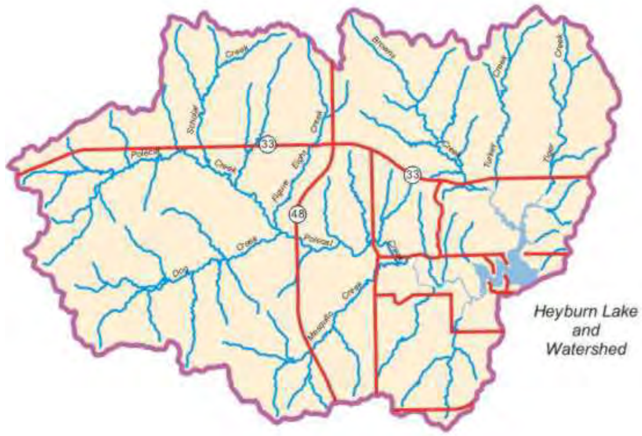


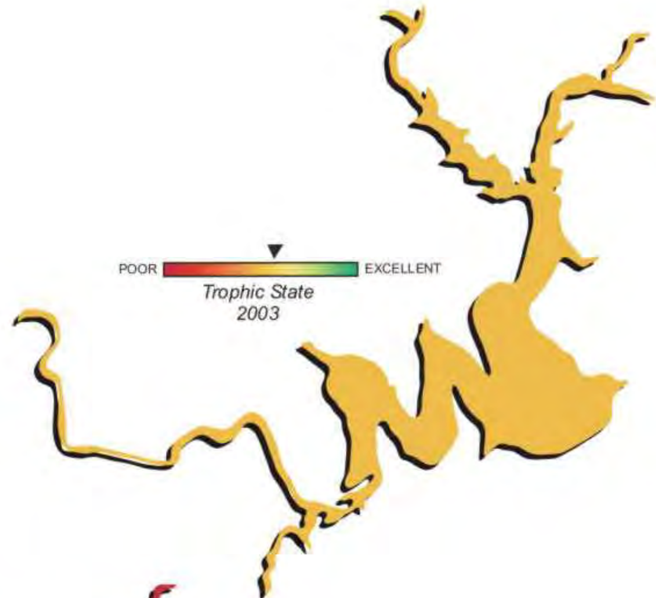
Figure 100a-98e. Graphical representation of data results for Heyburn Lake.

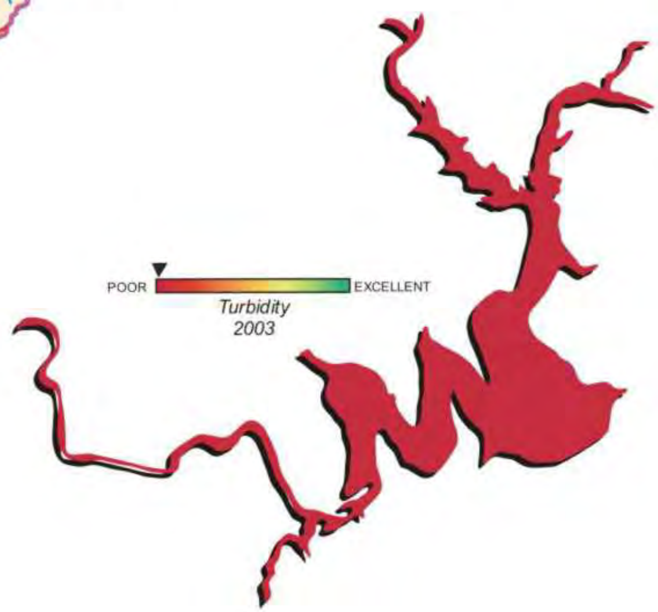


Heyburn Lake
Location



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 43 - Lake Water Quality for
Heyburn Lake

Holdenville Lake

Holdenville Lake was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Additional samples were collected at the lake surface at sites 4 and 5 for chlorophyll-a and turbidity analysis in order to meet minimum data requirements. 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 44), true color was 34 units, and secchi disk depth was 78 centimeters in 2001-2002. Based on these three parameters, Holdenville Lake had good water clarity in 2001-2002. 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 54 (Plate 44), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values were all eutrophic with the exception of the spring quarter when the lake was upper mesotrophic in nature (see Figure 101). Only one of the turbidity values collected in 2001-2002 was above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 102a). 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 OWQS (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 samples collected in 2001-2002 above the standard Holdenville Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use for turbidity. Seasonal true color values are displayed in Figure 102b. All true color values were below the aesthetics OWQS of 70 units, however, insufficient data was available to determine the Aesthetics beneficial use support. Collected data does strongly suggest the Holdenville Lake would meet the Aesthetics beneficial use based on true color (see Figure 102b).

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Salinity ranged from 0.04 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 conductance values were also well within the expected range for Oklahoma reservoirs, coinciding with the low salinity values seen for the lake. Values ranged from 92.1 mS/cm in the spring quarter to 171.8 mS/cm in the summer quarter. Oxidation-reduction potentials (redox) ranged from –1 mV at the sediment-water interface at the lake bottom in the summer to 600 mV in the summer in the water column. Reducing conditions were only present in the hypolimnion at the sediment water interface in the summer and did not constitute a serious concern. Lake pH values were neutral with values ranging from 6.71 to 7.90 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 should be listed as not supporting beneficial uses. If 10 to 25% of the pH values

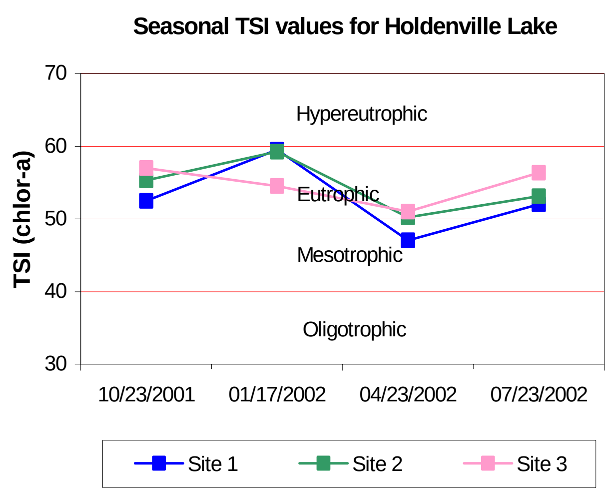


Figure 101. TSI values for Holdenville Lake.

fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. Holdenville Lake is fully supporting its FWP beneficial use based on pH. Thermal stratification was not evident in the fall or winter quarters and dissolved oxygen (D.O.) remained above 4.0 mg/L and was generally above 7.0 mg/L (see Figure 102c-100d). The lake was thermally stratified in the spring quarter but D.O. values were still above the 2.0 mg/L threshold (see Figure 102e). In the summer, both thermal stratification and anoxic conditions were present in Holdenville Lake. The lake was stratified between 4 and 5 meters below the surface and D.O. concentrations were 1.0 mg/L or less from 6 meters to the lake bottom at 12.4 meters (see Figure 102f). 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 is considered partially supported at Holdenville Lake with approximately 57% of the water column being anoxic (<2.0 mg/L) in the summer. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.69 mg/L at the lake surface. The TN at the surface ranged from 0.53 mg/L to 1.00 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 for sample year 2001-2002 was 0.032 mg/L at the lake surface. The TP ranged from 0.019 mg/L to 0.061 mg/L. The highest surface TP value was reported in the fall quarter and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 22:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Holdenville Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Holdenville Lake is currently eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 44). Holdenville Lake is fully supporting its FWP beneficial use for turbidity and pH. 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 though sufficient data was not available to definitively assess the use for true color, information strongly supports the supposition that it would be fully supporting. In general, the water quality of the lake is good. 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.

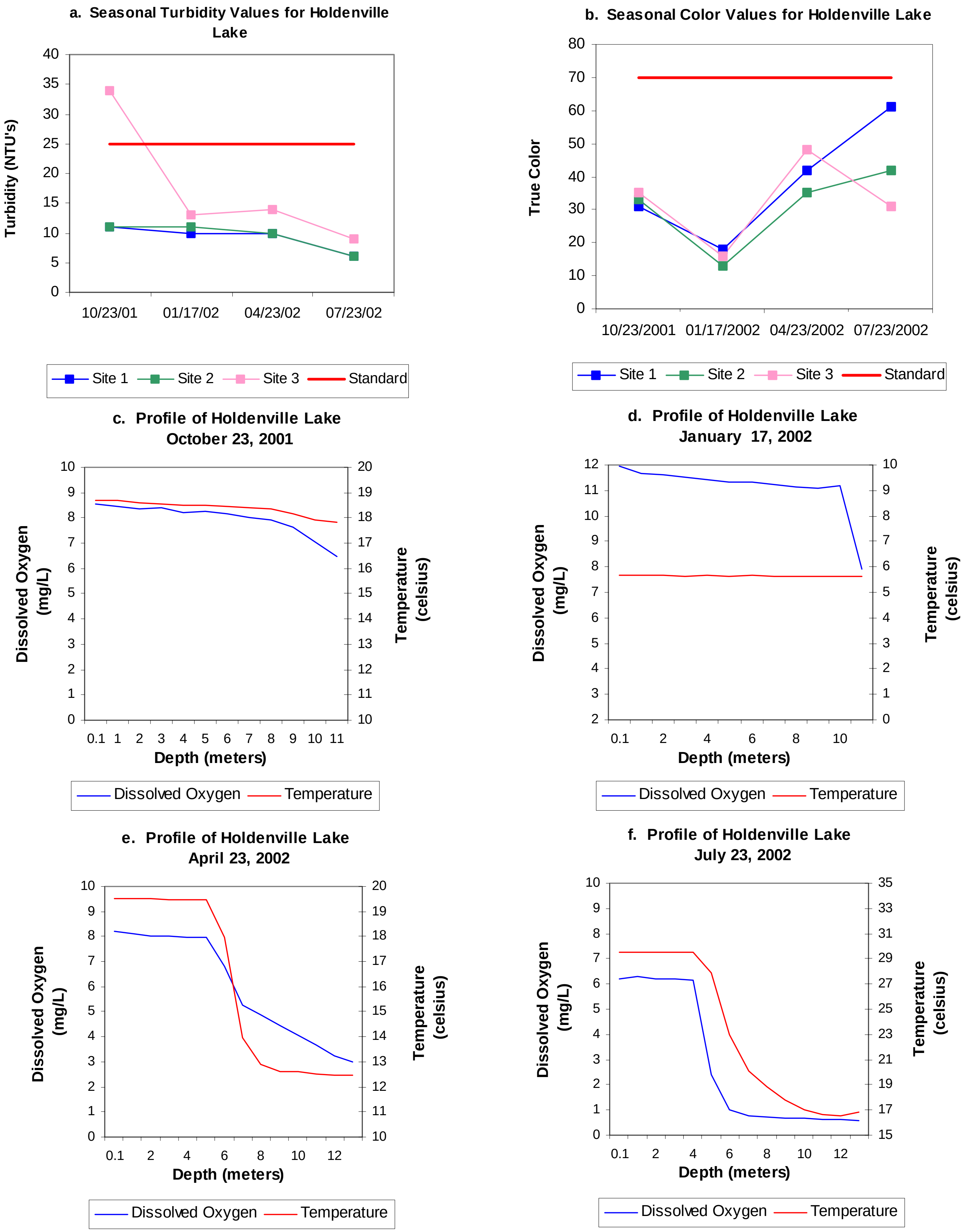
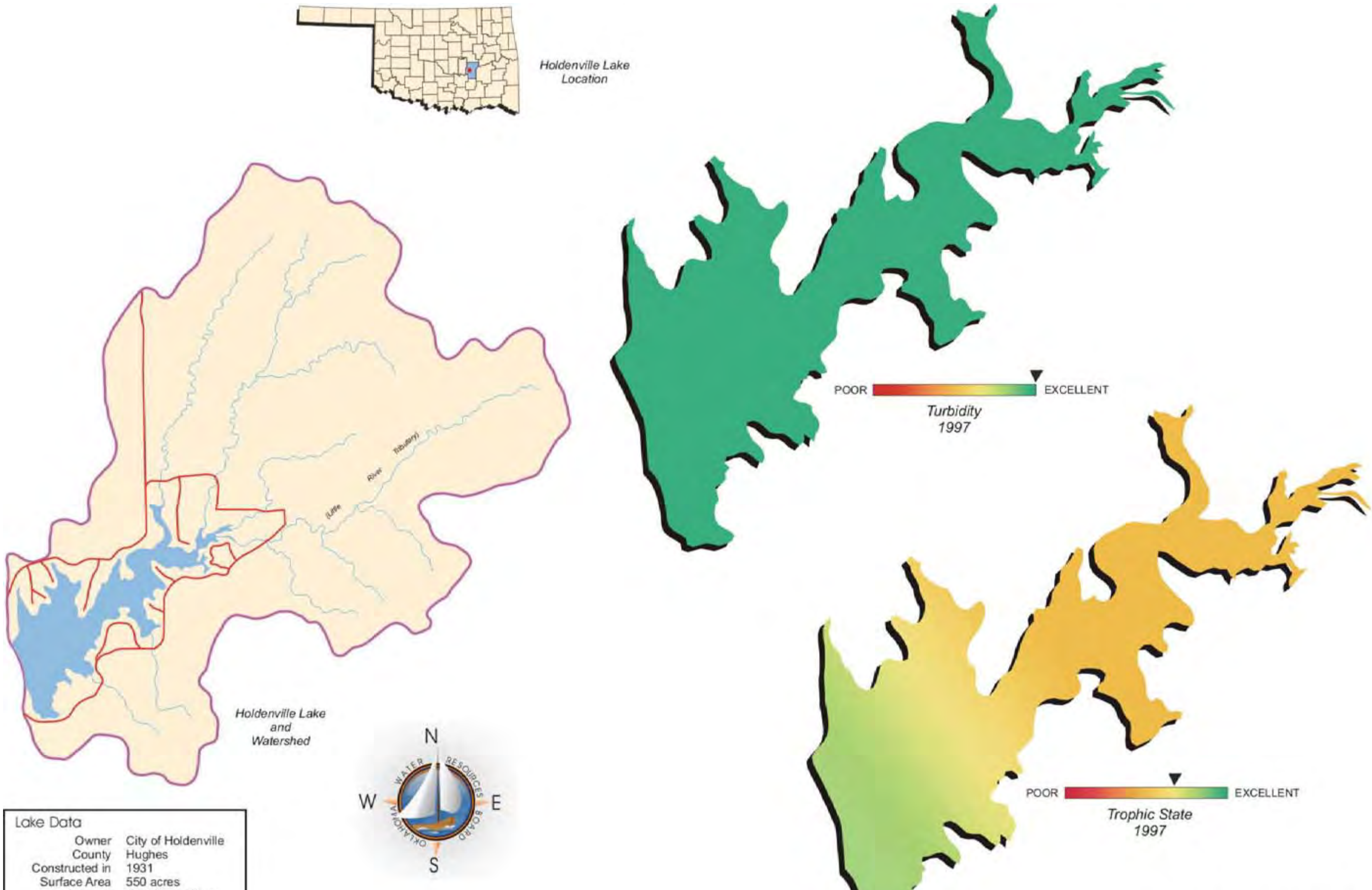


Figure 102a-100f. Graphical representation of data results for Holdenville Lake.



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

Plate 44 - Lake Water Quality for
Holdenville Lake

Hominy Municipal Lake

Hominy Municipal Lake was sampled for four quarters, from October 2001 through July 2002. 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 6 NTU (Plate 45), true color was 21 units, and secchi disk depth was 127 centimeters in 2001-2002. Based on these three parameters, Hominy Municipal Lake had excellent water clarity in 2001-2002 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 46 (Plate 45), classifying the lake as mesotrophic, indicative of low to moderate levels of productivity and nutrients. The TSI values were consistent throughout the sampling period with only one eutrophic value recorded at site 3 in the spring (see Figure 103). All turbidity values collected in 2001-2002 were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 104a). 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 OWQS (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 2001-2002 below the standard, the Fish & Wildlife Propagation (FWP) beneficial use is fully supported. Seasonal true color values are displayed in Figure 104b. True color values were fairly consistent between seasons and were all below the aesthetics OWQS of 70 units (see Figure 104b). 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 conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity values ranged from 0.09 parts per thousand (ppt) to 0.16 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 187.4 mS/cm in the spring to 334 mS/cm in the fall quarter. These values indicated low concentrations of electrical current conducting materials (salts) were present in the lake system, which parallels the low salinity values. In general, pH values were neutral to slightly alkaline, ranging from 6.63 to 8.29 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 should be listed as not supporting beneficial uses. 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 beneficial uses. Hominy Municipal Lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 0.0 mV near the sediment-water interface to 530 mV in the winter quarter. Redox readings

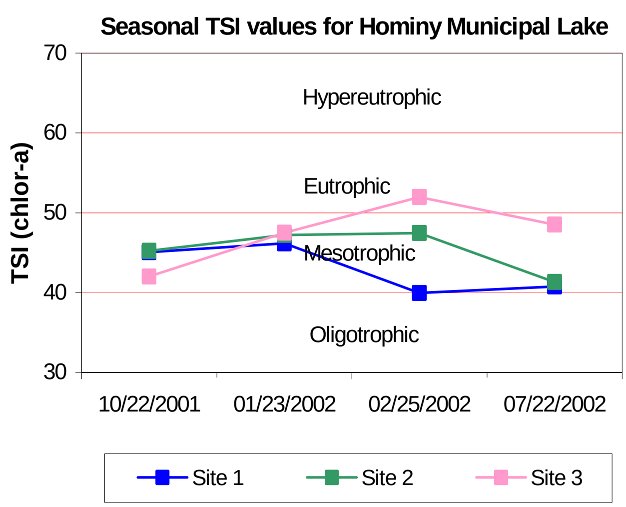


Figure 103. TSI values for Hominy Municipal Lake.

indicated that reducing conditions were not present in the reservoir in an appreciable way during the course of the sampling period. The lake was thermally stratified in the fall quarter between 10 and 11 meters below the surface at which point dissolved oxygen (D.O.) concentrations in the water column fell below 2.0 mg/L and stayed below 2.0mg/L all the way to the lake bottom at 14.8 meters. Hominy Municipal Lake was actually thermally stratified in all four seasons that it was sampled which is very unusual for Oklahoma reservoirs. This lake is the only instance where Oklahoma Water Resources Board staff can think of this occurring where release of water from a dam or sluice gate structure was not involved (see Figure 104c-102f). However, the lake did not experience D.O. concentrations below 4.0 mg/L in either the winter or spring quarters. In the summer the lake was strongly thermally stratified between 4 and 5 meters at which point D.O. values fell below 2.0 mg/L and jumped up above 2.0 mg/L at 6 and 7 meters and again fell below 2.0mg/L at 8 meters and remained so all the all the way to the lake bottom at 12.8 meters (see Figure 104f). 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 could be considered partially supported at Hominy Municipal Lake because approximately 50% of the water column was anoxic at site 1 in the summer. During the fall only 38% of the water column exceeded the thresholds mentioned above. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.60 mg/L at the lake surface. The TN at the surface ranged from 0.45 mg/L to 0.73 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.017 mg/L at the lake surface. The surface TP ranged from 0.011 mg/L to 0.28 mg/L. The highest surface TP value was reported in the summer and the lowest was also recorded in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was 35:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Hominy Municipal Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Hominy Municipal Lake was classified as mesotrophic, indicating moderate productivity and nutrient levels (Plate 45). 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 determination of mesotrophic. 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.

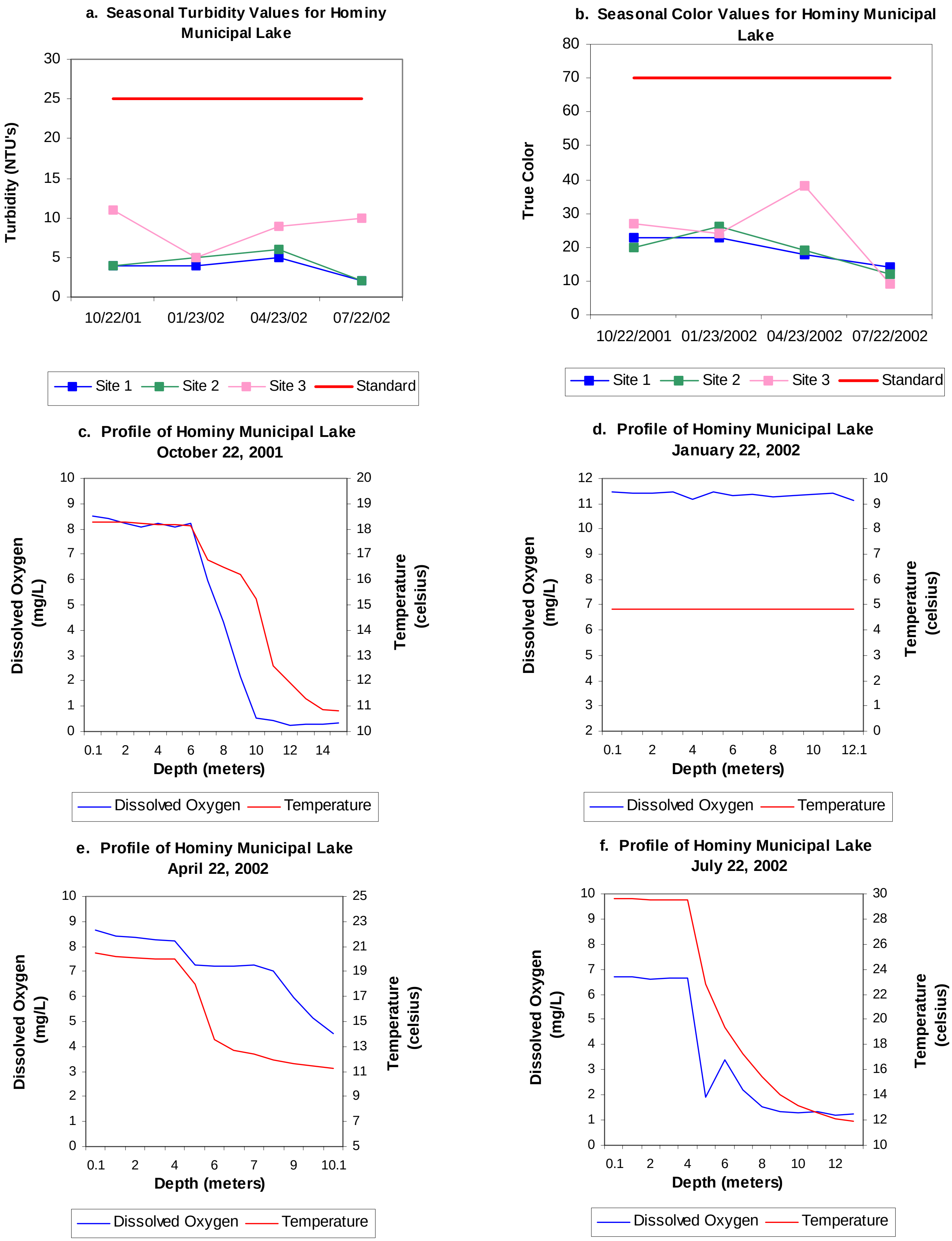
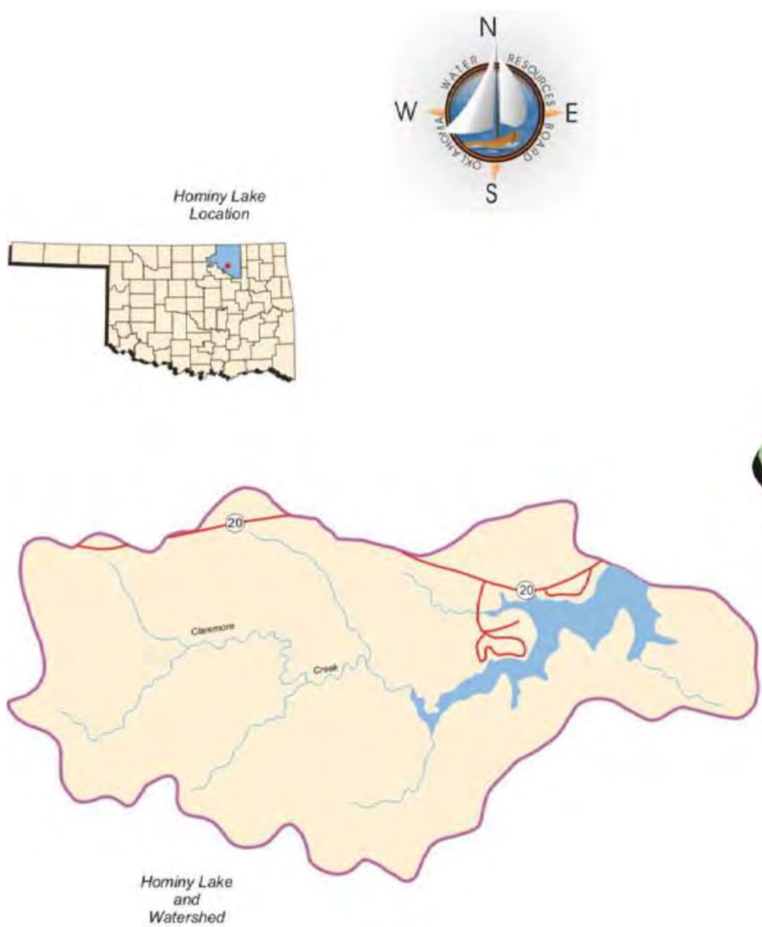


Figure 104a-102f. Graphical representation of data results for Hominy Municipal Lake.



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

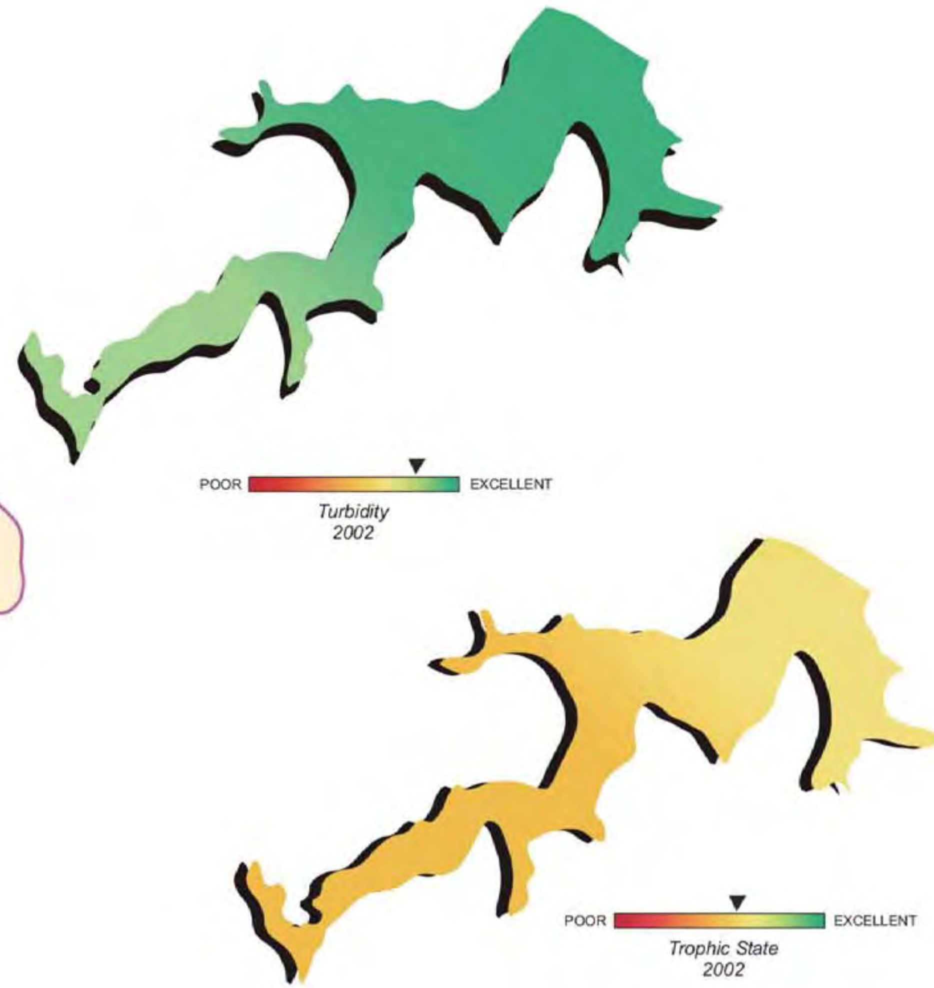


Plate 45 - Lake Water Quality for
Hominy Lake

Hudson Lake (Osage County)

Hudson Lake (Osage County) was sampled for four quarters, from October 2001 through July 2002. 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 12 NTU (Plate 46), true color was 22 units, and secchi disk depth was 82 centimeters in 2001-2002. Based on these three parameters, Hudson Lake (Osage County) had good water clarity in 2001-2002. 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 56 (Plate 46), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values varied seasonally at Hudson Lake (Osage County) throughout 2001-2002 from mesotrophic in the winter, to eutrophic in the fall and spring to hypereutrophic in the summer (see Figure 105). All turbidity values in 2001-2002 with the exception of one value in the fall were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 106a). 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 OWQS (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% of the values exceeding the OWQS, Hudson Lake is meeting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 106b. True color values varied seasonally and were all well below the aesthetics OWQS of 70 units (see Figure 106b). The Aesthetics beneficial use is currently considered fully supported based on true color concentrations in the water column.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.15 parts per thousand (ppt) to 0.19 ppt, which was slightly higher than the expected range of values reported for Oklahoma lakes. Readings for specific conductance ranged from 309.7 mS/cm to 383.3 mS/cm, indicating moderate concentrations of electrical current conducting compounds (salts) were present in the water column throughout the year. These values also corresponded with the moderate salinity values. In general, pH values were neutral to very slightly alkaline, ranging from 7.27 to 8.19 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 should be listed as not supporting beneficial uses. 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 beneficial uses. Hudson Lake is fully supporting its FWP beneficial use based on pH values in the water column. Oxidation-reduction potentials (redox) ranged from 85 mV at the sediment-water interface in the spring to 588 mV in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir,

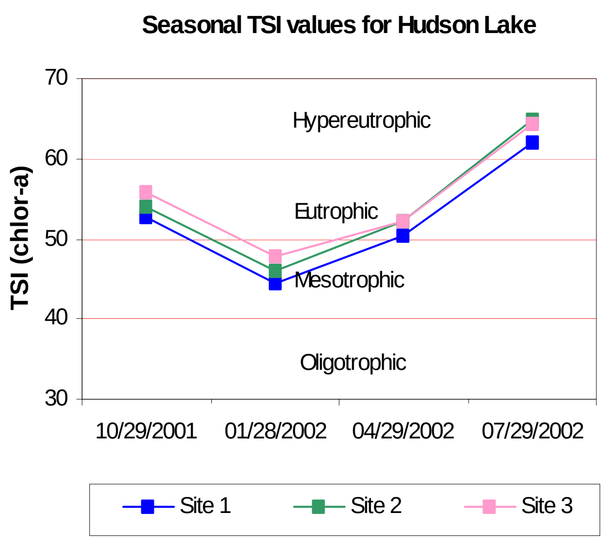


Figure 105. TSI values for Hudson Lake.

in fact; only 4 readings were less than 200 mV in 2001-2002. The lake did not exhibit thermal stratification in the fall, winter, or spring quarters (see Figure 106c-104e). Dissolved oxygen (D.O.) values were above 5.0 mg/L in all four quarters throughout the water column (see Figure 106c-104d). In the summer the lake was stratified between 6 and 7 meters at site 1 and the D.O. concentration was less than 2.0 mg/L below 6 meters extending to the lake bottom at 8.9 meters (see Figure 106f). 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 Hudson Lake (Osage County) because only 30% of the water column was anoxic at site 1 in the summer. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.67 mg/L at the lake surface and ranged from 0.45 mg/L to 0.73 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 for sample year 2001-2002 was 0.036 mg/L at the lake surface. The surface TP ranged from 0.011 mg/L to 0.026 mg/L. The highest surface TP value was reported in the fall and the lowest was in the summer. The nitrogen to phosphorus ratio (TN:TP) was approximately 35:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Hudson Lake (Osage County) was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) 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 46). The lake had good water clarity and the turbidity, pH and D.O. concentrations were fully supporting the FWP beneficial use. True color values and trophic status of the lake indicated the Aesthetics beneficial use was fully supported as well. Anoxic conditions in the summer were present, although not a level high enough to deem the lake as partially or not supporting. 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 the public.

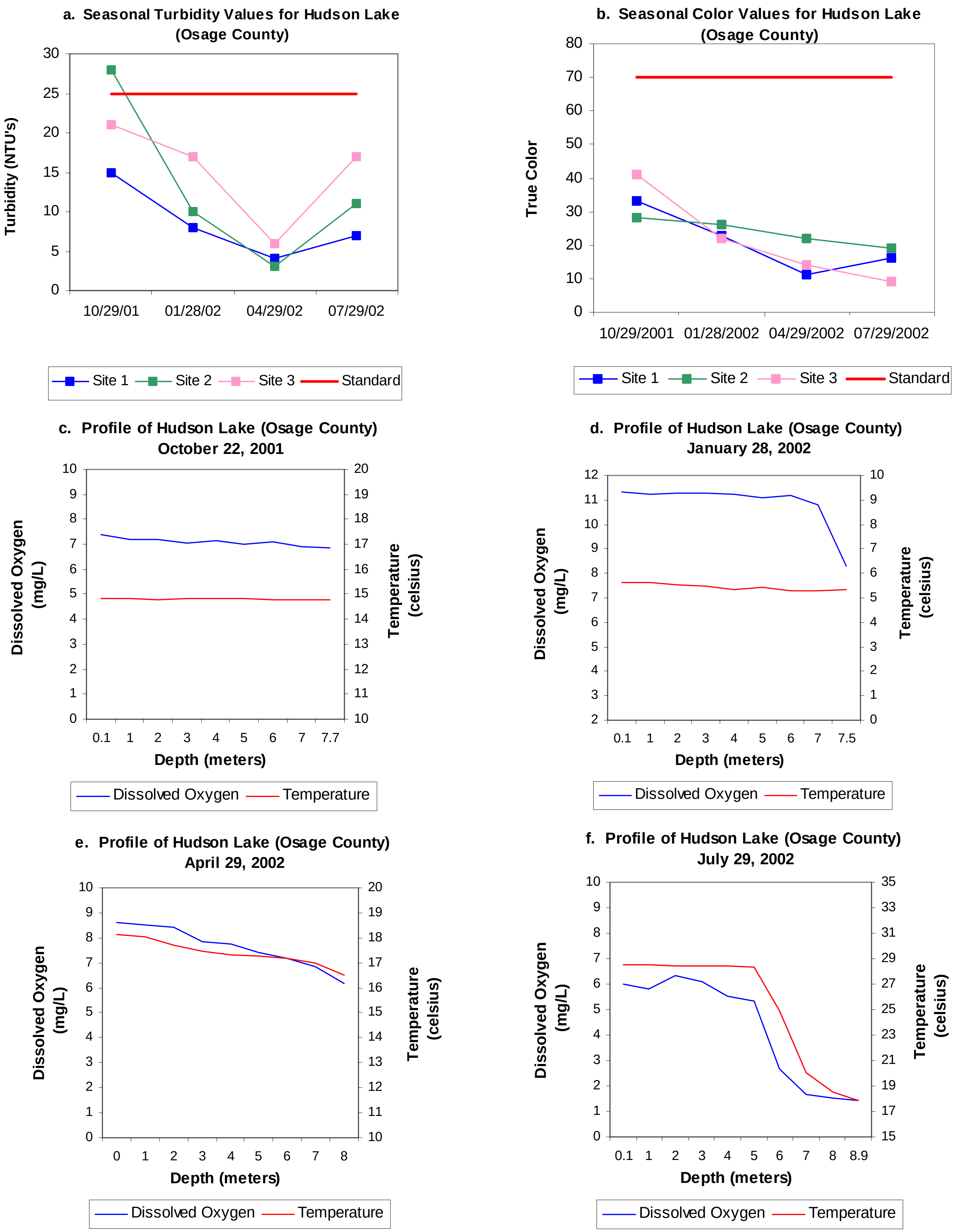
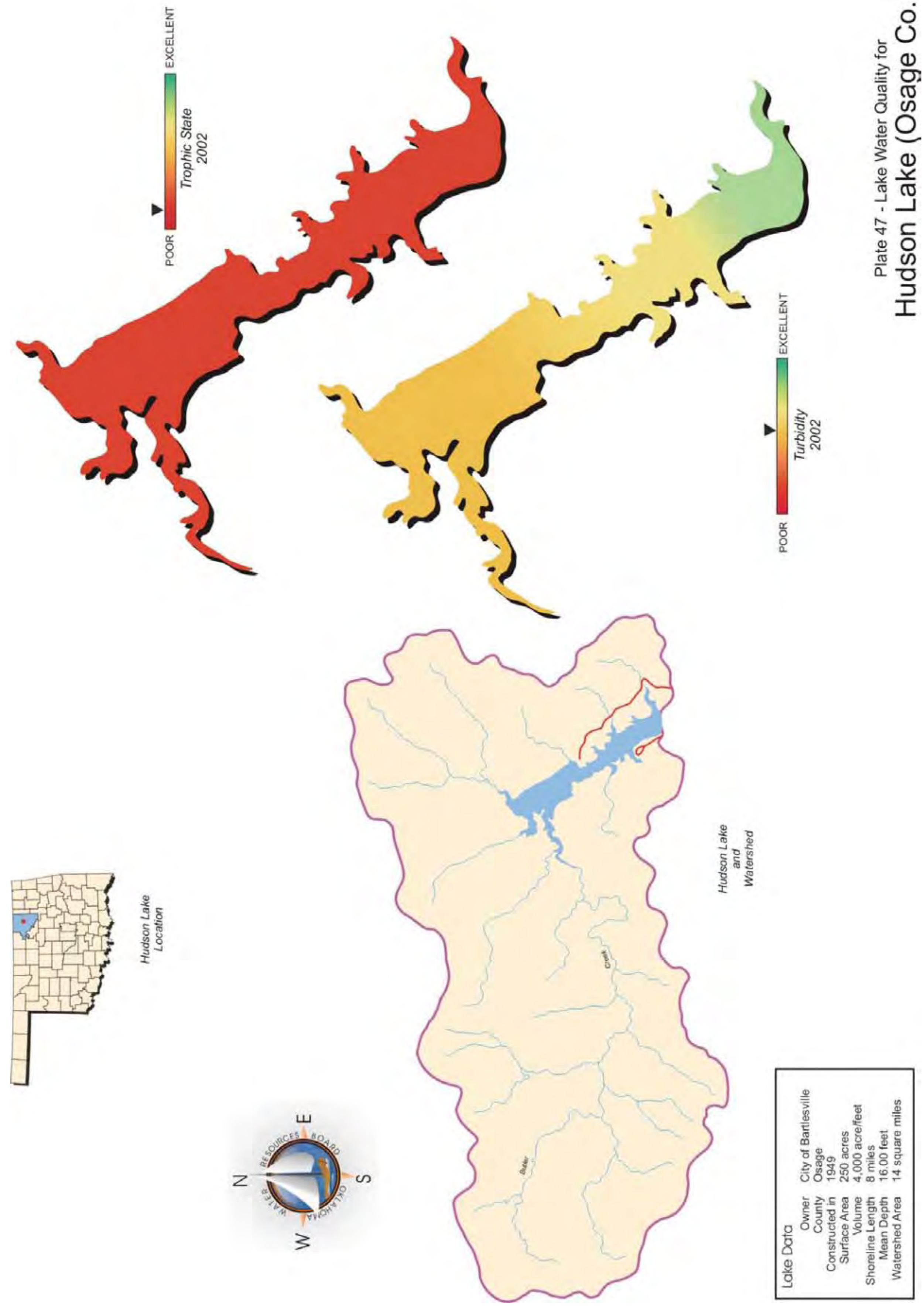


Figure 106a-104f. Graphical representation of data results for Hudson Lake (Osage County).


Hudson Lake
Location
W
N
E
S
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
POOR
EXCELLENT
Trophic State
2002
POOR
EXCELLENT
Turbidity
2002
Plate 47 - Lake Water Quality for
Hudson Lake (Osage Co.)

Lake Hudson (Mayes Co.)

Lake Hudson was sampled for four quarters from November 2002 through August 2003. 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 9 NTU (Plate 47), true color was 17 units and average secchi disk depth was 97 centimeters. Based on these three parameters Lake Hudson had good water clarity in 2003. These values are similar to the values reported in 2000 with true color and secchi disk depth showing some improvement since 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 55 (Plate 47), indicating the lake was eutrophic in sample year 2002-2003. Although this differs from the value reported in 2000, (TSI= 61), the current calculation is based on data collected year round as opposed to growing season only and is likely a more accurate depiction of productivity within the lake. The TSI values for all sites were fairly consistent and ranged from mesotrophic (sites 1-4) to eutrophic/hypereutrophic in the upper lake (sites 5-8) in the fall and winter and all sites were eutrophic in the spring and summer quarters (see Figure 107). Seasonal turbidity values are displayed in Figure 108a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU although site 6 came close with a value of 23 NTU reported during the summer. 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 108b. All true color values were well below the OWQS 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 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential and salinity were recorded at all three sample sites. Salinity ranged from 0.03 parts per thousand (ppt) to 0.14 ppt for this sample year. This is within the average range of values reported for Oklahoma lakes. Specific conductance ranged from 230.3 mS/cm to 287.6 mS/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 Lake Hudson ranged from 6.77 to 8.68, representing a neutral to slightly alkaline system.

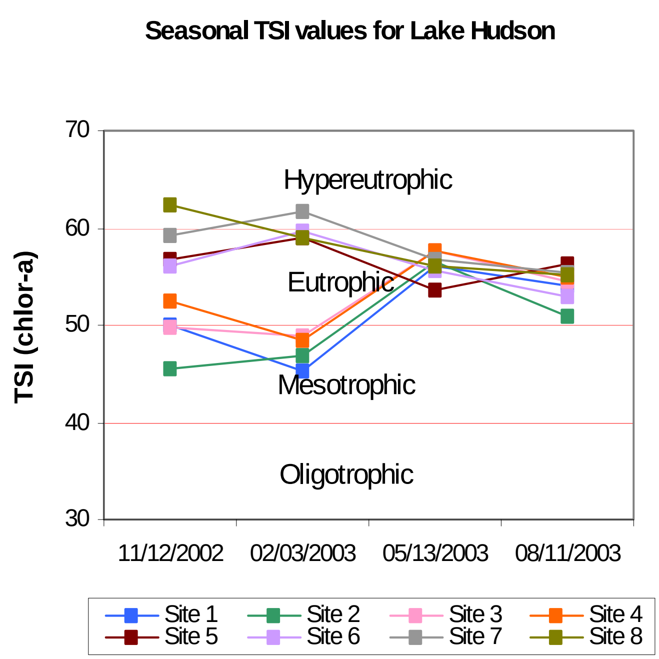


Figure 107. TSI values for Lake Hudson.

Oxidation-reduction potentials ranged from 379 mV in the fall to 636 mV in the summer. Reducing conditions were not present in this reservoir during the 2002-2003-sample year. During the fall, winter, and spring sampling intervals stratification was not present (Figure 108c-106e). In the summer stratification was evident occurred at several 1-meter intervals throughout the water column and dissolved oxygen ranged from 8.47 mg/L at the surface to 0.26 mg/l at the lake bottom at site 1. The lake exhibited strong thermal stratification between 6 and 7 meters at which point the dissolved oxygen dropped below 2 mg/L for the remainder of the water column (Figure 108f). 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 in the summer falling below 2.0 mg/L the FWP beneficial use is partially supported at Lake Hudson. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 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 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.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.46 mg/L at the surface and 0.46 mg/L at the lake bottom. Surface TN ranged from 0.18 mg/L to 0.72 mg/L, with the highest values seen in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.055 mg/L at the surface and 0.073 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.034 mg/L to 0.089 mg/L. Surface TP was highest in the fall quarter and lowest during the summer. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003. 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 in sample year 2002-2003. Although this differs from the classification reported in 2000, (TSI= 61), the current TSI calculation is based on data collected year round as opposed to growing season only and is likely a more accurate depiction of productivity within the lake. Water clarity is good based on true color, turbidity and secchi disk depth and is consistent with finding from previous sampling efforts. The FWP beneficial use is supported based on turbidity and pH, but is partially supporting based on dissolved oxygen levels in the summer. The lake is also supporting the Aesthetics beneficial use based on its trophic status and true color. 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.

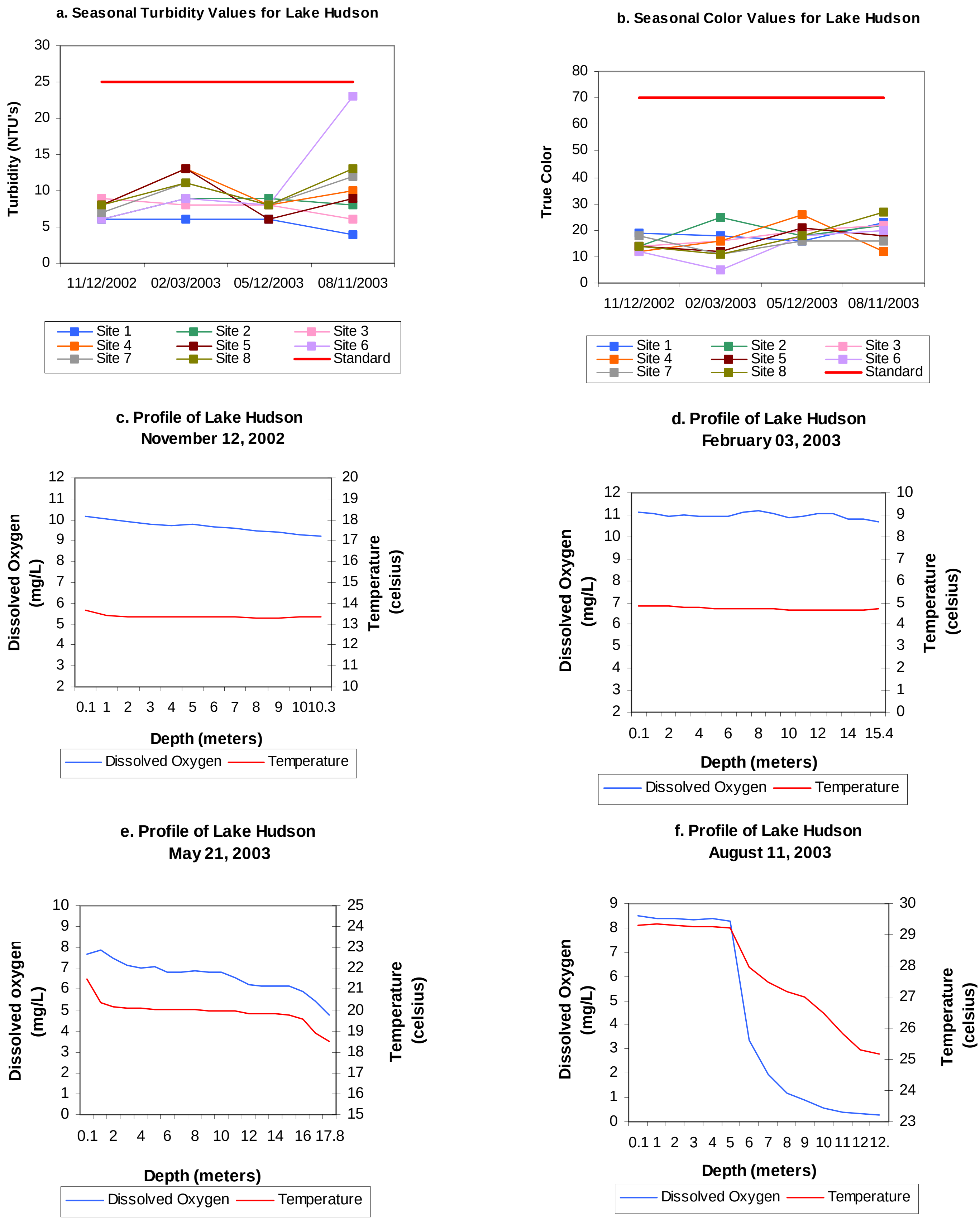


Figure 108a-106f. Graphical representation of data results for Lake Hudson (Mayes Co.).

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 46 - Lake Water Quality for

Lake Hudson (Mayes Co.)

Hugo Lake

Hugo Lake was sampled for four quarters from November 2002 through August 2003. 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 40 NTU (Plate 48), true color was 116 units, and secchi disk depth was 37 centimeters. Based on these three parameters, Hugo Lake had poor water clarity in 2003. Water clarity is similar compared 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=19). The average TSI was 55 (Plate 48), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. This value is the same as the TSI in 2000 (TSI=55), indicating no change in productivity has occurred since the last evaluation. The values at all sites in the fall were eutrophic; two out of five sites were hypereutrophic in the winter and spring and summer values ranged from mesotrophic to eutrophic (Figure 109). A similar pattern was observed during the 2000 sample year. Seasonal turbidity values are displayed in Figure. In general turbidity values in 2003 exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU with the exception of sites 1-3 in the fall (see Figure 110a). 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 (OWQS) 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 85% of the collected values exceeding the standard. Seasonal true color values are displayed in Figure 110b. True color values were at or near the aesthetics OWQS of 70 units in the fall and above the standard for the remainder of the year. With 90% of the collected values exceeding the standard the lake is not supporting the Aesthetics beneficial use.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, 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 0.04 ppt, which is within the range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 31.1 mS/cm to 103

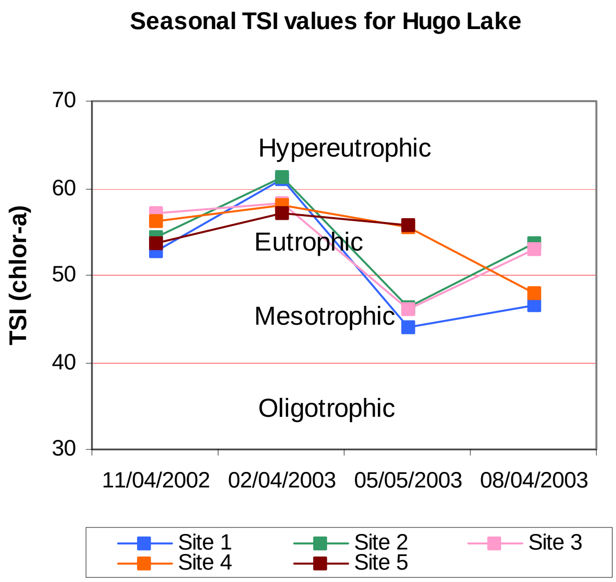


Figure 109. TSI values for Hugo Lake.

mS/cm, indicating minimal concentrations of current conducting compounds (chlorides and salts) in the lake system. The pH values ranged from 6.33 to 7.86 representing a neutral to slightly acidic system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With only 6% of the values falling outside the acceptable range the lake is considered supporting the beneficial use based on pH. The slightly acidic conditions are also seen in other lakes in this region of the state and are like due to natural conditions. Oxidation-reduction potential (ORP) ranged from 418 mV in the spring to 591 mV in the hypolimnion during the summer. All ORP values were positive and above 100 mV indicating reducing conditions were not present in the lake. 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 110c-108e). The lake was stratified in the summer at site 1 and 4 between 8 and 9 meters in depth at which point the dissolved oxygen (D.O) fell below 2.0 mg/L to the lake bottom (see Figure 110f). 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 18 to 28 % of the water column less than 2.0 mg/L, therefore the FWP Benicia use is partially supported at Hugo Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 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 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.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the surface and 0.39 mg/L at the lake bottom. Surface TN ranged from 0.05 mg/L to 0.75 mg/L, with the highest values seen in the summer and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.064 mg/L at the surface and 0.065 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.044 mg/L to 0.091 mg/L. Surface TP was highest in the spring quarter and lowest during the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 7:1 for sample year 2003. This is consistent 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 2000 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, partially supporting based on dissolved oxygen, but not supporting based turbidity. The Aesthetics beneficial use is supported based on its trophic status, but not supporting due to reported true color values. In 1999, a bathymetric survey was conducted at Hugo Lake (Figure 111) 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 Kathy Koon 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.

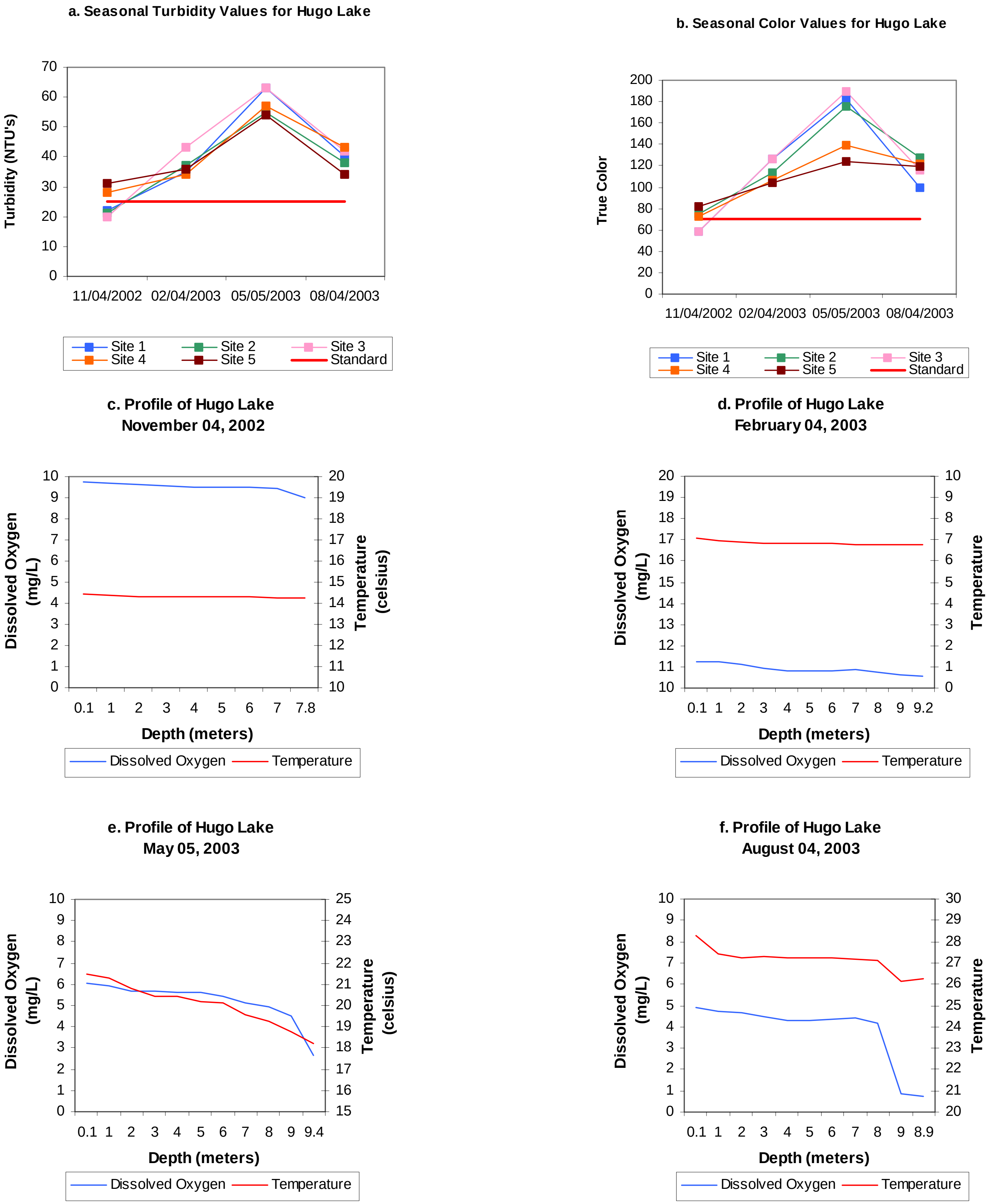
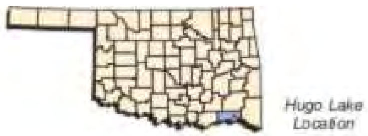


Figure 110a-108f. Graphical representation of data results for Hugo Lake.



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

Plate 48 - Lake Water Quality for

Hugo Lake

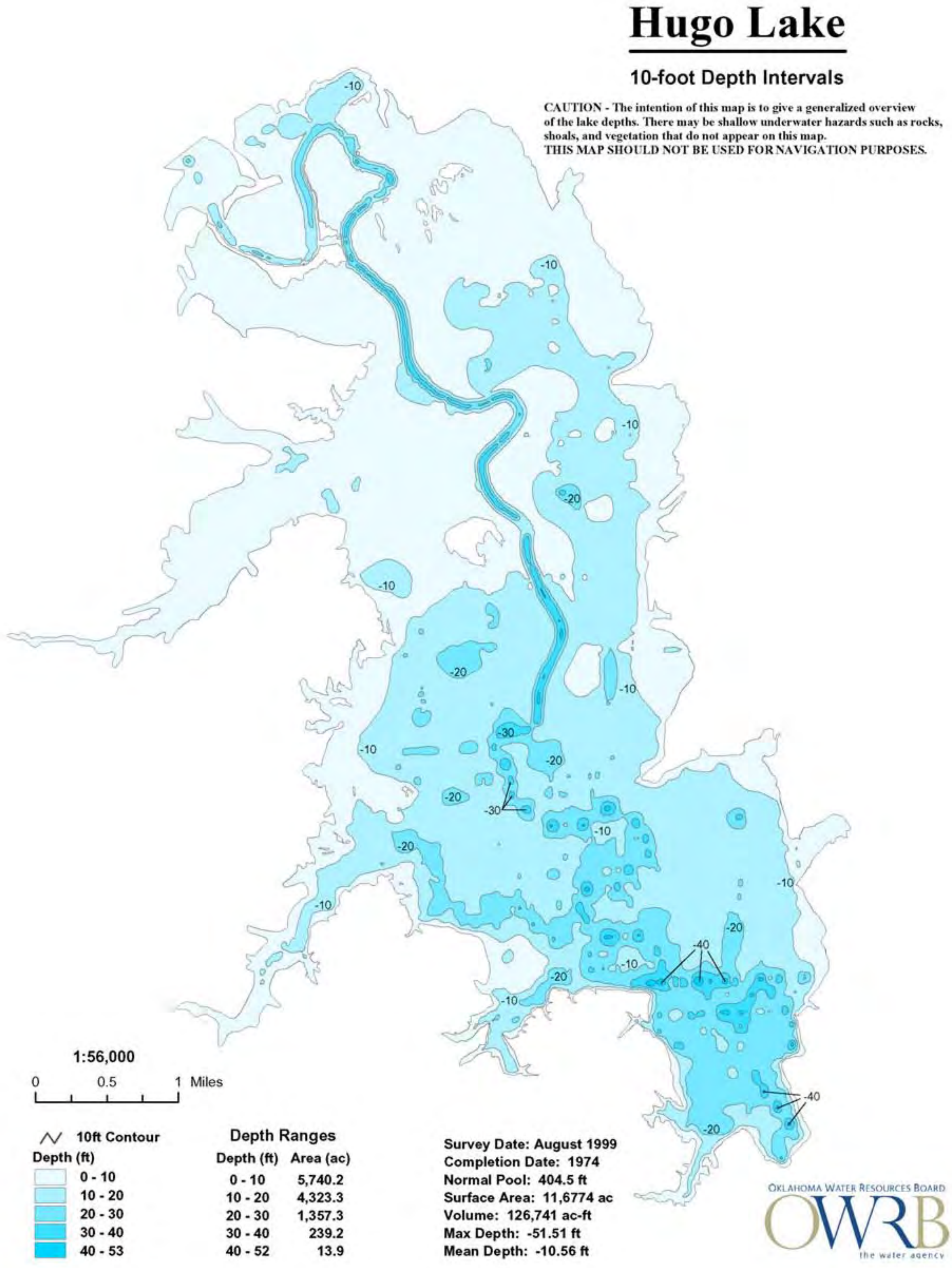


Figure 111. Bathymetric Map of Hugo Lake.

Hulah Lake

Hulah Lake was sampled for four quarters from October 2002 through July 2003. Water quality samples were collected from three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for lakes larger than the 250 surface acres. 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 42 NTU (Plate 49), true color was 48 units and average secchi disk depth was 34 centimeters in sample year 2003. Based on these three parameters water clarity was poor at Hulah Lake in 2003, consistent with results from 2000. 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 55 (Plate 49), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. This value is the similar to the TSI in 2000 (TSI=58), indicating no significant change in productivity has occurred. The TSI values for all sites were eutrophic except for one mesotrophic value for site 1 during the summer (Figure 112). The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient impaired. A nutrient impairment study should be conducted to determine if uses are impaired. Seasonal turbidity values are displayed in Figure 113a. Only five of the twenty values collected were below the Oklahoma Water Quality Standard (OWQS) 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 OWQS 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 75% of the collected values exceeding the numerical criteria the Fish and Wildlife Propagation (FWP) beneficial use is not supported. Seasonal true color values are displayed in Figure 113b. True color values ranged from 1 to 83 units with higher values occurring in the spring and summer. Applying the same default protocol the Aesthetics beneficial use should be considered partially supported; however the minimum data requirement of 20 samples for lakes larger than 250 surface acres.

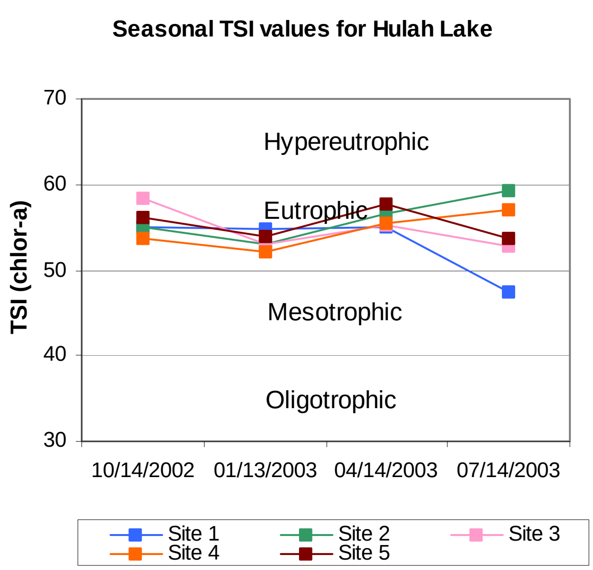


Figure 112. TSI values for Hulah Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values at Hulah Lake ranged from 0.11 parts per thousand (ppt) to 0.17 ppt. This is within the average range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 238.6 mS/cm to 336.6 mS/cm, indicating moderate concentrations of electrical current conducting compounds (chlorides and salts) in the lake system. The pH values ranged from 7.03 to 8.12 representing a neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all values within the acceptable range the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 275 mV in the spring to 493 mV during the winter. 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 113c-111e). In the summer dissolved oxygen (D.O) only fell below 2.0 mg/L at the sediment-water interface (see Figure 113f). 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. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 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 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.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.50 mg/L at the surface and 0.56 mg/L at the lake bottom. Surface TN ranged from 0.10 mg/L to 0.90 mg/L, with the highest values seen in the summer and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.059 mg/L at the surface and 0.075 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.014 mg/L to 0.114 mg/L. Similar to TN surface TP was highest in the summer and lowest during the winter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003. This slightly higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Hulah Lake was eutrophic, indicative of high primary productivity and nutrient levels in 2002-2003. This is consistent with the evaluation in 2000, 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 (OWQS) and is considered nutrient impaired. A nutrient impairment study should be conducted to determine if uses are impaired. 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. The Aesthetics beneficial is supported based on its trophic status, however use support based on true color could not be made due to minimum data requirements of samples not being met. 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.

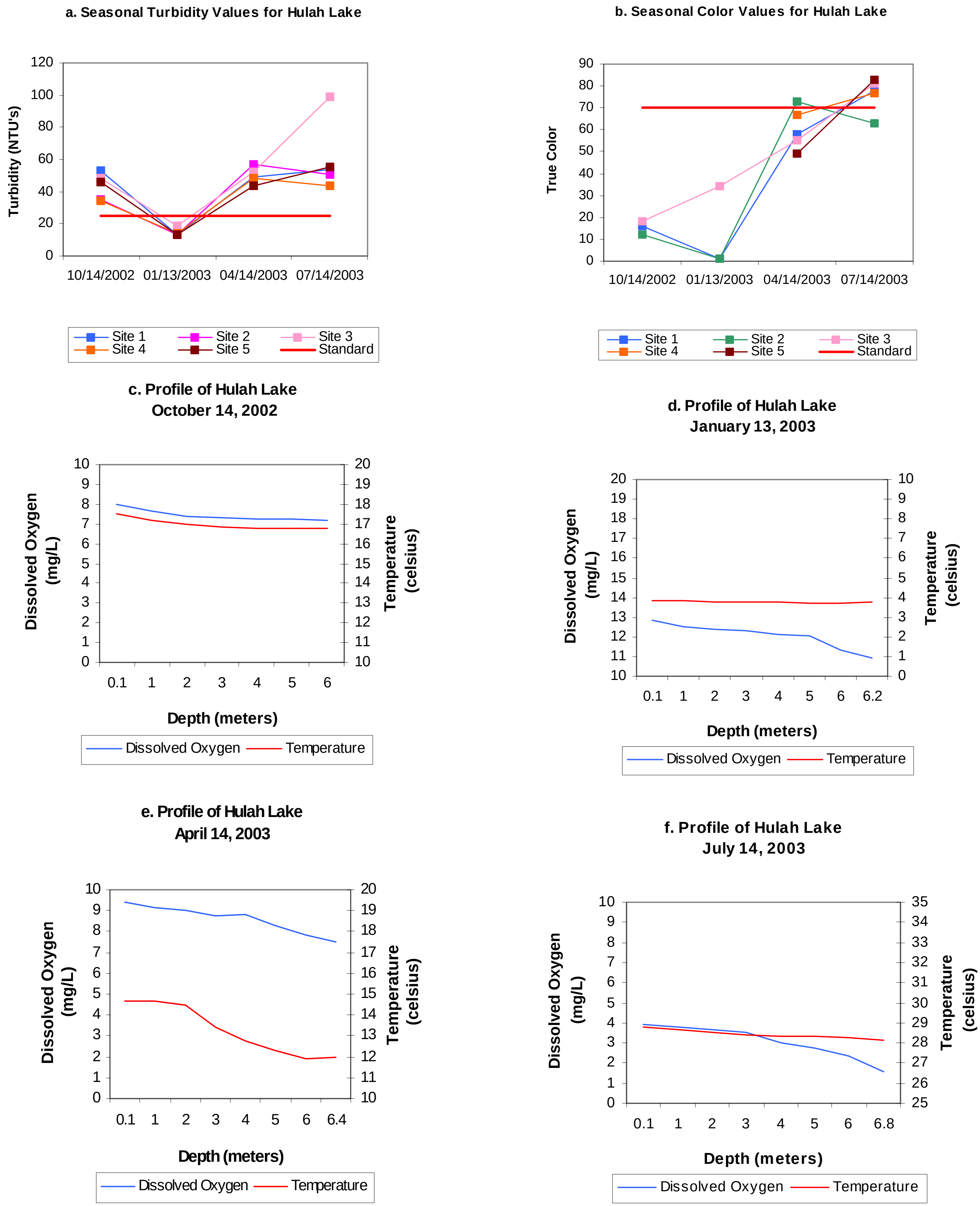
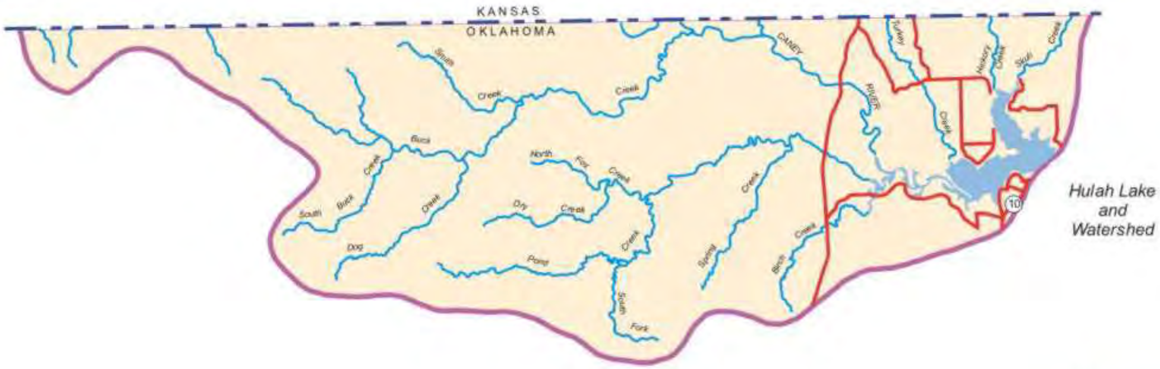
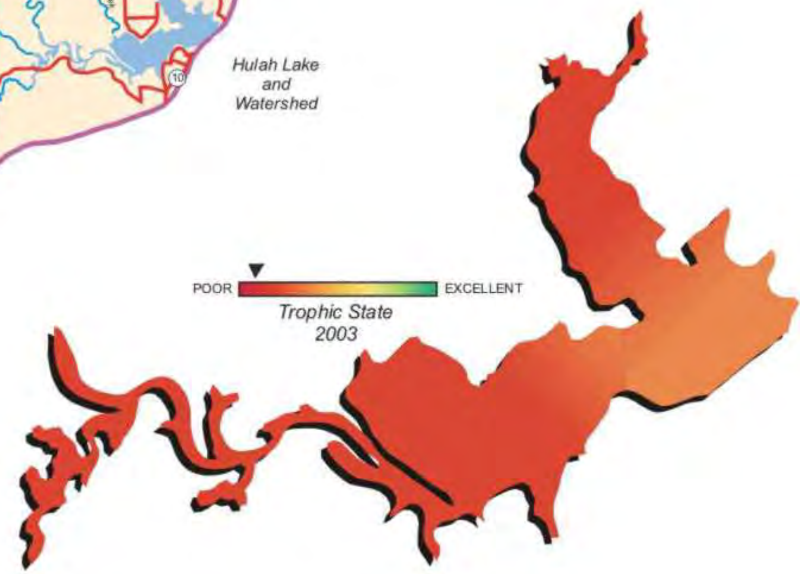


Figure 113a-111f. Graphical representation of data results for Hulah Lake.



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



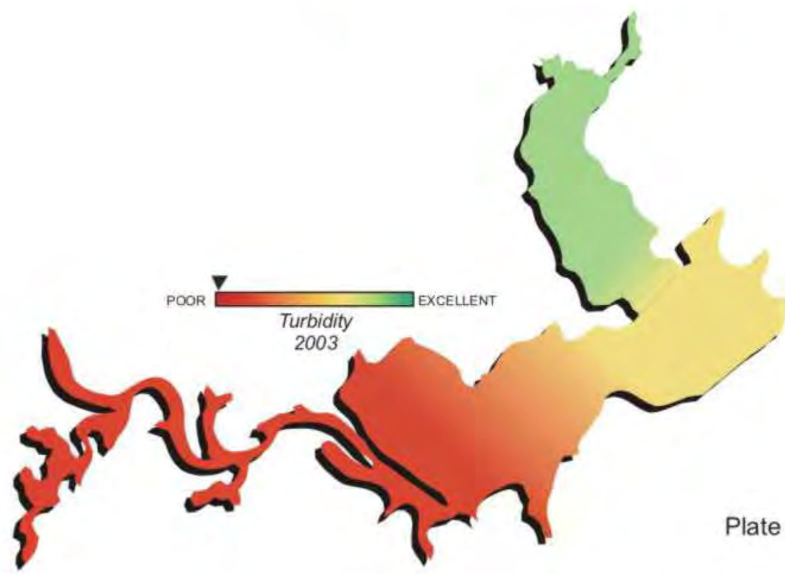


Plate 49 - Lake Water Quality for

Hulah Lake

Humphreys Lake

Humphreys Lake was sampled for four quarters, from November 2002 through July 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition, and lacustrine zones of the reservoir. Addition al sites were added to ensure sample size would be representative of lakes larger than 250 surface acres. 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 15 NTU (Plate 50), true color was 17 units, and secchi disk depth was 48 centimeters in 2001. Based on these three parameters, Humphreys Lake had average water clarity in 2003. The water clarity was very similar in sample year 2001. 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 50), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is similar to the one calculated in 2001 (TSI=53) indicating no significant increase or decrease in productivity has occurred. The TSI values were eutrophic throughout the year except in the spring quarter when two of the five sites were hypereutrophic (Figure 114). Seasonal turbidity values are displayed in Figure 115a. 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 (OWQS) 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 all turbidity values in 2003 at or below the OWQS of 25 NTU the Fish and Wildlife Propagation beneficial use is considered supported. The annual turbidity value of 15 NTU seems representative of turbidity at Humphreys Lake. Seasonal true color values are displayed in Figure 115b. All true color values were below the OWQS of 70 units, however due to the minimum data requirements of 20 samples, for lakes 250 surface acres or greater, not being met a use support determination couldn't be made at this time.

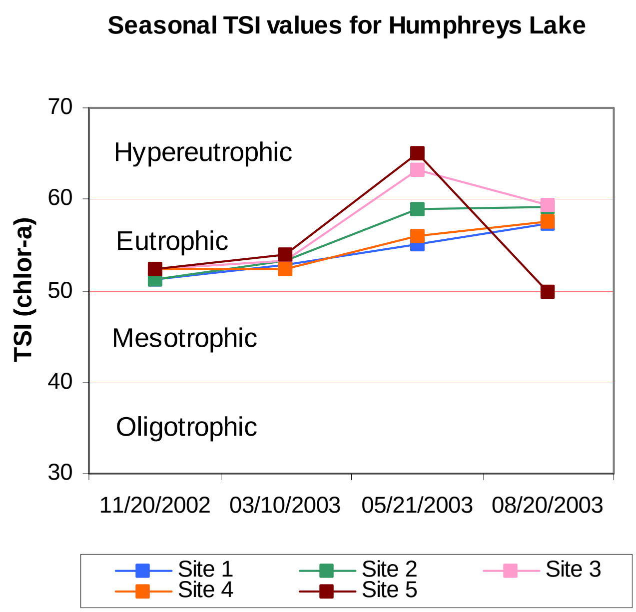


Figure 114. TSI values for Humphreys Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values at Humphreys Lake ranged from 0.27 parts per thousand (ppt) to 0.33 ppt. This is within the average range of expected values for most Oklahoma reservoirs. Specific conductivity ranged from 528.1 mS/cm to 636.6 mS/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 7.06 to 8.25 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 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 100% of the collected values within the acceptable range the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from -2 mV to 627 mV. In general, reducing conditions were not present with all recorded values above 100 mV with the exception of two values recorded at the lake bottom at the dam in the summer quarter. Thermal stratification was not present during the fall, winter and spring sampling intervals and the lake was well mixed with dissolved oxygen levels above 5.0 mg/L (see Figure 115c-113e). In the summer stratification occurred at several 1-meter intervals with dissolved oxygen concentrations (D.O.) falling below 2.0 mg/L from 4 meters in depth to the lake bottom of 9.5 meters accounting for approximately 55 % of the water column to be experiencing anoxic conditions (see Figure 115f). 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 Humphreys Lake. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling 2002-2003 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 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.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.1.00 mg/L at the surface and 1.59 mg/L at the lake bottom. Surface TN ranged from 0.74 mg/L to 1.57 mg/L, with both the highest and lowest values occurring in the spring. The lake-wide total phosphorus (TP) average was 0.042 mg/L at the surface and 0.103 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.026 mg/L to 0.090 mg/L. Surface TP was highest in the summer and lowest during the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 24:1 for sample year 2003. 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 in 2002-2003. This is consistent with findings from the 2001 evaluation indicating that little or no change in productivity has occurred. The lake is supporting the FWP beneficial use based on turbidity and pH, but partially supporting based on dissolved oxygen levels. The Aesthetics beneficial use is supported based on its trophic status and although minimum data requirements were not met for true color it is likely that it would be supported. Humphreys Lake is owned by the City of Duncan and serves as a flood control, water supply, and recreational reservoir.

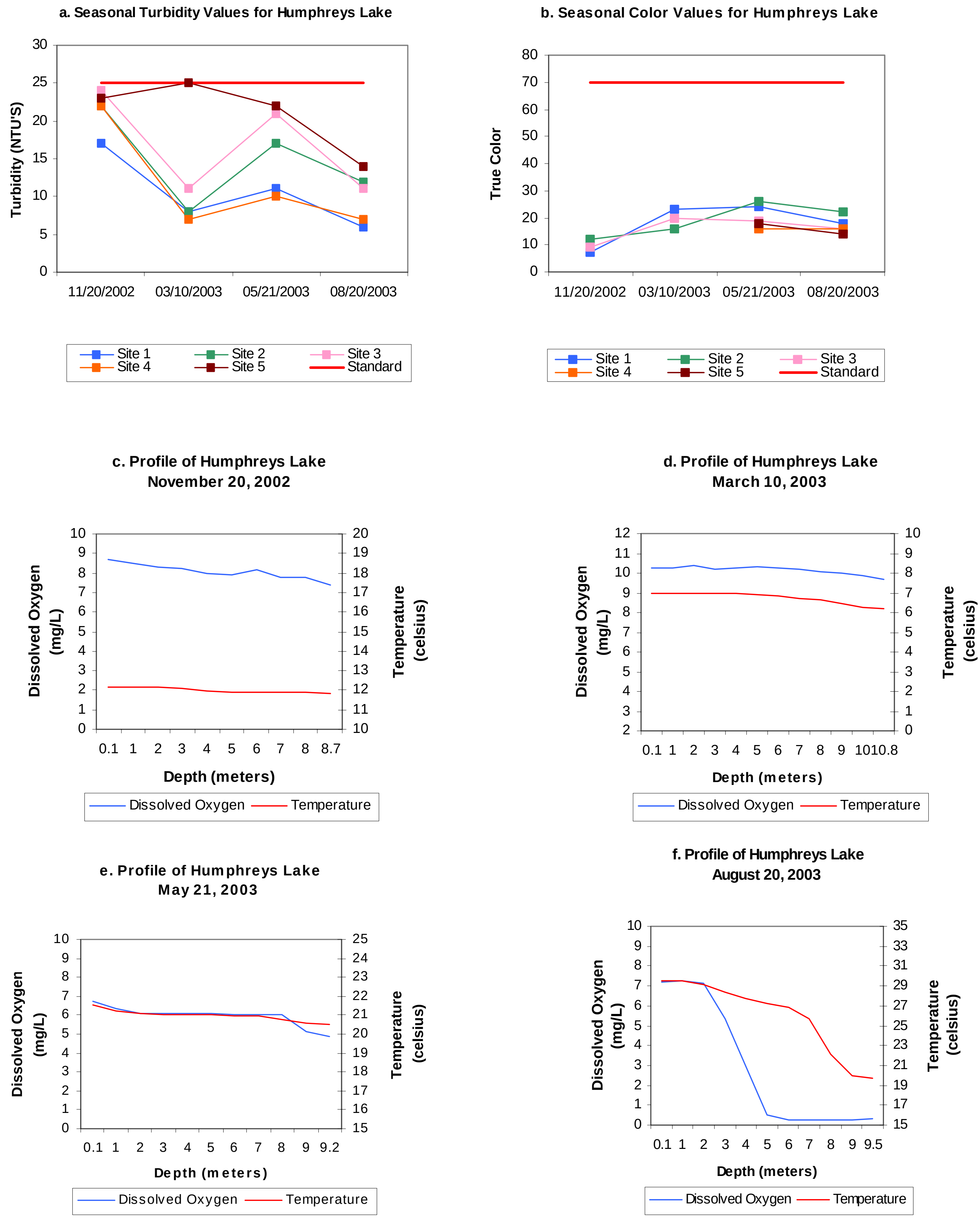
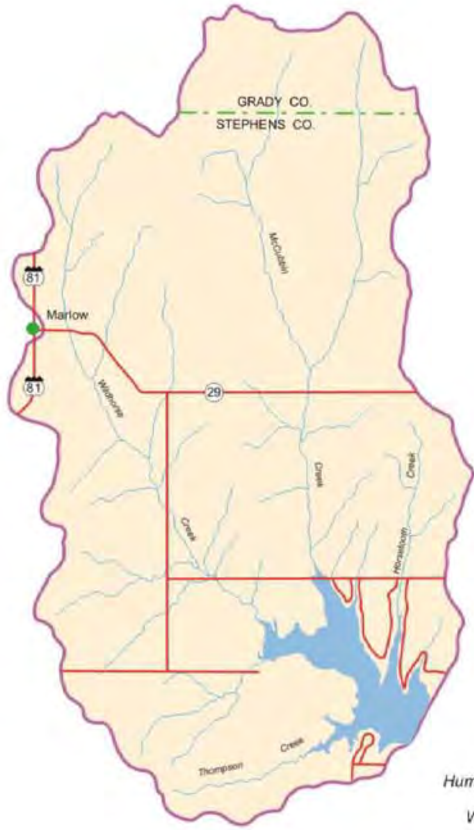
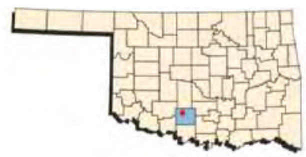


Figure 115a-113f. Graphical representation of data results for Humphreys Lake.



Humphreys Lake
and
Watershed



Humphreys Lake
Location

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

POOR ▼ EXCELLENT
Trophic State
2003

POOR ▼ EXCELLENT
Turbidity
2003

Plate 50 - Lake Water Quality for
Humphreys Lake

Lake Jean Neustadt

Lake Jean Neustadt was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for lakes greater than 250 surface acres in size. 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 10 NTU (Plate 51), true color was 15 units, and secchi disk depth was 55 centimeters. Based on these three parameters, Lake Jean Neustadt had good water clarity 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 47 (Plate 51), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. This value is lower than the one calculated in 2001 (TSI=58) but is most likely a more accurate depiction of the trophic status at Lake Jean Neustadt as the value is based on a larger dataset. The TSI values were fairly consistent with values ranging from lower mesotrophic in the summer to the upper end of mesotrophy the rest of the sample year (Figure 116). Seasonal turbidity values per site are displayed in Figure 117a. All turbidity values in 2003 were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU therefore supporting the Fish and Wildlife Propagation (FWP) beneficial use. The annual turbidity value of 10 NTU accurately reflects turbidity at Lake Jean Neustadt. Seasonal true color values are displayed in Figure 117b. All true color values were below the aesthetics OWQS of 70 units at all sites. Although 100% of the samples collected in 2003 were below the standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres. However, upon reviewing current and historical data, it is likely the Aesthetics beneficial use is fully supported.

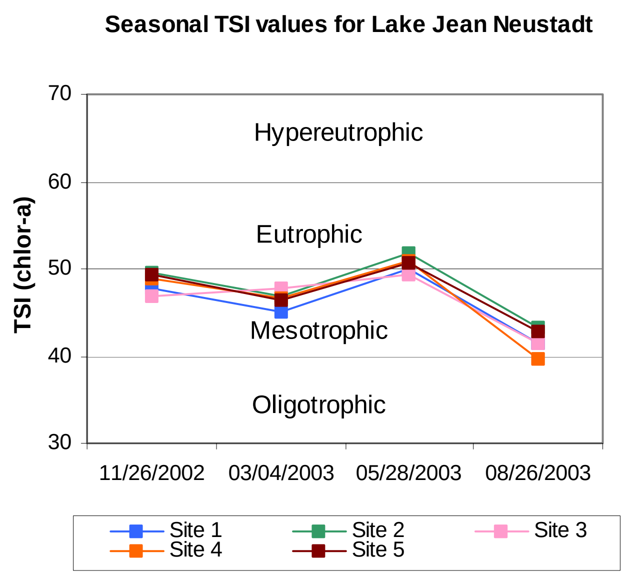


Figure 116. TSI values for Lake Jean Neustadt.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values at Lake Jean Neustadt ranged from 0.02 parts per thousand (ppt) to 0.17 ppt. This is within the average range of values for most Oklahoma reservoirs. Specific conductivity ranged from 232.2 mS/cm to 339.1 mS/cm, indicating minimal concentrations of electrical current conducting compounds (chlorides and salts) in the lake system consistent with salinity readings. The pH values ranged from 7.07 to 8.25 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 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 100% of the collected values within the acceptable range the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 311 mV to 490 mV. Reducing conditions were not present with all recorded values above 100 mV. The lake was not stratified during the fall and winter sampling intervals and the lake was well mixed with dissolved oxygen levels above 7.0 mg/L (see Figure 117c-115d). Thermal stratification was evident and anoxic conditions were present in the both spring and summer quarters. In the spring, stratification occurred between 5 and 7 meters with dissolved oxygen falling below 2.0 mg/L from 6 meters to the lake bottom of 9.2 meters accounting for approximately 36% of the water column to be anoxic (Figure 117e). In the summer quarter, similar conditions were found with dissolved oxygen concentrations (D.O.) falling below 2.0 mg/L for greater than 60 % of the water column at sites 1 and 4 (see Figure 117f). 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 on low D.O. in the spring and summer months. The lake was also sampled for total dissolved solids, chlorides and sulfates to assess the Agriculture beneficial use. Sampling in 2002-2003 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 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.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.47 mg/L at the surface and 0.94 mg/L at the lake bottom. Surface TN ranged from 0.28 mg/L to 0.69 mg/L, with the highest values reported in the winter and the lowest values in the fall. The lake-wide total phosphorus (TP) average was 0.022 mg/L at the surface and 0.095 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.012 mg/L to 0.053 mg/L. Similar to TN, surface TP was highest in the winter and lowest during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 21:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Lake Jean Neustadt was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions. Although this is lower than the TSI calculated in 2001, (TSI=58), it is likely a more accurate depiction of productivity as it is based on a larger dataset. Water clarity was good based on true color, turbidity, and secchi disk depth in sample year 2002-2003. The FWP beneficial use is supported based on turbidity and pH, but partially supporting based on dissolved oxygen levels. The lake is supporting the Aesthetics beneficial use based on its trophic status, however no listing can be made for true color as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres. Lake Jean Neustadt, located in Carter County, serves as a recreational reservoir for the City of Ardmore.

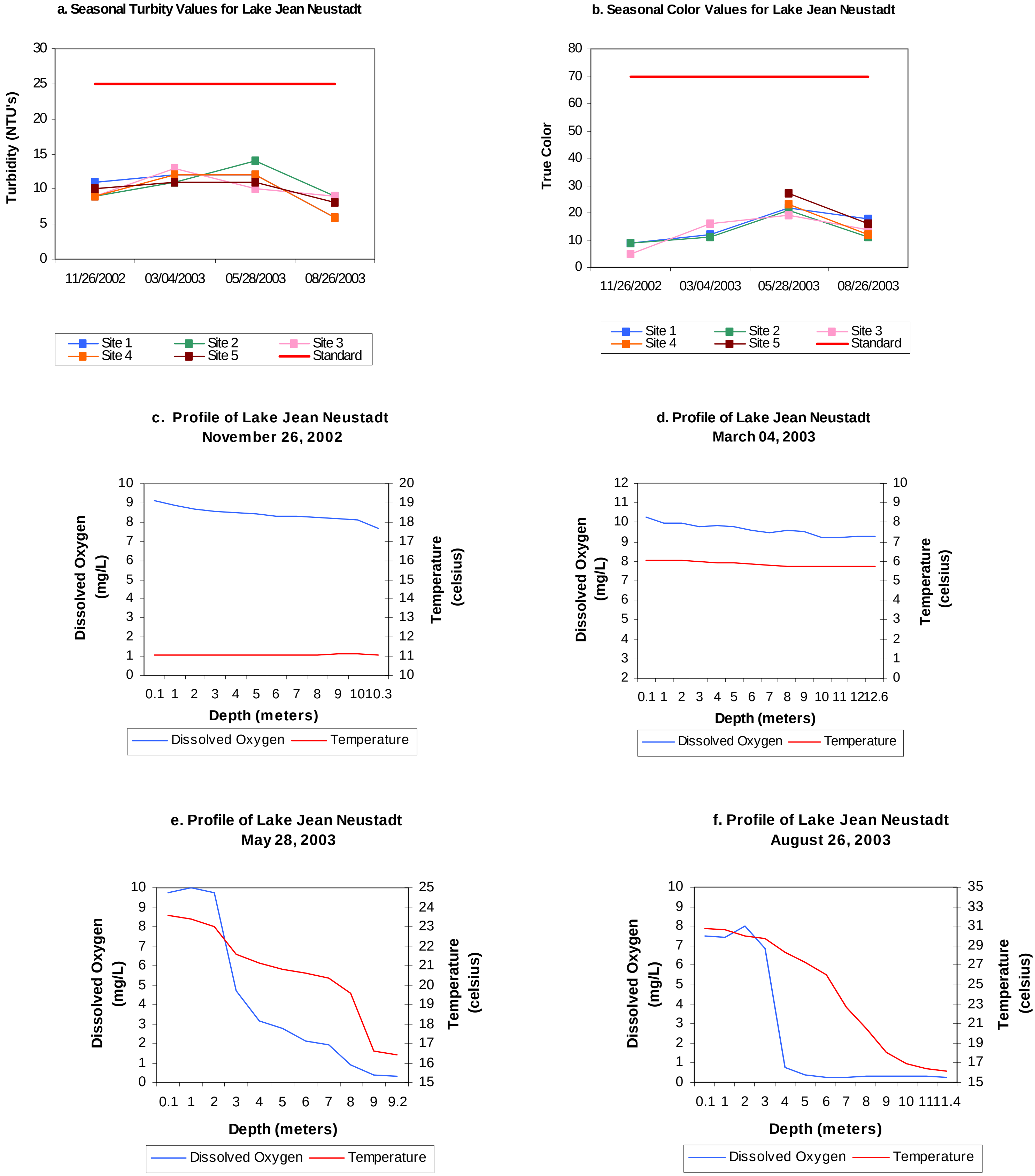


Figure 117a-115f. Graphical representation of data results for Lake Jean Neustadt.

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
2003

Trophic State
2003

Plate 51 - Lake Water Quality for
Lake Jean Neustadt

John Wells Lake

John Wells Lake was sampled for four quarters, from October 2001 through July 2002. 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 8 NTU (Plate 52), true color was 27 units, and secchi disk depth was 106 centimeters in 2001-2002. Based on these three parameters, John Wells Lake had good water clarity in 2001-2002. 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 52), classifying the lake as mesotrophic, indicative of moderate levels of productivity and moderate nutrient conditions. The TSI values varied slightly on a seasonal basis with the lake being at the extreme lower end of eutrophy in the fall, at the lower end of mesotrophy in the spring and summer and mesotrophic in the winter (see Figure 118). All turbidity values in 2001-2002 were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 119a). 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 OWQS (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 fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 119b. True color values were all well below the aesthetics OWQS of 70 units at all sites. The lake is fully supporting its Aesthetics beneficial use based on true color values. 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 conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.06 ppt, well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance ranged from 10.3 mS/cm to 135.3 mS/cm, indicating low concentrations of electrical current conducting compounds (salts) were present in the water column. In general, pH values were neutral to acidic, ranging from 6.21 in the summer to 7.42 units in the winter. John Wells had pH values below 6.5 units in both the spring and summer quarters. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. The low pH values recorded in the water column in the spring and summer are cause to list John Wells Lake as "provisionally partially supporting"* its FWP beneficial use

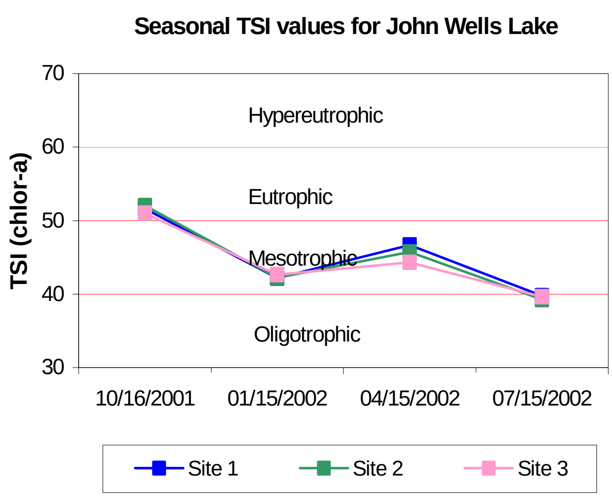


Figure 118. TSI values for John Wells Lake.

based on pH with 15% of the data falling outside the acceptable range. Oxidation-reduction potentials (redox) ranged from 39 mV at the sediment-water interface in the summer to 698 mV in the fall. Redox readings indicated that reducing conditions were not present in the reservoir in an appreciable way. The lake was not thermally stratified in the fall (except at the very bottom of the lake) or winter with dissolved oxygen (D.O.) values remaining above 7.0 mg/L throughout the water column at all sites with the exception of site 1 in the fall where a D.O. reading of 1.03 mg/L was recorded at the very bottom of the lake (see Figure 119c-117d). In the spring the lake was strongly thermally stratified at several 1-meter intervals, the first one between 1 and 2 meters and then again between 3 and 4 meters below the surface (see Figure 119e). Concentrations of D.O. remained above 5.0 mg/L throughout the water column. The lake was also strongly thermally stratified in the summer quarter between 4 and 5 meters at which point D.O. values fell below 1.0 mg/L extending all the way to the lake bottom at 11.8 meters (see Figure 119f). 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 John Wells Lake with 69% of the water column being anoxic at site 1 in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.42 mg/L at the lake surface. The TN at the surface ranged from 0.11 mg/L to 0.72 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 for sample year 2001-2002 was 0.028 mg/L at the lake surface and 0.067 mg/L on the lake bottom. The surface TP ranged from 0.010 mg/L to 0.023 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 15:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

John Wells Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, John Wells Lake was classified as mesotrophic in 2001-2002, indicative of moderate productivity and nutrient conditions (Plate 53). Both true color and trophic status were fully supporting the Aesthetics beneficial use. Water clarity was very good in 2001-2002. According to USAP, John Wells Lake was partially supporting the FWP beneficial use based on low pH and D.O. values. The lake was fully supporting the FWP beneficial use for turbidity. 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.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

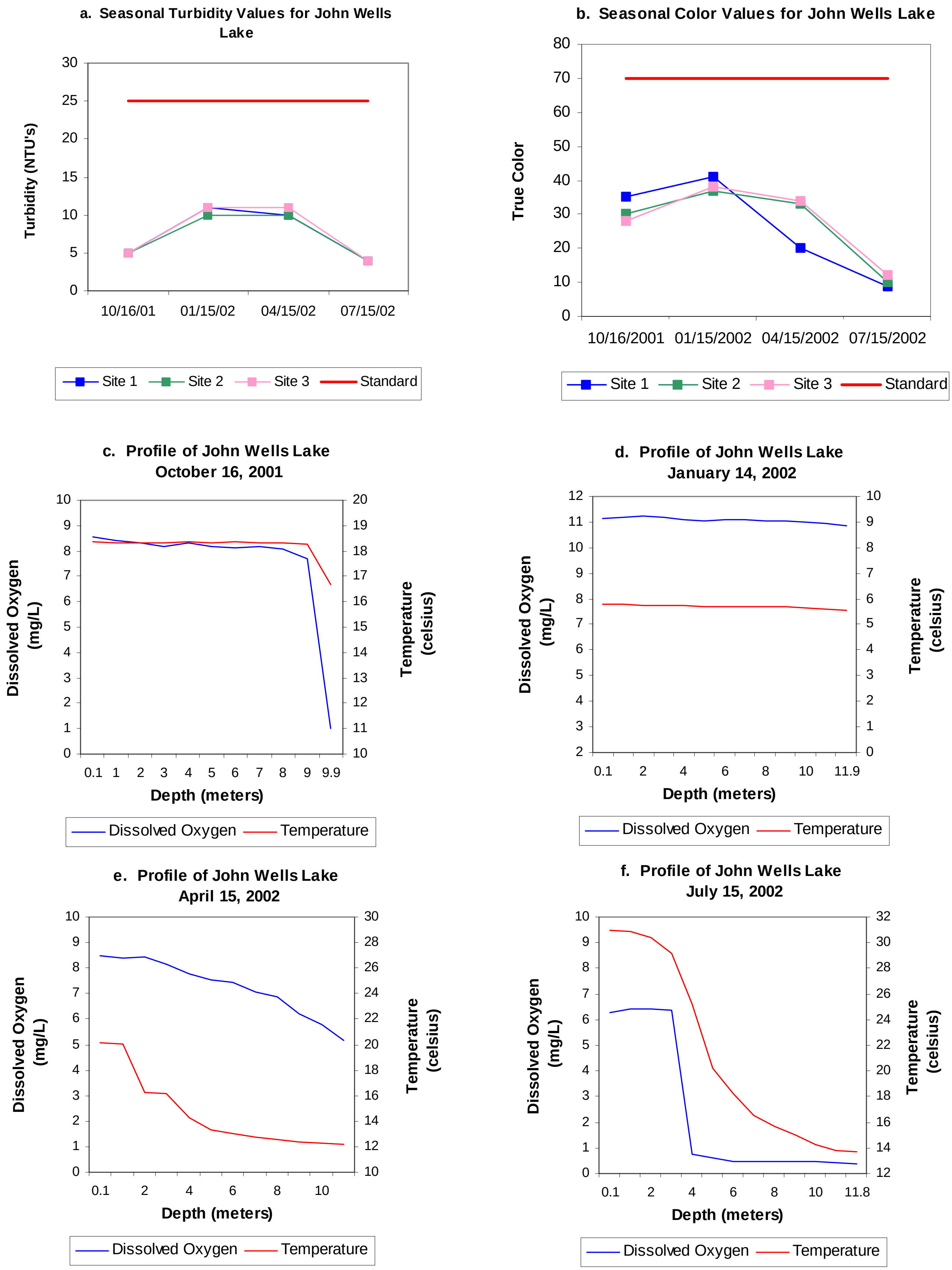
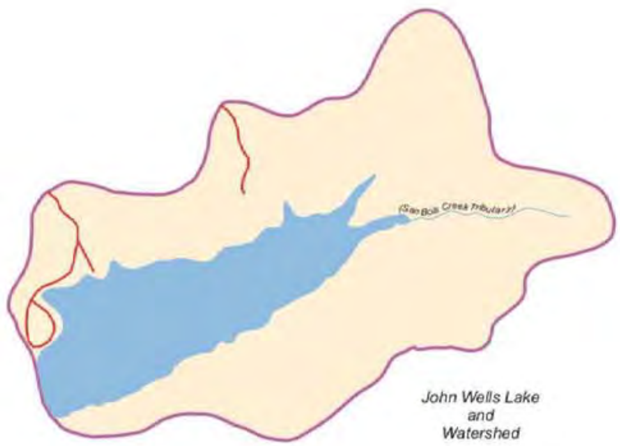


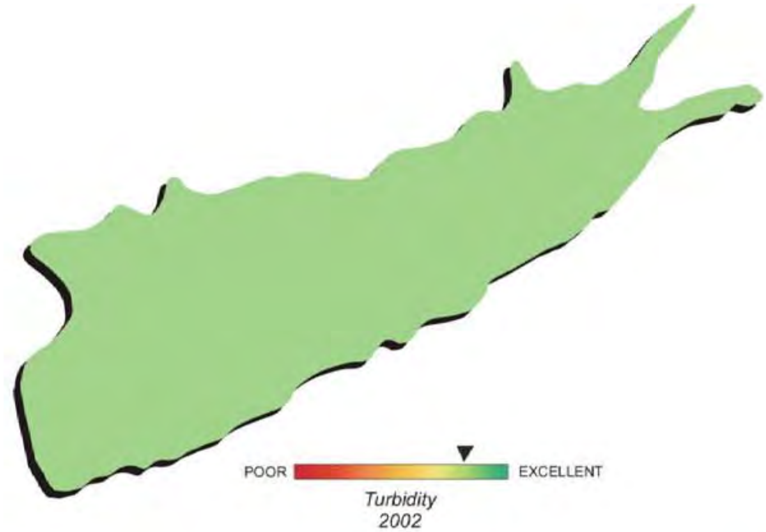
Figure 119a-117f. Graphical representation of data results for John Wells Lake.

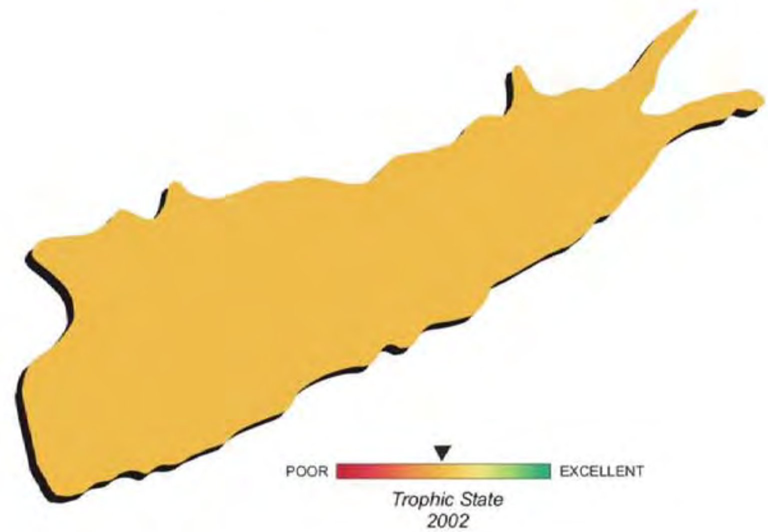
Plate 52 - Lake Water Quality for John Wells Lake



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





Kaw Lake

Kaw Lake was sampled for four quarters from October 2002 through July 2003. 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 132 NTU (Plate 53), true color was 94 units, and average secchi disk depth was 42 centimeters. Based on these three parameters Kaw Lake had fairly poor water clarity in sample year 2002-2003. 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 53), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient conditions. This value is consistent with that from 2000 (TSI=54), therefore 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 2003. In the fall, winter, and spring sampling quarters values were generally oligotrophic to mesotrophic. In the spring, values ranged from oligotrophic at sites 1 and 2, to mesotrophic at site 4, eutrophic at site 3, and hypereutrophic at site 5 (Figure 120). TSI values in the summer were all eutrophic to hypereutrophic. 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 121a. Turbidity ranged from a low of 12 NTU to a maximum of 1158 NTU in 2003. 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 OWQS (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 65% of the recorded values exceeding the OWQS of 25 NTU, Kaw Lake is not supporting its Fish and Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 121b. Applying the same default protocol to determine the short-term average for true color, the Aesthetics beneficial use is not supported with 35% of the true color values exceeding the OWQS of 70 units.

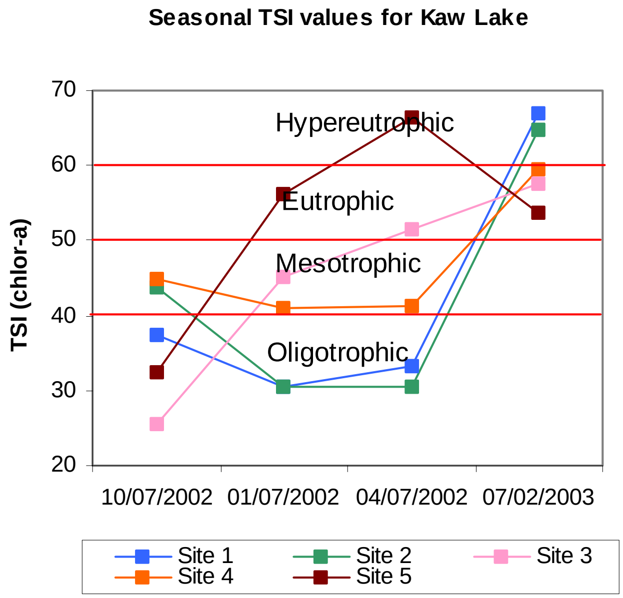


Figure 120. TSI values for Kaw Lake.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sites. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.75 ppt. This is higher than most values reported for Oklahoma lakes. Specific conductivity ranged from 234.3 mS/cm to 1415 mS/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 lowest salinity and specific conductivity values occurred at sites 3 and 5 in the Arkansas River arm during the fall. The highest recorded values also were reported at sites 3 and 5 during the other three sampling quarters. The pH values at Kaw Lake ranged from 6.47 to 8.39, representing a slightly acidic to neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With only 1 (0.3%) of the collected values falling outside the acceptable range the lake is considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 80 mV to 537 mV. 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 121c-119e). Thermal stratification was evident in the summer and anoxic conditions were present. In the summer stratification occurred at several 1-meter intervals throughout the lake with 25 to 66% of the water column experiencing anoxic conditions (Figure 121f). 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 25 to 66% 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 2002-2003 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. The PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.80 mg/L at the surface and 1.81 mg/L at the lake bottom. Surface TN ranged from 1.26 mg/L to 2.73 mg/L, with both the highest and lowest values in the fall. The lake-wide total phosphorus (TP) average was 0.226 mg/L at the surface and 0.202 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.117 mg/L to 0.800 mg/L. Surface TP was highest in the winter and lowest during the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003. This is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Kaw Lake was classified as eutrophic, indicative of high levels of primary productivity and nutrient conditions. This value is consistent with that from the 2000 (TSI=54), therefore no significant change in productivity has occurred since the last evaluation. Water clarity was fairly poor at Kaw Lake based on true color, secchi disk depth and high turbidity readings. The lake is partially supporting the FWP beneficial use based on dissolved oxygen and pH, but not supporting based on turbidity. The Aesthetics beneficial use is supported based on its trophic status, but not supported based on true color with 35% of the collected values exceeding the OWQS of 70 units. 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.

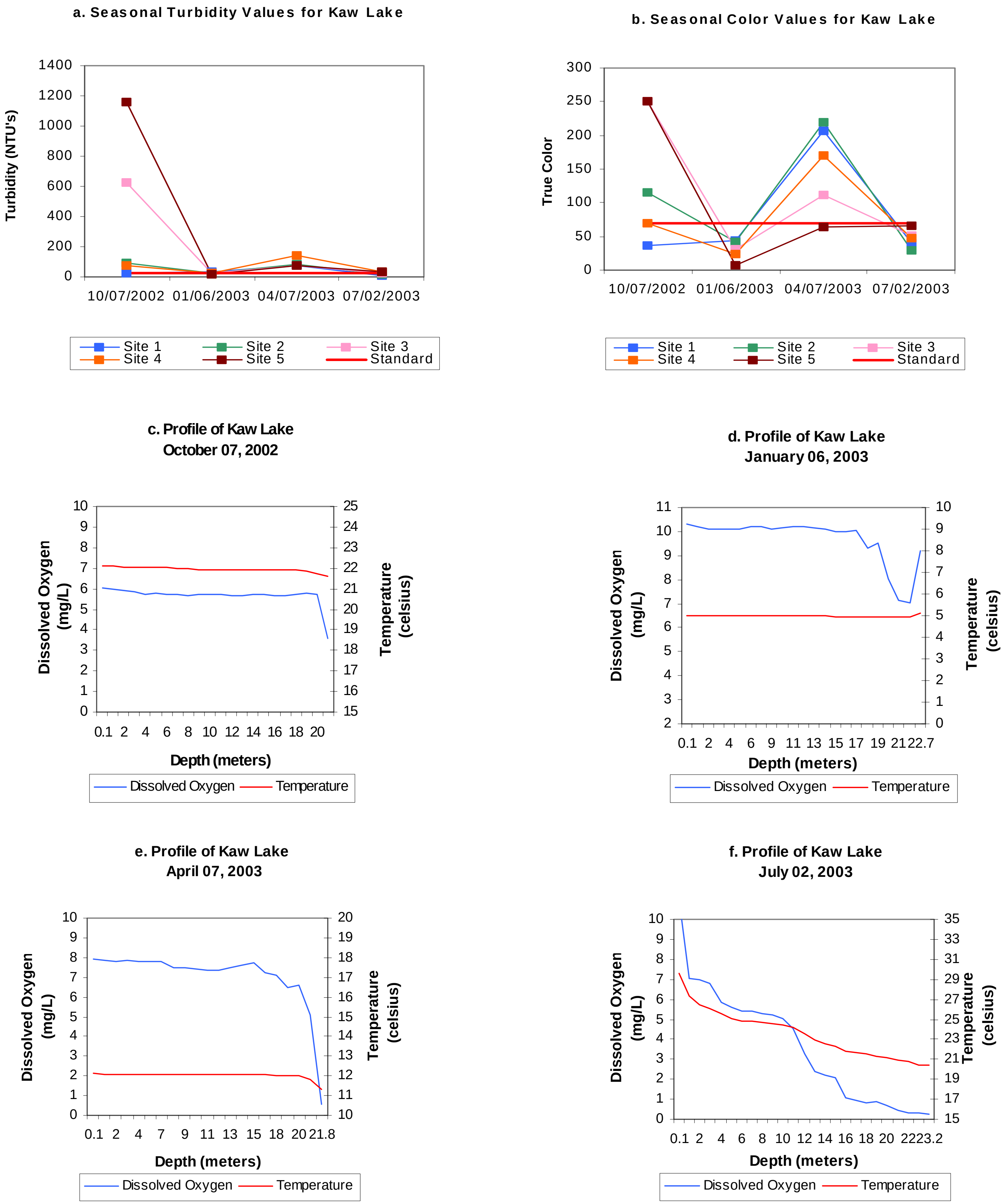
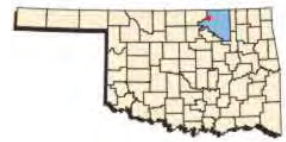


Figure 121a-119f. Graphical representation of data results for Kaw Lake.

Kaw Lake
and
Watershed



Kaw Lake
Location

POOR EXCELLENT
Trophic State
2003

POOR EXCELLENT
Turbidity
2003

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 53- Lake Water Quality for
Kaw Lake

Keystone Lake

Keystone Lake was sampled for four seasons, from October 2001 through July 2002. 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 12 sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 21 NTU (Plate 54), true color was 34 units, and secchi disk depth was 58 centimeters in 2001-2002. Based on these three parameters, Keystone 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=48). The average TSI was 62 (Plate 54), classifying the lake as hypereutrophic, indicative of excessive levels of productivity and nutrients. The TSI values were mesotrophic in the fall and winter near the dam area and eutrophic or hypereutrophic in the rest of the lake (see Figure 122). In the spring and summer quarters the vast majority of the lake was hypereutrophic in nature. With the excessive amount of productivity in Keystone Lake the Water Resources Board will recommend the lake be listed as a Nutrient Limited Watershed (NLW) during the next Oklahoma Water Quality Standards (OWQS) revision process. NLW waters are specifically identified in the OWQS and the Aesthetics beneficial use is considered threatened until a more intensive study can be conducted to verify if the lake is “not supporting”. The turbidity values in the lake were average to good with only 15% of the values exceeding the OWQS 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 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. Keystone is “partially supporting” its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity (see Figure 123a). Seasonal true color values are displayed in Figure 123b. With 6% of the true color values above the numeric criteria of 70 units, the Aesthetics beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.02 to 4.73 parts per thousand (ppt) indicating low to very high salt content within the lake depending where the sample site was located. A reading of 0.02 ppt was recorded on a couple of occasions at the lake surface and appears to be spurious in nature. In general, salinity values are very high in the Cimarron River arm of the reservoir, especially in the spring with rainfall runoff events occurring. Salinity readings across the entire lake were higher than the normal range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were also very high, ranging from 0.0 mS/cm (which again seem to be spurious readings at the lake surface) to 7976 mS/cm, indicating extremely high amounts of electrical current conducting compounds (salts) in the water column throughout the year. Lake Keystone

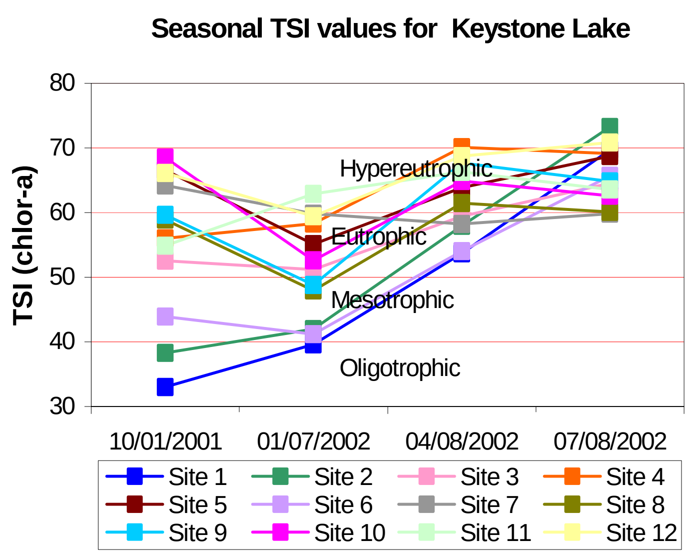


Figure 122. TSI values for Keystone Lake.

continues to live up to its historical reputation as one of the “saltiest” lakes in Oklahoma. In general, pH values were slightly neutral to alkaline, ranging from 6.7 to 9.56 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 should be listed as not supporting beneficial uses. 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 beneficial uses. With 6% of pH values falling outside the acceptable range the lake was fully supporting its FWP beneficial use. Oxidation-reduction potentials (redox) ranged from 36 mV at the sediment-water interface in the spring to 530mV in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir. The lake was not thermally stratified in the fall, winter or spring quarters and dissolved oxygen (D.O.) values remained above 3.0 mg/L except at the lake bottom and were generally above 5.0 mg/L throughout the majority of the water column (see Figure 123c-121e). In the summer, the lake was not thermally stratified but appeared to be chemically stratified between 10 and 11 meters below the lake surface and D.O. values around the 12 meter depth to the lake bottom of 20 meters at site 1 were less than 2.0 mg/L (see Figure 123f). 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 Keystone Lake with only 43% of the water column anoxic. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 1.08 mg/L at the lake surface. The TN at the surface ranged from 0.75 mg/L in the spring to 1.76 mg/L in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.103 mg/L at the lake surface. The surface TP ranged from 0.042 mg/L in the spring quarter to 0.384 mg/L in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Keystone Lake was sampled for metals at twelve sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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, Keystone Lake was classified as hypereutrophic, indicative of excessive productivity and nutrient levels (Plate 54). The Water Resources Board will recommend the lake be listed as a Nutrient Limited Watershed (NLW) during the next OWQS revision process meaning the Aesthetics beneficial use is threatened based on nutrients. The lake is fully supporting its Aesthetics use based on true color. Keystone is partially supporting its FWP beneficial use based on turbidity values, but is fully supporting based on D.O. and pH values. 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.

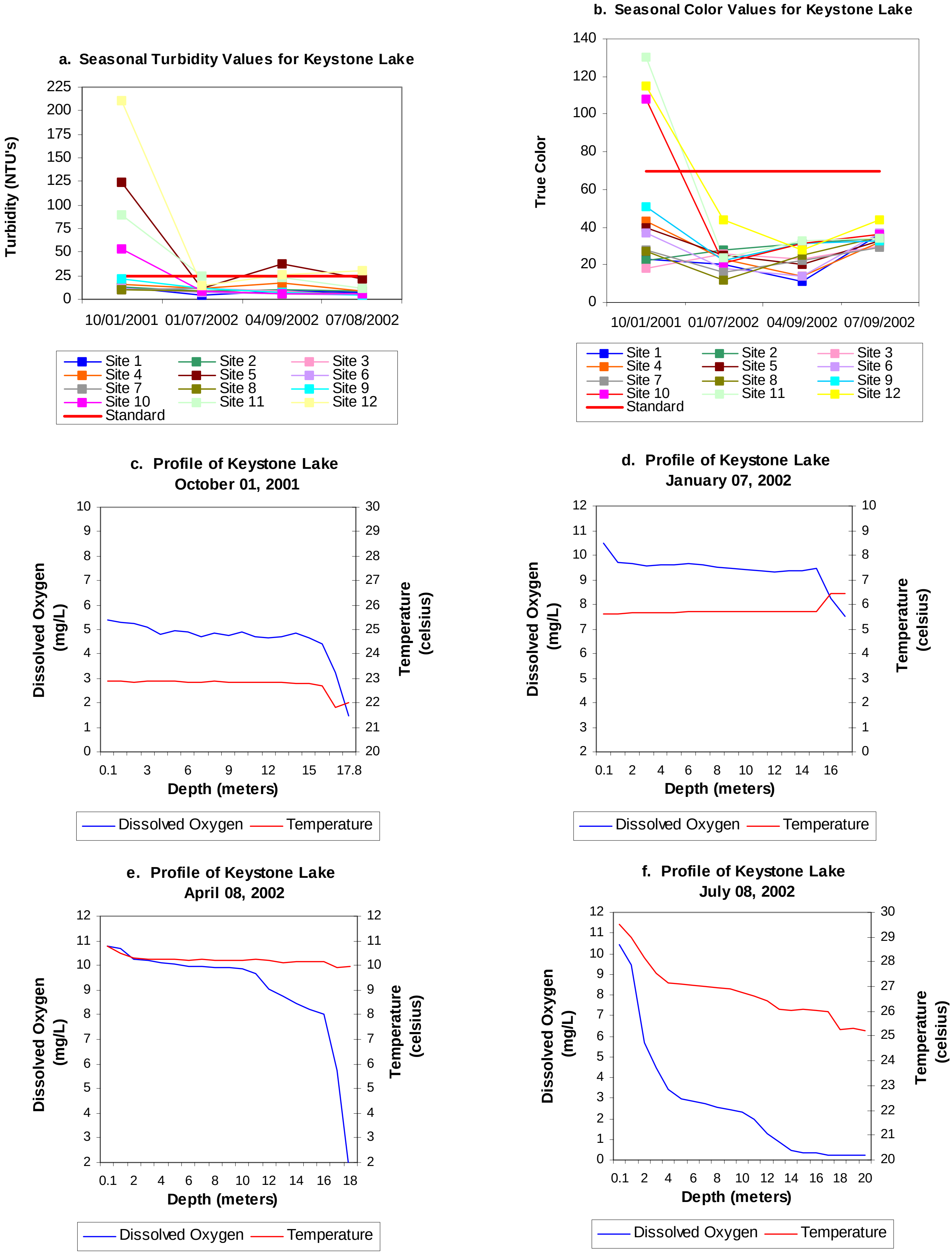
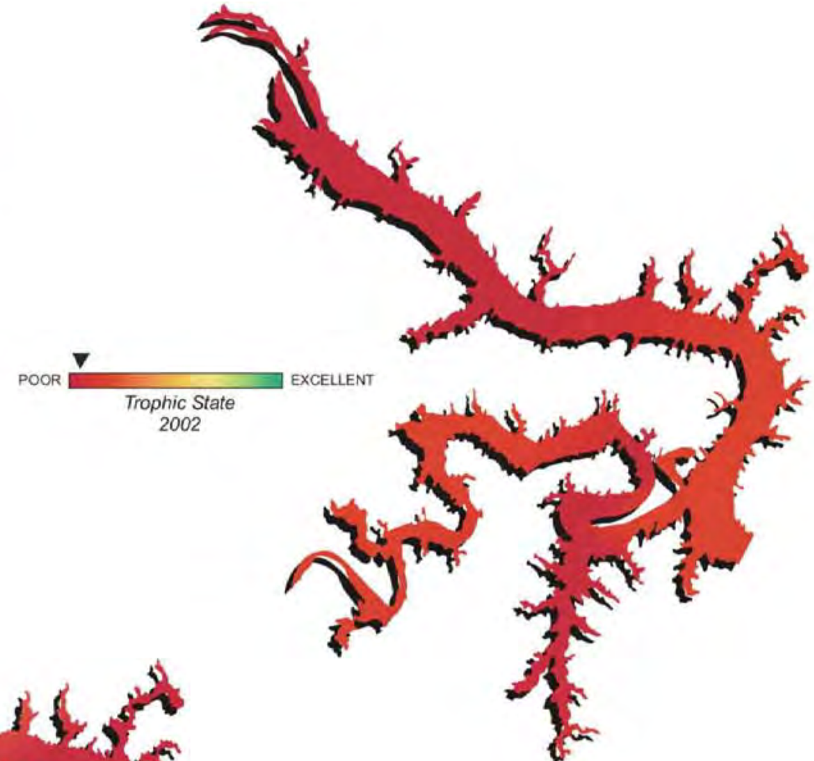
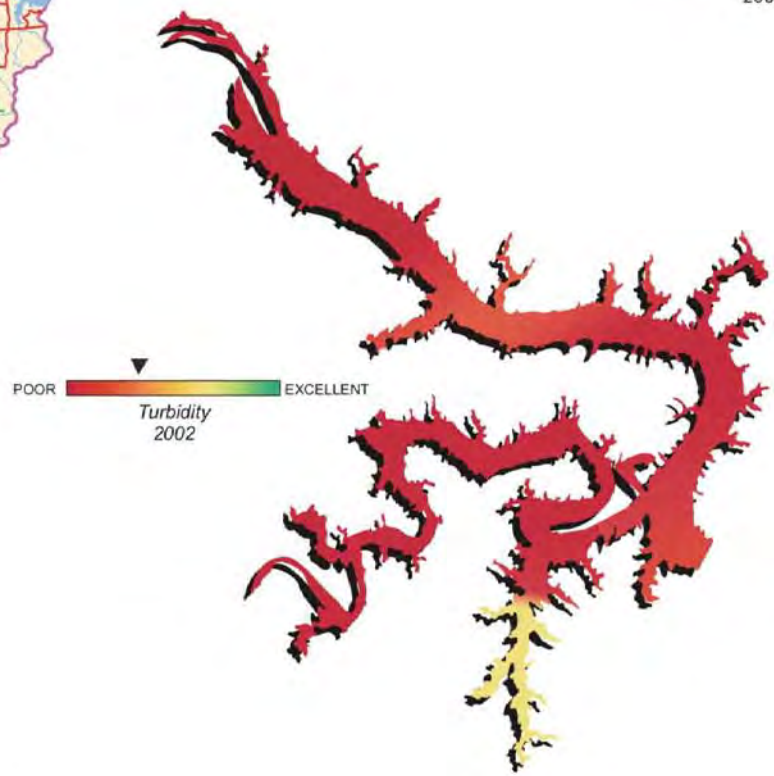


Figure 123a-121f. Graphical representation of data results for Keystone Lake.

Keystone Lake and Watershed


Keystone Lake Location





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 54 - Lake Water Quality for
Keystone Lake

Konawa Reservoir

Konawa Reservoir was sampled for three seasons, from November 2001 through May 2002. Water quality samples were collected at five (5) sites to represent the riverine, transition, and lacustrine zones of the reservoir. However, the chemistry samples collected for analysis at the contract laboratory were not run in he summer quarter due to an accident which decreased the available data set to make use support determinations. 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 6 NTU (Plate 55), true color was 26 units, and secchi disk depth was 90 centimeters in 2001-2002. 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 three quarters (n=15). The average TSI was 54 (Plate 55), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. The TSI values were 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 (see Figure 124). The turbidity values collected on the lake were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see 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 OWQS (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 no violations of the criteria detected Konawa Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it pertains to turbidity. Seasonal true color values are displayed in Figure 125b. All of the true color values were below the numeric criteria of 70 units, however, a definitive determination of the Aesthetics beneficial use cannot be made as insufficient data was available due to lack of information for the summer quarter. Collected data strongly suggests that the lake would be supporting its Aesthetics beneficial use related to true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.53 parts per thousand (ppt) to 0.55 ppt much higher than the range of values normally seen for Oklahoma reservoirs. Values indicated high salt content and were much higher than the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were elevated above the expected range normally seen in most Oklahoma reservoirs with values ranging from 1015 mS/cm to 1053 mS/cm, indicating the substantial presence of electrical current conducting compounds (salts) in the water column throughout the year. These values were also paralleled by the salinity values to some extent. In general, pH values were slightly alkaline to neutral, ranging from 6.94 to 8.43

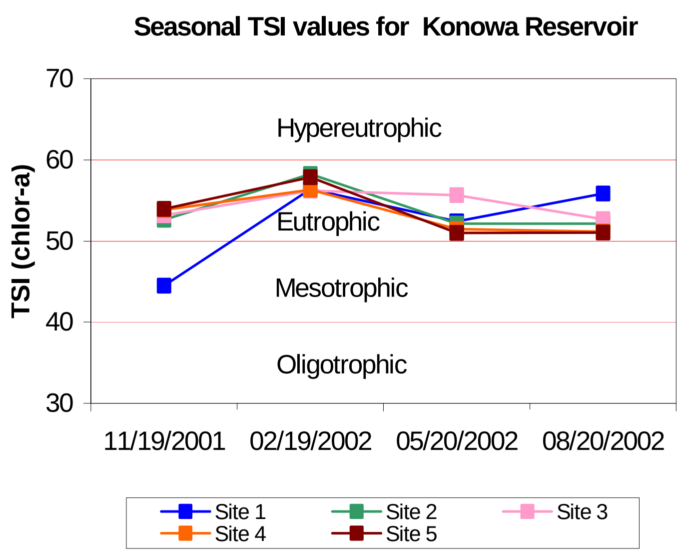


Figure 124. TSI values for Konawa Reservoir.

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 should be listed as not supporting beneficial uses. 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 beneficial uses. Konawa Reservoir is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from –66 mV at the sediment-water interface in the summer to 571 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, winter, or spring and dissolved oxygen (D.O.) values were above 3.0 mg/L throughout the water column at all sites and were generally above 6.0 mg/L except near the lake bottom (see Figure 125c-123e). In the summer, the lake exhibited weak thermal stratification in the bottom 2 or 3 meters of the water column with 25% of the values collected at site 1 less than 2.0 mg/L (see Figure 125f). 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 Konawa Reservoir based on D.O. readings in the water column.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.75 mg/L at the lake surface. The TN at the surface ranged from 0.52 mg/L in the spring quarter to 1.04 mg/L in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.078 mg/L at the lake surface. The surface TP ranged from 0.028 mg/L in the spring to 0.160 mg/L in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Konawa Reservoir was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use based on metal (toxic) compounds in the water column.

In summary, Konawa Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 55). Konawa Reservoir was meeting its FWP beneficial use for pH, turbidity, and D.O. Konawa Reservoir was meeting its Aesthetics beneficial use for nutrients and true color could not be assessed due to insufficient information. 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.

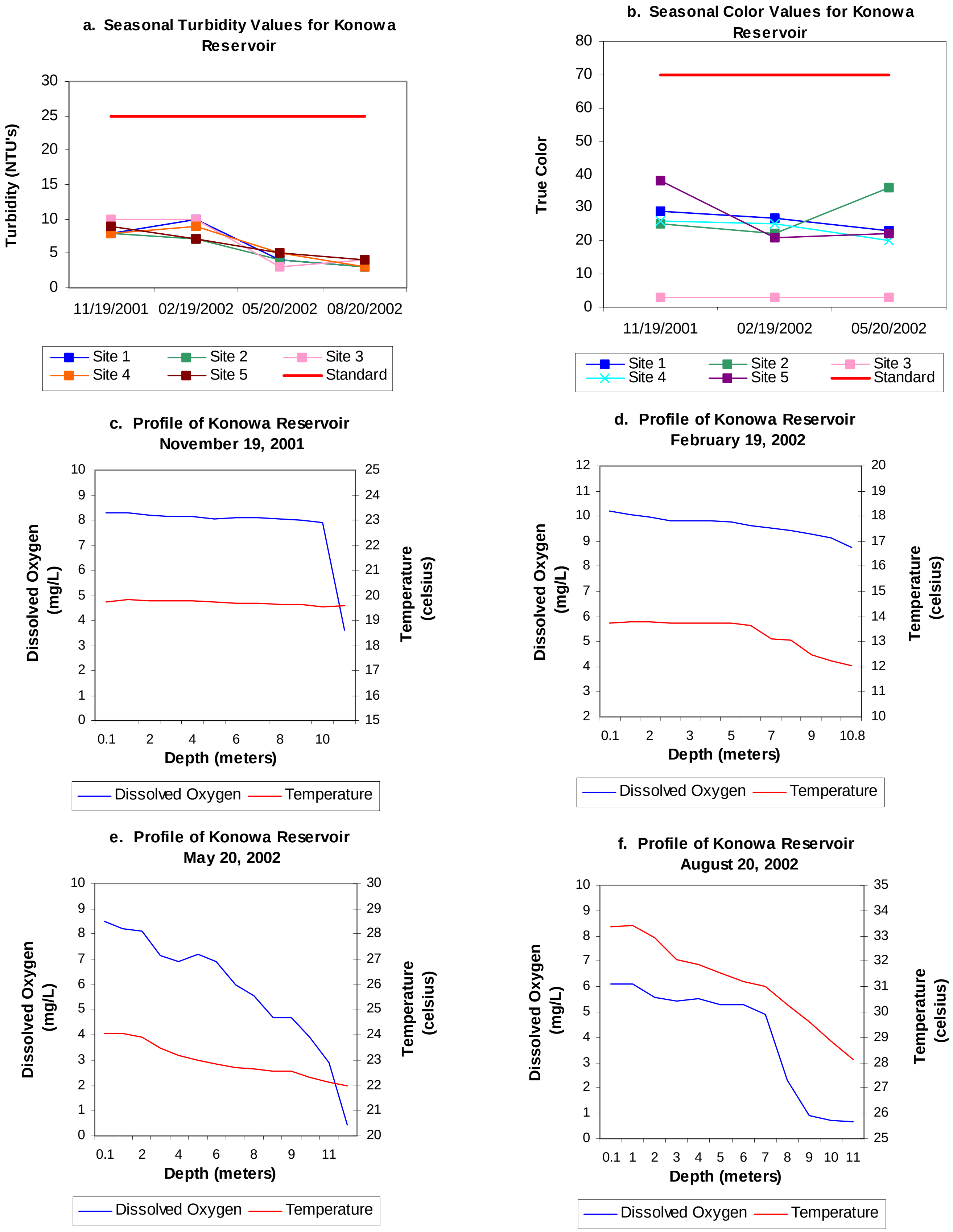


Figure 125a-123f. Graphical representation of data results for Konawa Reservoir.

Konawa Lake
and
Watershed

Konawa Lake
Location

Turbidity
2002

Trophic State
2002

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

Plate 55 - Lake Water Quality for
Konawa Lake

Langston Lake

Langston Lake was sampled for four seasons, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the lake. In addition, samples were also collected at the lake surface at sites 4, 5, 7, and 8 for chlorophyll-a and turbidity analysis to meet minimum data requirements. Samples were collected at all sites 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 56), true color was 23 units, and secchi disk depth was 83 centimeters in 2001-2002. Based on these three parameters, Langston 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=20). The average TSI was 44 (Plate 56), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. The TSI values were consistently mesotrophic throughout all four quarters sampled 2001 (see Figure 126). All turbidity values collected, with the exception of 2 values in the spring, were less than the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see 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 OWQS (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 OWQS, Langston Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Seasonal true color values are displayed in Figure 127b. All of the true color values were below the numeric criteria of 70 units, however, the Aesthetics beneficial use cannot be assessed, as the minimum data requirements were not met. True color values collected strongly suggest that the lake is meeting its Aesthetics beneficial use as it relates to true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.14 parts per thousand (ppt) to 0.18 ppt, which was generally within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific ranged from 239.9 mS/cm to 361.3 mS/cm, indicating that low to moderate amounts of electrical current conducting compounds (salts) were present in the water column throughout the year. In general, pH values were neutral to slightly alkaline, ranging from 6.96 to 8.65 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 should be listed as not supporting beneficial uses. 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 beneficial uses. With all pH values falling within the acceptable range of values the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 108 mV at the sediment-water interface in the summer to 608 mV recorded in the fall quarter. Redox

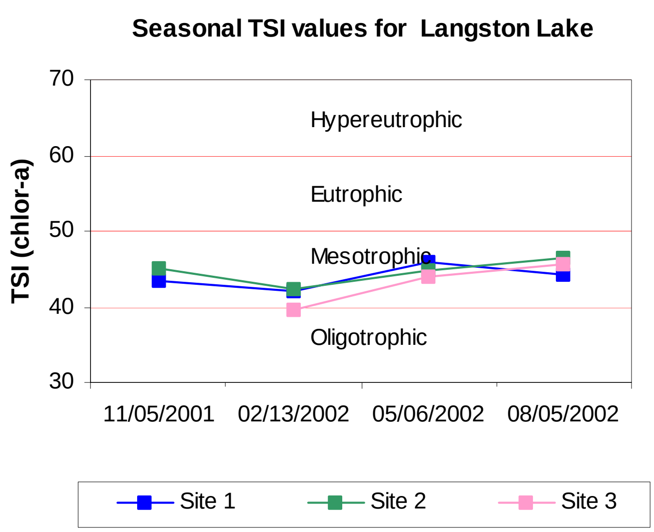


Figure 126. TSI values for Langston Lake.

readings indicated that reducing conditions were not present in the reservoir at any point during the sample season. The lake was not thermally stratified in either the fall or winter quarters and dissolved oxygen (D.O.) values were above 8.0 mg/L throughout the water column at all sites (see Figure 127c-123d). In the spring, the lake was weakly thermally stratified, although D.O. concentrations remained above 2.0 mg/L throughout the water with the exception of the area near the sediment-water interface at the very bottom of the lake (see Figure 127e). In the summer, the lake was stratified between 5 and 6 meters and below 6 meters; D.O. values were less than 1.0 mg/L to the lake bottom at 12.8 meters at site 1 (see Figure 127f). 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 Langston Lake because 50% of the water column was anoxic at site 1 in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.44 mg/L at the lake surface. The TN at the surface ranged from 0.24 mg/L in the fall quarter to 0.63 mg/L in the summer quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.015 mg/L at the lake surface. The surface TP ranged from 0.008 mg/L in the fall quarter to 0.028 mg/L in the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 29:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Langston Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Langston Lake was classified as mesotrophic, indicative of moderate productivity and nutrient levels (Plate 56). The lake was meeting its FWP beneficial use at it relates to turbidity and pH, however the use was only partially supporting based on D.O. readings during the summer. Insufficient data was available to assess the Aesthetics beneficial use as it relates to true color, however based on the trophic status of the lake, the Aesthetics beneficial use is fully supporting (USAP 785:46). Langston Lake 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.

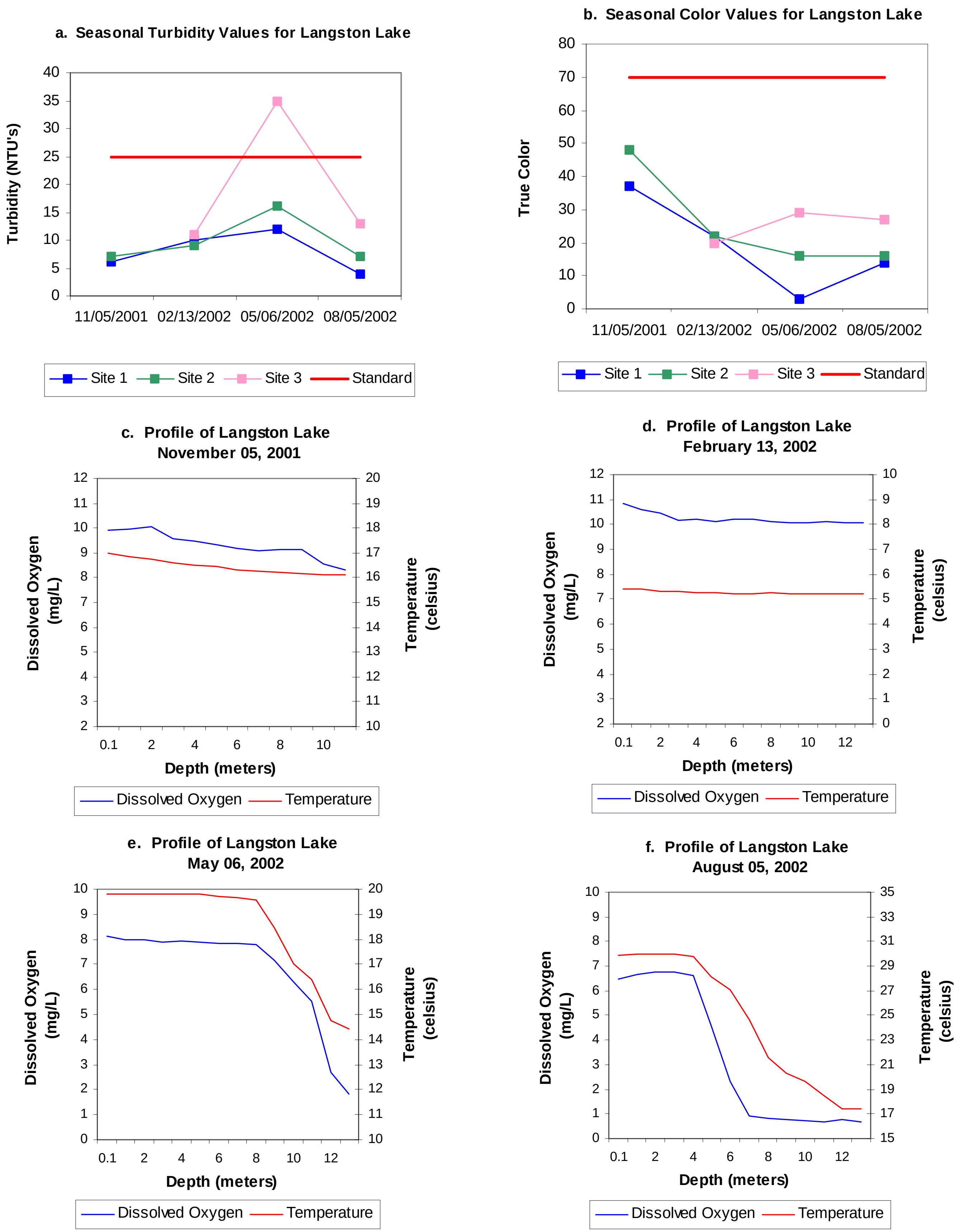
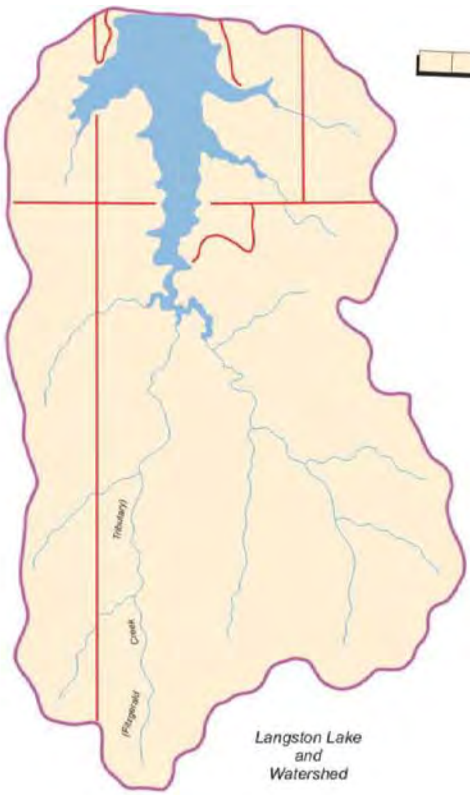


Figure 127a-125f. Graphical representation of data results for Langston Lake.



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
2002

Trophic State
2002

Plate 56 - Lake Water Quality for
Langston Lake

Lake Lawtonka

Lake Lawtonka was sampled for four quarters, from November 2001 through August 2002. 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 and at 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 10 NTU (Plate 57), true color was 20 units, and secchi disk depth was 81 centimeters in 2001-2002. Based on these three parameters, Lake Lawtonka 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=20). The average TSI was 53 (Plate 57). The TSI values varied greatly depending on the season of the year. The trophic status in the fall varied between oligotrophic, mesotrophic, and eutrophic depending on the location of the sample site in the lake. The trophic status of Lawtonka in the winter was upper oligotrophic to lower mesotrophic. In the spring and summer Lake Lawtonka was upper eutrophic to slightly hypereutrophic (see Figure 128). The turbidity values for Lake Lawtonka were all less than the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 129a). 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 OWQS (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 129b. 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 conductance, oxidation-reduction potential, and salinity were recorded at all five (5) sample sites. Salinity values ranged from 0.15 parts per thousand (ppt) to 0.19 ppt and were well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were also within the range of expected values for Oklahoma lakes, ranging from 311.4 mS/cm to 389.8 mS/cm, indicating little to 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 6.71 in the summer to 8.65 units in the winter quarter. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. None of the collected pH values were outside the acceptable range so Lake Lawtonka is fully supporting its FWP beneficial use based on pH concentrations. Oxidation-reduction potentials (redox) ranged from –37 mV at

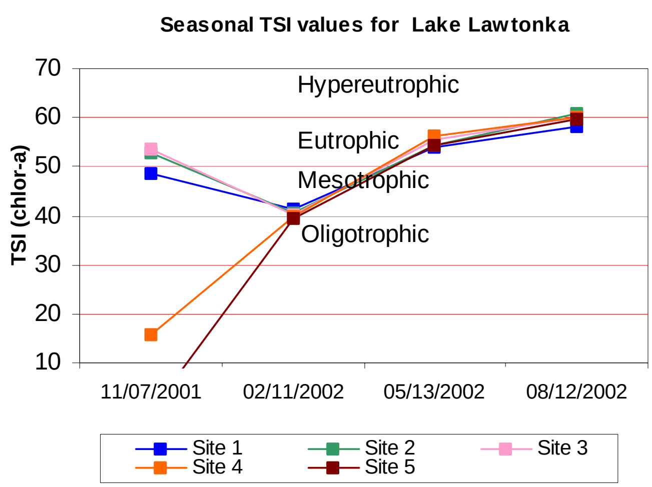


Figure 128. TSI values for Lake Lawtonka.

the sediment-water interface in the summer to 485 mV in the fall quarter. 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 above 5.0 mg/L throughout the water column at all sites and were generally above 7.0 mg/L throughout most of the water column. (see Figure 129c-127e). In the summer, the lake was thermally stratified between 8 and 9 meters below the lake surface. D.O. readings below 8 meters were less than 2.0 mg/L extending all the way to the lake bottom at 14.8 meters at site 1 (see Figure 129f). 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. According to USAP, the FWP beneficial use is considered fully supported at Lake Lawtonka because only 44% of the water column was anoxic at site 1 during the summer. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.44 mg/L at the lake surface. The TN at the surface ranged from 0.19 mg/L in the fall quarter to 1.43 mg/L in the winter quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.0442 mg/L at the lake surface. The surface TP ranged from 0.008 mg/L in the fall quarter to 0.042 mg/L in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Lawtonka was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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 57). Lake Lawtonka was fully supporting the FWP beneficial use based on turbidity, pH and D.O. values recorded at the lake surface and in the water column. The lake was also fully supporting its Aesthetics beneficial use based on true color values and its trophic status. Lake Lawtonka is the municipal water supply for the City of Lawton and is owned and operated by the city. The lake is also used for numerous recreational pursuits. In general, Lake Lawtonka has good water quality and should be managed to maintain current water quality conditions.

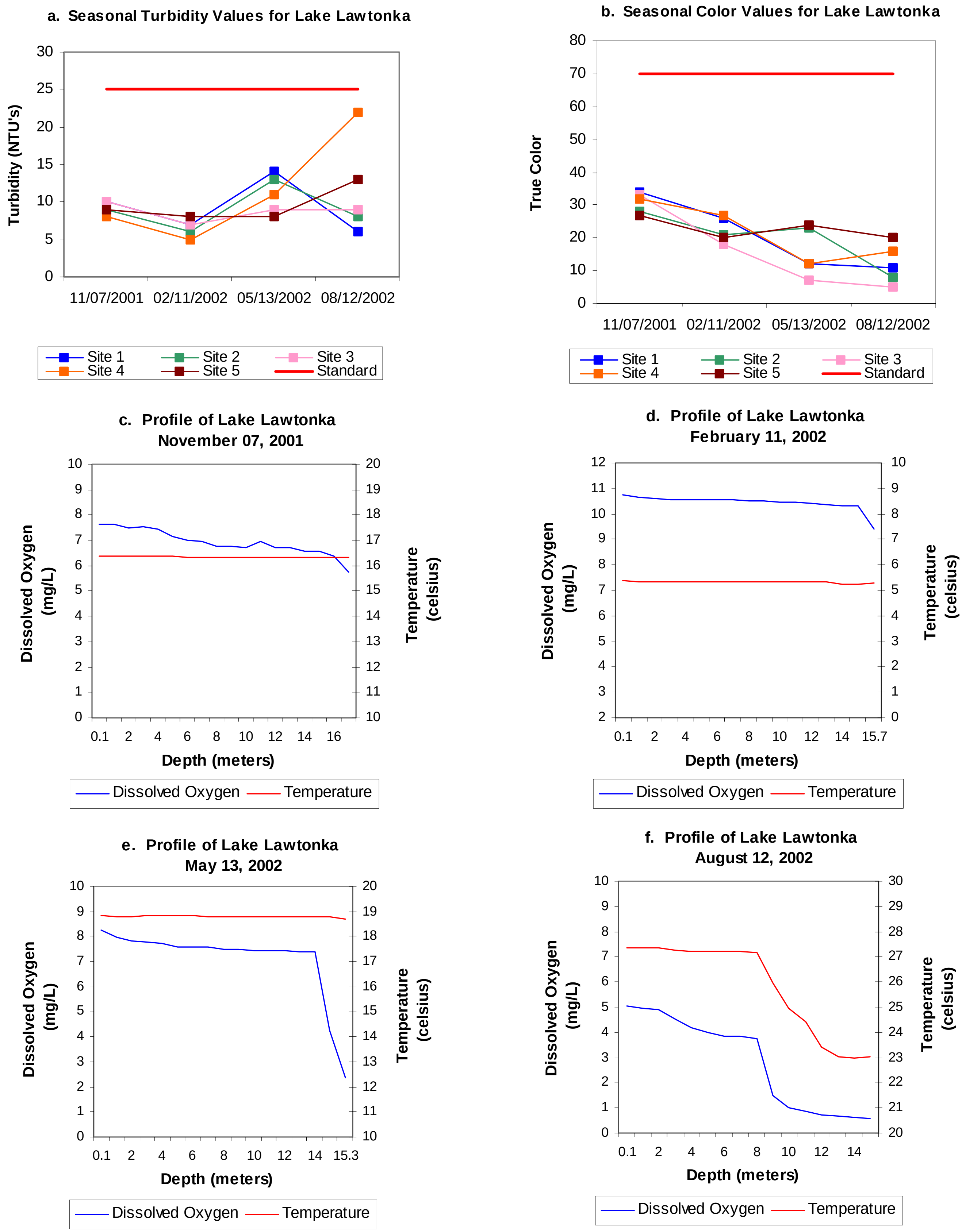
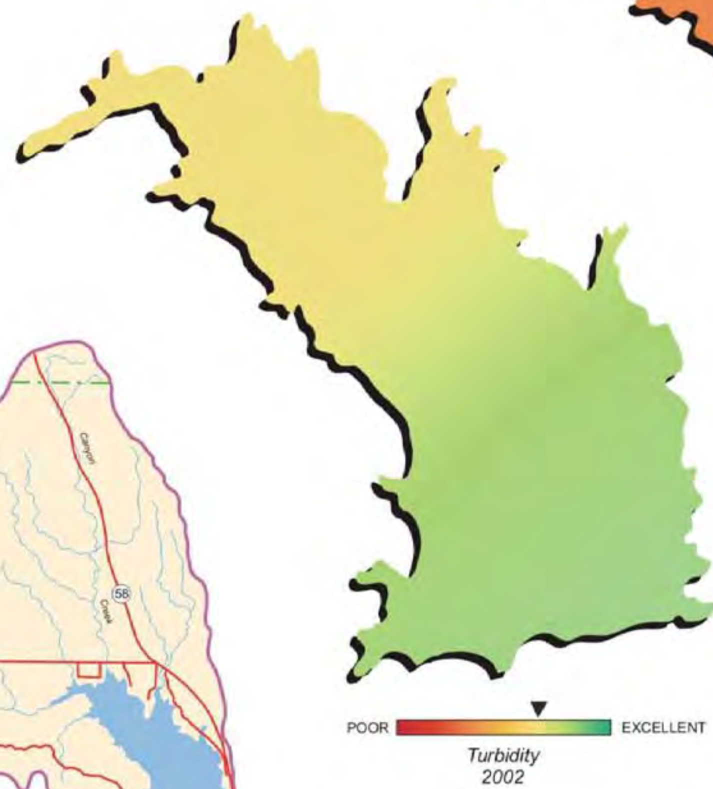


Figure 129a-127f. Graphical representation of data results for Lake Lawtonka.

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



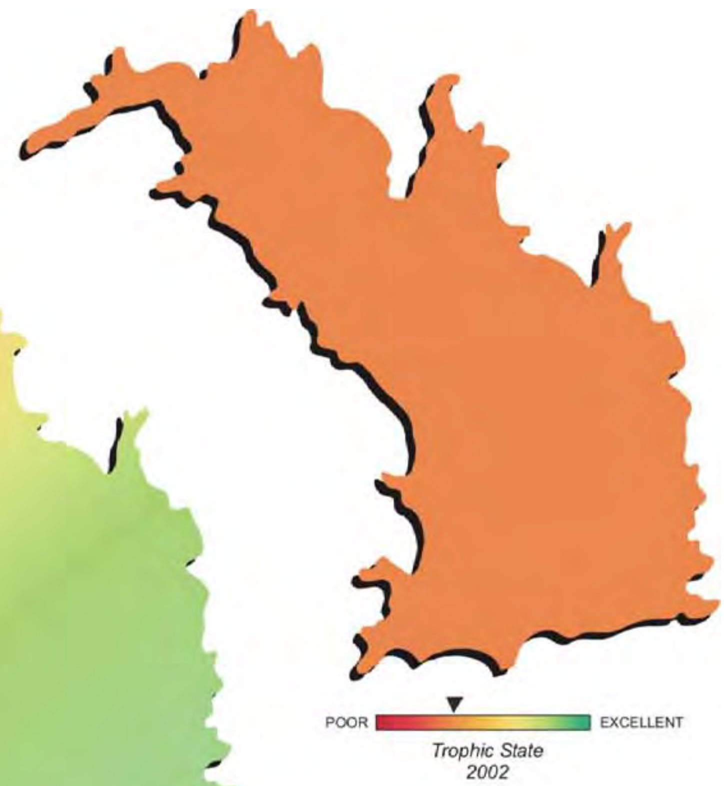


Plate 57 - Lake Water Quality for
Lake Lawtonka

Liberty Lake

Liberty Lake was sampled for four quarters, from November 2001 through August 2002. 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 and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 15 NTU (Plate 58), true color was 31 units, and secchi disk depth was 56 centimeters in 2001-2002. Based on these three parameters, Liberty Lake had good 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 all quarters (n=12). The average TSI was 55 (Plate 58), classifying the lake as eutrophic, indicative of high levels of productivity and nutrients. The TSI values were consistently in the eutrophic range for every quarter sampled fluctuating between lower and upper eutrophy in 2001-2002 (see Figure 130). The turbidity values for the lake were all below the Oklahoma Water Quality Standard (OWQS) of 25 NTU except for one value recorded in the spring quarter at the upper end of the lake (see Figure 131a). 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 OWQS (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 fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity concentrations in the lake as only 8% of the collected values exceeded the criteria. Seasonal true color values are displayed in Figure 131b. 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 conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.24 parts per thousand (ppt) to 0.28 ppt, which is higher than the expected range of values for Oklahoma lakes indicating above average salt content levels. Readings for specific conductance ranged from 476.5 mS/cm to 544.6 mS/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 6.9 units in the summer quarter to 8.78 units in the spring quarter. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. All pH values collected on Liberty Lake were within the allowable range so the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 21 mV at the sediment-water interface in the spring

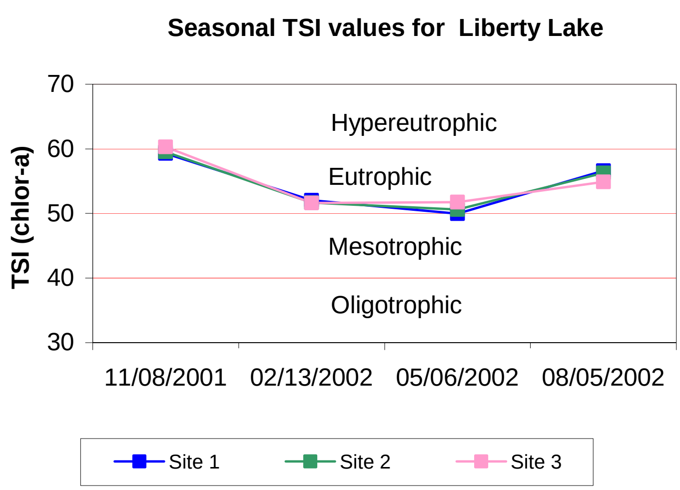


Figure 130. TSI values for Liberty Lake.

to 612 mV recorded in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir during the period the lake was sampled. 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 with the exception of the spring near the sediment-water interface where values fell to slightly below 5.0 mg/L (see Figure 131c). In the summer, the lake was thermally stratified between 4 and 5 meters and at 4 meters below the surface the D.O. values were less than 2.0 mg/L and remained so all the way to the lake bottom at 6.8 meters at site 1 (see Figure 131f). 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. According to USAP, the FWP beneficial use is considered partially supported at Liberty Lake because approximately 50% of the water column was anoxic at site 1 in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.82 mg/L at the lake surface. The TN at the surface ranged from 0.74 mg/L recorded in the fall and winter quarters to 1.01 mg/L in the spring quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.042 mg/L at the lake surface. The surface TP ranged from 0.031 mg/L in the winter quarter to 0.064 mg/L recorded in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 19:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Liberty Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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, Liberty Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 58). The lake is meeting its FWP beneficial use for turbidity and pH. The lake is partially supporting the FWP beneficial used based on D.O. readings in the water column (OAC 785:46). Liberty Lake was fully supporting its Aesthetics beneficial use for true color and its trophic status also indicated that the Aesthetics use was fully supported. Liberty Lake was constructed in 1948 and a municipal water supply for the City of Guthrie. The lake is also used as a recreational outlet for the general public.

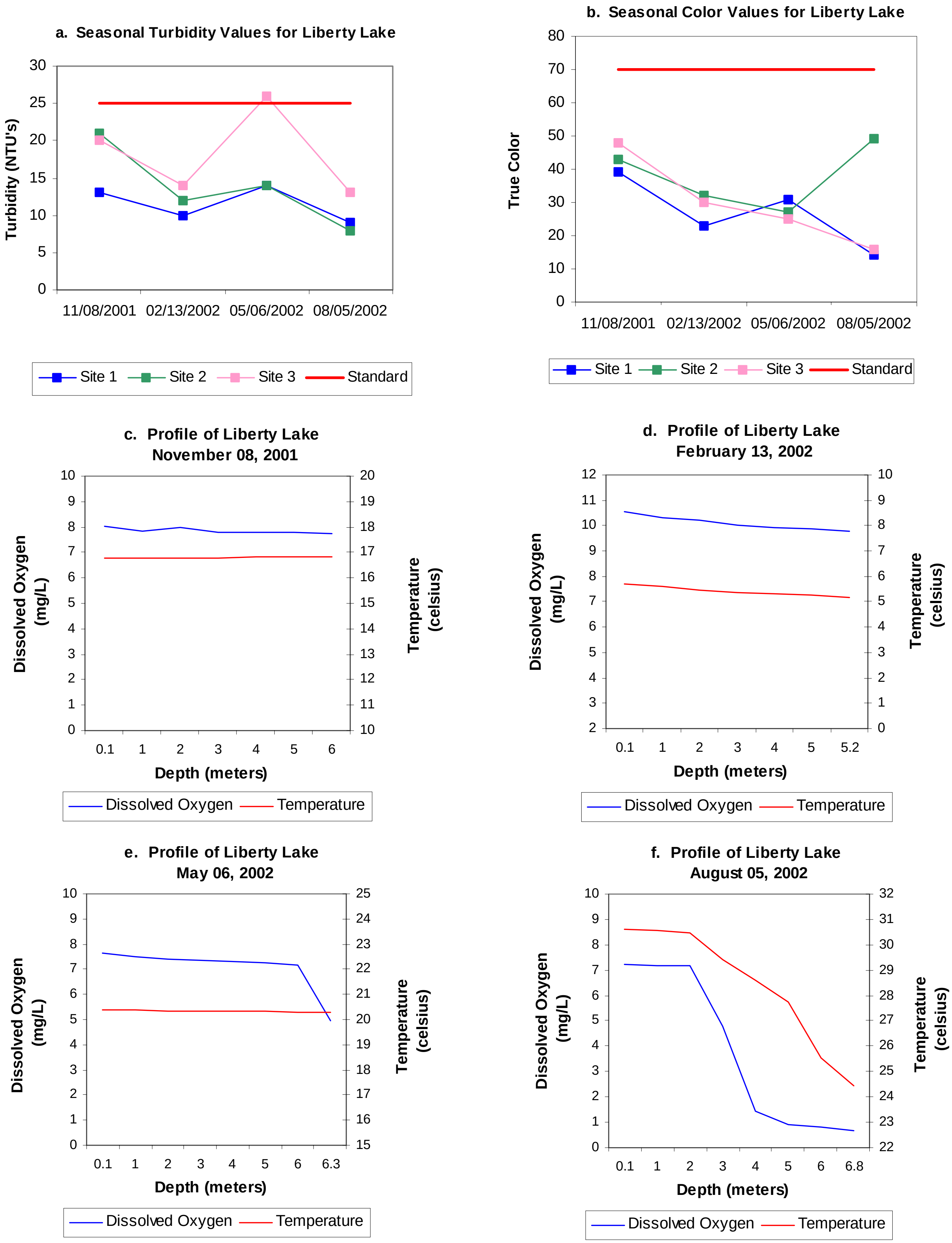


Figure 131a-129f. Graphical representation of data results for Liberty Lake.

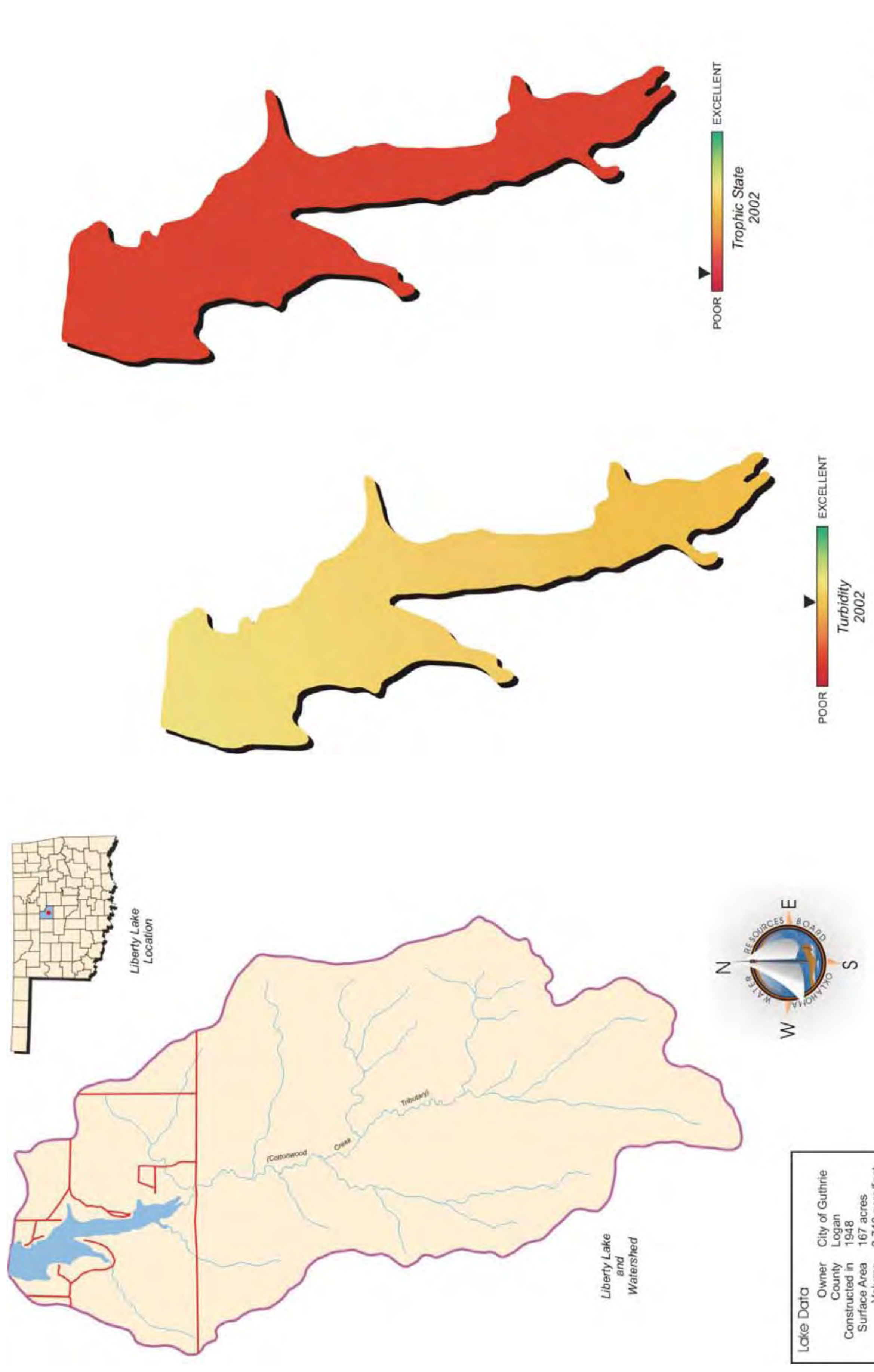


Plate 58- Lake Water Quality for
Liberty Lake

Lloyd Church (Wilburton) Lake

Lloyd Church Lake was sampled for three seasons, from February 2001 through August 2001. Several attempts were made in the fall quarter to sample the lake, however, due to drought conditions; the lake level was too low to launch a boat until late in the winter quarter. Water quality samples were collected at 3 sites to represent the riverine, transition, and lacustrine zones of the reservoir in the winter, spring, and summer. Although there are only 3 sites designated for Lloyd Church Lake (160 surface acres), an extra sample was collected in the winter to meet the minimum data requirements (n=10) listed in the Use Support Assessment Protocols (USAP) outlined in the Oklahoma Administrative Code (OAC) 785:46-15-3 for lakes under 250 surface acres. 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 19 NTU, true color was 27 units, and secchi disk depth was 69 centimeters in 2001. Based on these three parameters, Lloyd Church Lake had fair water clarity in comparison to other Oklahoma reservoirs. Water clarity was fairly similar in the summer of 1997, although based on only three samples. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters plus the additional site in the winter (n=10). The average TSI was 49, classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is slightly lower than the one calculated in 1997 (TSI=52) but is most likely a more accurate depiction of the trophic status at Lloyd Church Lake as the 2001 value is based on more samples collected in seasons other than just the summer. The TSI values were mesotrophic in the winter and the lower end of eutrophic in the spring and summer of 2001. The turbidity values in the winter quarter exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU constituting a listing as “partially supporting” the Fish & Wildlife Propagation (FWP) beneficial use. 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 OWQS (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 of the true color values were below the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is considered fully supported.

Please refer to the “Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report” for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency’s web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Lone Chimney Lake

Lone Chimney Lake was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. In addition, samples were collected at the lake surface at sites 4 and 5 for the analysis of chlorophyll-a and turbidity in order to meet minimum data requirements. 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 14 NTU (Plate 59), true color was 30 units, and secchi disk depth was 56 centimeters in 2001-2002. Based on these three parameters, Lone Chimney Lake had good 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 all quarters (n=20). The average TSI was 55 (Plate 59), 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 (see Figure 132). The turbidity values were all at or below the Oklahoma Water Quality Standard (OWQS) of 25 NTU with the exception of one value collected in the fall quarter at site 2 (see Figure 133a). 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 OWQS (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 collected data exceeding the turbidity criteria Lone Chimney Lake is meeting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 133b. All of the true color values were below the numeric criteria of 70 units, however, the Aesthetics beneficial use could not be definitively assessed due to insufficient data. Data collected strongly suggest that the lake is fully supporting its Aesthetics beneficial use for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.08 parts per thousand (ppt) to 0.13 ppt indicating low to moderate salt content and well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were somewhat lower, ranging from 287.9 mS/cm to 266 mS/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 6.94 units near the lake bottom in the summer quarter to 8.18 units near the lake surface also recorded in the summer quarter. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. With all collected pH values falling well within the acceptable range of pH, Lone Chimney

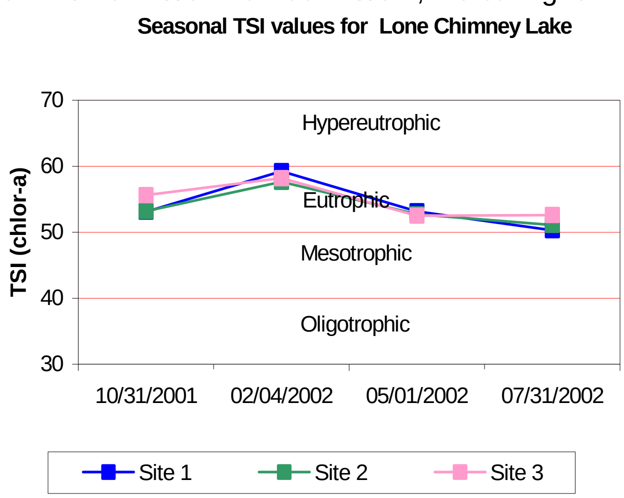


Figure 132. TSI values for Lone Chimney Lake.

Lake was fully supporting its FWP beneficial use. Oxidation-reduction potentials (redox) ranged from 26 mV at the sediment-water interface in the summer to 476 mV in the fall quarter. Redox readings indicated that slightly reducing conditions were present in the reservoir in the summer at sites 1 and 3, but not to an extent that would cause a concern. The lake was not thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 7.5 mg/L throughout the water column at all sites (see Figure 133c-129d). In the spring, the lake was strongly thermally stratified between 8 and 9 meters below the surface. Levels of D.O. were less than 2.0 mg/L from 10 meters to the lake bottom at 13.8 meters at site 1 (see Figure 133e). 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 all sites (see Figure 133f). 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 Lone Chimney Lake because 58% of the water column was anoxic in the summer quarter. With only 33% of the column less than 2.0 mg/L, the lake was fully supporting in the spring quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.60 mg/L at the lake surface. The TN at the surface ranged from 0.50 mg/L in the spring quarter to 0.69 mg/L recorded in the winter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.042 mg/L at the lake surface. The surface TP ranged from 0.026 mg/L in the summer to 0.062 mg/L in the fall. The nitrogen to phosphorus ratio (TN:TP) was approximately 16:1. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lone Chimney Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Lone Chimney Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 59). The lake was fully supporting its FWP beneficial use based on turbidity and pH values, however, anoxic conditions were present in the summer and constituted listing as partially supporting the FWP beneficial use based on D.O. values (OAC 785:46). Lone Chimney was supporting its Aesthetics beneficial used based on its assessed trophic status and no determination could be made on true color due to insufficient data, but collected information strongly suggests that the lake would support for true color. 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.

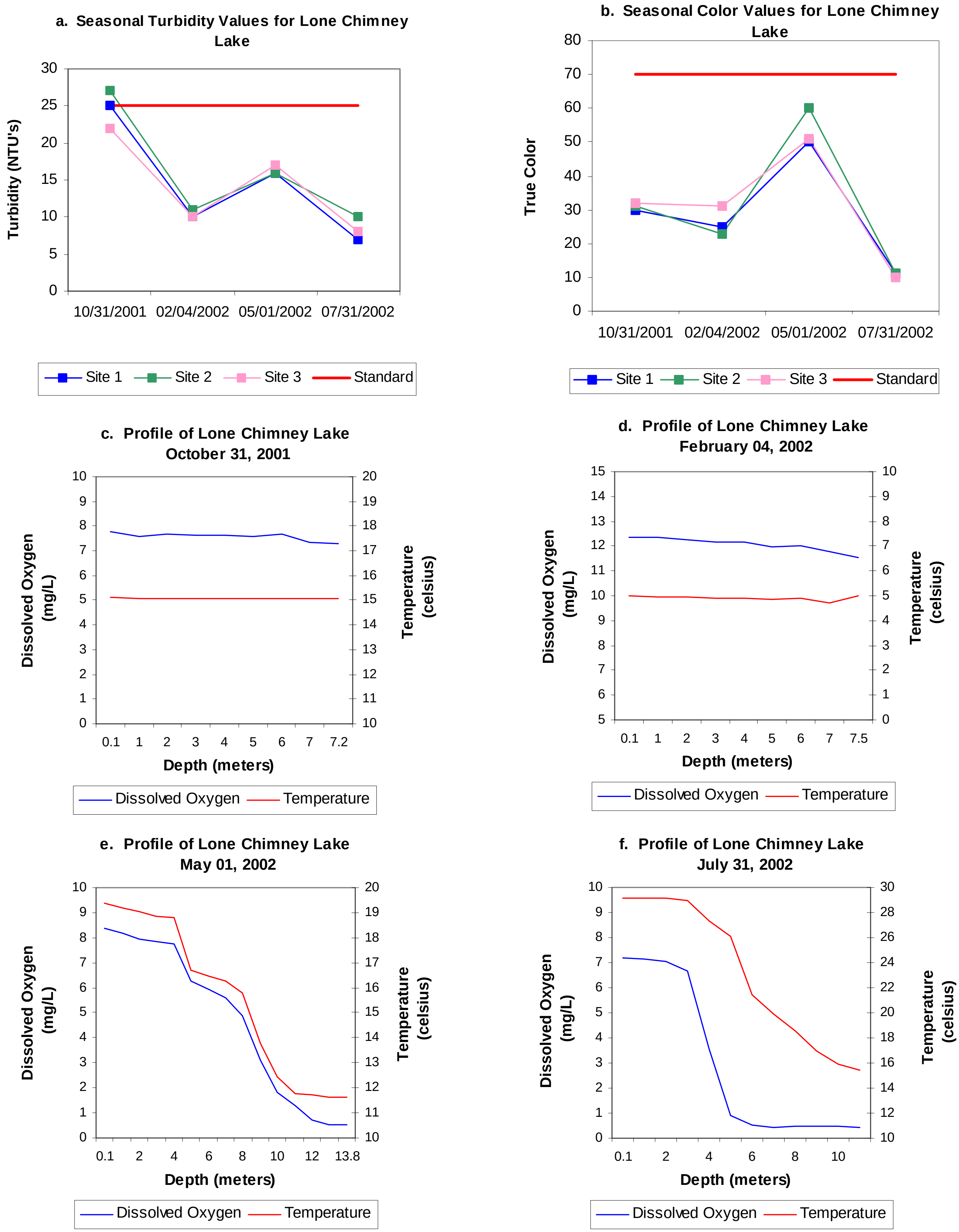
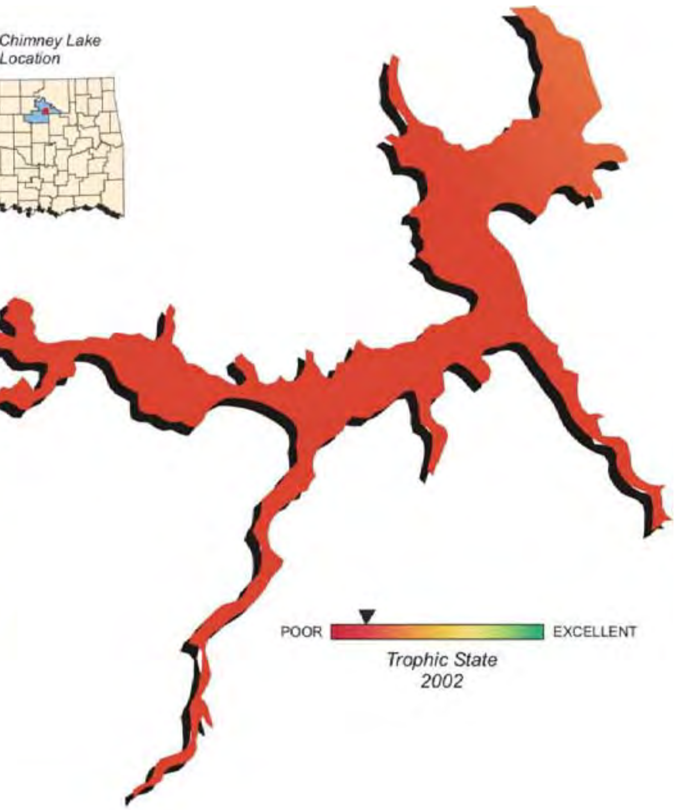
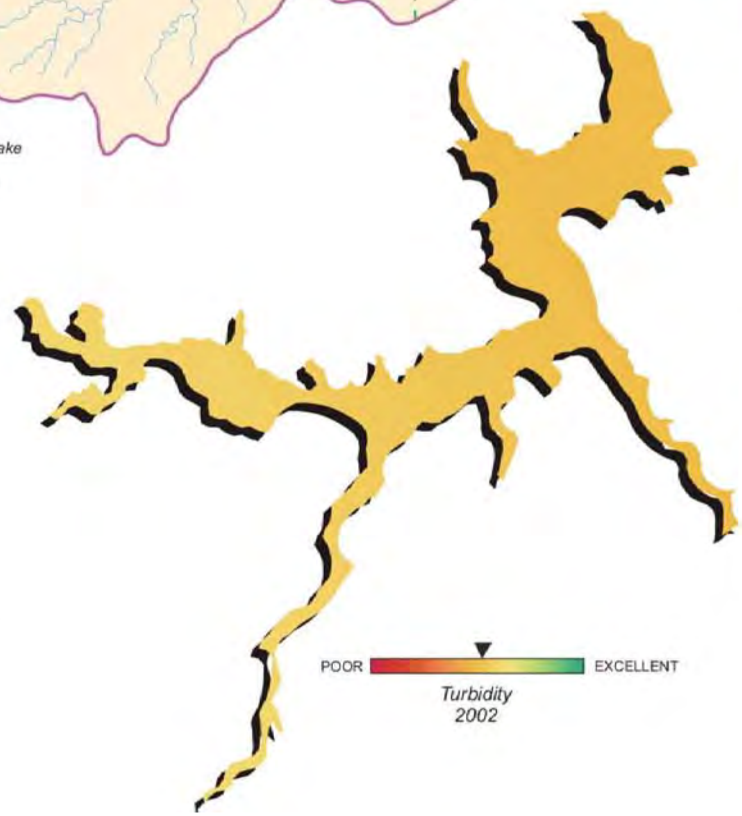


Figure 133a-131f. Graphical representation of data results for Lone Chimney Lake.

Lone Chimney Lake
and
Watershed

Lone Chimney Lake
Location





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 59 - Lake Water Quality for
Lone Chimney Lake

Lugert-Altus Reservoir

Lugert-Altus Reservoir was sampled for four quarters from November 2002 through June 2003. 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 19 NTU (Plate 60), true color was 22 units, and average secchi disk depth was 51 centimeters in sample year 2003. 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=20). The result was a TSI of 63 (Plate 60), indicating the lake was hypereutrophic in sample year 2003. The TSI values for all sites throughout the sample year were fairly consistent, with values ranging from upper eutrophic to lower hypereutrophic (Figure 134). This value is slightly higher than that in 2000 (TSI=57); however, fewer samples were used to calculate trophic status in 2000. Seasonal turbidity values are displayed in Figure 135a. Turbidity values ranged from a low of 6 NTU to a maximum of 46 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 (OWQS) of 25 NTU for turbidity. With 33% of the samples exceeding 25 NTU, the beneficial use of Fish and Wildlife propagation (FWP) should be considered not supported in regards to turbidity; however due to an accident in the lab there is not enough data to make an assessment. Seasonal true color values are displayed in Figure 135b. All color values were well below the aesthetics OWQS of 70 units.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all five sample sites. The salinity values for Lugert-Altus Reservoir ranged from 1.16 parts per thousand (ppt) to 1.25 ppt for this sample year. Specific conductance ranged from 2166 to 2346 mS/cm, which is higher than most Oklahoma reservoirs. These values indicate the presence of electrical current conducting compounds (salts) in the lake, consistent with higher salinity concentrations. The pH values at Lugert-Altus Reservoir were slightly acidic, ranging from 5.07 in the winter to 8.38 in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9

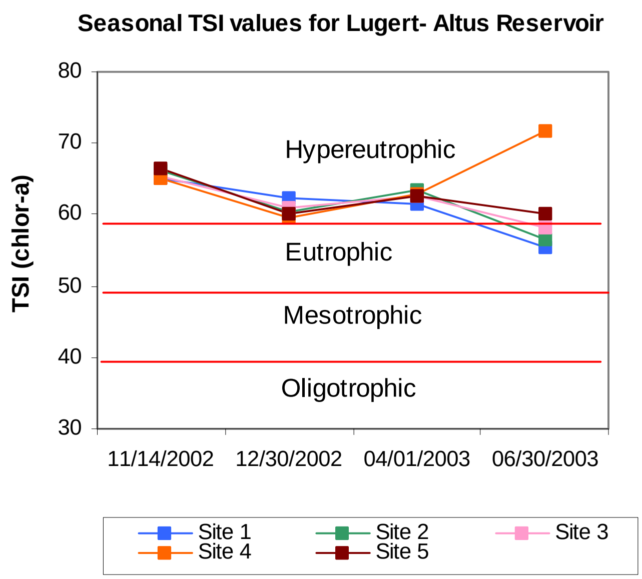


Figure 134. TSI values for Lugert-Altus Reservoir.

range the lake is considered partially supporting. With 22% of the values recorded being less than 6.5 the lake should be listed as partially supporting based on pH. The low pH values recorded primarily in the winter at Lugert-Altus may be due to natural conditions, and will be listed as "provisionally partially supporting"* the FWP. Oxidation-reduction potentials ranged from 401 mV in the summer to 564 mV in the fall. Reducing conditions were not present at this reservoir in the 2002-2003-sample year. During the fall, winter, and spring quarters stratification was not present and dissolved oxygen values were generally above 7 mg/L (see Figure 135c-133e). Thermal stratification was evident during the summer quarter, although, anoxic conditions were not present. Dissolved oxygen (D.O.) concentrations reached a low of 3.13 mg/L at the bottom of the lake (Figure 135f). 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 2002-2003 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 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

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.76 mg/L. The TN at the surface ranged from 0.44 mg/L to 1.38 mg/L in the upper reaches of the lake. Surface total nitrogen was highest in the summer and lowest in the spring. The lake-wide total phosphorus (TP) was 0.043 mg/L. The TP at the surface ranged from 0.028 mg/L to 0.087 mg/L. Similar to nitrogen, surface TP was highest in the summer but the lowest values were seen during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 18:1 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 hypereutrophic, indicative of excessive primary productivity and nutrients in 2003. This is a slight increase from 2000 where the calculated TSI resulted in a value of 57, which had placed the lake in the eutrophic category. More data was available this past sample year, resulting in a more accurate determination of trophic state and does not necessarily indicate that there was an increase in productivity. Water clarity was fair based on secchi disk depth and turbidity. The lake will be considered for addition to the OWQS as a nutrient-limited watershed (NLW). The lake is supporting its FWP beneficial use based on dissolved oxygen values and partially supporting based on pH. A determination based on turbidity could not be made at this time, as a minimum sample requirement was not met. The lake is supporting the Aesthetics beneficial use based on true color, but not supporting based on its trophic status (TSI=63). Lugert-Altus Reservoir is located in Greer county and is utilized for water supply, flood control and irrigation purposes.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

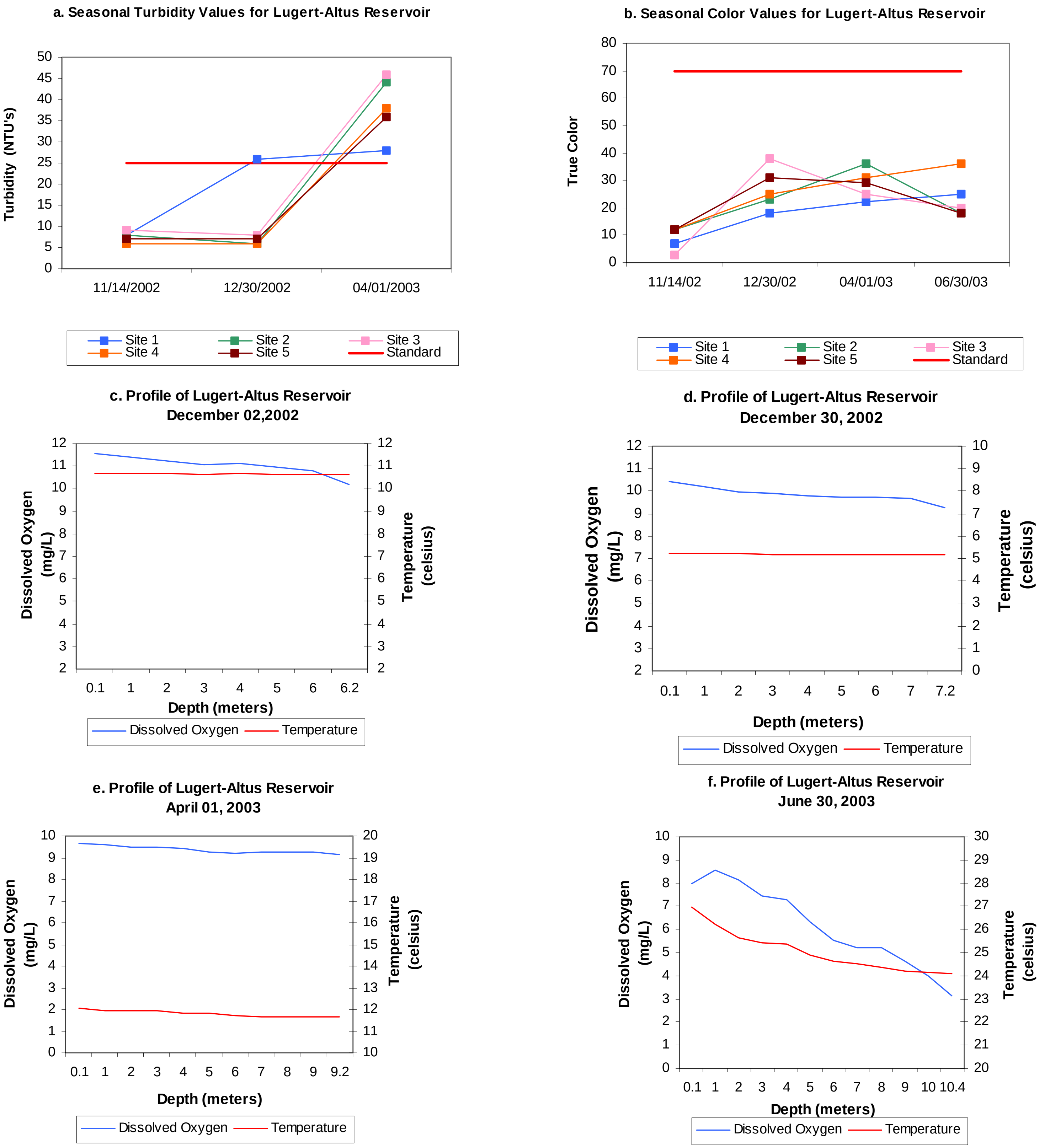


Figure 135a-133f. Graphical representation of data results for Lugert-Altus Reservoir.

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 60 - Lake Water Quality for
Lugert-Altus Lake

Maysville (Wiley Post) Lake

Maysville Lake was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transition, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 at the lake surface for the purpose of assessing chlorophyll-a and turbidity concentrations. 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 44 NTU (Plate 61), true color was 64 units, and secchi disk depth was 31 centimeters in 2001-2002. Based on these three parameters, Maysville 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 57 (Plate 61), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. The TSI values varied seasonally with the lake being mesotrophic in the fall, eutrophic in the winter and spring and bordering on hypereutrophic in the summer quarter (see Figure 136). The turbidity values collected on this lake almost always exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU constituting a listing as not supporting the Fish & Wildlife Propagation (FWP) beneficial use (see Figure 137a). 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 OWQS (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 exceeding the criteria, turbidity is a beneficial use problem in Maysville Lake. Seasonal true color values are displayed in Figure 137b. Of the true color values collected 42% were above the numeric criteria of 70 units, however, the Aesthetics beneficial could not be definitively assessed due to insufficient data. Available data strongly suggested that the lake would not be supporting its Aesthetics beneficial use for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.18 parts per thousand (ppt) to 0.25 ppt indicating moderate salt content and the values were well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance ranged from 357.5 mS/cm to 503.7 mS/cm, 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 7.48 units in the summer quarter to 8.79 units in the winter. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. With none of the collected values falling outside the specified range, Maysville Lake is fully supporting its FWP beneficial use. Oxidation-reduction potentials (redox) ranged

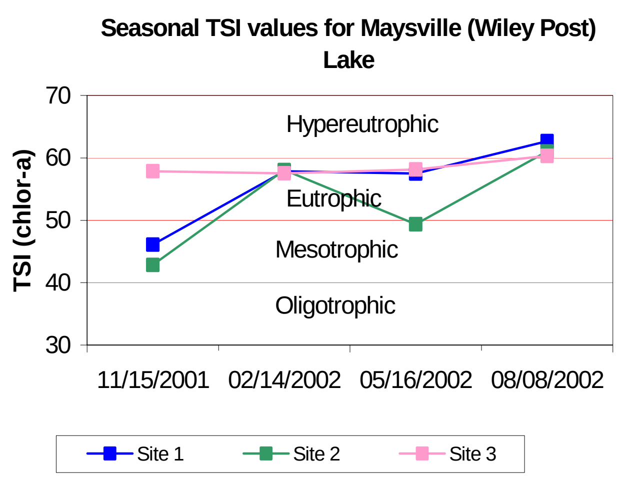


Figure 136. TSI values for Maysville Lake.

from 142 mV at the sediment-water interface in the summer to 380 mV in the fall quarter. Redox readings indicated that reducing conditions were not present in the reservoir at any point when the lake was sampled. The lake was not thermally stratified in the fall, winter or spring quarters and dissolved oxygen (D.O.) values were above 5.7 mg/L throughout the entire water column at all sites and were generally above 7.3 mg/L in most of the water column (see Figure 137c-135e). 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 4.5 meters deep when sampled in the summer quarter this was an unexpected occurrence. The water column at site 1 had D.O. readings less than 1.0 mg/L from 3 meters to the lake bottom (see Figure 137f). 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. 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 partially supported at Maysville Lake because approximately 50% of the water column was anoxic at site 1 in the summer. 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 occurs. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.73 mg/L at the lake surface. The TN at the surface ranged from 0.51 mg/L in the winter to 0.87 mg/L in the spring quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.087 mg/L at the lake surface. The surface TP ranged from 0.053 mg/L in the winter quarter to 0.114 mg/L in the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2001-2002. This value is slightly greater than 7:1, characterizing the lake as potentially phosphorus-limited (Wetzel, 1983).

Maysville Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Maysville Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 34). Most of the turbidity values were above the OWQS of 25 NTU, constituting a non-support of the FWP beneficial use based on turbidity (OAC 785:46). The lake was fully supporting the FWP beneficial use based on pH, however, anoxic conditions present in the summer constituted a non-support of the FWP beneficial use based on D.O. values collected in the water column (OAC 785:46). Maysville is fully supporting its Aesthetics beneficial use based on the lakes trophic status but not enough information was available to assess the Aesthetics use for true color. 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.

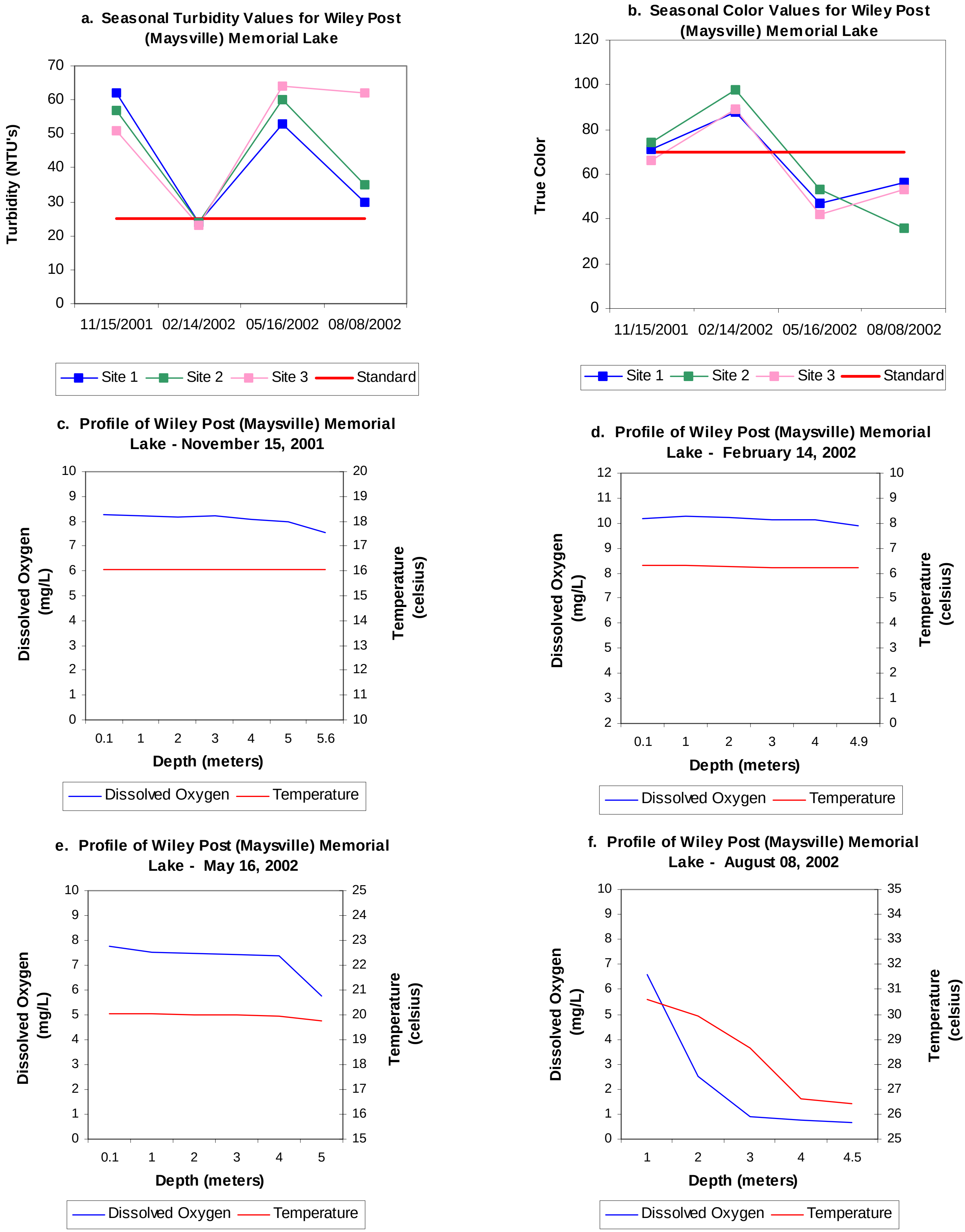
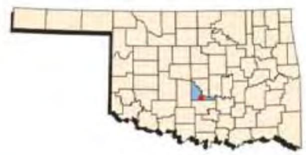
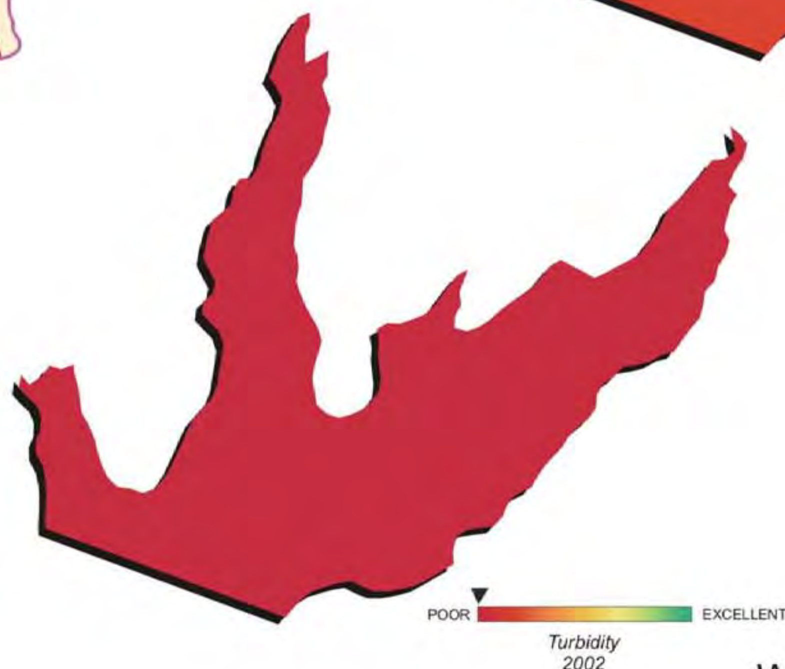


Figure 137a135f. Graphical representation of data results for Maysville Lake.



N
W E
S



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 61 - Lake Water Quality for

Wiley Post (Maysville) Lake

Lake McAlester

Lake McAlester was sampled for four quarters, from October 2002 through July 2002. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for a reservoir larger than 250 surface acres in size. 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 83 NTU (Plate 62), true color was 244 units, and secchi disk depth was 20 centimeters in 2003. Based on these three parameters, Lake McAlester had poor 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 average TSI was 45 (Plate 62), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is similar to the one calculated in 2001 (TSI=47), and in the same trophic category, but is likely a more accurate depiction of trophic status as more samples were collected throughout the year. 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 values in 2003 were primarily mesotrophic although values at site 1 were oligotrophic in the fall and eutrophic in the winter (Figure 138). All turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see 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 OWQS (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 exceeding the OWQS of 25 NTU, the lake is not supporting the Fish and Wildlife Propagation (FWP) beneficial use. True color was fairly consistent and was above the aesthetics OWQS of 70 units at all sites (Figure 139b). Although 100% of the samples collected in 2003 were above the standard, a use determination cannot be made as the minimum data requirements of 20 samples for lakes greater than 250 surface acres were not met

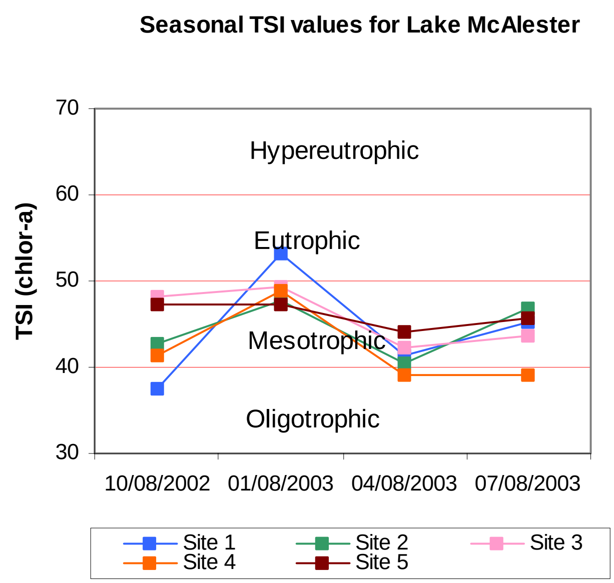


Figure 138. TSI values for Lake McAlester.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.03 ppt. This is within the average values reported for Oklahoma lakes. Specific conductivity ranged from 61.8 mS/cm to 91.3 mS/cm indicating that minimal concentrations of electrical current conducting compounds were present in the lake system. The pH values at Lake McAlester ranged from 6.56 to 7.79, representing a slightly acidic to neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all of the collected values within the acceptable range the lake is considered to be supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 400 mV in the summer to 593 mV in the fall. Reducing conditions were not present at this reservoir with all values being positive and above 100 mV through the study period. 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 139c-137e). Thermal stratification was evident in the summer and anoxic conditions were present. In the summer, stratification occurred between 5 and 6 meters at which point the D.O. fell below 2.0 mg/L to the lake bottom of 10 meters accounting for approximately 45% of the water column, at site 1, to be anoxic (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. 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 McAlester based on D.O. values in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2002-2003 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. The PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.66 mg/L at the surface and 0.56 mg/L at the lake bottom. Surface TN ranged from 0.33 mg/L to 0.96 mg/L, with the highest values reported in the summer and the lowest values in the winter. The lake-wide total phosphorus (TP) average was 0.110 mg/L at the surface and 0.098 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.035 mg/L to 0.174 mg/L. Similar to TN, surface TP was highest in the summer and lowest during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 6:1 for sample year 2003. This is slightly lower than 7:1, characterizing the lake as potentially nitrogen limited to co-limited (Wetzel, 1983).

In summary, Lake McAlester was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in sample year 2002-2003. Similar conditions were found during the 2000 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, partially supporting based on dissolved oxygen and not supporting based on the extremely high turbidity values. The Aesthetics beneficial use is supported based on its trophic status, however a use determination based on true color cannot be made as the minimum data requirements of 20 samples for lakes greater than 250 surface acres were not met. Lake McAlester is located in Pittsburg County and was constructed in 1930 for water supply and recreational purposes.

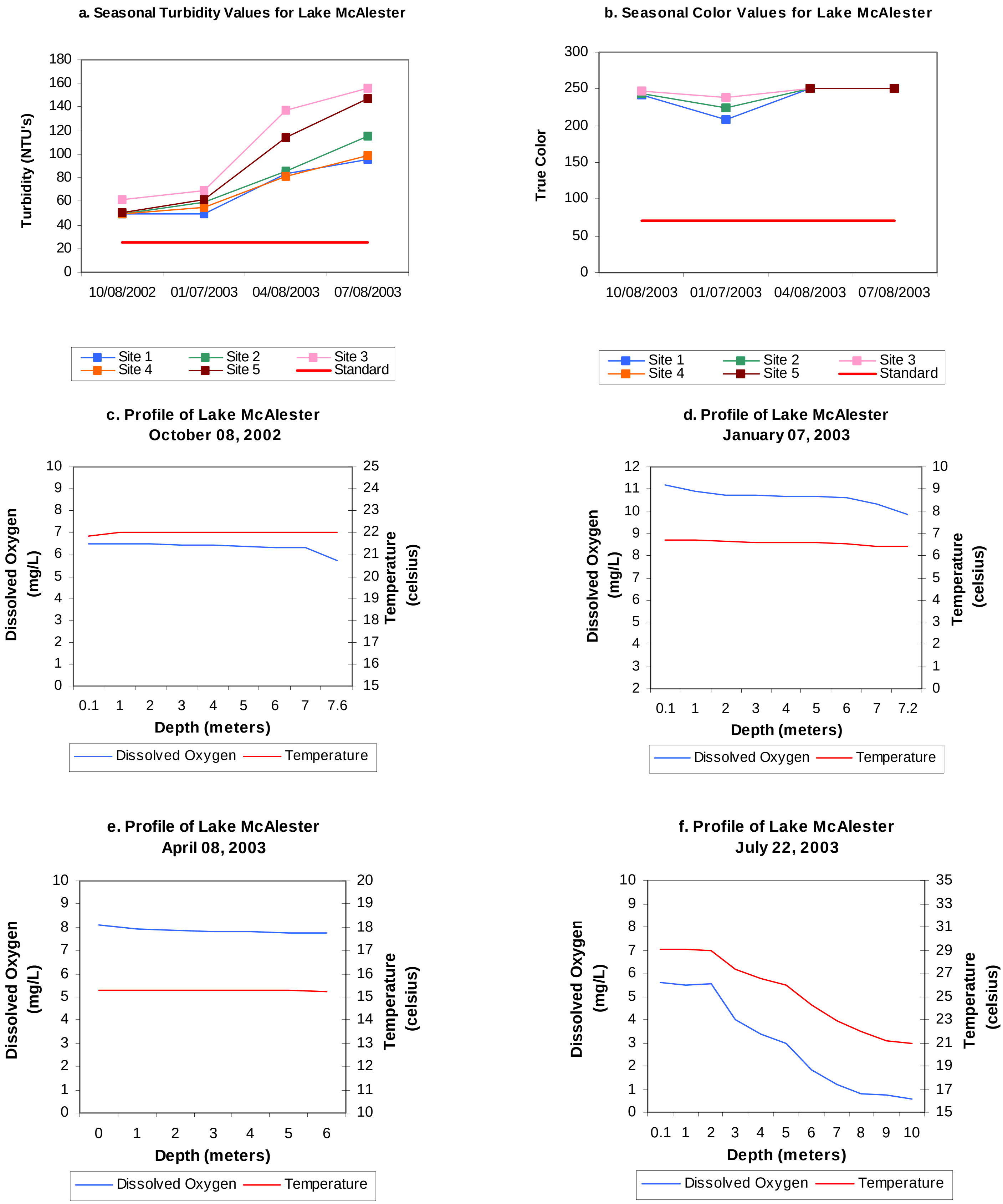


Figure 139a-137f. Graphical representation of data results for Lake McAlester.

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

Plate 62 - Lake Water Quality for
Lake McAlester

McGee Creek Lake

McGee Creek Lake was sampled for four quarters, from November 2001 through August 2002. 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. 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 8 NTU (Plate 63), true color was 63 units, and secchi disk depth was 103 centimeters in 2001-2002. Based on these three parameters, McGee Creek Lake had excellent water clarity in comparison to other Oklahoma reservoirs. McGee Creek is a slightly "stained" lake and true color values are elevated over the normal range of values characteristic of most Oklahoma lakes. 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 46 (Plate 63), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. The TSI values were consistent across all sample seasons varying from lower mesotrophic to upper mesotrophic at all sites. The most productive quarter observed in the lake was actually in the wintertime, which is not a common occurrence for Oklahoma reservoirs (see Figure 140). All of the collected turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see 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 OWQS (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 141b. Approximately 35% of the true color values were above 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 not supported based on the true color values. A violation of the true color criteria is not a common occurrence and McGee Creek is one of the very few lakes that is not supporting due to color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.07ppt indicating the presence of low levels of "salts" in the lake and levels were well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were extremely low, ranging from 0.0 mS/cm to 154 mS/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 5.81 in the spring quarter to 8.23 units in the summer quarter. 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 should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall

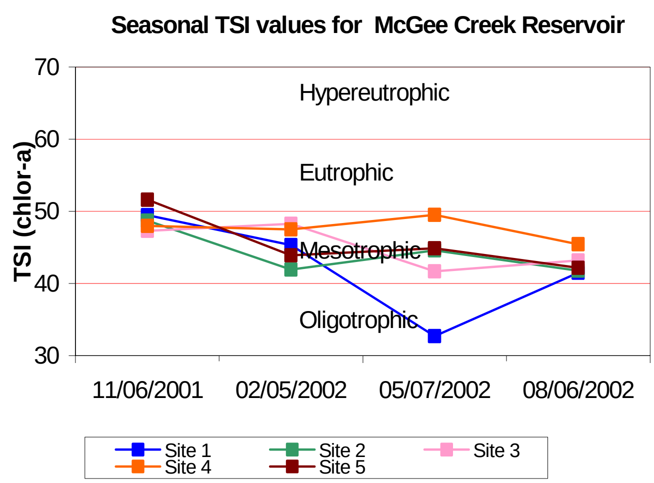


Figure 140. TSI values for McGee Creek Lake.

outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. The low pH values (below 6.5 units) recorded throughout the water column in the fall, spring and summer are cause to list McGee Creek Lake as “provisionally not supporting”* its FWP beneficial use. Oxidation-reduction potentials (redox) ranged from 0.0 mV at the sediment-water interface in the fall quarter to 454 mV in the summer. Redox readings indicated that reducing conditions were not present in the reservoir in the winter, spring, or summer sampling intervals, but the lake was experiencing slightly reducing conditions in the fall quarter site 1. The lake was not thermally stratified in fall quarter to any appreciable degree, however approximately 43% of the water column was experiencing dissolved oxygen (D.O.) concentrations below 1.5 mg/L at site 1 near the dam (see Figure 141c). 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 141d). In the spring, the lake was strongly thermally stratified at several 1-meter intervals, the first one between 3 and 4 meters below the lake surface and another thermal stratification event observed at the 10 to 11 meter depth. All D.O. concentrations remained above 2.0 mg/L throughout the water column at all sites (see Figure 141e). In the summer quarter, the lake was very strongly thermally stratified at several discrete levels from 3 meters below the surface extending to 10 meters below the lake surface. From 5 meters below the surface to the lake bottom at 30 meters at site 1 near the dam, D.O. values were generally less than 1.5 mg/L (see Figure 141f). 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 84% of the water column experiencing anoxic conditions near the lake dam, McGee Creek Lake is not supporting its FWP beneficial use based on low D.O. readings in the water column. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.42 mg/L at the lake surface. The TN at the surface ranged from 0.25 mg/L in the winter quarter to 0.67 mg/L in the spring. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.025 mg/L at the lake surface. The surface TP ranged from 0.011 mg/L in the summer to 0.100 mg/L also recorded in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 17:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

McGee Creek Lake was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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 mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 63). The lake was fully supporting its FWP based on turbidity readings, however it is not supporting the FWP beneficial use based on low pH and D.O. readings in the water column. The lake was not supporting its Aesthetics beneficial use based on high true color readings. This is not a common occurrence in Oklahoma reservoirs. The lake was supporting its Aesthetics use based on its trophic state though. 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 142) was generated to determine current storage capacity and identify areas of extreme sedimentaion. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

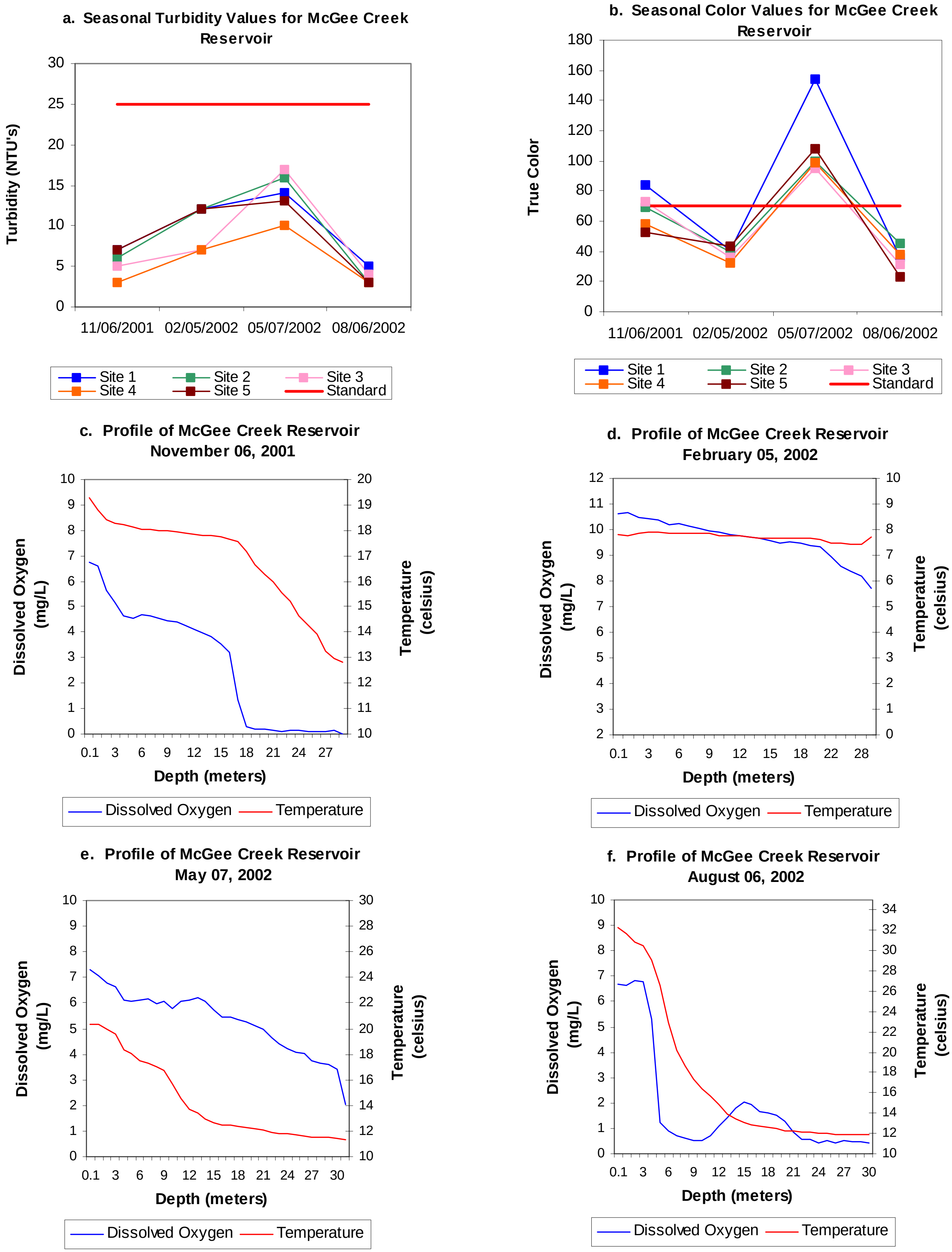
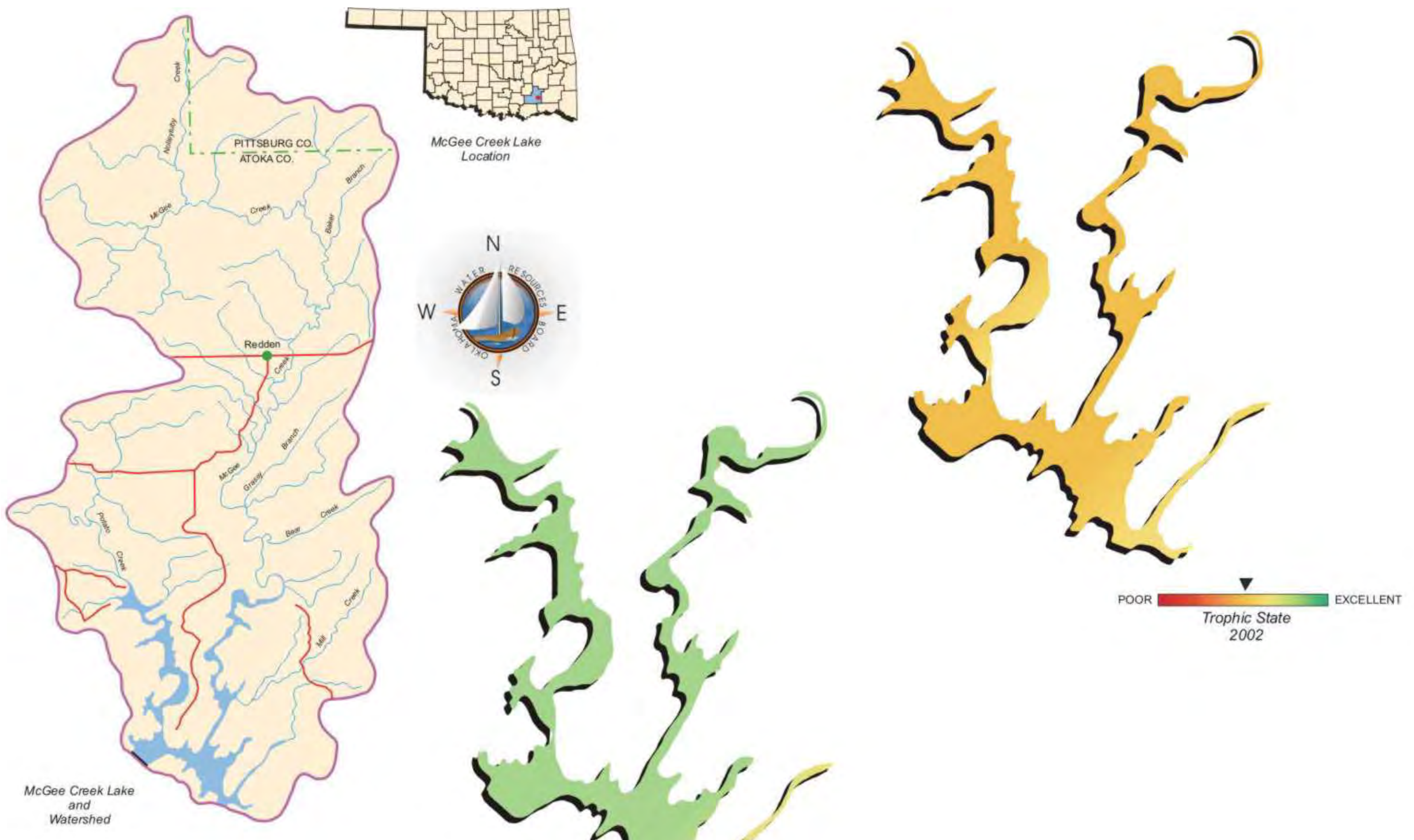


Figure 141a-139f. Graphical representation of data results for McGee Creek Lake.



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 63 - Lake Water Quality for
McGee Creek Lake

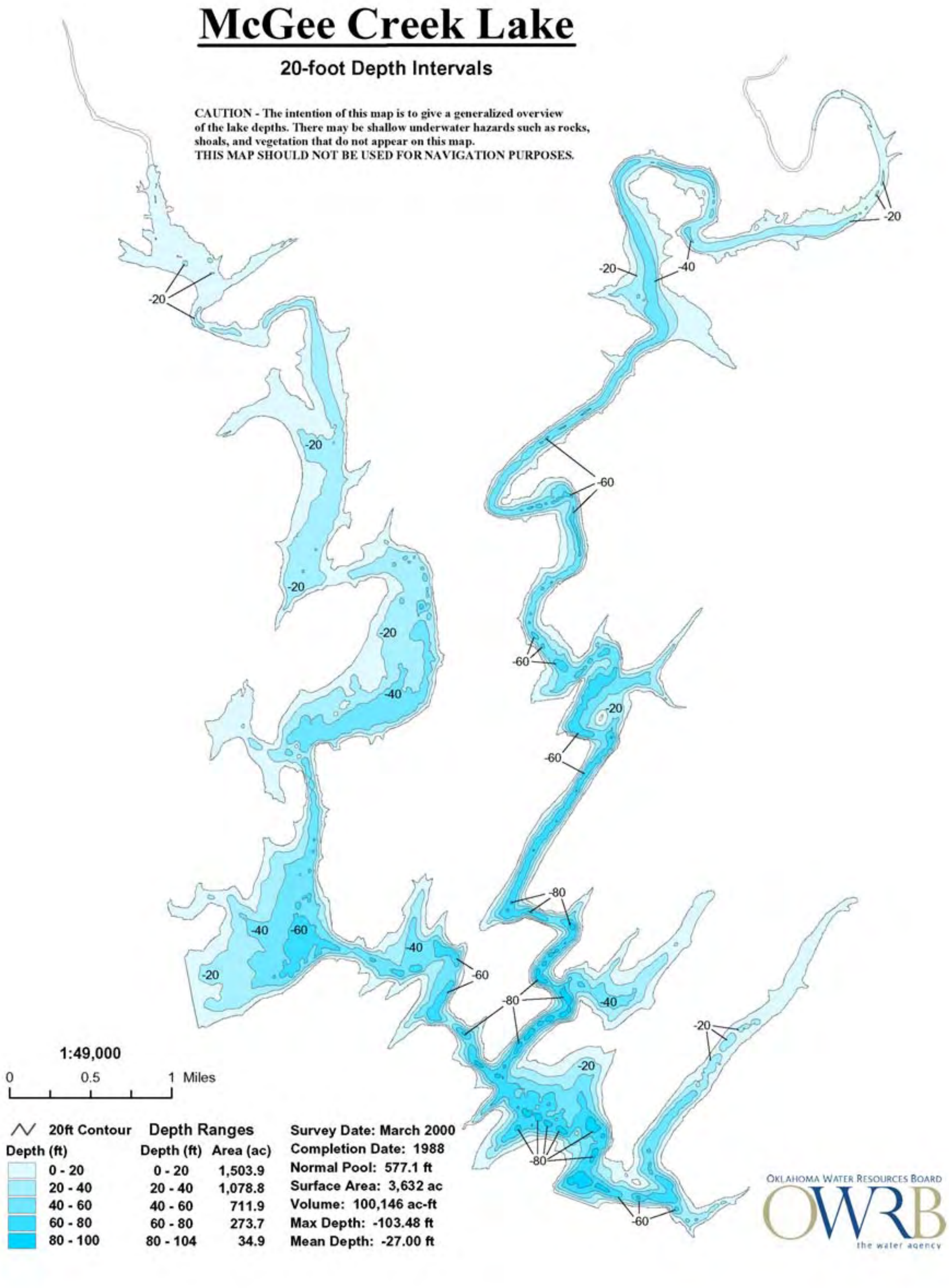


Figure 142. Bathymetric map of McGee Creek Reservoir.

Lake McMurtry

Lake McMurtry was sampled for four quarters from October 2001 through July 2002. 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 15 NTU (Plate 64), true color was 39 units, and secchi disk depth was 69 centimeters in 2002. Based on these three parameters, Lake McMurtry had average 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=20). The average TSI was 50 (Plate 64), classifying the lake at the upper end of mesotrophy, indicative of moderate levels of primary productivity and nutrients. The TSI values in 2001-2002 varied seasonally with the lake at the lower end of eutrophy in the fall and in the spring. The lake was upper mesotrophic in the summer and oligotrophic during the winter quarter (see Figure 143). Almost all of the turbidity values collected were less than the Oklahoma Water Quality Standard (OWQS) of 25 NTU except for one value collected in the spring at the upper end of the lake (see Figure 144a). 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 OWQS (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 samples collected above the standard the lake is fully supporting its Fish & Wildlife Propagation (FWP) based on nephelometric turbidity. Seasonal true color values are displayed in Figure 144b. Much like the turbidity data collected, almost all readings were below the OWQS of 70 units with the exception of one site in the upper end of the lake in the spring quarter (see Figure 144b). With only 5% of the collected data violating the OWQS the Aesthetics beneficial use is considered fully supported.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.21ppt, indicating low to elevated salt content. Collected values were well within the expected range of salinity values reported for most Oklahoma lakes though some readings were above the expected range. Readings for specific conductance were also within the range of normally encountered values, ranging from 0.0 mS/cm (probably due to operator error) to 426.2 mS/cm, 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 7.32 units at the lake bottom in the spring quarter to 8.49 units recorded at the lake surface in the summer quarter. 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 should be listed as not supporting beneficial uses. If 10 to 25% of the pH values

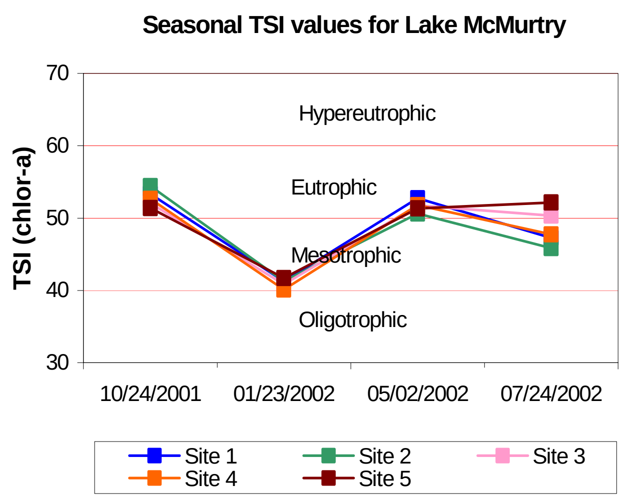


Figure 143. TSI values for Lake McMurtry.

fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. None of the collected values fell outside the acceptable range so the FWP beneficial use is fully supported based on pH. Oxidation-reduction potentials (redox) ranged from 39 mV in the summer to 457 mV in the fall quarter, indicating an absence of reducing conditions in the water column. Lake McMurtry was not thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 7.5 mg/L throughout the water (see Figure 144c-141d). In the spring quarter the lake was strongly thermally stratified near the lake bottom indicating the initial onset of stratification. One D.O. values below 2.0 mg/L was recorded near the sediment-water interface at site 1 near the dam (see Figure 144e). In the summer, the lake was thermally stratified near the 5 to 6 meter depth. Below a depth of 5 meters the D.O. values were less than 2.0 mg/L to the lake bottom at 12.5 meters (see Figure 144f). 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 Lake McMurtry because 57% of the water column was anoxic at site 1 in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.56 mg/L at the lake surface. The TN at the surface ranged from 0.32 mg/L to 0.78 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 for sample year 2001-2002 was 0.024 mg/L at the lake surface. The surface TP ranged from 0.17 mg/L to 0.34 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 23:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake McMurtry was sampled for metals at five sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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, Lake McMurtry was classified as upper mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 64). According to USAP (OAC 785:46), the lake was fully supporting its FWP beneficial use based on turbidity and pH values and partially supporting the use based on low D.O. readings. The lake was fully supporting its Aesthetics beneficial use based on true color and lake trophic status findings. 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.

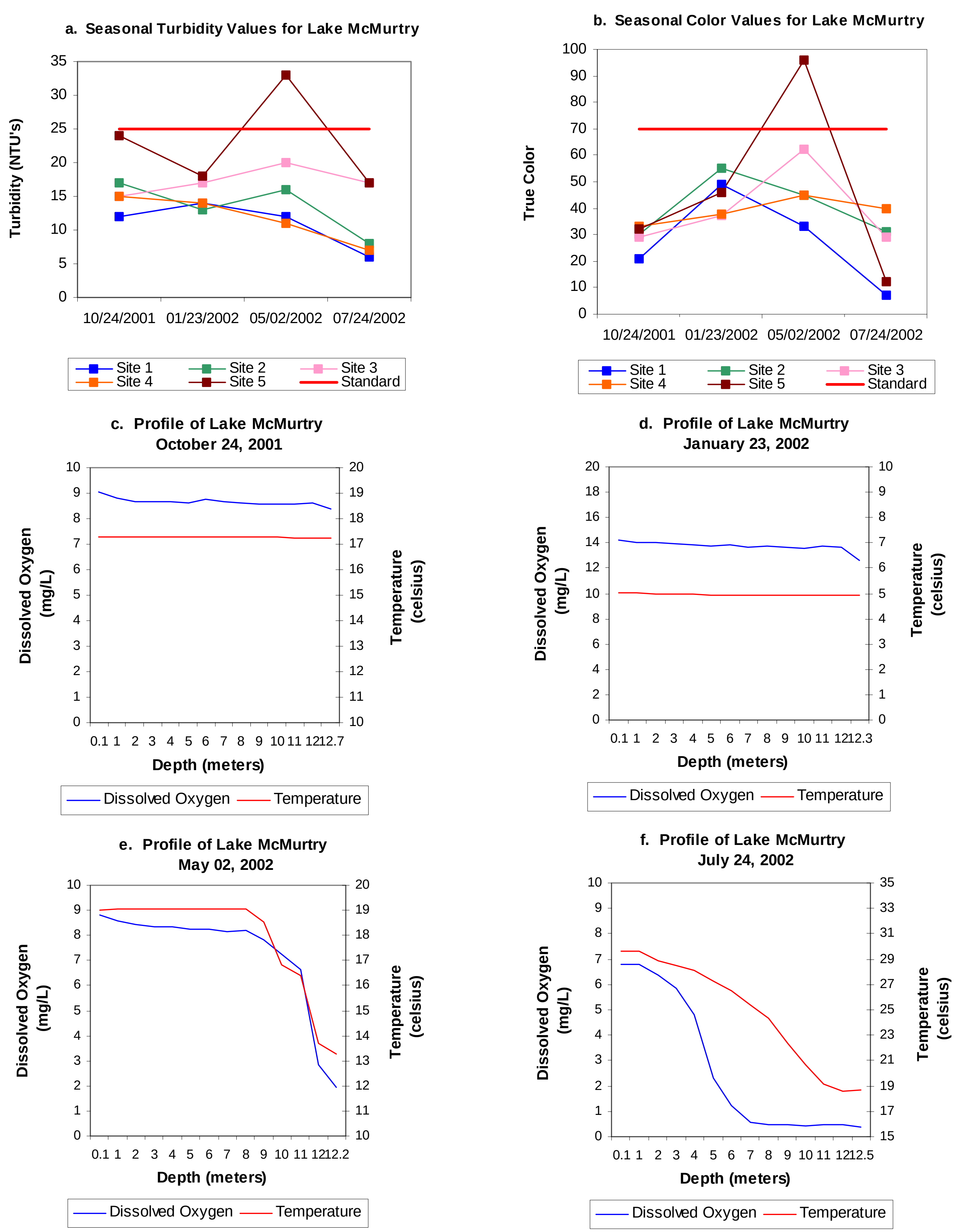


Figure 144a-141f. Graphical representation of data results for Lake McMurtry.

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

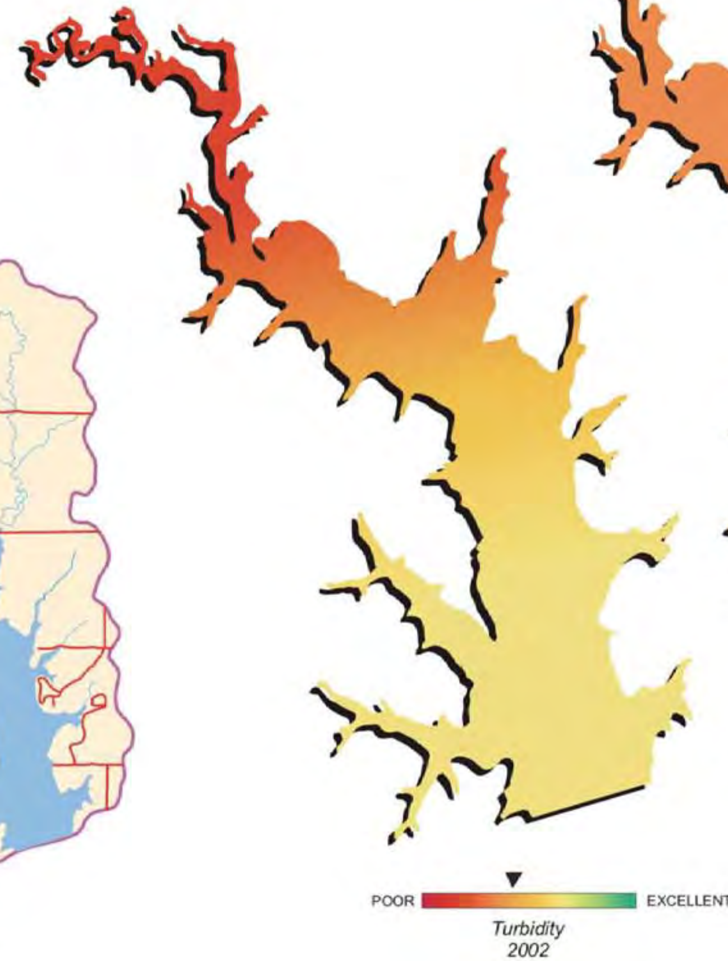


Plate 64 - Lake Water Quality for
Lake McMurtry

Meeker Lake

Meeker Lake was sampled for four quarters, from October 2001 through July 2002. 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 99 NTU (Plate 65), true color was 155 units, and secchi disk depth was 14 centimeters in 2001-2002. Based on these three parameters, Meeker Lake had poor water clarity in 2001-2002 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 46 (Plate 65), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. The TSI values varied seasonally from Oligotrophic in the fall quarter to lower mesotrophy in the winter and upper mesotrophy in the spring and summer (see Figure 145). The low primary productivity in this lake was no doubt due in large measure to the high turbidity limiting the light available for biological use. All turbidity values in 2001-2002 were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU and in many instances were almost 4 times the standard (see Figure 146a). The annual turbidity value of 99 NTU accurately reflects turbidity at Meeker Lake based on historical data collection efforts. 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 OWQS (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 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 146b. True color values varied somewhat seasonally and were all well above the aesthetics OWQS of 70 units at all sites. Based on the available data, the Aesthetics beneficial use for Meeker Lake is not supporting as well (see Figure 146b).

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.10ppt, indicating low to moderate salt content and within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were also within the expected range of values reported for most Oklahoma lakes, ranging from 165.3 mS/cm to 223.4 mS/cm, indicating the presence of small concentrations of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were neutral to very slightly alkaline with values ranging from 7.22 units in the summer to 8.39 in the winter quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside

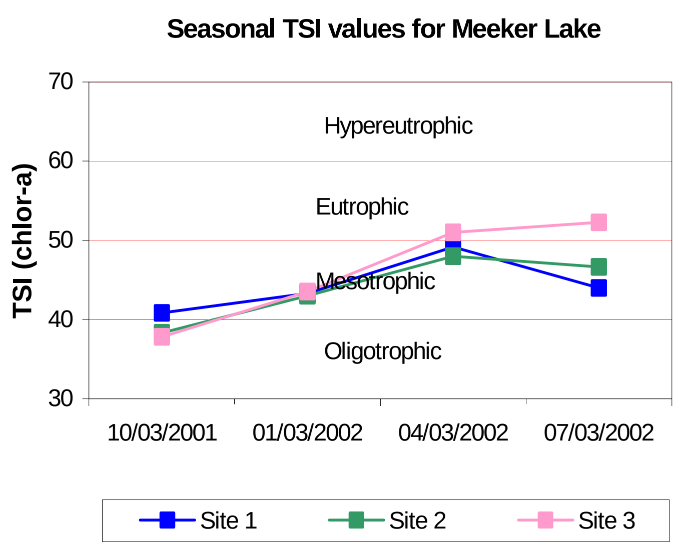


Figure 145. TSI values for Meeker Lake.

the 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With no values falling outside the acceptable range the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 141 mV in the spring to 542 mV in the fall 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 7.3 mg/L throughout the water column in all three seasons (see Figure 146c-143e). In the summer the lake was thermally stratified between 4 and 5 meters, and below 4 meters D.O. values were less than 1.0 mg/L all the way to the lake bottom at 6.6 meters at site 1 near the dam (see Figure 146f). 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 Meeker Lake because only 38% of the water column was anoxic at site 1 in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.68 mg/L at the lake surface. The TN at the surface ranged from 0.45 mg/L to 0.89 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was reported in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.067 mg/L at the lake surface. The surface TP ranged from 0.049 mg/L to 0.090 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 10:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Meeker Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Meeker Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 65). The lake is fully supporting its Aesthetics beneficial use based on a trophic state of mesotrophic, but is not supporting the use based on excessive levels of true color in the water column. 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 (USAP 785:46). 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 is one of Oklahoma's more turbid reservoirs.

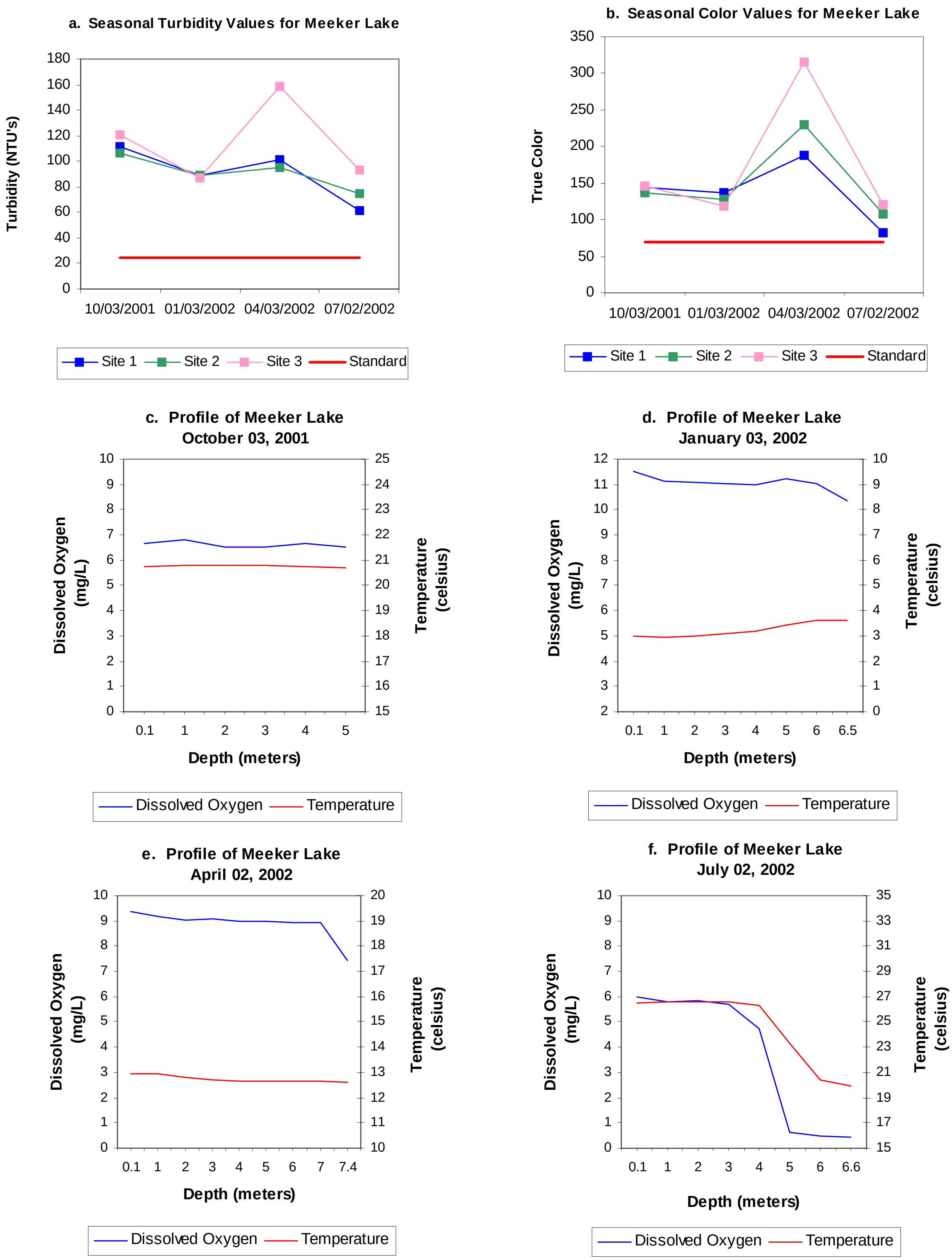


Figure 146a-143f. Graphical representation of data results for Meeker Lake.

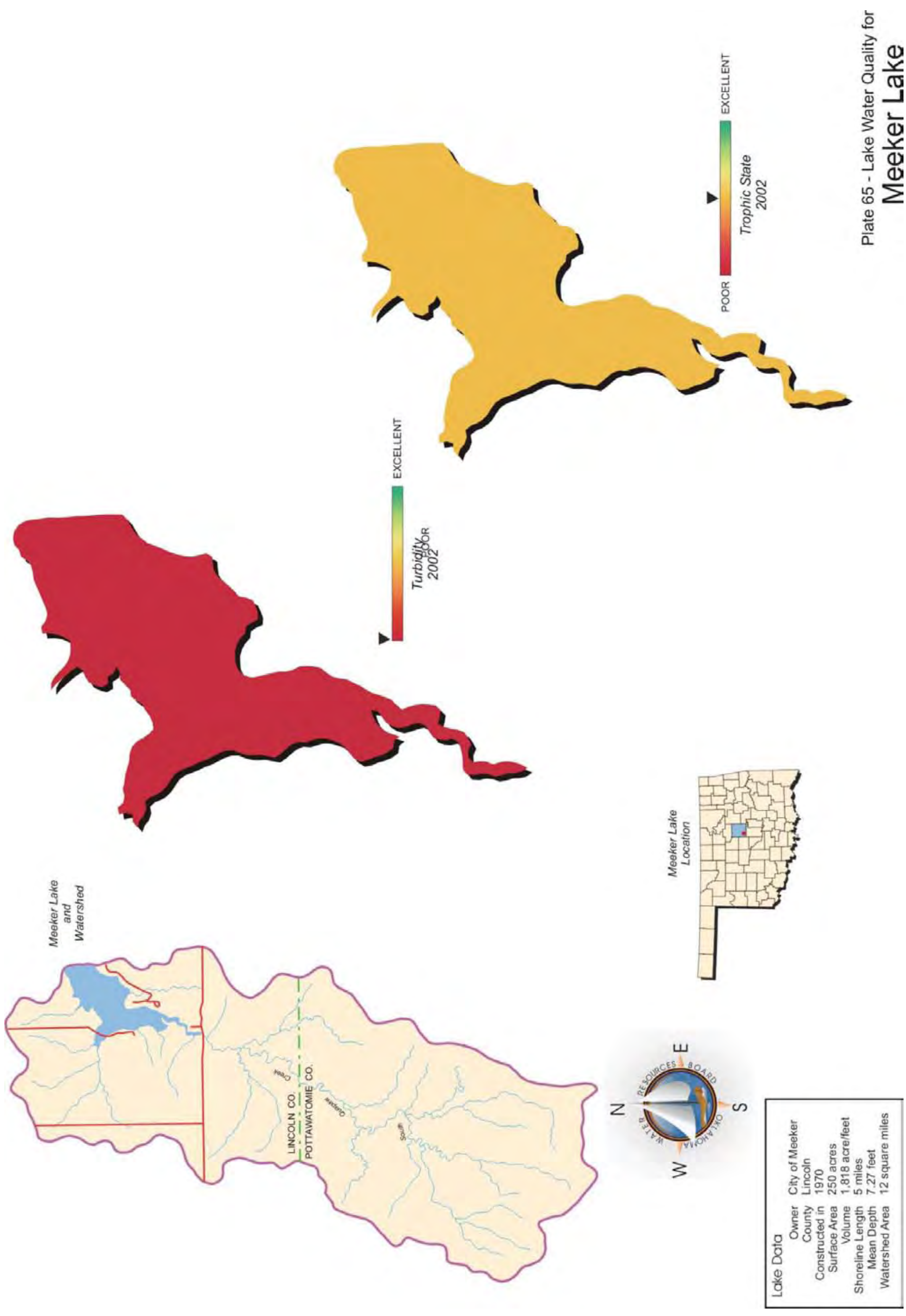


Plate 65 - Lake Water Quality for
Meeker Lake

Lake Murray

Lake Murray was sampled for four quarters, from November 2000 through August 2001. Water quality samples were collected at 5 sites to represent the riverine, transitional, and lacustrine zones and 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 7 NTU, true color was 17 units, and secchi disk depth was 144 centimeters in 2001. Based on these three parameters, Lake Murray had excellent water clarity in 2001. These values are similar to values reported for the summer of 1998, indicating there has been no significant change 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 42, classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is very close to the one calculated in 1998 (TSI=43) although only based on five values collected in the summer. The TSI values varied seasonally but the trends were similar lake-wide with an increase from fall to winter and then a decrease for the next two seasons. The peak in chlorophyll-a at all sites was in the winter, which is uncommon in most lakes, ranging from oligotrophic at site 1 to eutrophic at site 5. As expected, generally site 1 (the dam site) has the lowest chlorophyll-a value and site 5 has the highest, as this is the upper end of the lake. The lake-wide annual TSI of 42 seems representative of Lake Murray as most values were either the upper end of eutrophic or mesotrophic. All turbidity values in 2001 were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU except site 5 in the winter. The annual turbidity value of 7 NTU accurately reflects turbidity at Lake Murray. True color values varied seasonally and were well below the Aesthetics OWQS of 70 units at all sites and in fact several values were zero. The Oklahoma Department of Environmental Quality (ODEQ) sampled the lake in 1997 as part of their Toxics Monitoring Program and detected chlordane at the FDA Action level, ODEQ warning level and ODEQ concern level. The ODEQ sampled the lake again 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 2001 a bayhmetric survey (Figure 147) was conducted to determine current strorage capacity and volume as well as create a database for future determination of sedimentation, assess shoreline exposure during lake level flucuations. The data collected was also used to create a water usage plan for the reservoir. For mor information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

Please refer to the “Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report” for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency’s web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

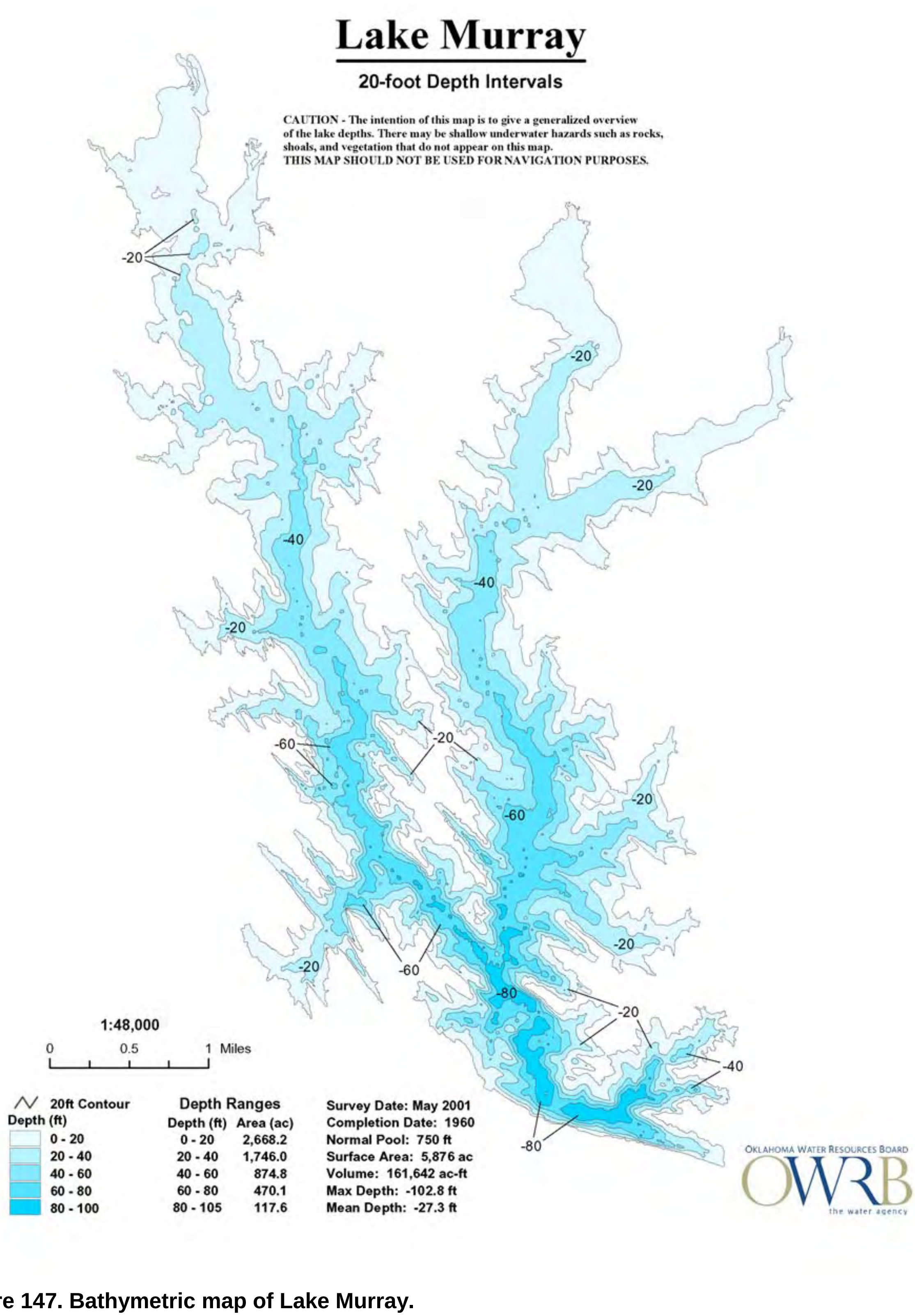


Figure 147. Bathymetric map of Lake Murray.

Lake Nanih Waiya

Lake Nanih Waiya was sampled for four quarters, from November 2002 through August 2003. 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 66), true color was 13 units, and average secchi disk depth was 132 centimeters. Based on these three parameters Lake Nanih Waiya had excellent water clarity in sample year 2002-2003, similar to that observed in 2000. 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 66), classifying the lake as mesotrophic, indicative of moderate primary productivity and nutrient conditions. This is lower than the calculated values in 2000 (TSI=53), however the current value is based on data from the entire year as opposed to growing season only and is likely a more accurate depiction of productivity within the lake. The TSI values were fairly consistent with all values in the mesotrophic category with the exception of site 3, in the summer, which dipped down to the oligotrophic category (see Figure 148). All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU therefore meeting the Fish and Wildlife Propagation (FWP) beneficial use (see Figure 149a. Seasonal turbidity values per site are displayed in Figure. Seasonal true color values are displayed in Figure 149b. Applying the same default protocol, the Aesthetics beneficial use is considered fully supported with 100% of the collected values below the OWQS of 70 units.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sites. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.03 ppt. This is lower than the average range of values reported for Oklahoma lakes. Readings for specific conductivity ranged from 41 mS/cm to 209.8 mS/cm, indicating that low concentrations of electrical current conducting compounds (salts) were present in the lake system. The pH values at Lake Nanih Waiya ranged from 6.27 units to 8.18 units, representing a slightly acidic to neutral system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With only 2 (3.3%) of the collected values falling outside the acceptable range, the lake is

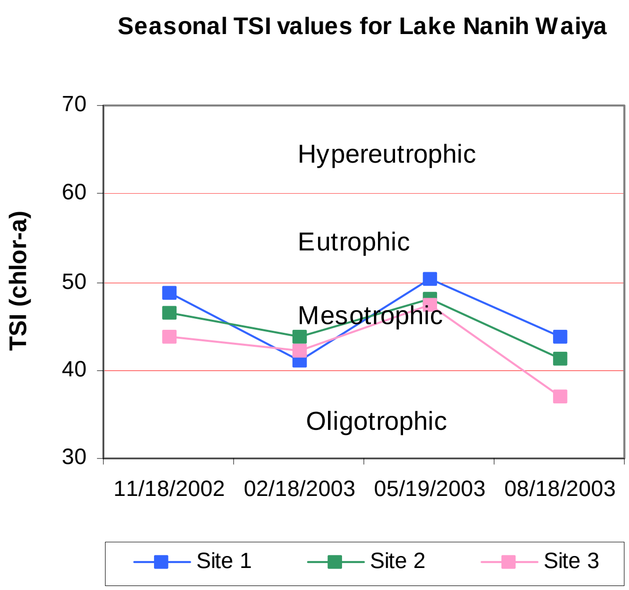


Figure 148. TSI values for Lake Nanih Waiya.

considered supporting the beneficial use based on pH. Oxidation-reduction potential (ORP) ranged from 358 mV in the summer to 643 mV in the fall. 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 and winter and the lake was well mixed with dissolved oxygen (D.O.) levels generally above 5.0 mg/L (see Figure 149c-145d). Thermal stratification was evident in both spring and summer and anoxic conditions were present. During the spring, the lake was stratified between 4 and 5 meters with dissolved oxygen falling below 2.0 mg/L for approximately 29% of the water column at site 1 (see Figure 149e-145f). In the summer sampling quarter, stratification occurred between 3 and 4 meters at which point the D.O. fell below 2.0 mg/L to the lake bottom of 5.3 meters accounting 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 partially supported at Lake Nanih Waiya based on D.O. values in the spring and summer quarters. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2002-2003 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. The PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there is currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.38 mg/L at the surface and 0.55 mg/L at the lake bottom. Surface TN ranged from 0.05 mg/L to 0.65 mg/L, with the highest values reported in the summer and lowest values in the winter. The lake-wide total phosphorus (TP) average was 0.017 mg/L at the surface and 0.030 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.008 mg/L to 0.028 mg/L. Surface TP was highest in the winter and lowest during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 22:1 for sample year 2003. This is higher 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 during sample year 2002-2003. This is lower than the calculated value in 2000 (TSI=53), however the current value is based on data from the entire year as opposed to growing season only and is likely a more accurate depiction of productivity within the lake. Water clarity was excellent based on turbidity, true color and secchi disk depth. The lake is supporting the FWP beneficial used based on turbidity and pH values and only partially supporting based on low D.O. values in the spring and summer months. The Aesthetics beneficial use is fully supported based on its trophic status and true color values. Lake Nanih Waiya, located in Pushmataha County, is owned by the State of Oklahoma and is utilized for recreational purposes.

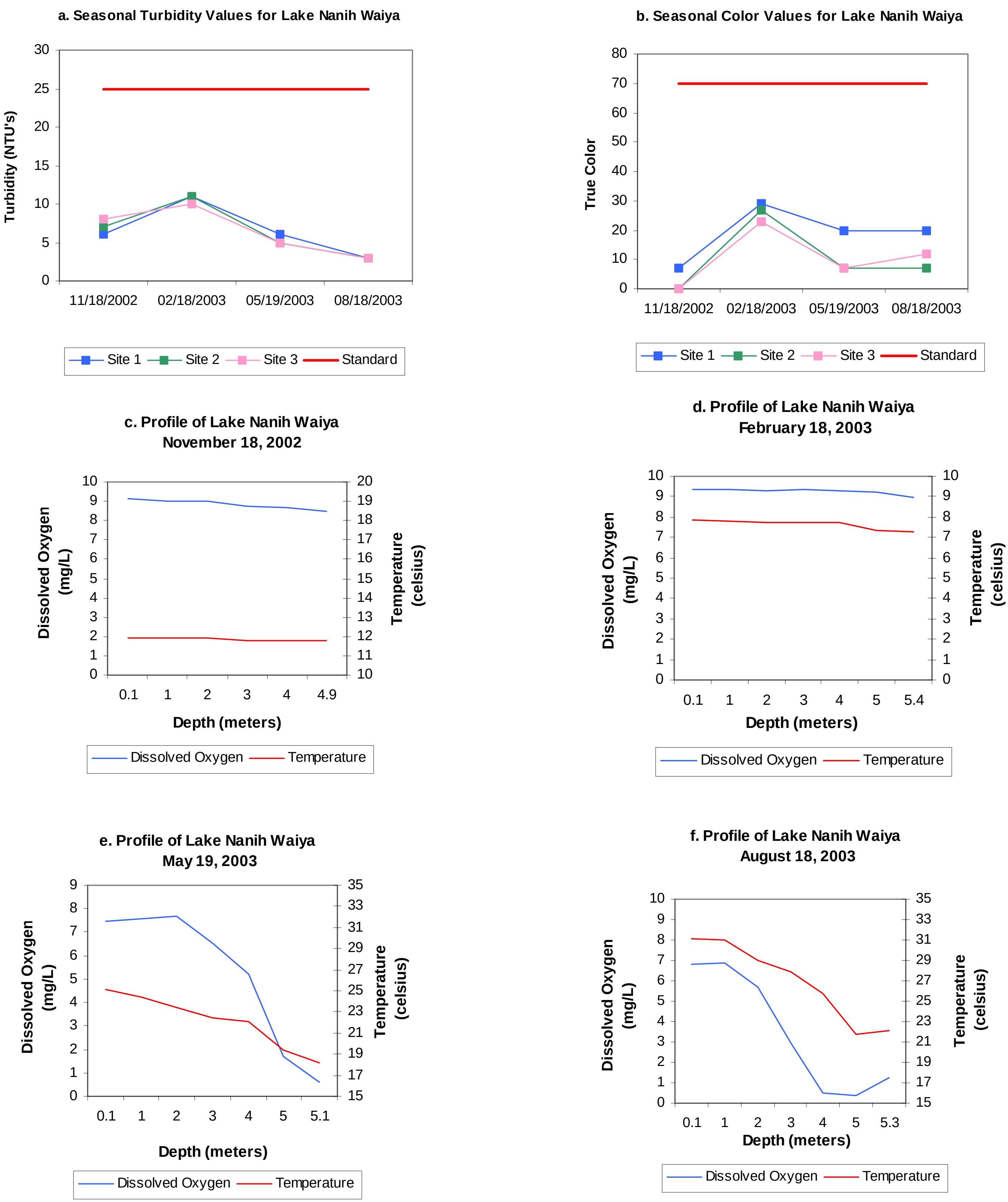
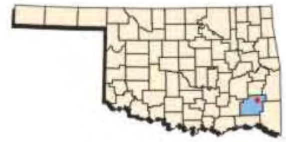


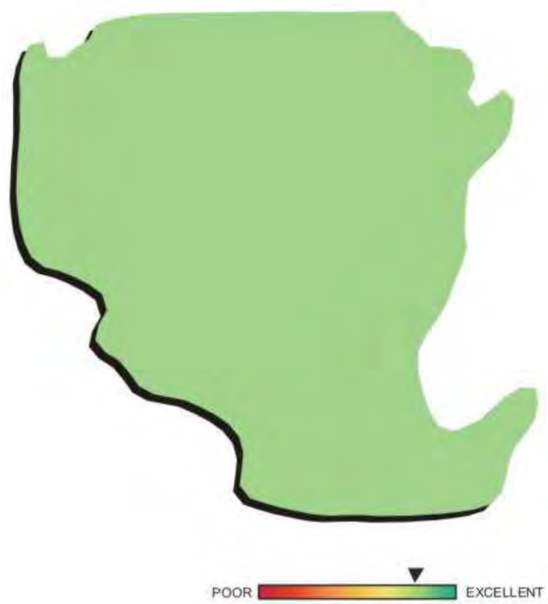
Figure 149a-145f. Graphical representation of data results for Lake Nanih Waiya.

Lake Nanih Waiya and Watershed



Lake Nanih Waiya Location

Trophic State 2003



Turbidity 2003

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 66 - Lake Water Quality for
Lake Nanih Waiya

New Spiro Lake

New Spiro Lake (254 surface acres) was sampled for four quarters, from October 2000 through August 2001. 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 three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 26 NTU, true color was 55 units, and secchi disk depth was 44 centimeters in 2001. Based on these three parameters, New Spiro Lake had fair water clarity in comparison to other Oklahoma reservoirs. Water clarity was very similar in the summer of 1998, based on only three samples, indicating no 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 61, indicating the lake was hypereutrophic in sample year 2001. The TSI values throughout the sample year varied seasonally from primarily eutrophic in the winter to hypereutrophic in the summer. Based on three summer values in 1998, the calculated TSI value was eutrophic (TSI=57), lower than the 2001 trophic evaluation. Late summer/early fall is the more productive time of year at New Spiro Lake, and therefore it is important to sample throughout the year and not just during one season. Turbidity values in the fall, spring and summer seasons were below the turbidity standard of 25 NTU. There was an apparent spike in turbidity in the winter quarter, at which point the values were well above the standard at all three sites. Although 25% of the samples collected in 2001 were above the standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres. True color values varied seasonally and were below the Aesthetics Oklahoma Water Quality Standard (OWQS) of 70 units at all sites in the winter and spring, but above at all sites in the summer. Although 33% of the samples collected in 2001 were above the standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres, therefore, the Aesthetics beneficial use is considered fully supported.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Okemah Lake

Okemah Lake (761 surface acres) was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at four (4) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. In addition, a sample was also collected at the lake surface at site 5 for chlorophyll-a and turbidity analysis in order to meet minimum data requirements. 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 14 NTU (Plate 67), true color was 26 units, and secchi disk depth was 98 centimeters in 2001-2002. Based on these three parameters, Okemah Lake had good to excellent water clarity in comparison to other Oklahoma reservoirs. Nephelometric turbidity readings would have been much lower for this lake if a couple of very high readings recorded in the upper end of the in the spring quarter had not occurred. In general lake turbidity readings were below 14 NTU and were often in the single digits. 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 43 (Plate 67), indicating the lake was mesotrophic in sample year 2001-2002 indicative of moderate to low primary productivity and nutrients present in the lake. The TSI values throughout the sample year varied seasonally. The lake was generally mesotrophic in the fall and winter and oligotrophic in the spring and summer. This is a reversal of the normal pattern seen in Oklahoma lakes (see Figure 150). Turbidity values were all well below the turbidity standard of 25 NTU with the exception of two values in the spring discussed above (see Figure 151a). 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 OWQS (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 values exceeding the OWQS the lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 151b. True color values were below the aesthetics OWQS of 70 units at all times (see Figure 151b). A definitive determination of beneficial use support for true color could not be made due to insufficient data, though collected information strongly suggests the lake would fully support its Aesthetics use.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.03 parts per thousand (ppt) to 0.09 ppt, indicating low salt content in the lake and were well within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were low, ranging from 92.6 mS/cm to 191.3 mS/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 6.72 units in the summer quarter to 9.1 in the winter quarter. 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

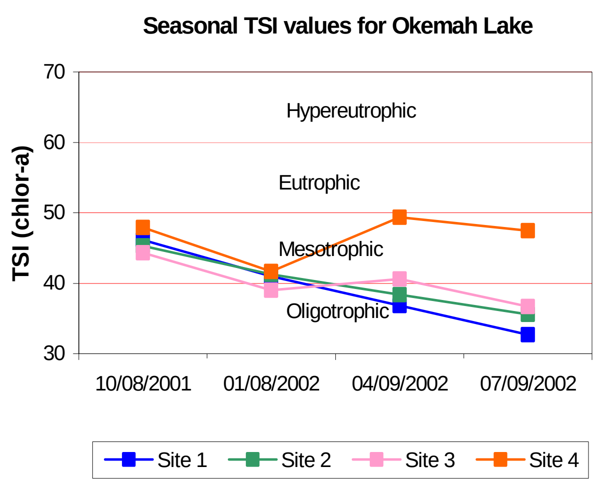


Figure 150. TSI values for Okemah Lake.

values and should be listed as not supporting beneficial uses. 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 beneficial uses. Although several values were above the 9.0 unit threshold, the lake is fully supporting its FWP beneficial use based on pH values with only 6% of the collected values falling outside the acceptable range. Oxidation-reduction potentials (redox) ranged from 88 mV in the summer to 524 mV in the fall, indicating an absence of any significant reducing conditions in the lake. Okemah Lake was not stratified in the fall, winter or spring quarters and dissolved oxygen (D.O.) values were above 5.0 mg/L throughout the water column in all three seasons and were generally above 6.0 mg/L (see Figure 151c-1475e). In the summer quarter, the lake was strongly thermally stratified between 4 and 5 meters and between 5 and 6 meters at site 1 (see Figure 151f). 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 12 meters. 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, with 62% of the water column less than 2.0 mg/L at site 1 in the summer, 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 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.42 mg/L at the lake surface. The TN at the surface ranged from 0.25 mg/L to 0.81 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 for sample year 2001-2002 was 0.024 mg/L at the lake surface. The surface TP ranged from 0.009 mg/L to 0.121 mg/L. The highest surface TP value was reported in the spring quarter and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 17:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Okemah Lake was sampled for metals at four sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Okemah Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 67). The lake was fully supporting its Aesthetics beneficial use based on its trophic status but a definitive determination could not be made based on true color, though collected data suggests it would be fully supporting. Okemah Lake was fully supporting its FWP beneficial use based on turbidity and pH. The FWP beneficial use was partially supported based on D.O. values. 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.

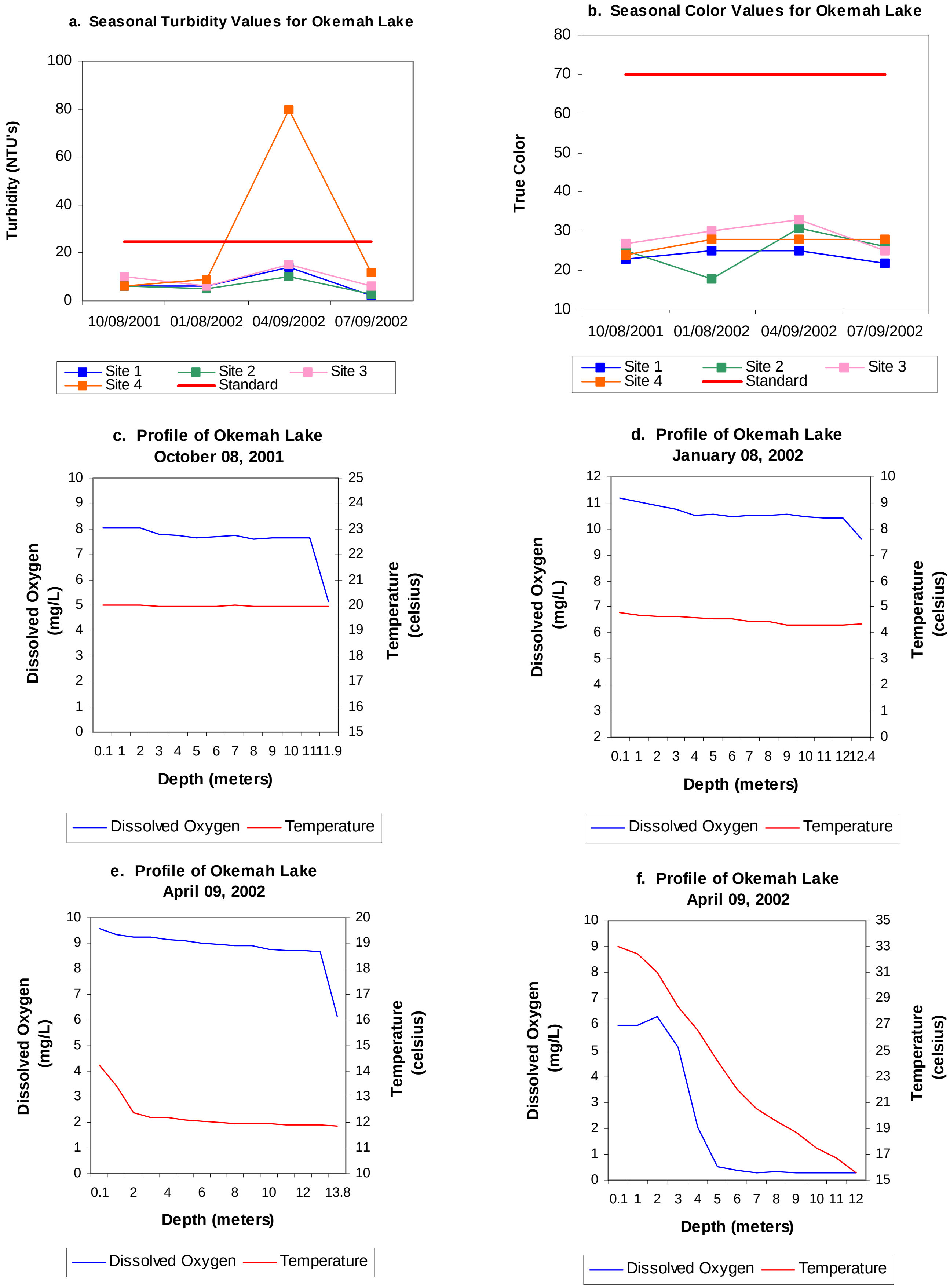
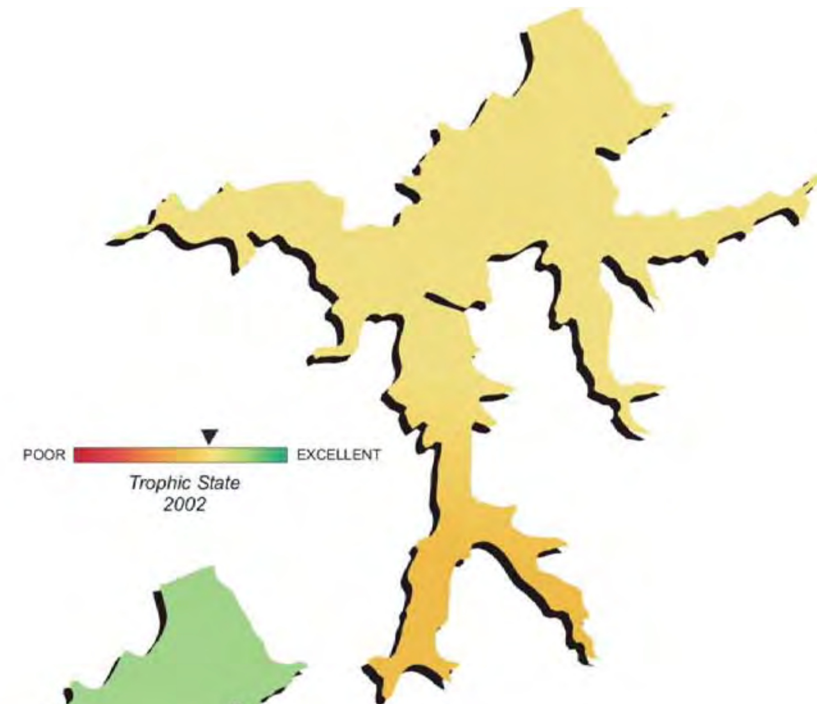


Figure 151a-147f. Graphical representation of data results for Okemah Lake.

Okemah Lake
Location

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



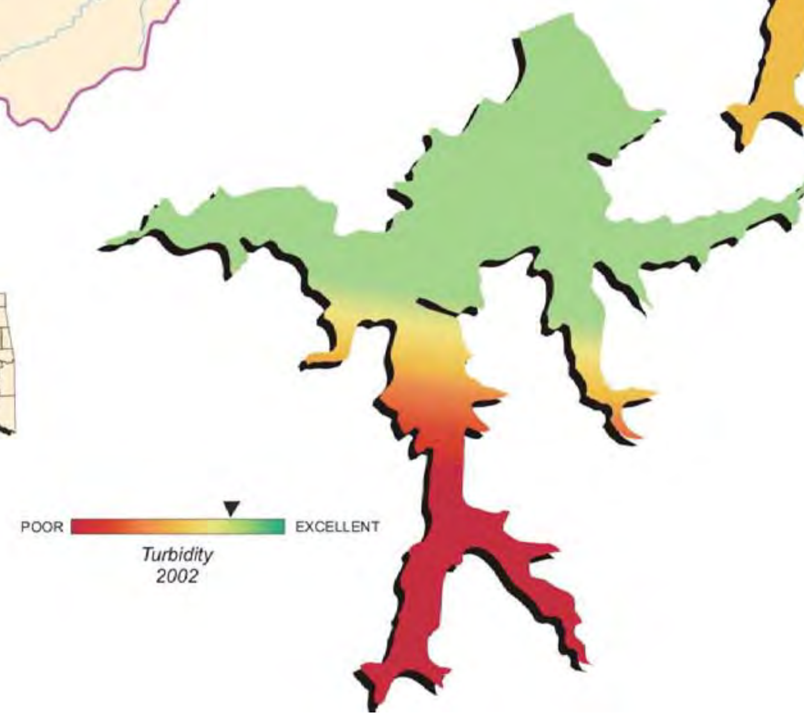


Plate 67 - Lake Water Quality for
Okemah Lake

Okmulgee Lake

Okmulgee Lake was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. In addition, samples were collected at the lake surface at sites 4 and 5 for chlorophyll-a and turbidity analysis in order to meet minimum data requirements. 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 12 NTU (Plate 68), true color was 37 units, and secchi disk depth was 95 centimeters in 2001-2002. Based on these three parameters, Okmulgee Lake 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 TSI was 45 (Plate 68), indicating the lake was mesotrophic in sample year 2001-2002. The TSI values throughout the sample year varied seasonally from upper mesotrophic in the fall, to the middle of the mesotrophic range in the winter and spring, to oligotrophic in the summer quarter (see Figure 152). It is not common to see lower primary productivity occurring in the warmer summer months and to have your highest productivity in the fall. High primary productivity in the fall/winter does occur, but the minimum in the summer was unexpected and cannot be easily explained. Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU with the exception of one values recorded in the spring quarter at site 3 (see Figure 153a). 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 OWQS (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. Only 5% of the recorded turbidity values were above 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 153b. True color values were all below the OWQS of 70 units at all sites, however no definitive determination of Aesthetics use support could be made due to insufficient data. Collected data strongly supports the supposition that the lake would be fully supporting the use.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, 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, indicating low salt content and all values were well within the expected range of salinity reported for most Oklahoma lakes. Readings for specific conductance were very low, ranging from 38.6 mS/cm to 98.3 mS/cm, indicating the very slight presence of electrical current conducting compounds (salts) in the water column throughout the year. In general, pH values were slightly neutral to alkaline with values ranging from 6.49 units in the summer quarter to 9.24 in the summer at site 1 at the lake surface. 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 should be listed as not supporting beneficial uses. If 10 to 25% of the

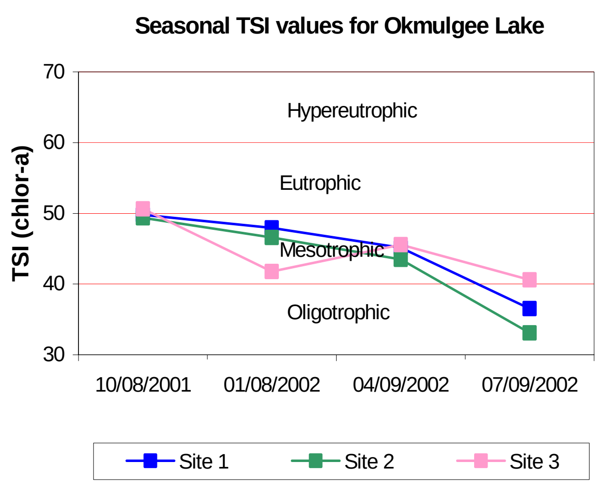


Figure 152. TSI values for Okmulgee Lake.

pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. Okmulgee Lake had only 2% of its pH values falling outside the acceptable range and for this reason it is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 98 mV in the summer to 489 mV in the fall quarter, indicating an absence of reducing conditions. Okmulgee Lake was thermally stratified in the fall very near the lake bottom and dissolved oxygen (D.O.) concentrations in the bottom three meters of the lake were less than 1.0 mg/L (see Figure 153c). In the winter and spring quarters the lake was not thermally stratified and D.O. concentrations never fell below 8.25 mg/L at any point in the water column (see Figure 153d-149e). In the summer the lake was strongly thermally at several depths throughout the water column (see Figure 153f) and D.O. values below the 3-meter depth were all less than 2.0 mg/L and were generally less than 1.0 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 (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 not supported with 73% of the water column experiencing anoxic conditions. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.52 mg/L at the lake surface. The TN at the surface ranged from 0.32 mg/L to 1.32 mg/L. The highest surface TN value was reported in the winter and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.20 mg/L at the lake surface. The surface TP ranged from 0.009 mg/L to 0.042 mg/L. The highest surface TP value was reported in the spring and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 26:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Okmulgee Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Okmulgee Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 68). The lake was fully supporting its FWP beneficial use based on turbidity and pH concentrations, however the lake was not supporting based on low D.O. readings in the water column in the summer quarter. The lake was fully supporting its Aesthetics beneficial use basic on trophic state and sufficient data was not available to assess use support related to true color. True color data did strongly suggest that the lake would be meeting its Aesthetics use for color. 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.

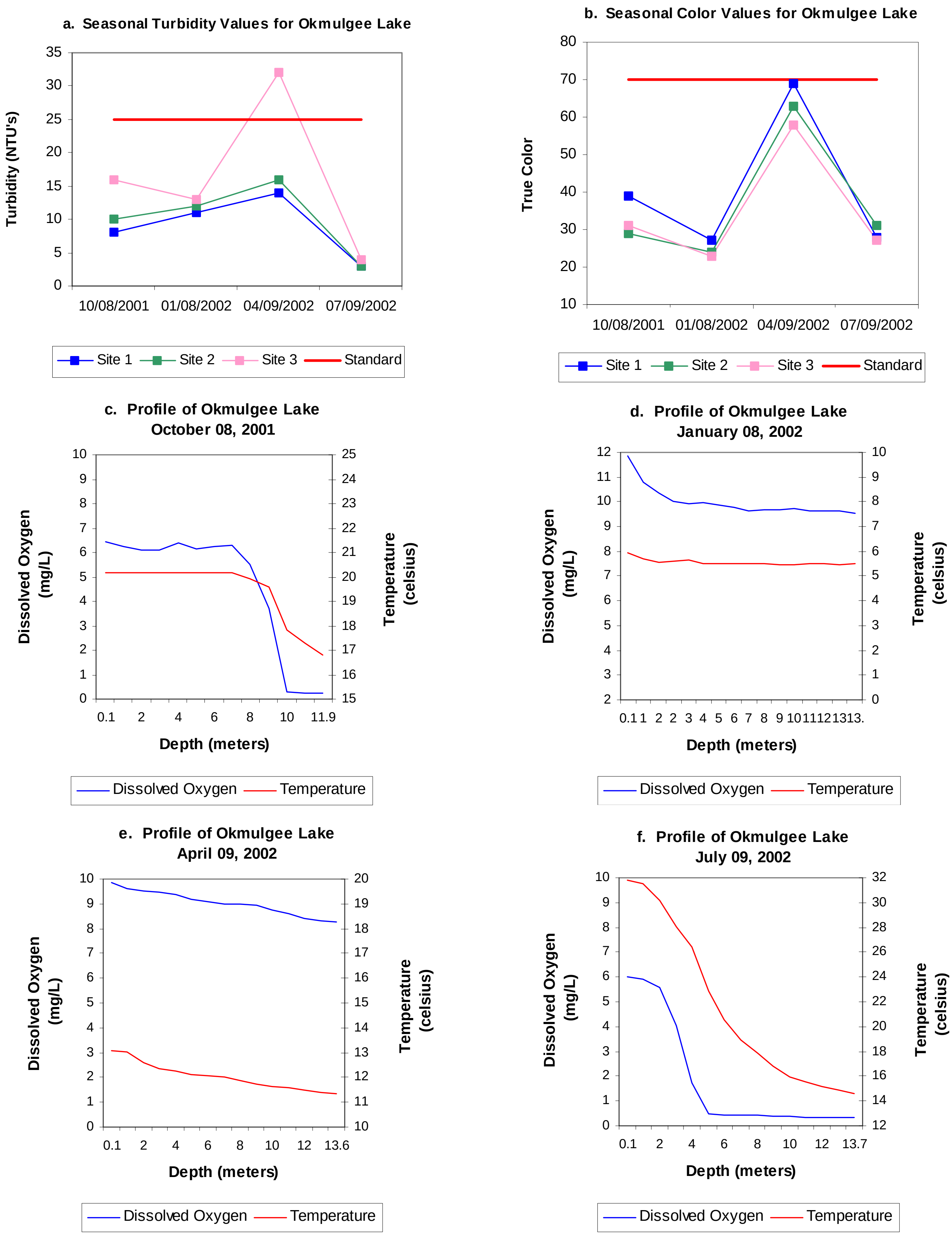
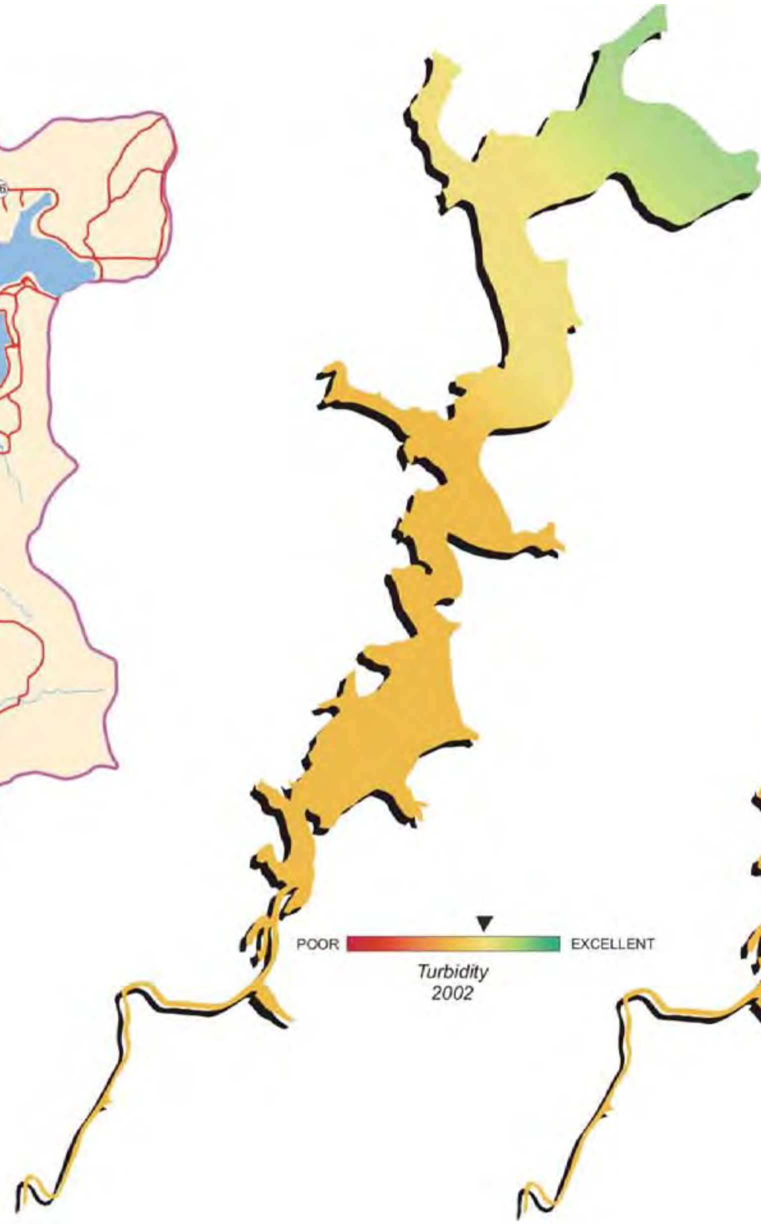


Figure 153a-149f. Graphical representation of data results for Okmulgee Lake.

Lake Data	
Owner	City of Okmulgee
County	Okmulgee
Constructed in	1928
Surface Area	668 acres
Volume	14,170 acre/feet
Shoreline Length	19 miles
Mean Depth	21.21 feet
Watershed Area	14 square miles



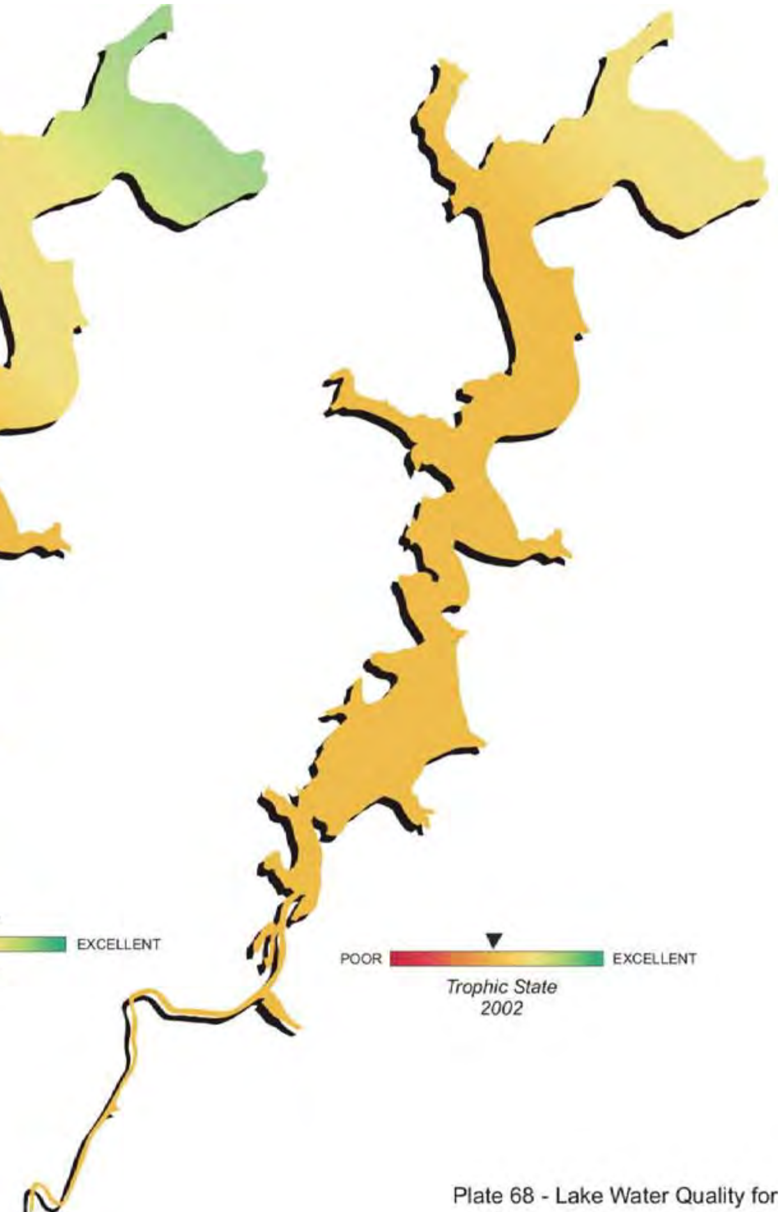


Plate 68 - Lake Water Quality for
Okmulgee Lake

Oologah Lake

Oologah Lake was sampled for four quarters, from October 2002 through July 2003. 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 three sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide average turbidity value was 22 NTU (Plate 69), true color was 23 units, and secchi disk depth was 41 centimeters in 2001-2002. 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 48 (Plate 69), indicating the lake was mesotrophic with moderate primary productivity and nutrient conditions in sample year 2002-2003. This is lower than the value calculated in 2000, (TSI=51), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of lake productivity. The TSI values were fairly consistent and ranged from mesotrophic to the lower end eutrophic during the study period (see Figure 154). Seasonal turbidity values are displayed in Figure. In the fall, five of the seven sites were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, but varied the other three quarters. In the winter and spring most values were near or below the standard while in the summer about half were above and half were below (see Figure 155a). 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 OWQS (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 31% of the recorded turbidity values above the standard the Fish and Wildlife Propagation (FWP) beneficial use is partially supported based on turbidity. Seasonal true color values are displayed in Figure 155b. All true color values were below the OWQS of 70 units except for site 5, which had a value of 84 units recorded in the spring. Applying the same default protocol, the Aesthetics beneficial use is fully supported based on true color values (see Figure 155b).

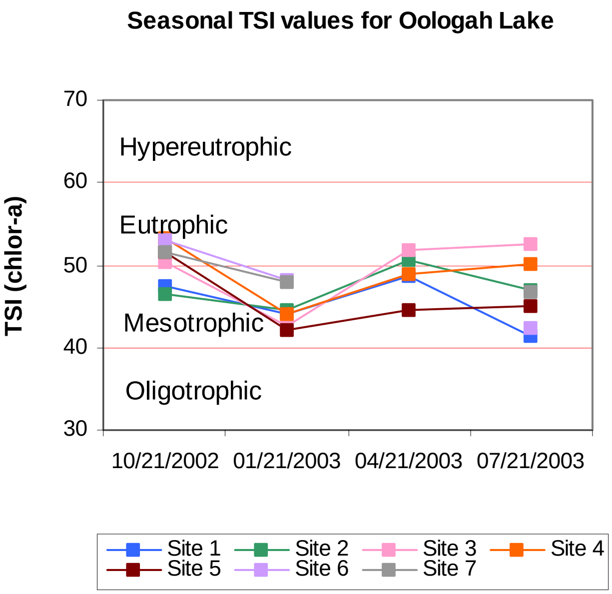


Figure 154. TSI values for Oolagah Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sites during sample year 2002-2003. Salinity values at Oolagah Lake ranged from 0.13 parts per thousand (ppt) to 0.23 ppt. This is within the average range of values reported for Oklahoma reservoirs.

Specific conductivity ranged from 263.1 mS/cm to 635 mS/cm, indicating that low to moderate concentrations of electrical current conducting materials (salts) were present in the lake system. The pH values collected at Oologah Lake ranged from 7.07 to 8.22 representing a neutral to slightly alkaline system. Oxidation-reduction potentials ranged from 317 mV in the fall to 635 mV in the summer. Reducing conditions were not present in 2003, with all recorded values positive and above 100 mV. 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 155c-151e). In the summer, stratification was evident and anoxic conditions were present. The lake was stratified at several 1-meter intervals with dissolved oxygen generally below 2.0 mg/L from the thermocline to the bottom of the lake accounting for 10 to 56% of the water column to be experiencing anoxic conditions (see Figure 155f). 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. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2002-2003 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. The PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.41 mg/L at the surface and 0.48 mg/L at the lake bottom. Surface TN ranged from 0.22 mg/L to 0.71 mg/L, with the highest values reported in the spring and lowest values in the fall. The lake-wide total phosphorus (TP) average was 0.048 mg/L at the surface and 0.072 mg/L at the lake bottom. Total phosphorus at the surface ranged from 0.022 mg/L to 0.097 mg/L. Similar to TN, surface TP was highest in the spring and lowest during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 8:1 for sample year 2003. 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 condition. Although this is lower than the previous classification in 2000 (TSI=51), the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. 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 reported true color values. 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.

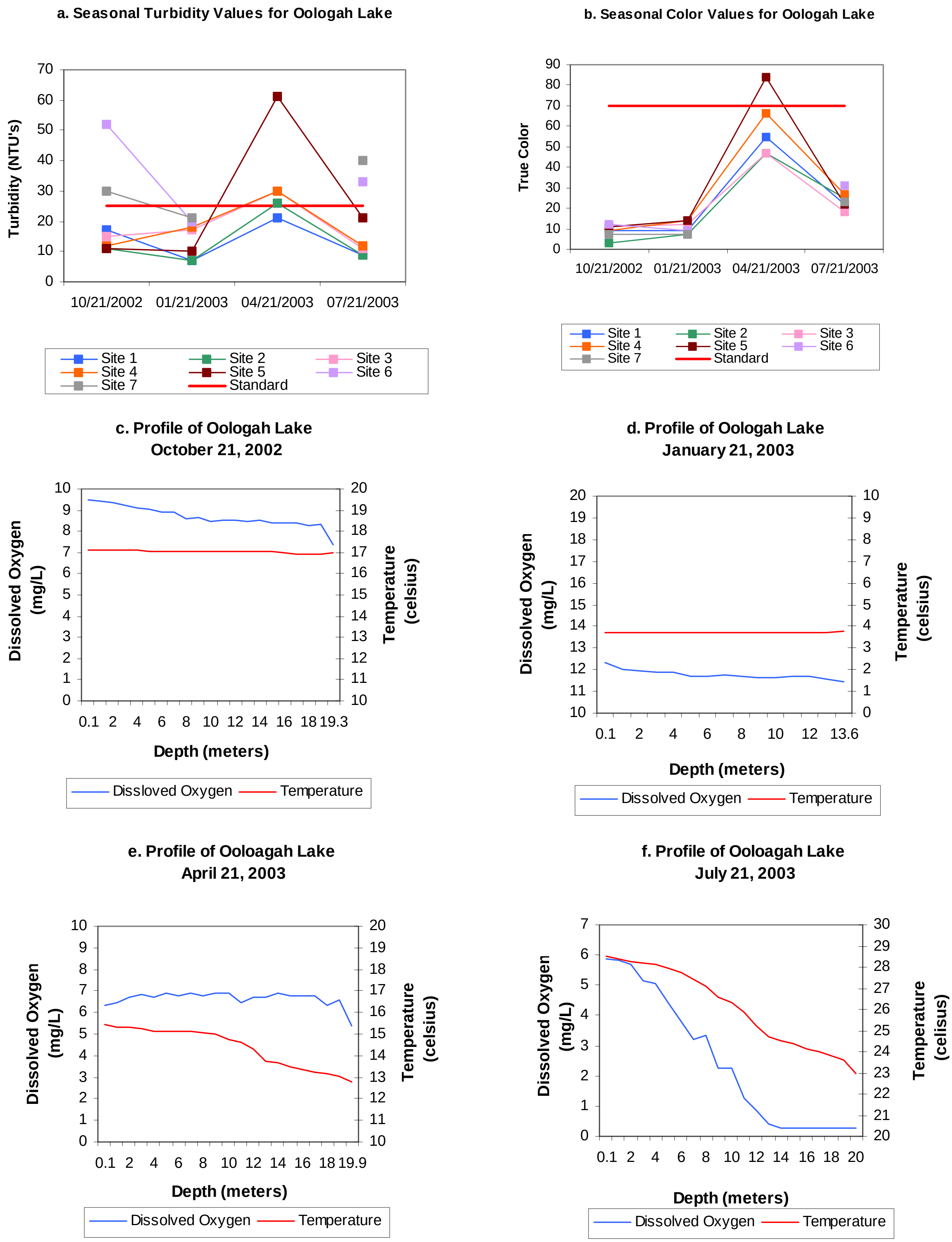


Figure 155a-151f. Graphical representation of data results for Oologah Lake.

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 69 - Lake Water Quality for
Oologah Lake

Lake Overholser

Lake Overholser was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional samples were collected at the lake surface at sites 4 and 5 for the purpose of looking at nephelometric turbidity and chlorophyll-a concentrations in the lake. 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 39 NTU (Plate 70), true color was 39 units, and secchi disk depth was 33 centimeters in 2001-2002. 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 68 (Plate 70), indicating the lake was hypereutrophic with excessive primary productivity and nutrient levels in sample year 2001-2002. The TSI values were consistent from season to season and were only eutrophic in the winter quarter and were hypereutrophic for the other three quarters of the year (see Figure 156). Based on the trophic classification, the lake will be recommended for listing in the next Oklahoma Water Quality Standards (OWQS) 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 OWQS of 25 NTU (see Figure 157a). 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 OWQS (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. Overholser Lake 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 157b. True color values were below the Aesthetics OWQS of 70 units at all sites, however, due to insufficient data a definitive determination of Aesthetics use support for true color could not be made. Data does strongly suggest that the lake would be fully supporting.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.04 parts per thousand (ppt) to 0.68ppt, indicating moderate to high amounts of salts in the water column when compared to most Oklahoma lakes. Readings for specific conductance were also generally very high, ranging from 105.6 mS/cm to 1291 mS/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 6.89 units in the summer quarter to 8.79 units in the spring. 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 should be listed as not supporting beneficial uses. If 10 to

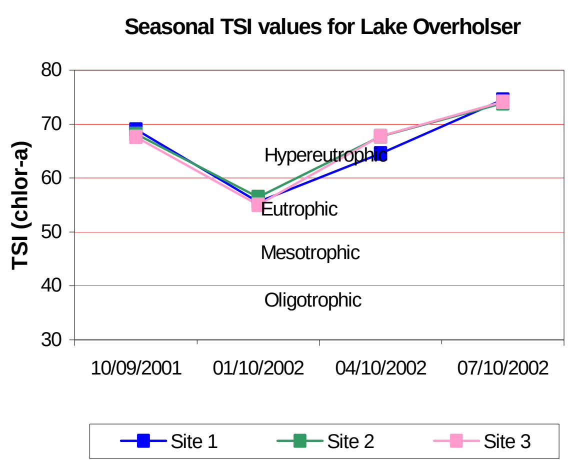


Figure 156. TSI values for Lake Overholser.

25% of the pH values fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. All pH values were within the accepted range so the FWP beneficial use is fully supported based on pH. Oxidation-reduction potentials (redox) ranged from –17 mV in the summer to 465mV in the winter quarter, indicating an absence of reducing conditions in the fall, winter and spring and reducing conditions in the lake in the summer quarter. Lake Overholser was not thermally stratified in the fall, winter, or spring quarters and dissolved oxygen (D.O.) values were above 7.5 mg/L throughout the water column in all three seasons (see Figure 157c-153e). In the summer quarter, the lake was thermally stratified just below the lake surface and anoxic conditions were present below 1 meter at site 1. Although this lake is very shallow (about 2.5 meters deep), about 50% of the water column was anoxic with D.O. readings less than 2.0 mg/L. Usually wind mixing precludes the onset of thermal stratification in reservoirs that are this shallow in nature, so the occurrence of stratification and low D.O. was unexpected. 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 partially supported at Lake Overholser. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 1.01 mg/L at the lake surface. The TN at the surface ranged from 0.69 mg/L to 1.61 mg/L. The highest surface TN value was reported in the summer and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.253 mg/L at the lake surface. The surface TP ranged from 0.177 mg/L to 0.387 mg/L. The highest surface TP value was reported in the fall 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 4:1. This value is less than 7:1, characterizing the lake as nitrogen-limited (Wetzel, 1983).

Lake Overholser was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Lake Overholser was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels (Plate 70). The lake will be recommended for listing as an NLW in the next OWQS revision process and its Aesthetics beneficial use is considered nutrient threatened. Insufficient data was available to definitively assess the Aesthetics use based on true color, but data suggest the use would be supported. The lake is fully supporting its FWP beneficial use based on pH, however, the lake is only partially supporting the use based on D.O. values and is not supporting the use based on elevated nephelometric turbidity readings. Lake Overholser was constructed in 1919 and is owned and operated by the City of Oklahoma City. It is serves as a municipal water supply and offers recreational opportunities to the public. 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 156) was generated to determine current storage capacity and identify areas of extreme sedimentaion. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

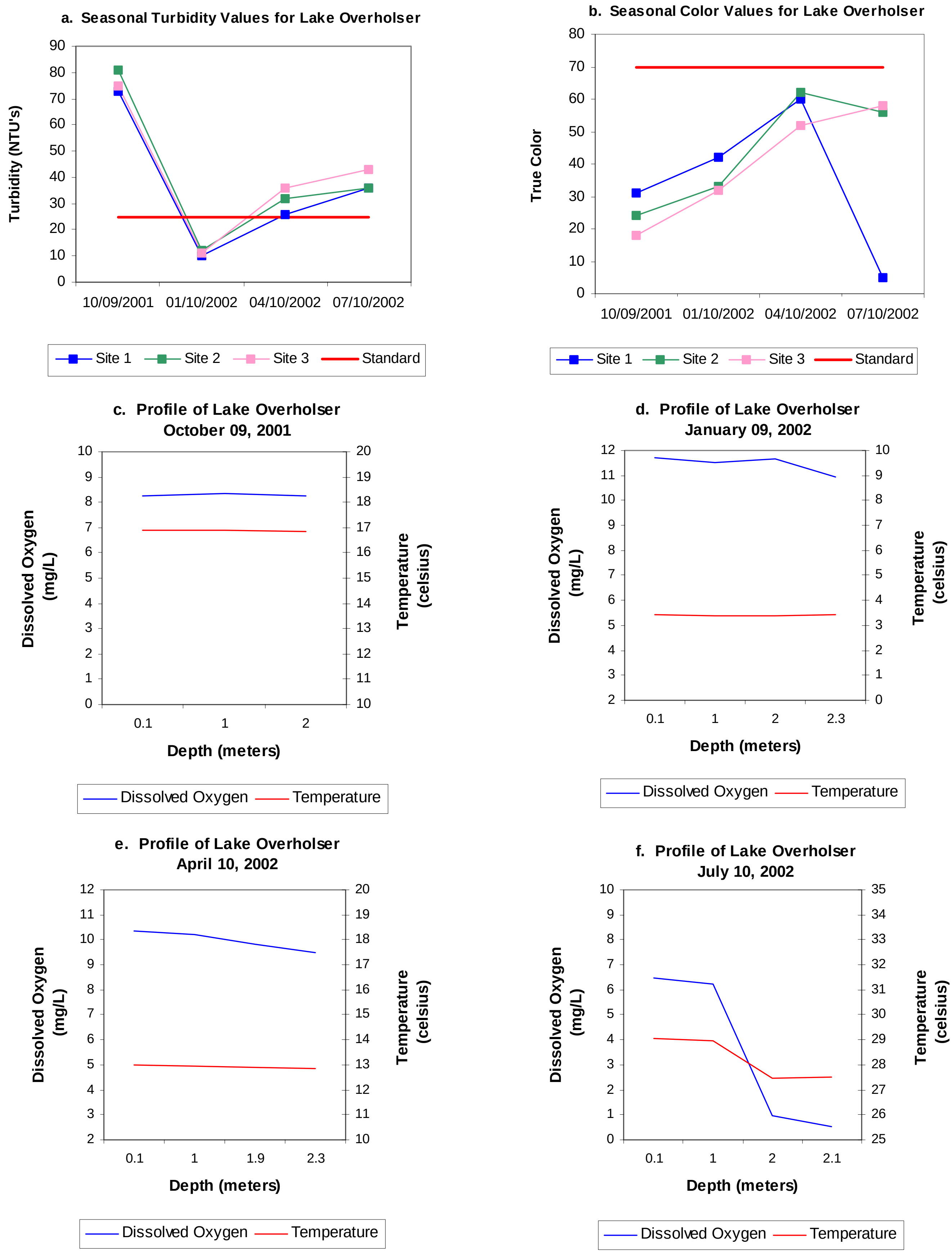
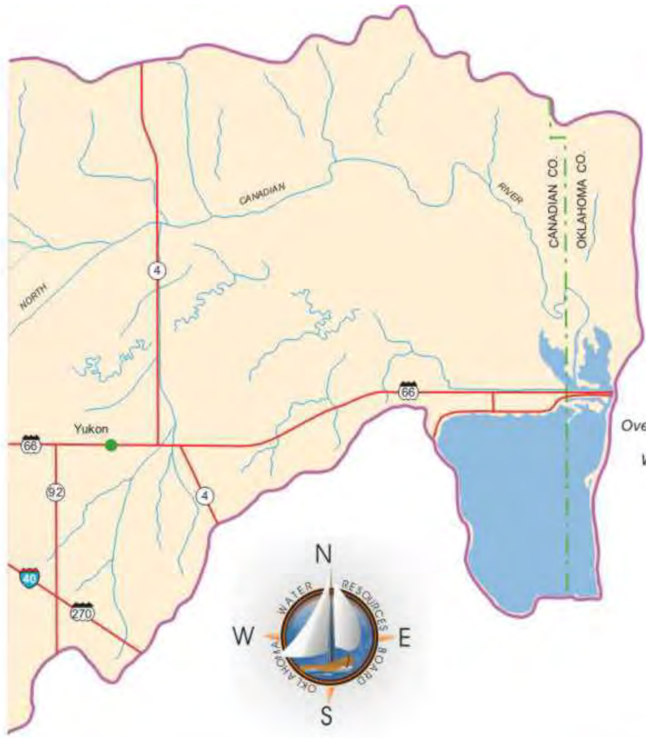


Figure 157a-153f. Graphical representation of data results for Lake Overholser.



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

Turbidity 2002

Trophic State 2002

Plate 70 - Lake Water Quality for
Overholser Lake

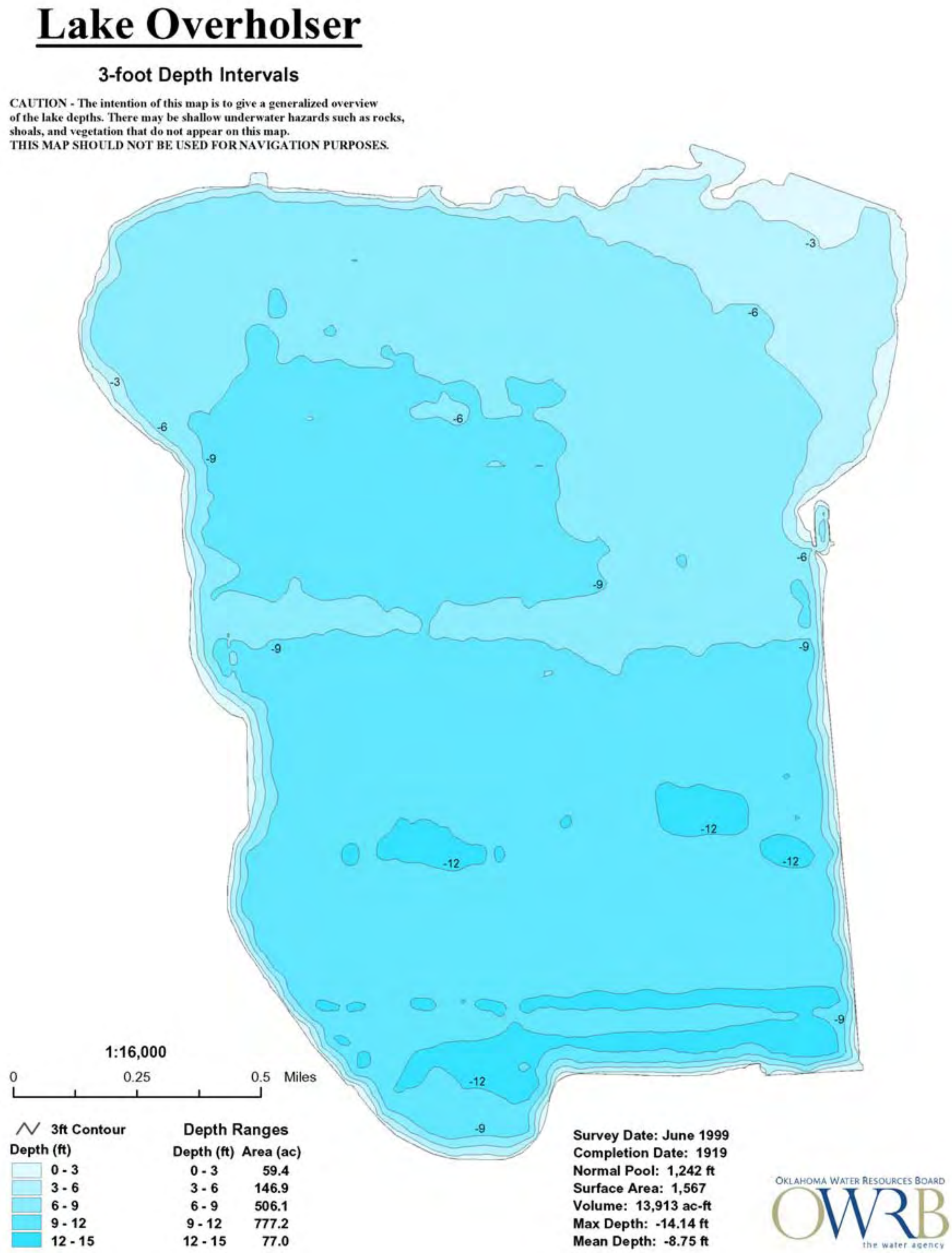


Figure 158. Bathymetric map of Lake Overholser.

Lake Ozzie Cobb

Lake Ozzie Cobb was sampled for four quarters, from November 2002 through August 2003. 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 71), true color was 74 units, and secchi disk depth was 65 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 54 (Plate 71), indicating the lake was eutrophic with high primary productivity and nutrient levels in sample year 2001-2002. This is lower than the value calculated in 2000, (TSI=65), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of lake productivity. Lake Ozzie Cobb is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW) indicating that its Aesthetics use is threatened due to nutrients (based on trophic status). A nutrient impairment study should be conducted to determine if uses are impaired. In general, the TSI values were eutrophic except during the winter, which had values ranging from oligotrophic to mesotrophic (see Figure 159). Seasonal turbidity values are displayed in Figure 160a. Turbidity values ranged from a low of 9 NTU to a maximum of 28 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 ≥ 25% of the samples exceed the screening level prescribed in the Oklahoma Water Quality Standards (OWQS) of 25 NTU for turbidity. With 25% 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 160b. Applying the same default protocols, the Aesthetics beneficial use is considered not supported with 50% of the reported values exceeding the OWQS of 70 units.

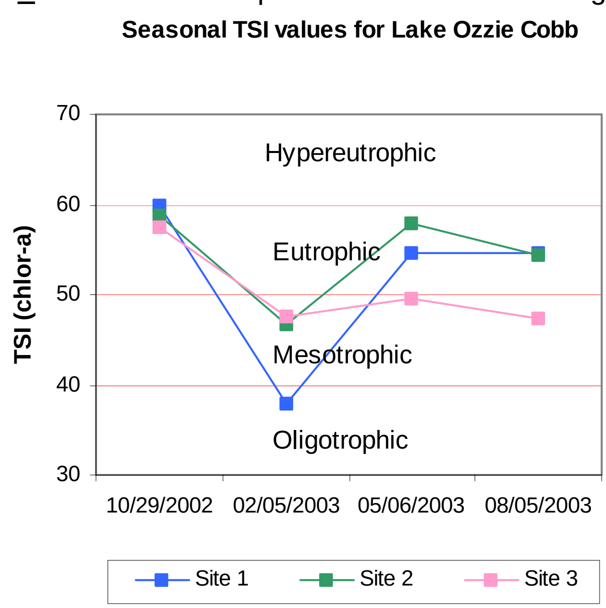


Figure 159. TSI values for Lake Ozzie Cobb.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all sample sites. The salinity values for Lake Ozzie Cobb ranged from 0.00 parts per thousand (ppt) to 0.07 ppt for this sample year. Specific conductivity ranged from 20.3 to 162.7 mS/cm, which is much lower than most Oklahoma reservoirs. These values indicate the 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, ranging from 5.86 to 6.84. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 56% of the values recorded being less than 6.5 the lake should be listed as not supporting the FWP beneficial use based on pH. The low pH values recorded at Lake Ozzie Cobb may be due to natural conditions, as slightly acidic conditions are also seen in other lakes in this region of the state and will be listed as "provisionally not supporting"***** the FWP. Oxidation-reduction potentials ranged from 436 mV to 557 mV. Reducing conditions were not present at this reservoir in the 2002-2003-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 160c-155d). Thermal stratification was evident in both spring and summer quarters, with anoxic conditions present below the thermocline. In the spring, anoxic conditions were present for 50% of the water column at sites 1 and 2 (Figure 160e). A similar pattern was observed in the summer with stratification occurring between 2 and 3 meters at which point dissolved oxygen fell below 2.0 mg/L accounting for 40% of the water column experiencing anoxic conditions (Figure 160f). 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 lake is partially 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.54 mg/L at the surface and 0.66 mg/L at the lake bottom. The TN at the surface ranged from 0.10 mg/L to 1.28 mg/L. Surface total nitrogen was highest in the summer and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.045 mg/L and 0.054 mg/L at the lake bottom. The TP at the surface ranged from 0.038 mg/L to 0.054 mg/L. Surface TP was highest in the spring and the lowest values were seen during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was 12:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Ozzie Cobb was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. This is lower than the value calculated in 2000, (TSI=65), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of lake productivity. The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient threatened and a nutrient impairment study is needed to determine if uses are impaired. Water clarity was fair to average based on true color, turbidity and secchi disk depth. The lake is partially supporting the FWP beneficial use and dissolved oxygen, but not supporting based on turbidity and low pH values reported throughout the year. Low pH values are common in this area of the state and may be due to natural causes and the lake will be listed as “provisionally not supporting”* the FWP. The Aesthetics beneficial use is supported based on its trophic status and not supporting based on true color with 50% of the recorded values exceeding the OWQS of 70 units. Lake Ozzie Cobb is owned by the State of Oklahoma and is utilized for recreation.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the “other than by natural causes” clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

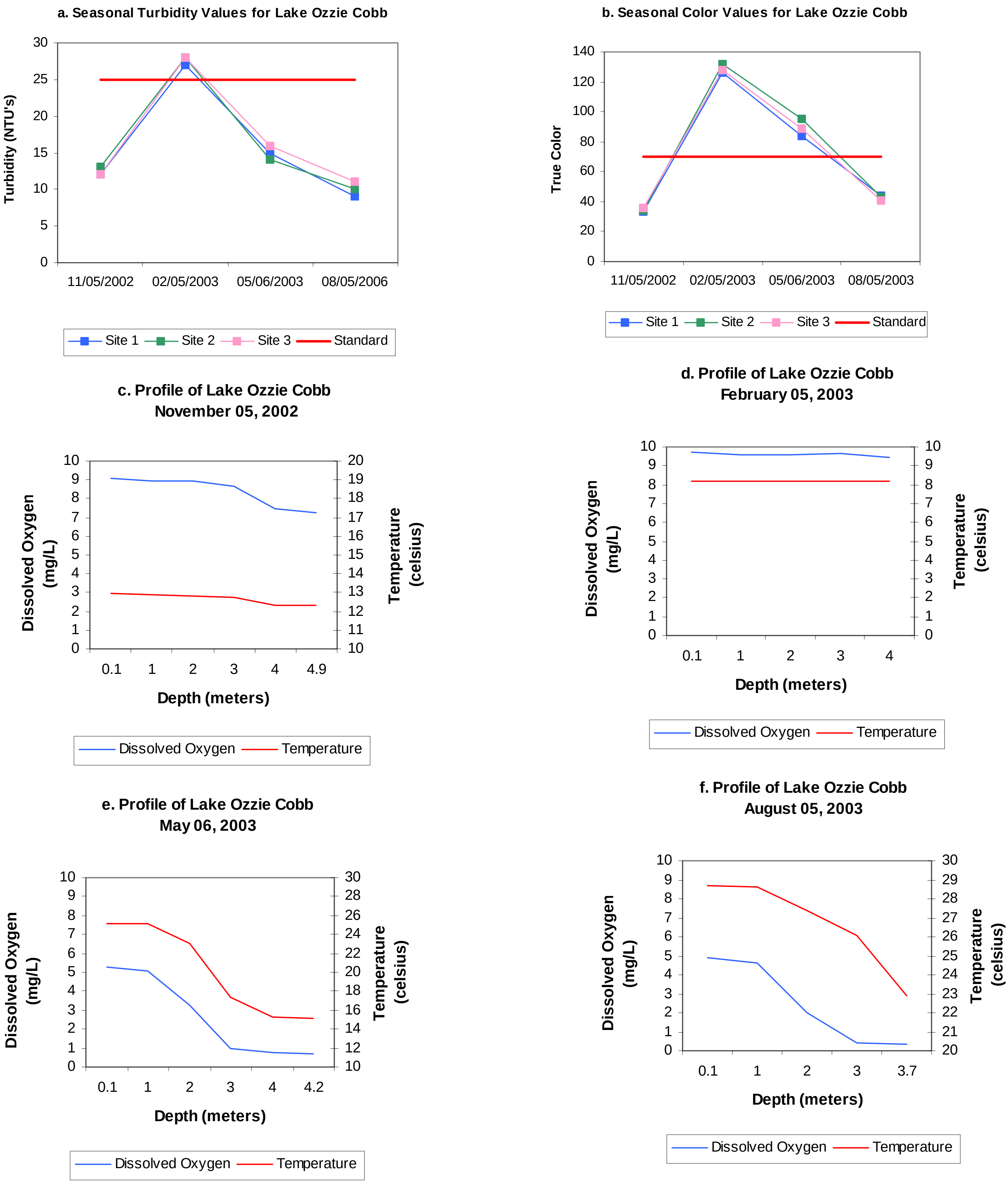
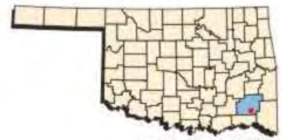


Figure 160a-155f. Graphical representation of data results for Lake Ozzie Cobb.



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 71 - Lake Water Quality for
Lake Ozzie Cobb

Pauls Valley City Lake

Pauls Valley City Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer quarters to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional samples were added to ensure sample size was representative for a lake greater than 250 surface acres. 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 15 NTU (Plate 72), true color was 27 units, and secchi disk depth was 72 centimeters. Based on these three parameters, Pauls Valley City Lake had good water clarity in sample year 2002-2003, even better than reported 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=20). The TSI was 41 (Plate 72), indicating the lake was mesotrophic/bordering oligotrophic in sample year 2003 (Plate 72). 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 (Figure 161). The only exception to this was site 1, which remained in the mesotrophic category throughout the year. This TSI value was lower than calculated in 2000 (TSI=50), however the current value is based on a larger dataset and is likely a more accurate depiction of productivity within the lake. Seasonal turbidity values are displayed in Figure 162a. Turbidity values in the winter, spring and summer seasons were below the turbidity standard of 25 NTU. In the fall quarter, there was a spike in turbidity, possibly due to seasonal rain events, at which point the values were at or near the standard at all sites. The Fish and Wildlife Propagation (FWP) beneficial use is considered supported based on turbidity. Seasonal true color values are displayed in Figure 162b. True color values followed the same pattern as turbidity with higher values observed in the fall sampling quarter. Although 100% of samples in 2003 were below the 70-unit standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all sample sites. Salinity values for Pauls Valley City Lake ranged from 0.11 parts per thousand (ppt) to 0.14 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductance ranged from 239.5 to 283.8 mS/cm, indicating the minimal presence of electrical current conducting compounds (salts) in the lake, consistent with salinity concentrations.

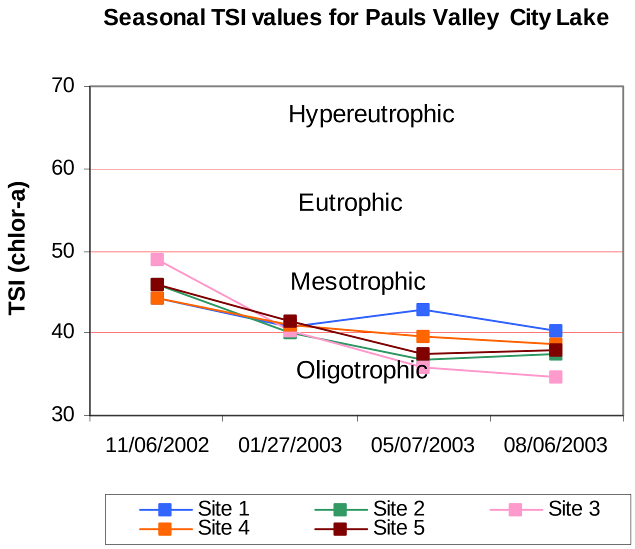


Figure 161. TSI values for Pauls Valley City Lake.

In general pH values were neutral to slightly alkaline with values ranging from 6.93 to 8.06 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. 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 379 mV to 550 mV, indicating an absence of reducing conditions. During the fall and winter quarters, stratification was not present and lake was well mixed (see Figure 162c-157d). 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 162f). In the summer stratification occurred at several 1-meter intervals with D.O. falling below 2.0 mg/L from 5 meters to the lake bottom of 7.5 meters, accounting for approximately 33% of the water column 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. Pauls Valley City Lake is partially 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.31 mg/L at the surface and 0.34 mg/L at the lake bottom. The TN at the surface ranged from 0.10 mg/L to 0.54 mg/L. The highest surface total nitrogen was reported in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.019 mg/L and 0.027 mg/L at the lake bottom. The surface TP ranged from 0.005 mg/L to 0.024 mg/L. The highest surface TP was reported in the summer and the lowest values were seen during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 16:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Pauls Valley City Lake was classified at the lower end of mesotrophic, indicative of moderate primary productivity and nutrient conditions. This differs from the 2001 evaluation, which placed the lake at the uppermost end of mesotrophic with a TSI of 50. The current TSI calculation is based on a larger dataset (n=20) and is likely a more accurate depiction of productivity with the lake system. 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 is only partially supported based on low dissolved oxygen values reported in the summer. The Aesthetic beneficial use is supported based on its trophic status, however use determination cannot be made for true color as a minimum of 20 samples are required in lakes greater than 250 surface acres. Pauls Valley City Lake is located in Garvin County and serves as a water supply and recreational reservoir for the city.

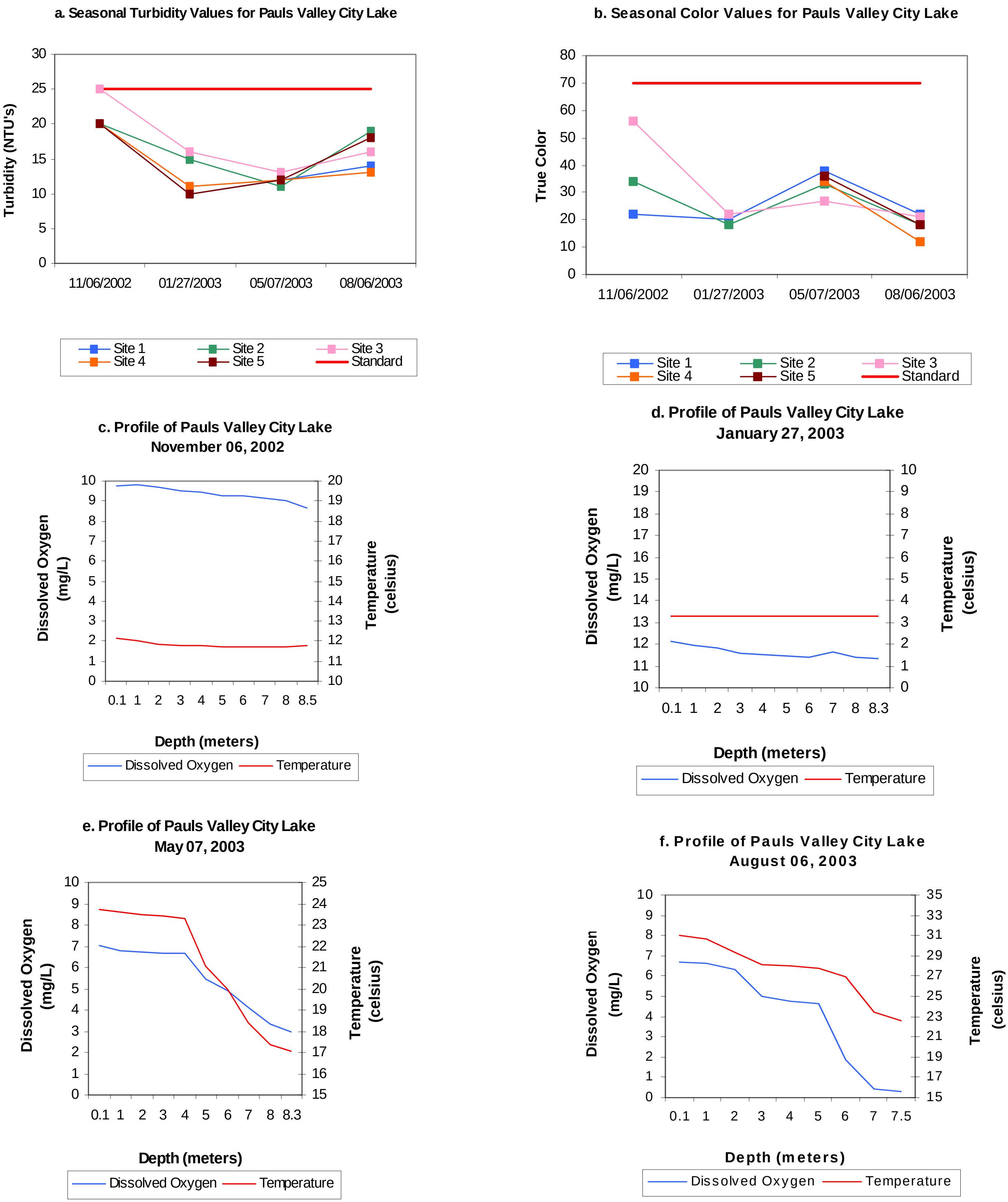


Figure 162a-157f. Graphical representation of data results for Pauls Valley City Lake.

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

Turbidity 2003

Trophic State 2003

Plate 72 - Lake Water Quality for

Pauls Valley Lake

Lake Pawhuska

Lake Pawhuska was sampled for four quarters, from October 2002 through July 2003. 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 3 NTU (Plate 73), true color was 10 units, and secchi disk depth was 280 centimeters. Based on these three parameters, Lake Pawhuska had excellent water clarity in sample year 2002-2003, consistent with data reported in 2000. 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 43 (Plate 73), indicating the lake was mesotrophic in sample year 2003 (Plate 73). This is similar to the TSI in 2000 (TSI=41), indicating no significant increase or decrease in productivity has occurred since the last evaluation. 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 (Figure 163). Seasonal turbidity values per site are displayed in Figure 164a. Turbidity values throughout the year were all well below the turbidity standard of 25 NTU. The Fish and Wildlife Propagation (FWP) beneficial use is considered supported based on turbidity. Seasonal true color values are displayed in Figure 164b. 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.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.14 parts per thousand (ppt) to 0.19 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductance ranged from 287.4 to 375 mS/cm, indicating the minimal 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 6.63 to 8.13 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use

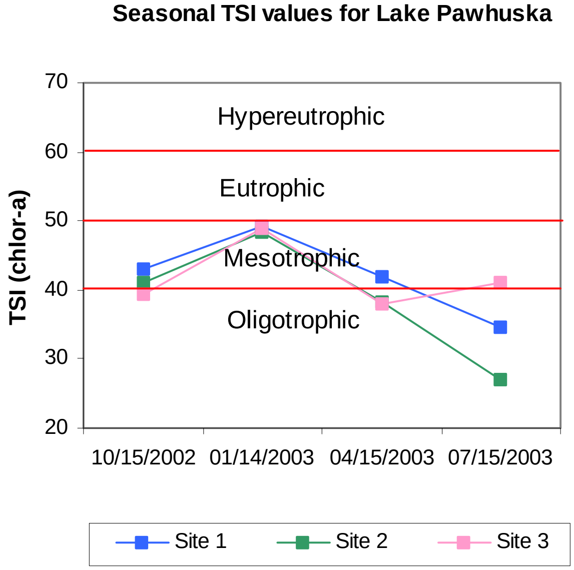


Figure 163. TSI values for Lake Pawhuska.

based on pH. Oxidation-reduction potentials (ORP) range d from 218 mV to 483 mV, indicating an absence of reducing conditions during the study period. During the fall and winter quarters, stratification was not present and lake was well mixed (see Figure 164c-159d). In the spring, the lake was weakly stratified, however dissolved oxygen (D.O.) remained above 7.0mg/L (Figure 164e). 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 5 meters to the lake bottom of 10.9 meters, accounting for approximately 50% of the water column at site 1 experiencing anoxic conditions (Figure 164f). 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 50% 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.23 mg/L at the surface and 0.32 mg/L at the lake bottom. The TN at the surface ranged from 0.06 mg/L to 0.35 mg/L. The highest surface total nitrogen was reported in the summer and the lowest in the winter. The lake-wide total phosphorus (TP) average was 0.009 mg/L and 0.012 mg/L at the lake bottom. The surface TP ranged from 0.005 mg/L to 0.017 mg/L. Similar to TN, the lowest surface TP was reported in the winter however the highest values were seen during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 24:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Pawhuska was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions. This is consistent with the previous evaluation, indicating no significant increase in productivity has occurred. 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, but only partially supporting based on low D.O. values in the summer. The Aesthetics beneficial use is also fully supported based on its trophic status and true color. 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.

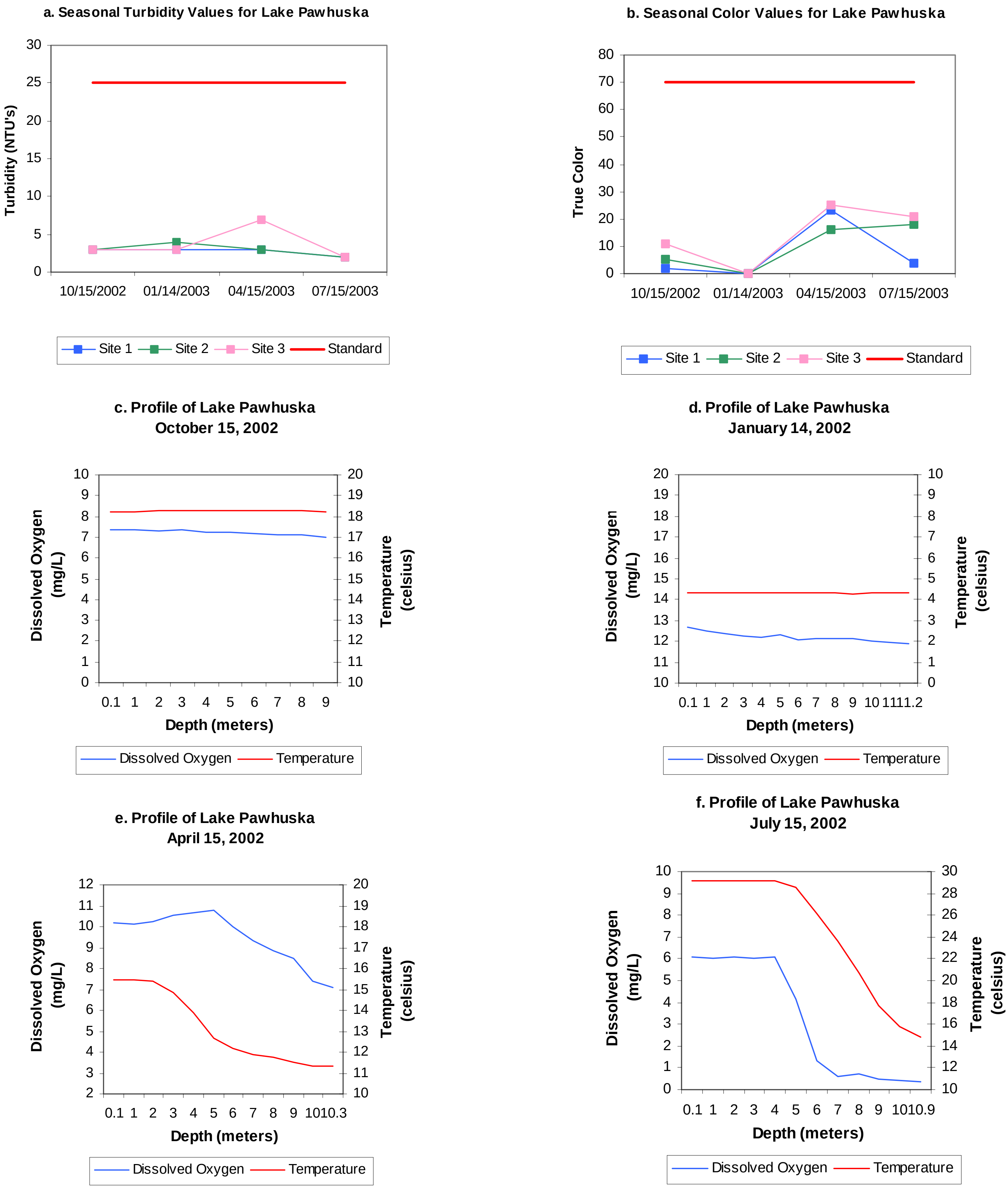
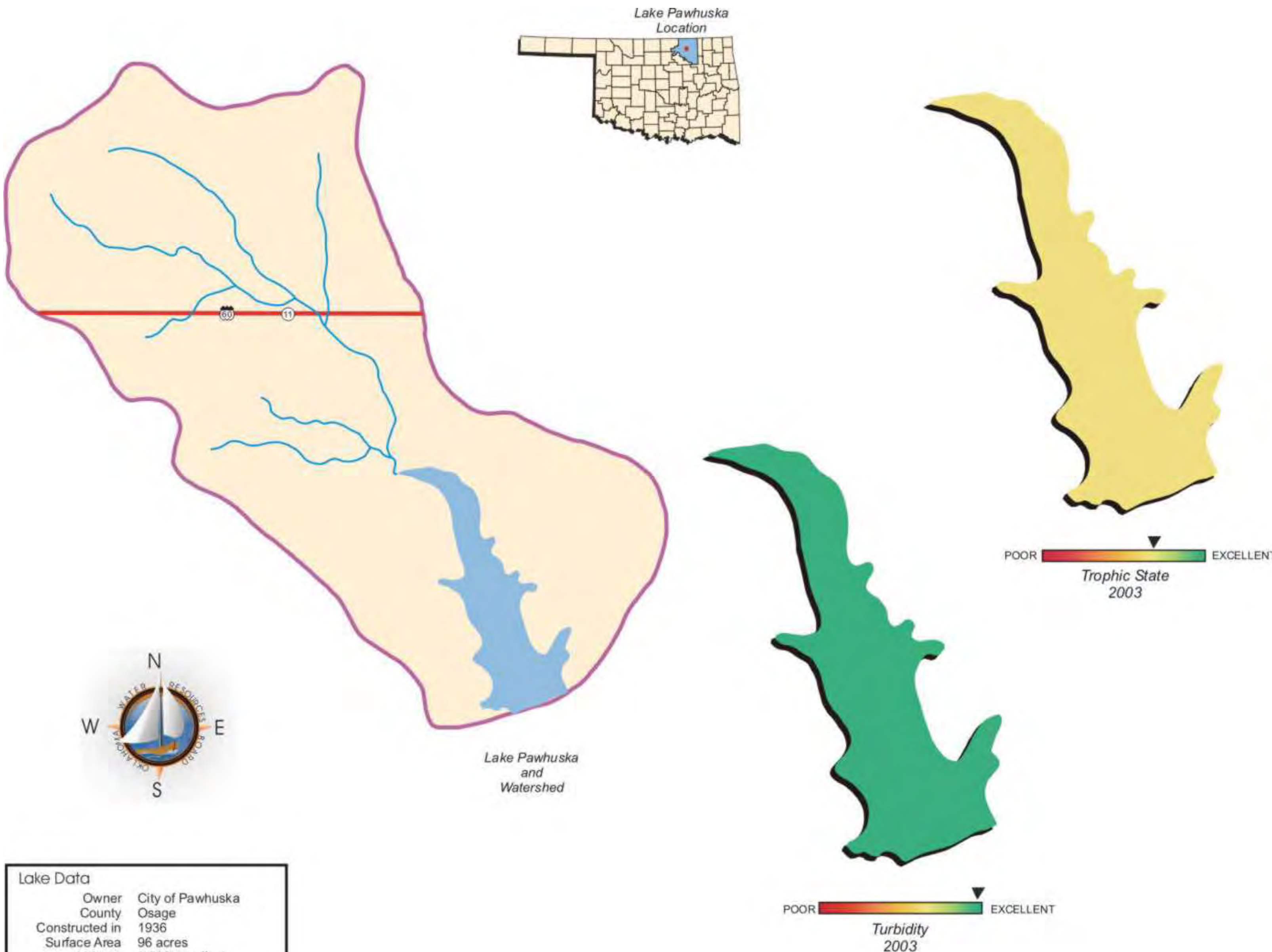


Figure 164a-159f. Graphical representation of data results for Lake Pawhuska.



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 73 - Lake Water Quality for
Lake Pawhuska

Pawnee Lake

Pawnee Lake was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 at the lake surface solely for the determination of chlorophyll-a and nephelometric turbidity. 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 14 NTU (Plate 74), true color was 38 units, and secchi disk depth was 58 centimeters in 2001-2002. Based on these three parameters, Pawnee Lake had average 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 four quarters (n=20). The TSI was 55 (Plate 74), indicating the lake was eutrophic in sample year 2001-2002 with high levels of primary productivity and nutrients. The TSI values throughout the sample year varied seasonally from primarily lower eutrophy in the fall, to mesotrophy in the winter, to upper eutrophy in the spring and summer (see Figure 165). Based on the trophic state of the lake, it is fully supporting its Aesthetics beneficial use as it relates to nutrients. Turbidity readings were below the turbidity Oklahoma Water Quality Standard (OWQS) of 25 NTU during all sampling events (see Figure 166a). 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 OWQS (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. Pawnee Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to nephelometric turbidity. Seasonal true color values are displayed in Figure 166b. True color values varied seasonally and were generally below the aesthetics OWQS of 70 units at all time with the exception of site 2 in the spring quarter (see Figure 166b). Although only 8% of the samples collected in 2001-2002 were above the standard, no definitive determination of Aesthetics use support listing can be made as a minimum of 20 samples are required to make beneficial use determinations on lakes greater than 250 surface acres, therefore, the Aesthetics beneficial use cannot be assessed for true color. Collected data does strongly suggest that Pawnee Lake would be fully supporting.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.15 parts per thousand (ppt) to 0.20 ppt, indicating moderate salt content and values were slightly higher than the expected range of salinity readings reported for most Oklahoma lakes. Readings for specific conductance were also within the range of expected values, ranging from 308 mS/cm to 394.9 mS/cm, indicating 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 6.82 units in the fall quarter to 8.36 units in the spring quarter. According to

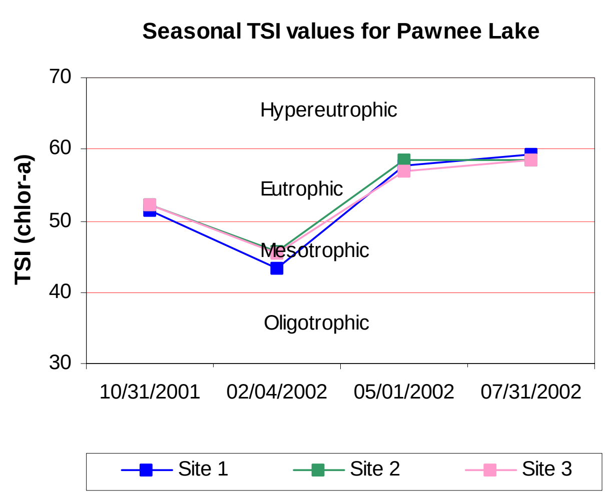


Figure 165. TSI values for Pawnee Lake.

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 should be listed as not supporting beneficial uses. 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 beneficial uses. The lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 66 mV in the spring to 624 mV in the fall quarter, indicating an absence of reducing conditions in any appreciable way at the lake at the time it was sampled. Pawnee Lake was not thermally stratified in the fall or winter quarters and dissolved oxygen (D.O.) values were above 7.6 mg/L throughout the water column in both seasons (see Figure 166c-161d). In the spring quarter the lake was strongly thermally stratified between 2 and 3 meters and D.O. concentrations in the water column fell below 2.0 mg/L at the lake bottom (see Figure 166e). In the summer, the lake was not thermally stratified, but, anoxic conditions were also present at the lake bottom at site 1(see Figure 166f). Although this lake is fairly shallow (about 4 to 5 meters deep), about 50% of the water column was anoxic. 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 Pawnee Lake with only 12.5% of the water column less than 2.0 mg/L in the spring quarter and 25% of the water column less than 2.0 mg/L in the summer. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.73 mg/L at the lake surface. The TN at the surface ranged from 0.55 mg/L to 1.34 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 for sample year 2001-2002 was 0.042 mg/L at the lake surface. The surface TP ranged from 0.029 mg/L to 0.053 mg/L. The highest surface TP value was reported in the summer quarter and the lowest was in the winter. The nitrogen to phosphorus ratio (TN: TP) was approximately 17:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Pawnee Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Pawnee Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 74). The lake was fully supporting its Aesthetics beneficial use based on trophic status and a determination of use support for true color could not be made. Pawnee was fully supporting its FWP beneficial use based on turbidity, pH, and D.O. readings taken. 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. Pawnee Lake is one of the nicer small municipal lakes in Oklahoma.

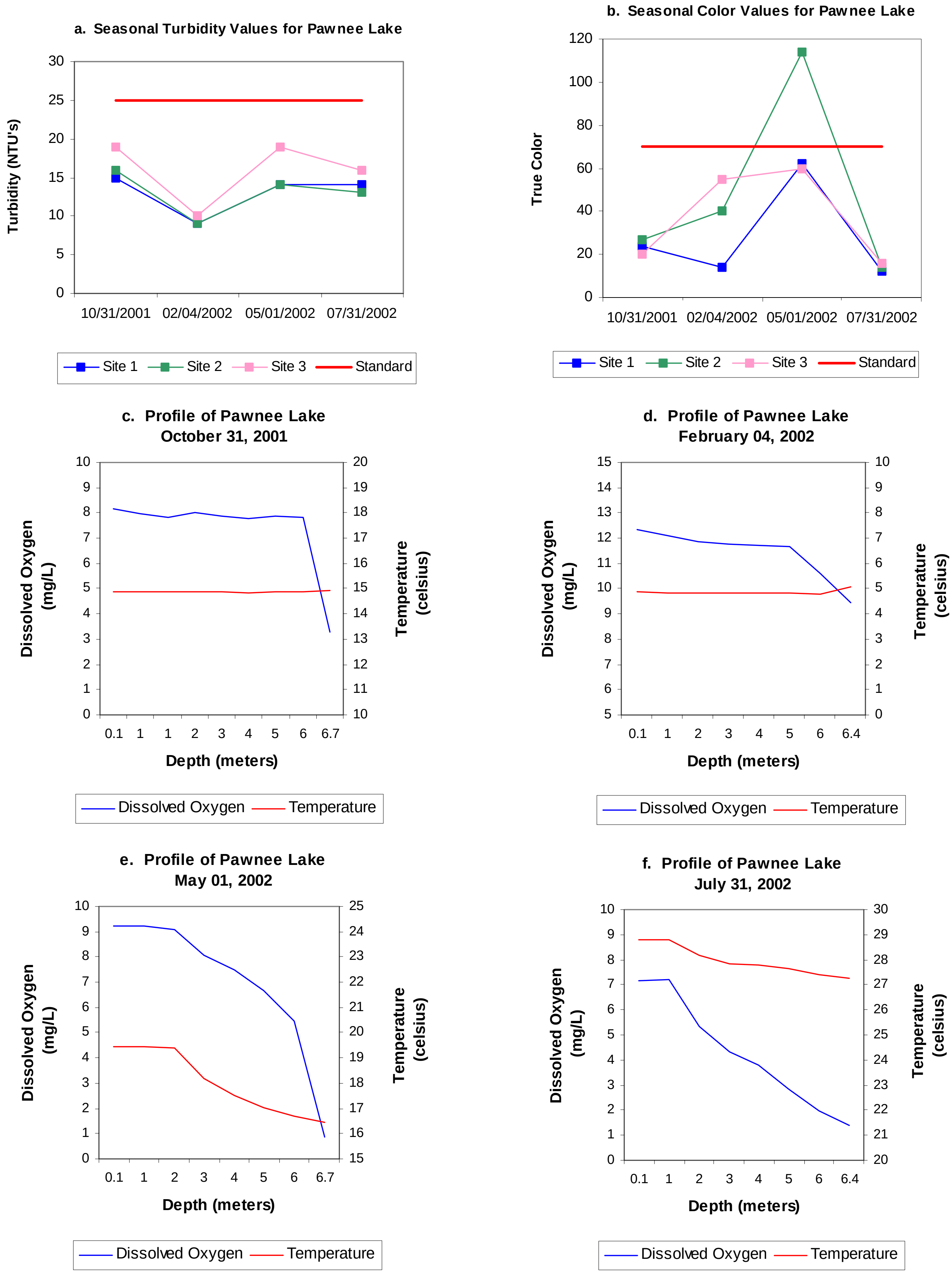


Figure 166a-161f. Graphical representation of data results for Pawnee Lake.

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

Plate 74 - Lake Water Quality for
Pawnee Lake

Perry Lake

Perry Lake was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected from three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for a lake larger than 250 surface acres in size. 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 70 NTU (Plate 75), true color was 144 units, and average secchi disk depth was 22 centimeters. Based on these three parameters, Perry Lake had poor water clarity. These results are similar to those in 2000 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 42 (Plate 75) indicating the lake was mesotrophic in sample year 2002-2003 with moderate levels of primary productivity and nutrients. This value is lower than the TSI calculated in 2000 (TSI=48), although 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 (Figure 167). Seasonal turbidity values are displayed in Figure 168a. Turbidity ranged from a low of 45 NTU to a maximum of 88 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 (OWQS) 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 100% 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 168b. Although all true color values (n=16) were above the aesthetics standard of 70 units, the minimum data requirements of 20 samples for lakes greater than 250 surface acres were not met and use determination cannot be made.

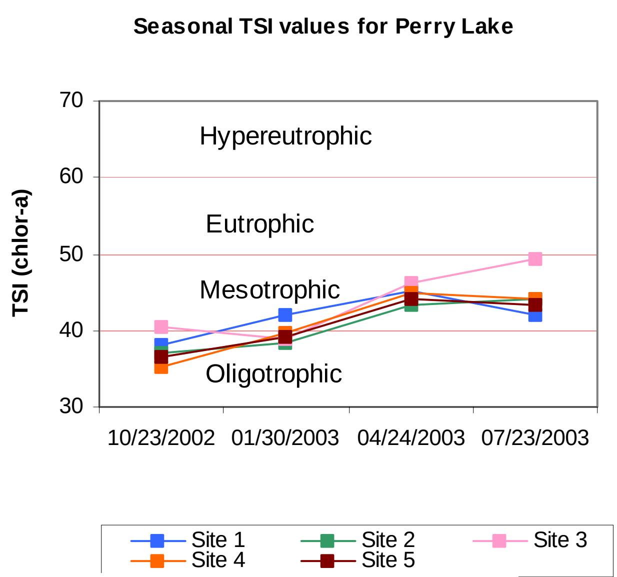


Figure 167. TSI values for Perry Lake.

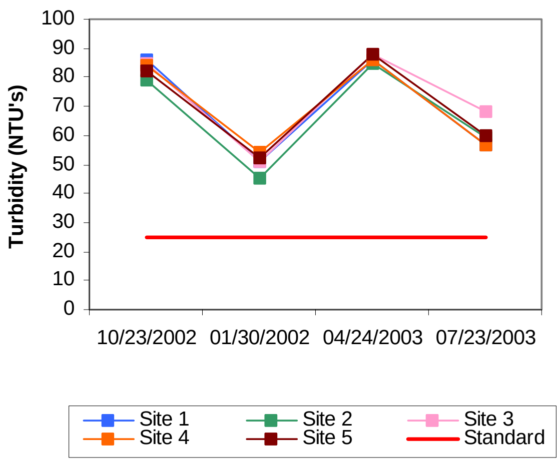
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at sample sites during the study period. The salinity values ranged from 0.15 parts per thousand (ppt) to 0.22 ppt, which is within the average range of values for most Oklahoma reservoirs. Specific conductivity ranged from 305.7 mS/cm to 438 mS/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 and ranged from 7.42 to 7.96. Oxidation-reduction potentials (ORP) ranged from 223 mV in the spring to 586 mV in the w inter, indicating reducing conditions were not present in sample year 2002-2003. Stratification was not evident in any of the first three sampling intervals and the lake was well mixed with dissolved oxygen (D.O.) remaining above 7.0 mg/L (Figure 168c-163e). In the summer, the lake was thermally stratified and anoxic conditions were present below the thermocline. Perry Lake was stratified between 7 and 8 meters with D.O. falling below 2.0 mg/l to the lake bottom of 11.7 meters, accounting for approximately 39% of the water column experiencing anoxic conditions at site 1 (see Figure 168f). 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 39% 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

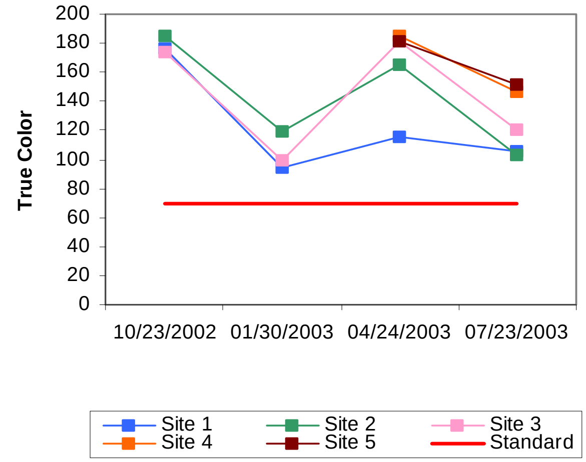
Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.78 mg/L at the surface and 0.82 mg/L at the lake bottom. The TN at the surface ranged from 0.56 mg/L to 1.02 mg/L. The highest surface total nitrogen was reported in the spring and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.084 mg/L at the surface and 0.089 mg/L at the lake bottom. The surface TP ranged from 0.062 mg/L to 0.102 mg/L. Similar to TN, the lowest surface TP was reported in the summer however the highest values were seen during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was 9:1 for sample year 2002-2003. This value is greater 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. The current trophic status is the same as that calculated in 2000, indicating little or no change in productivity has occurred. The FWP beneficial use is supported based on pH, only partially supporting based on dissolved oxygen and not supported based on high turbidity values. The Aesthetics beneficial use is supported based on trophic status, however a use determination based on true color cannot be made, as minimum data requirements were not met. Upon reviewing current and historical data it is likely the use would not be supported based on true color. Additional sites have been added to ensure data requirement will be met in the future. Perry Lake, located in Noble County, was constructed for the purpose of flood control, water supply, and recreation.

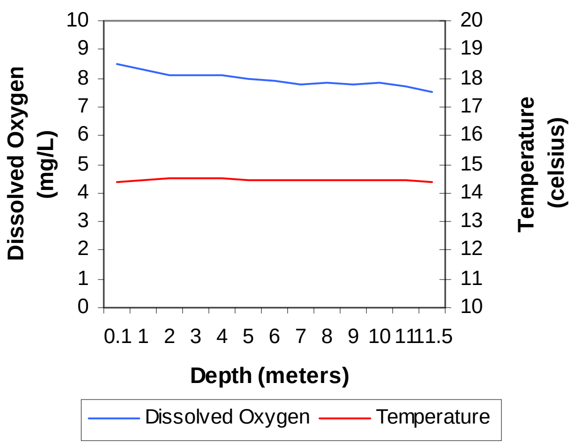
a. Seasonal Turbidity Values for Perry Lake



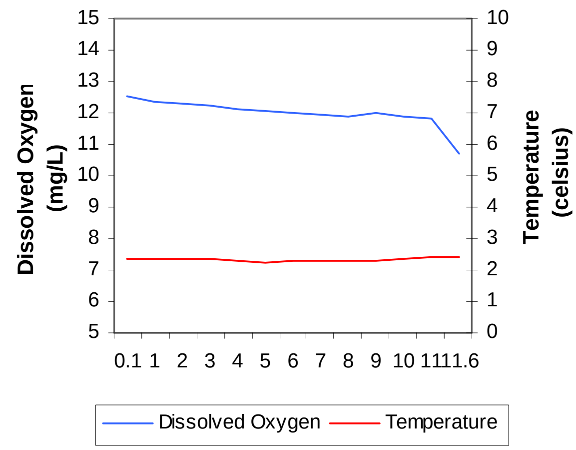
b. Seasonal Color Values for Perry Lake



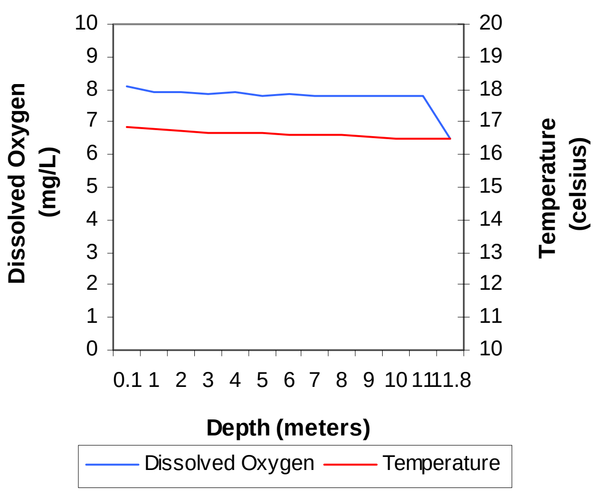
c. Profile of Perry Lake
October 23, 2002



d. Profile of Perry Lake
January 30, 2003



e. Profile of Perry Lake
April 24, 2003



f. Profile of Perry Lake
July 23, 2003

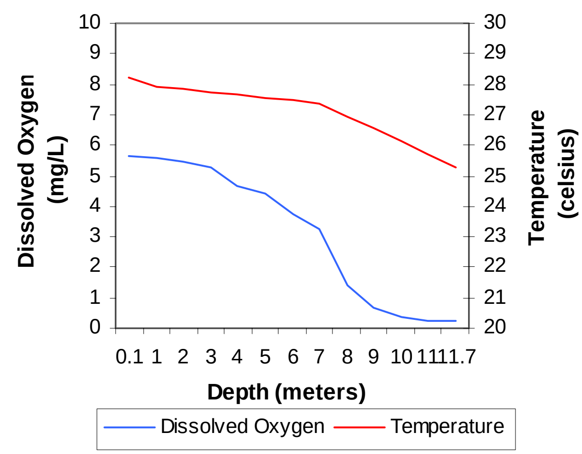


Figure 168a-163f. Graphical representation of data results for Perry Lake.

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 75 - Lake Water Quality for
Perry Lake

Pine Creek Lake

Pine Creek Lake was sampled for four quarters from November 2001 through August 2002. 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. 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 15 NTU (Plate 76), true color was 79 units, and secchi disk depth was 73 centimeters in 2001-2002. Based on these three parameters, Pine Creek Lake had good water clarity in comparison to other Oklahoma reservoirs, thought the true colors readings collected were higher than normally seen in 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 76), indicating the lake was eutrophic in sample year 2001-2002 with high levels of primary productivity and nutrients. The TSI values throughout the sample year were predominantly eutrophic with only the winter quarter experiencing mesotrophic conditions (see Figure 169). Turbidity values in the fall, spring and summer seasons were below the Oklahoma Water Quality Standard (OWQS) for turbidity of 25 NTU (see Figure 170a). There was a spike in turbidity in the winter quarter, possibly due to seasonal rain events, at which point values were above the standard at all sampling sites. 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 OWQS (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 15% 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 170b. True color values varied seasonally and with 55% of the sample values exceeding the OWQS of 70 units the lake is not supporting its Aesthetics beneficial use for true color (see Figure 170b). However, many of the lakes in southeastern Oklahoma are highly "stained" so true color readings may be due to natural causes.

In 2001-2002, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.05 ppt, well within the expected range of salinity values if not less than reported values for most Oklahoma lakes. Readings for specific conductance were lower than the expected range for most Oklahoma lakes, ranging from 0.0 mS/cm to 115.6 mS/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 5.81 units in the spring quarter to 7.76 in the fall quarter. 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 should be listed as not supporting beneficial uses. 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* beneficial uses. With 65% of the water column pH values falling outside the acceptable range the lake is provisionally not

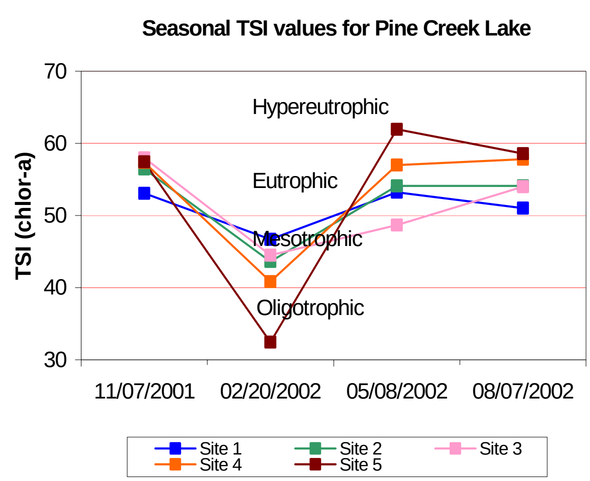


Figure 169. TSI values for Pine Creek Lake.

supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 5 mV in the summer to 447 mV also recorded at the lake surface in the summer quarter. Slightly reducing conditions were present in the water column in the summer, but nothing to cause concern. 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 except at the lake bottom where values fell below 2.0 mg/L. (see Figure 170c-165d). Pine Creek Lake was thermally stratified in the spring quarter between 1 and 2 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 15.9 meters (see Figure 170e). In the summer, the lake was thermally stratified between 6 and 7 meters at site 1, at which point D.O. levels fell below 2.0 mg/L extending all the way to the lake bottom at 15.8 meters (see Figure 170f). 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 12% and 20% of the water column having D.O. readings less than 2.0 mg/L in the fall and spring quarters respectively, the lake was fully supporting its FWP. In the summer quarter 71% of the water column was experiencing anoxic conditions which is cause for classifying the lake as 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 found the Agriculture beneficial use to be fully supported based on criteria in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.48 mg/L at the lake surface. The TN at the surface ranged from 0.26 mg/L to 0.73 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 for sample year 2001-2002 was 0.034 mg/L at the lake surface. The surface TP ranged from 0.020 mg/L to 0.45 mg/L. The highest surface TP value was reported in the winter quarter and the lowest was in the summer. The nitrogen to phosphorus ratio (TN: TP) was approximately 14:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Pine Creek Lake was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds. 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 76). The lake is fully supporting its Aesthetics beneficial use based on its trophic status, but is not supporting based on true color. The lake was partially supporting its FWP beneficial use based on D.O. and nephelometric turbidity. Pine Creek was not supporting based on collected pH values in 2001-2002. 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.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

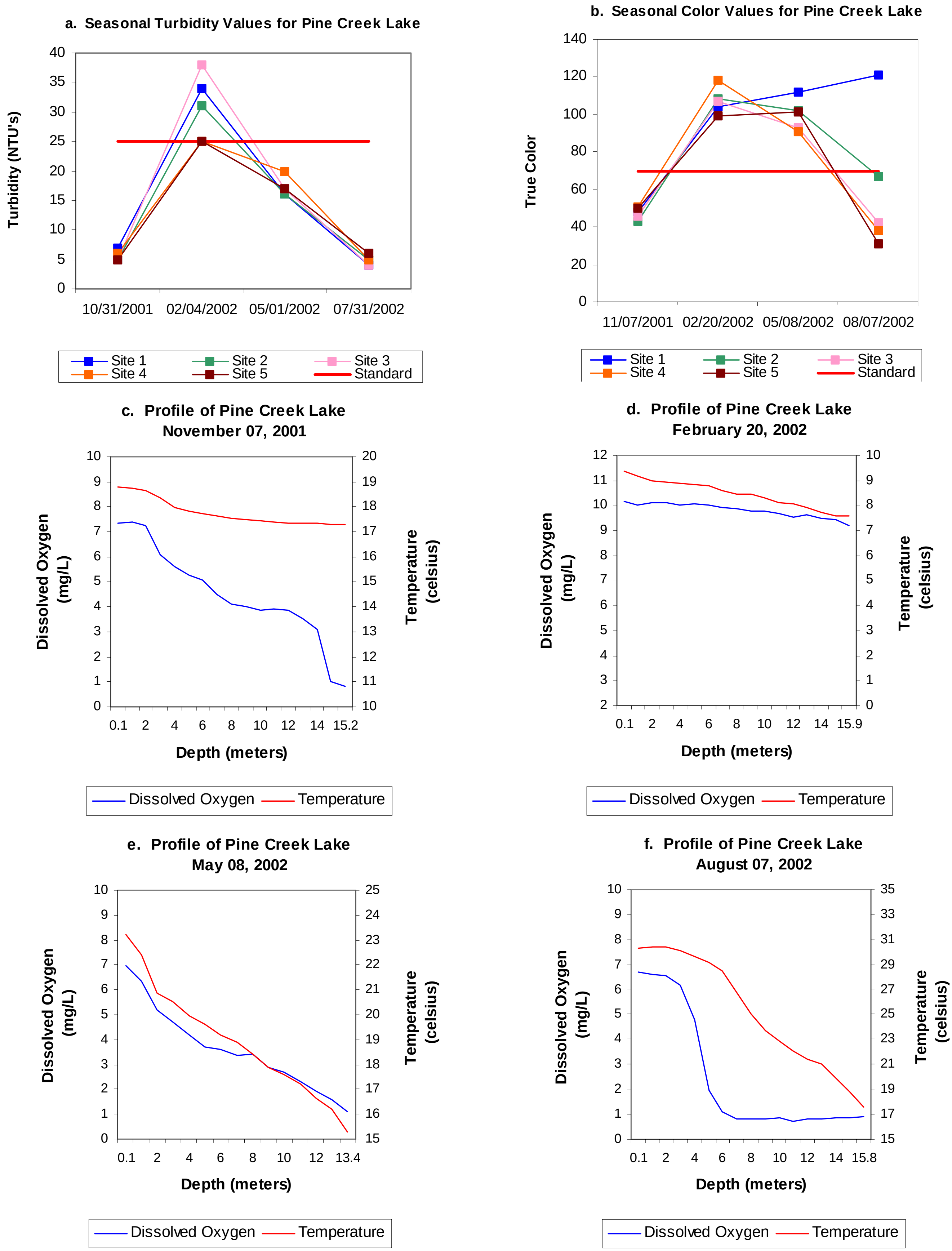
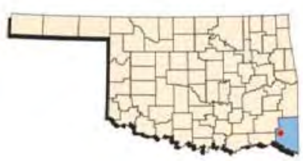


Figure 170a-165f. Graphical representation of data results for Pine Creek Lake.

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

Turbidity
2002

Trophic State
2002

Plate 76 - Lake Water Quality for
Pine Creek Lake

Lake Ponca

Lake Ponca was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected from three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative of a lake greater than 250 surface acres. 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 14 NTU (Plate 77), true color was 30 units and average secchi disk depth was 76 centimeters. Based on these three parameters, Lake Ponca had average water clarity. These values are similar to those in 2000, 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=19). The TSI was 54 (Plate 77), indicating the lake was eutrophic in sample year 2002-2003 with high levels of primary productivity and nutrients. This value is similar to that from 2000 (TSI=58), 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 2003. In the fall, spring, and summer sampling quarters values were generally eutrophic. In the fall values ranged from eutrophic at sites 1, 2, and 4 to hypereutrophic at sites 3 and 5 (Figure 171). TSI values in the winter were all mesotrophic. Seasonal turbidity values per site are displayed in Figure 172a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, therefore meeting the Fish and Wildlife (FWP) beneficial use. Although 100% of samples in 2003 were below the 70-unit color standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres (see Figure 172b).

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.12 parts per thousand (ppt) to 0.17 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductance ranged from 251.9 to 339.7 mS/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 6.63 in the summer to 8.05 in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH

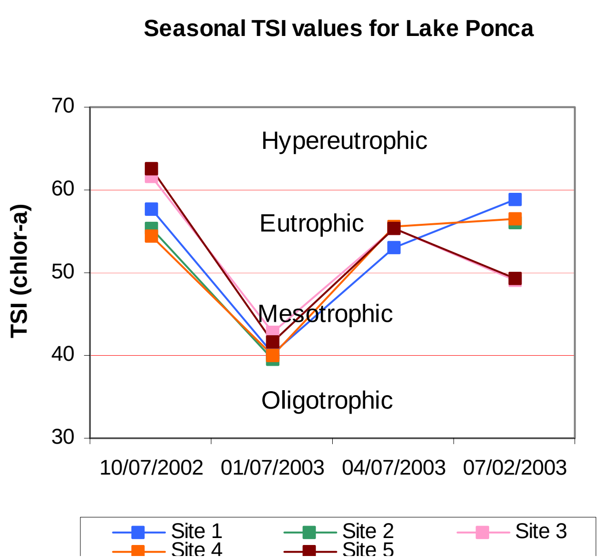


Figure 171. TSI values for Lake Ponca.

values fall outside the 6.5 to 9 range the lake is considered partially supporting. 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 87 mV in the hypolimnion in the fall to 467 mV in the summer. In general, reducing conditions present were not during the study period. During the fall, winter, and spring quarters stratification was not present and lake was well mixed (see Figure 172c-167e). In the fall dissolved oxygen was generally above 5.0 mg/L only falling below 2.0 mg/l at the lake bottom at the sediment-water interface (Figure 172f). 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 70% 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. 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.78 mg/L at the surface and 0.65 mg/L at the lake bottom. The TN at the surface ranged from 0.56 mg/L to 1.04 mg/L. The highest surface total nitrogen was reported in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.036 mg/L and 0.059 mg/L at the lake bottom. The surface TP ranged from 0.012 mg/L to 0.055 mg/L. The lowest surface TP was reported in the winter however the highest values were seen during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 22:1 for sample year 2002-2003. This value is greater 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 2002-2003. This is consistent with the 2000 evaluation indicating no significant change in productivity has occurred. Based on true color, turbidity, and secchi disk depth, Lake Ponca had average water clarity in comparison to other Oklahoma lakes. The lake is supporting the FWP beneficial use based on turbidity and pH, but only partially supporting based on low dissolved oxygen values in the summer. The Aesthetics beneficial use is supported based on its trophic status, however due to minimum data requirements not being met true color cannot be assessed. Lake Ponca is a water supply and recreational reservoir for the city of Ponca City.

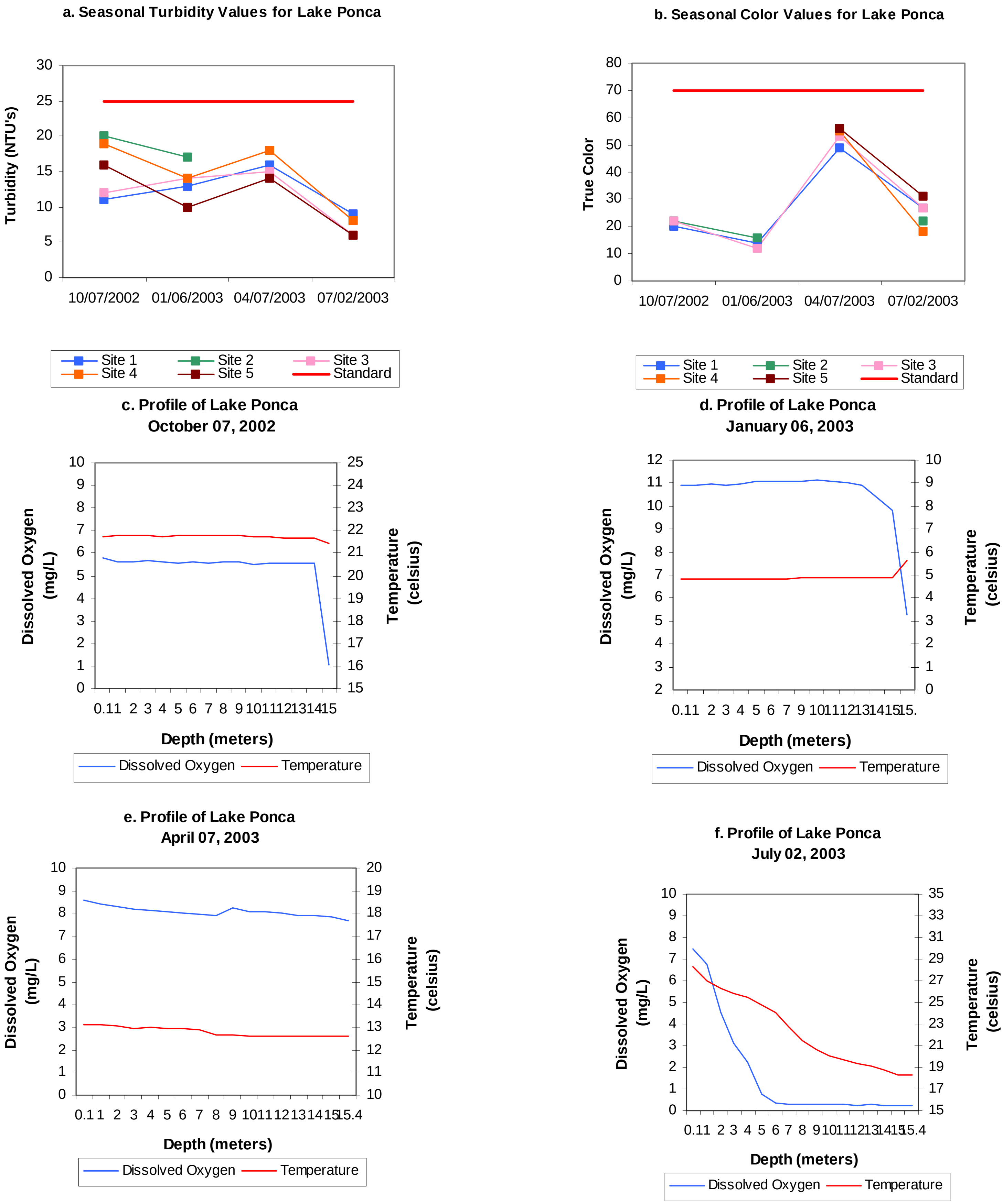
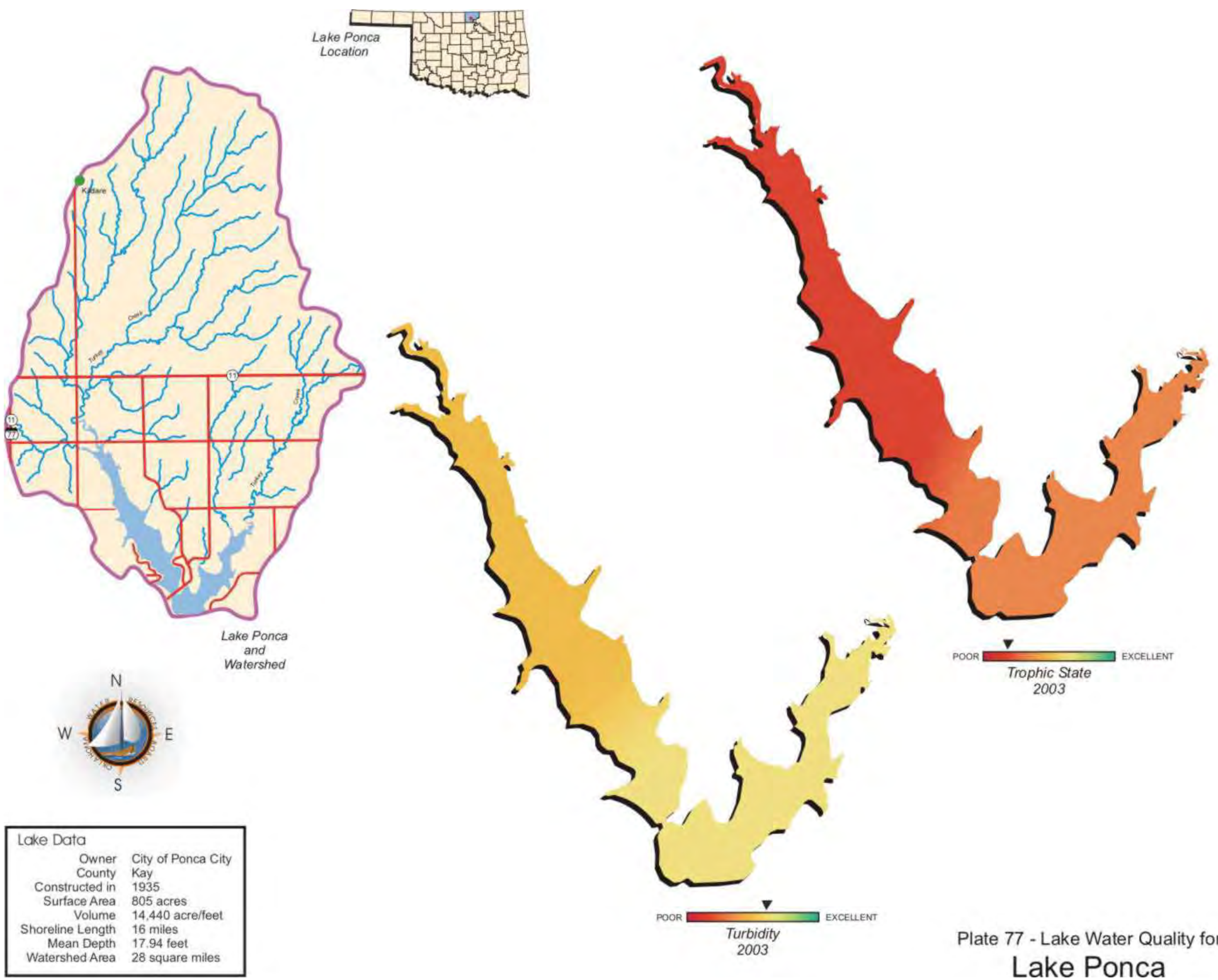


Figure 172a-167f. Graphical representation of data results for Lake Ponca.



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

Plate 77 - Lake Water Quality for
Lake Ponca

Prague City Lake

Prague City Lake was sampled for four quarters, from November 2002 through August 2003. 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 9 NTU (Plate 78), true color was 19 units and average secchi disk depth was 92 centimeters. Based on these three parameters, Prague City Lake had good water clarity in 2003. These values are similar to those in 2000, 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 43 (Plate 78), indicating the lake was mesotrophic indicative of moderate levels of primary productivity and nutrients. This value is similar to that from 2000 (TSI=45), indicating no significant change in productivity has occurred since the last evaluation. Seasonal TSI values were fairly consistent and ranged from oligotrophic in the fall and winter to mesotrophic in the spring and summer. Site 1 was the only mesotrophic site in the winter sampling quarter (see Figure 173). Seasonal turbidity values per site are displayed in Figure 174a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, therefore meeting the Fish and Wildlife (FWP) beneficial use. Seasonal true color values are displayed in Figure 174b. With 100% of the collected values well below the OWQS of 70 units the lake is supporting the Aesthetics beneficial use.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.13 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductance ranged from 231.8 to 273.4 mS/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 6.99 in the summer to 8.34 in the fall. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With all recorded values within the acceptable range the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials

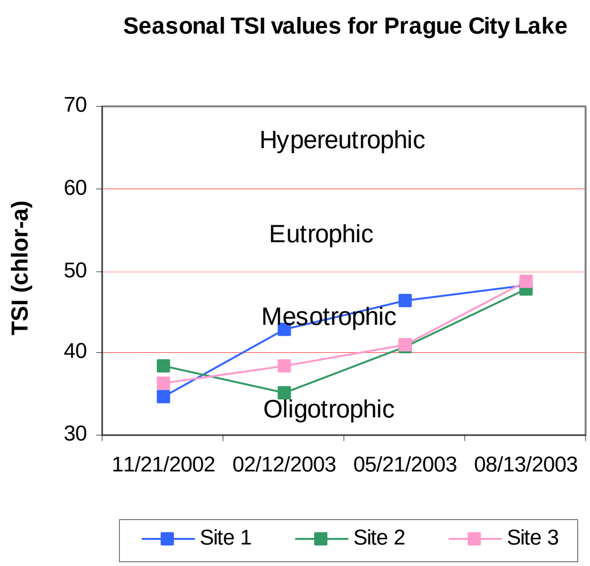


Figure 173. TSI values for Prague City Lake.

(ORP) ranged from 142 mV in the hypolimnion in the spring to 548 mV in the winter, indicating the absence of reducing conditions. The lake was not thermally stratified in the fall or winter quarters with dissolved oxygen (D.O) above 8.0 mg/L (Figure 174c-169d). Thermal stratification was evident and anoxic conditions present in both spring and summer quarters. In the spring, stratification occurred between 6 and 7 meters with dissolved oxygen falling below 2.0 mg/L to the lake bottom of 8.4 meters, accounting for approximately 30% of the water column at site 1 to be anoxic (Figure 174e). In the summer quarter, stratification was evident at all sites with anoxic conditions present in 28 to 40 % of the water column (Figure 174f). 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 partially supported at Prague City Lake 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.42 mg/L at the surface and 0.63 mg/L at the lake bottom. The TN at the surface ranged from 0.24 mg/L to 0.57 mg/L. The highest surface total nitrogen was reported in the fall and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.015 mg/L and 0.025 mg/L at the lake bottom. The surface TP ranged from 0.007 mg/L to 0.019 mg/L. The lowest surface TP was reported in the fall and the highest values were seen during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 28:1 for sample year 2002-2003. This value is greater 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 2002-2003. This is consistent with the 2000 evaluation (TSI=45), 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 low dissolved oxygen values in the spring and summer. The Aesthetics beneficial use is supported by both trophic status and true color. Prague City Lake was constructed in 1984 for the purpose of flood control, water supply and recreation.

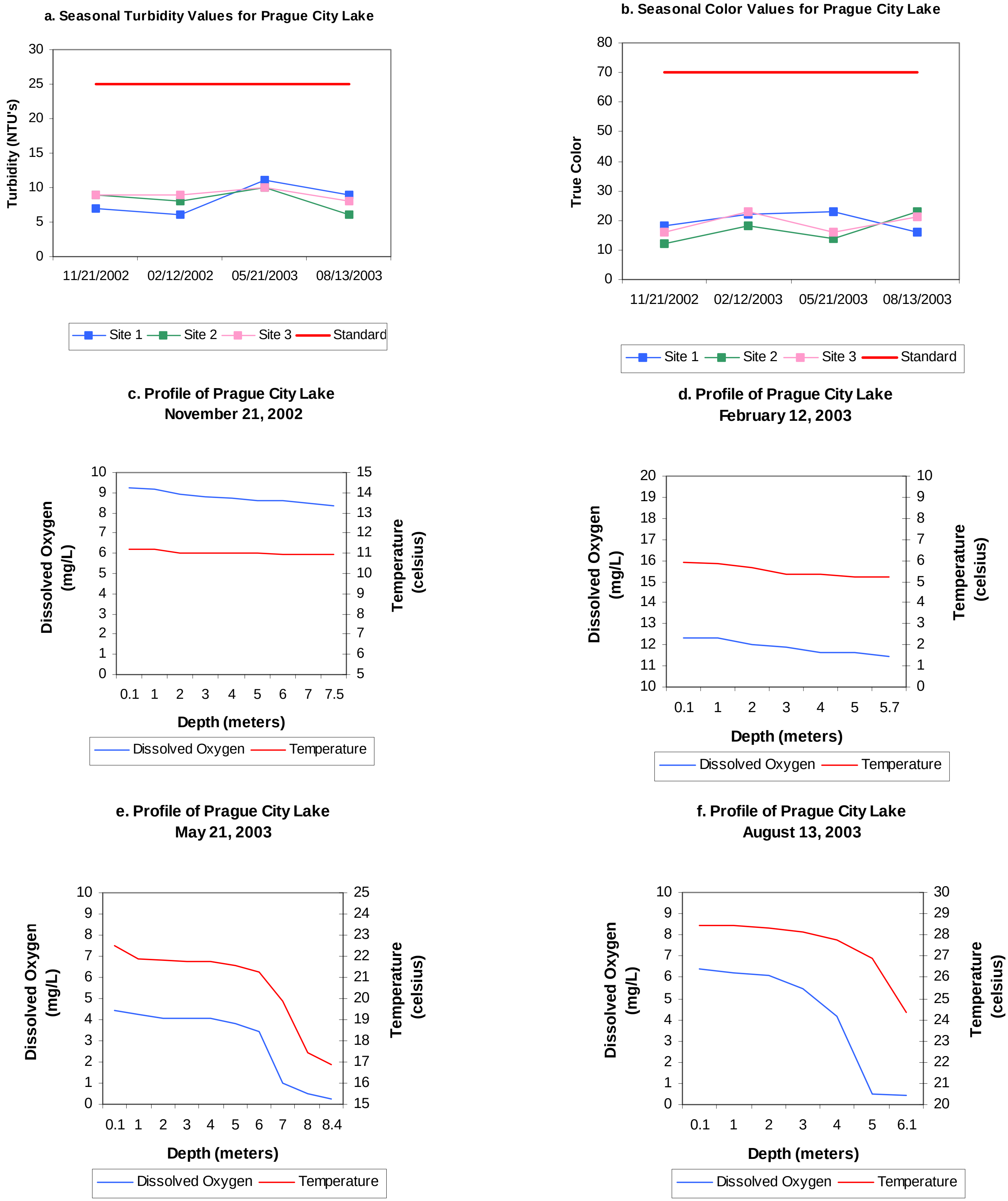
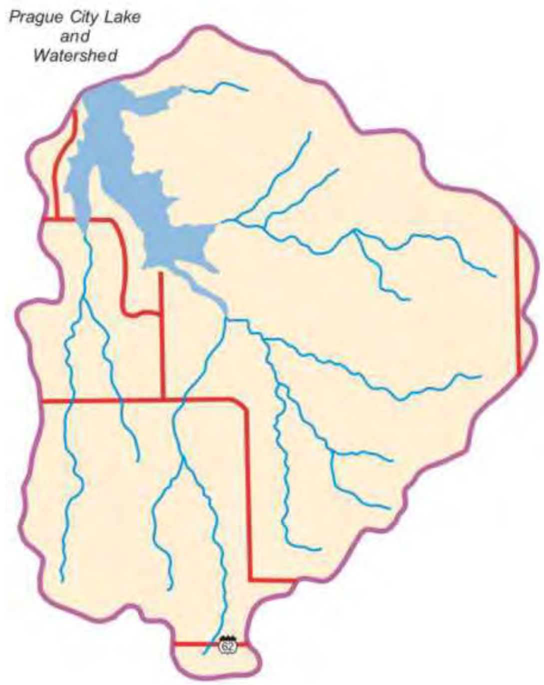


Figure 174a-169f. Graphical representation of data results for Prague City Lake.



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

Plate 78 - Lake Water Quality for

Prague City Lake

Purcell Lake

Purcell Lake was sampled for four quarters, from November 2001 through August 2002. 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 18 NTU (Plate 79), true color was 32 units, and secchi disk depth was 49 centimeters in 2001-2002. Water clarity was average based on secchi disk depth, turbidity, and true color values. 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 79), indicating the lake was eutrophic, with high levels of productivity and nutrient rich conditions. The TSI values were eutrophic in the fall, spring and summer quarters and were mesotrophic in the winter quarter (see Figure 175). The annual trophic assessment seems representative of conditions at Purcell Lake for 2001-2002. Turbidity values per site were all below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons (see Figure 176a). 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 OWQS (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 fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity concentrations. Seasonal true color values are displayed in Figure 176b. All true color values were below the Aesthetics OWQS of 70 units (see Figure 176b). Purcell Lake is fully supporting its Aesthetics beneficial use as it relates to true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites in 2001-2002. Salinity ranged from 0.17 parts per thousand (ppt) in the fall to 0.25 ppt in the spring, indicating moderate salt content and readings were within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 352.2 mS/cm in the fall quarter to 486.7 mS/cm in the spring 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 7.53 units in the spring to 8.62 units in the winter quarter. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. 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 13 mV to 481 mV in the summer indicating reducing conditions were not present during any of the sample quarters. The lake was not thermally stratified in the fall, winter or spring quarters and was well mixed with dissolved oxygen (D.O.) concentrations above 7.0 mg/L throughout the water column with the exception of site 1

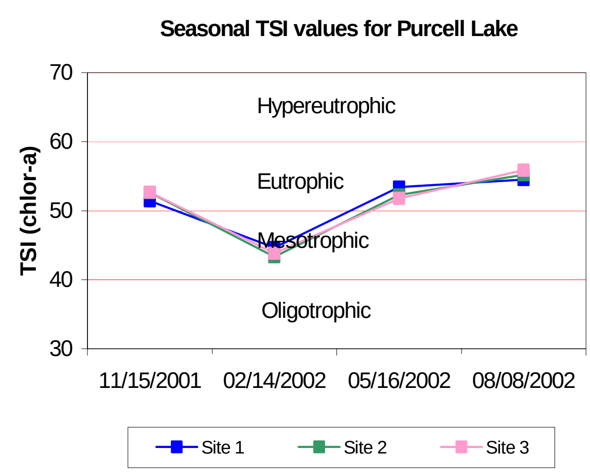


Figure 175. TSI values for Purcell Lake.

at the very bottom of the lake where a value less than 1.0 mg/L was recorded (see Figure 176c-171e). In the summer the lake was thermally stratified between 2 and 3 meters below the surface at the dam. Below 2 meters at site 1 to the lake bottom (5.1 meters), D.O. values were less than 2.0 mg/L, constituting about 57% of the water column (see Figure 176f). 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 Purcell Lake. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.67 mg/L at the lake surface. The TN at the surface ranged from 0.36 mg/L to 0.89 mg/L. The highest surface TN value was reported in the spring and the lowest was in the fall quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.034 mg/L at the lake. The surface TP ranged from 0.027 mg/L to 0.045 mg/L. The highest surface TP value was reported in the fall quarter and the lowest was in the winter. The nitrogen to phosphorus ratio (TN: TP) was approximately 19:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Purcell Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Purcell Lake was classified as eutrophic, indicating high primary productivity and nutrient rich conditions (Plate 79). The lake was fully supporting its Aesthetics beneficial use based on trophic status (nutrients) and on true color readings. The lake was fully supporting its FWP beneficial use based on nephelometric turbidity and pH, but only partially supporting based upon water column D.O. readings. 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.

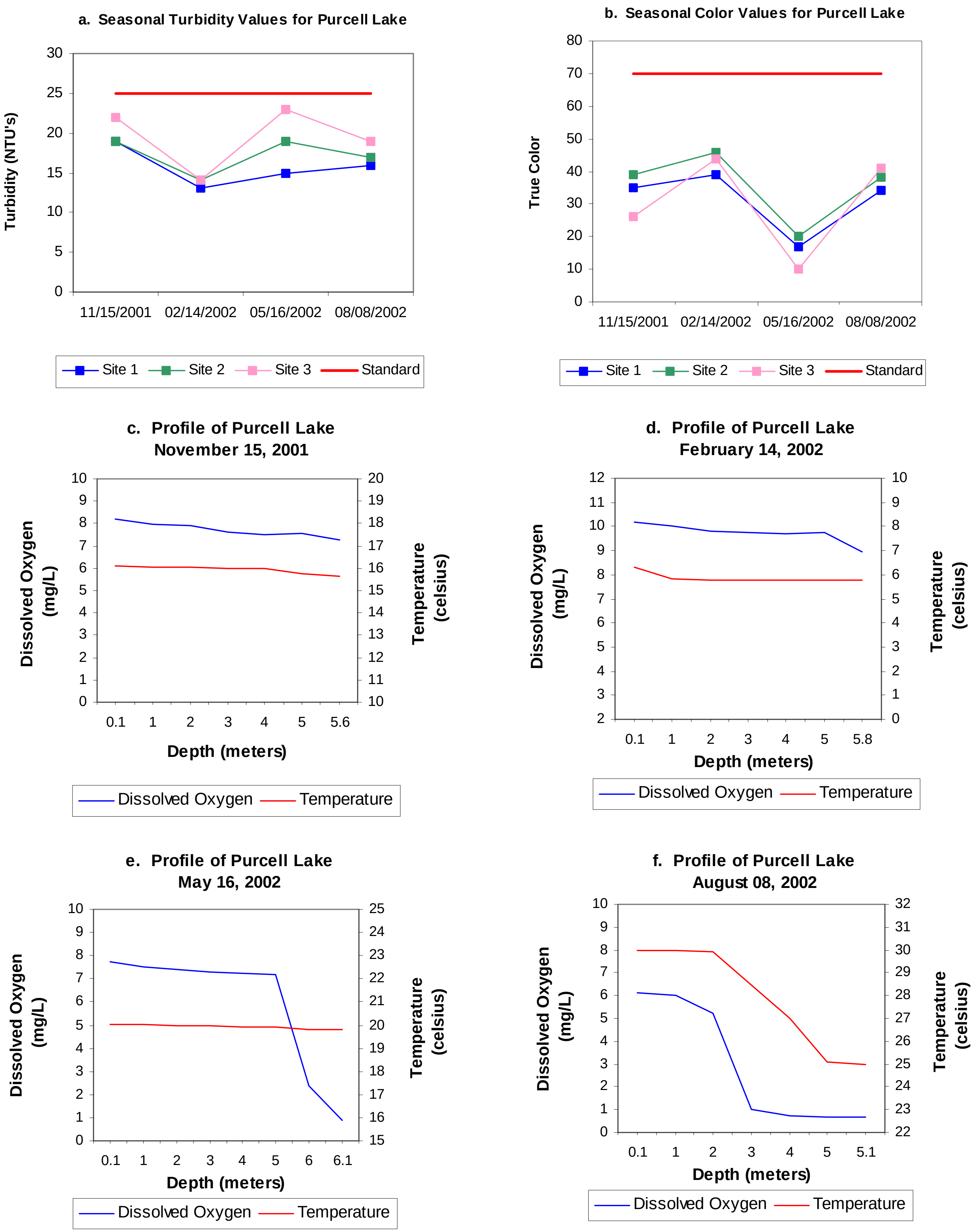


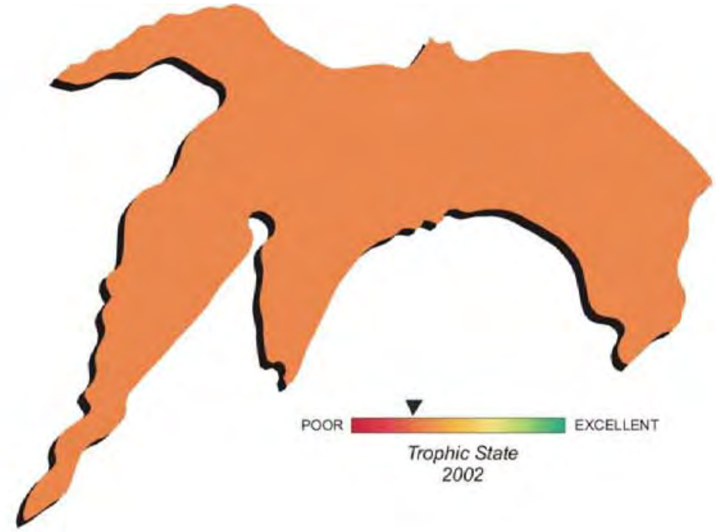
Figure 176a-171f. Graphical representation of data results for Purcell Lake.

Purcell Lake
and
Watershed

Purcell Lake
Location

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



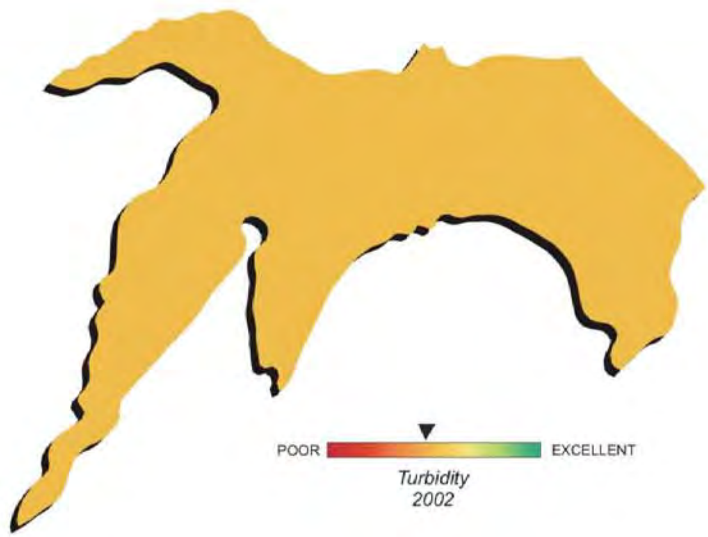


Plate 79 - Lake Water Quality for
Purcell Lake

Lake Raymond Gary

Lake Raymond Gary was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for a reservoir greater than 250 surface acres. 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 10 NTU (Plate 80), true color was 36 units, and secchi disk depth was 74 centimeters. Based on these parameters water clarity was good in 2003. Results for these parameters were similar to the results found in 2000. 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 55 (Plate 80), indicating the lake was eutrophic, with high levels of productivity and nutrient conditions. This value is the same as the TSI in 2000 (TSI=55), indicating no significant increase or decrease over time. The TSI values were primarily eutrophic in 2003, except at site 5 in the fall, which was mesotrophic (see Figure 177). Seasonal turbidity values are displayed in Figure 178a. Turbidity ranged from a low of 6 NTU to a maximum of 20 NTU, with higher values reported for all sites in the fall sampling quarter. With all collected values below the Oklahoma Water Quality Standard (OWQS) of 25 NTU the Fish and Wildlife Propagation beneficial use is fully supported in regards to turbidity. Seasonal true color values are displayed in Figure 178b. True color values were below the OWQS of 70 throughout the sample year, however the minimum data requirements of 20 samples for lakes greater than 250 surface acres were not met and a use determination cannot be made.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were performed at all sample sites during the sample year. Salinity values ranged from 0.00 parts per thousand (ppt) to 0.81 ppt. Readings for specific conductance ranged from 33.5 mS/cm in the winter to 1530 mS/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 and 4, both near the dam site. 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 6.2 in the summer to 7.33 in the winter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they

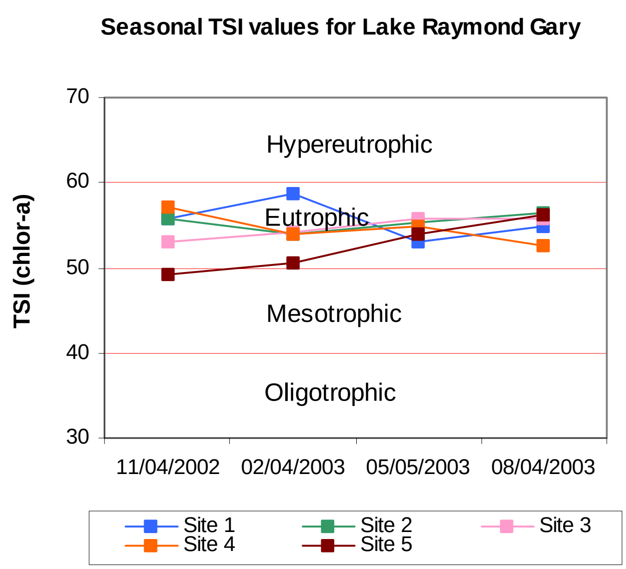


Figure 177. TSI values for Lake Raymond Gary.

fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 22% of the values recorded being less than 6.5 the lake should be listed as partially supporting based on pH. The low pH values may be due to natural conditions, and will be listed as "provisionally partially supporting"* the FWP. These slightly acidic conditions are commonly seen in lakes in the southeastern corner of the state. Oxidation-reduction potentials ranged from 373 mV to 534 mV, 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 7.0 mg/L throughout the water column (Figure 178c-173d). In the spring, site 1 was the only site to stratify with D.O. falling below 2.0 mg/L from 2 meters to the lake bottom of 4.3 meters (Figure 178e). Dissolved oxygen values in the summer were also below 2.0 mg/L for 25 to 50% of the water column at all sites (Figure 178f). 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. The lake was also sampled for chlorides, sulfates and total dissolved solids to assess the Agriculture beneficial use. Sampling in 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.36 mg/L at the surface and 0.52 mg/L at the lake bottom. The TN at the surface ranged from 0.05 mg/L to 0.70 mg/L. The highest surface total nitrogen was reported in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.033 mg/L and 0.065 mg/L at the lake bottom. The surface TP ranged from 0.023 mg/L to 0.053 mg/L. The lowest surface TP was reported in the fall and the highest values were seen during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 11:1 for 2002-2003. This value is greater than 7:1, indicating the lake was phosphorus-limited (Wetzel, 1983).

In summary, Lake Raymond Gary was classified as eutrophic, indicative of high primary productivity and nutrient conditions. This classification is consistent with data collected in 2000, indicating no change in productivity has occurred over time. Water clarity was good in sample year 2002-2003, based on turbidity, true color, and secchi disk depth. The lake is supporting the FWP beneficial use based on turbidity, but only partially supporting based on low dissolved oxygen values in both spring and summer quarters. With 22% of the recorded pH values less the 6.5 units the lake will be listed as " provisionally partially supporting", as low pH may be due to natural causes. The Aesthetics beneficial is supported based on its trophic status, however an assessment based on true color could not be made due to minimum data requirements not being met. Additional sites have been added to ensure sample size is representative of a lake this size. Lake Raymond Gary is a recreational reservoir owned by the State of Oklahoma.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

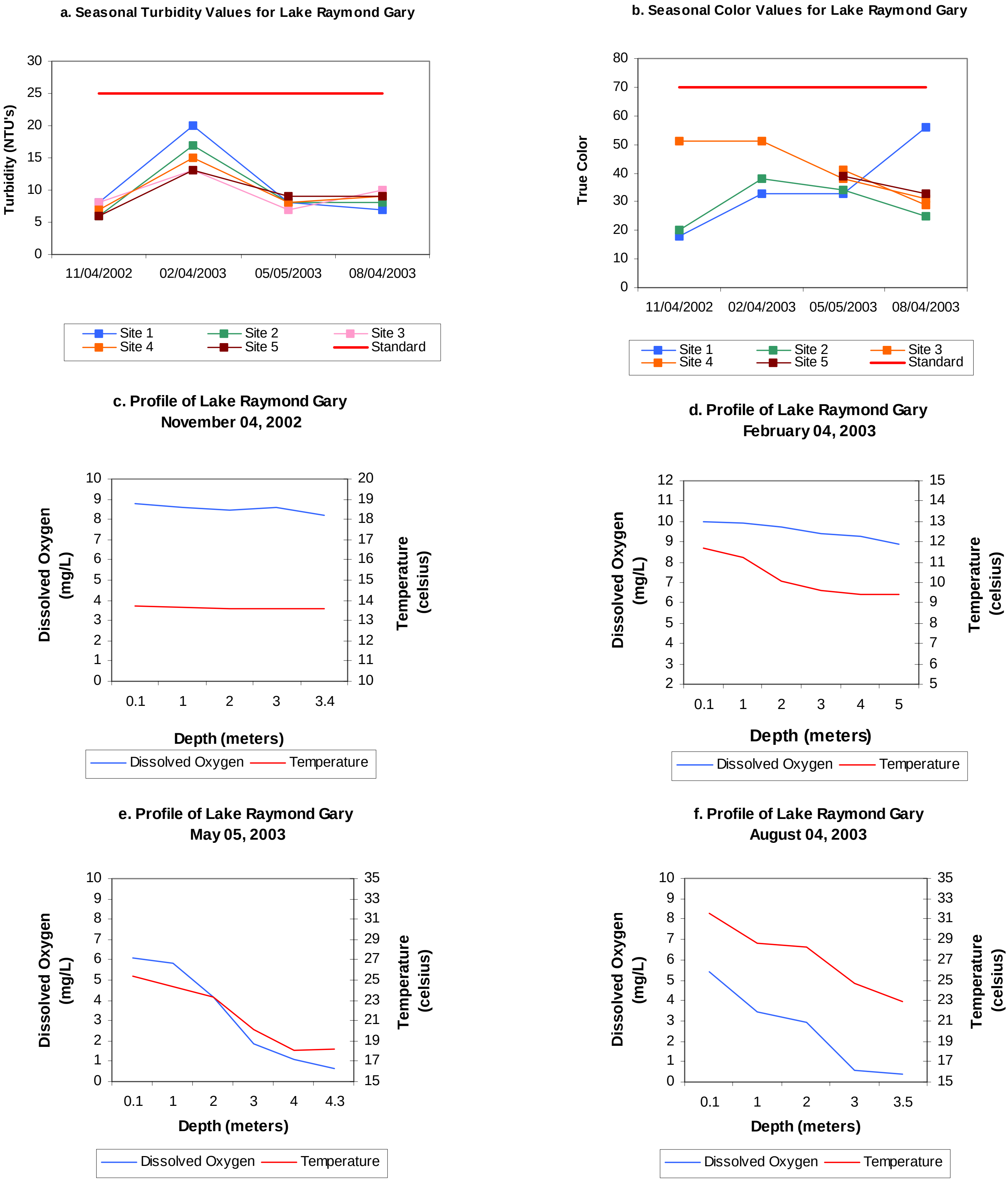
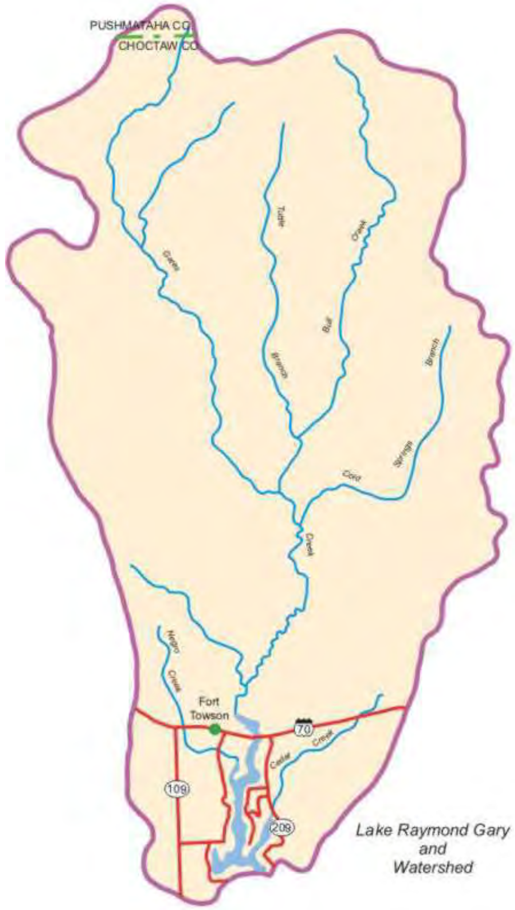


Figure 178a-173f. Graphical representation of data results for Lake Raymond Gary.



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

N W E S

Turbidity
2003

Trophic State
2003

Plate 80 - Lake Water Quality for
Lake Raymond Gary

R.C. Longmire Lake

R.C. Longmire Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative of a reservoir greater than 250 surface acres. 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 12 NTU (Plate 81), true color was 19 units, and secchi disk depth was 86 centimeters. Water clarity was good based on secchi disk depth, turbidity, and true color values. Results for these parameters are 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=19). The average TSI was 47 (Plate 81), indicating the lake was mesotrophic, with moderate levels of productivity and conditions. This value is lower than the TSI in 2001 (TSI=55). The TSI values were all mesotrophic in 2003, except site 2 in the spring, which was eutrophic (Figure 179). The annual trophic assessment seems representative of conditions at R.C. Longmire Lake for 2003. Turbidity values per site were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU for all seasons and are displayed in Figure 180a. The lake-wide annual turbidity of 12 NTU seems representative of conditions at R.C. Longmire Lake in 2003. All true color values were below the aesthetics OWQS of 70 units (Figure 180b). 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 OWQS (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. Although 100% (n=16) of samples in 2003 were below the 70-unit standard, no listing can be made as a minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres.

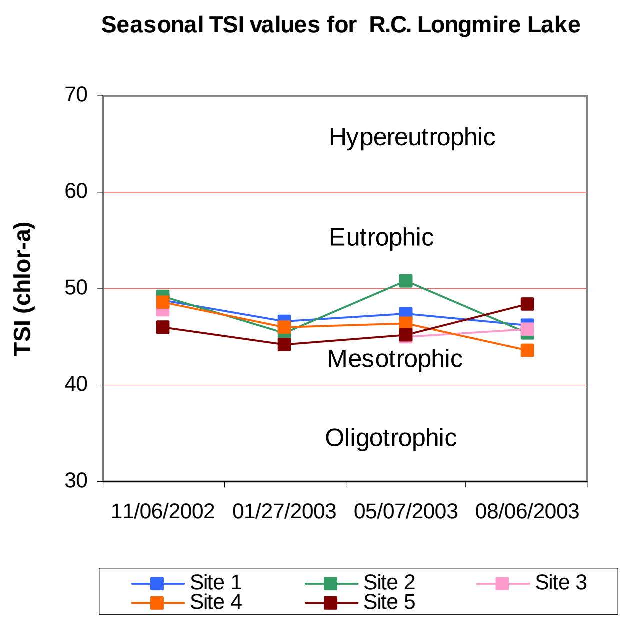


Figure 179. TSI values for R.C. Longmire Lake.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all sample sites. Salinity values for R.C. Longmire Lake ranged from 0.13 parts per thousand (ppt) to 0.16 ppt for this sample year. This is within the average range of values reported in most Oklahoma reservoirs. Specific conductance ranged from 269.2 to 364.5 mS/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 6.83 to 8.11 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the Fish and Wildlife Propagation (FWP) beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. 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 379 mV in the summer to 644 mV in the spring, indicating the absence of reducing conditions. During the fall and winter quarters stratification was not present and lake was well mixed (see Figure 180c-175d). In the spring the lake was stratified between 9 and 10 meters, with 21% of the dissolved oxygen (D.O.) values below 2.0 mg/L (Figure 180e). In the summer the lake was stratified between 6 and 7 meters, at site 1, with D.O. falling below 2.0 mg/L to the lake bottom of 10.8 meters (Figure 180f). 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 21% of the D.O. values in the spring and 42% 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.77 mg/L at the surface and 1.29 mg/L at the lake bottom. The TN at the surface ranged from 0.50 mg/L to 1.04 mg/L. The highest surface total nitrogen was reported in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.024 mg/L and 0.068 mg/L at the lake bottom. The surface TP ranged from 0.018 mg/L to 0.043 mg/L. The highest surface TP was reported in the winter and the lowest values were seen during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 32:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, R.C. Longmire Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient conditions in 2002-2003. Although this is lower than the TSI in 2001 (TSI=55), the current value is based on a larger dataset and is likely a more accurate depiction of productivity within the lake. Water clarity is good based on turbidity, true color and secchi disk depth, slightly better than clarity in 2001. The lake is supporting the FWP beneficial use based on turbidity and pH, but is partially supporting based on anoxic conditions present in the spring and summer. The lake is supporting the Aesthetics based on its trophic status, however assessment based on true color could not be made as the minimum data requirements of 20 samples for lakes larger than 250 surface acres were not met. R.C. Longmire Lake is located in Garvin County and is a popular fishing lake.

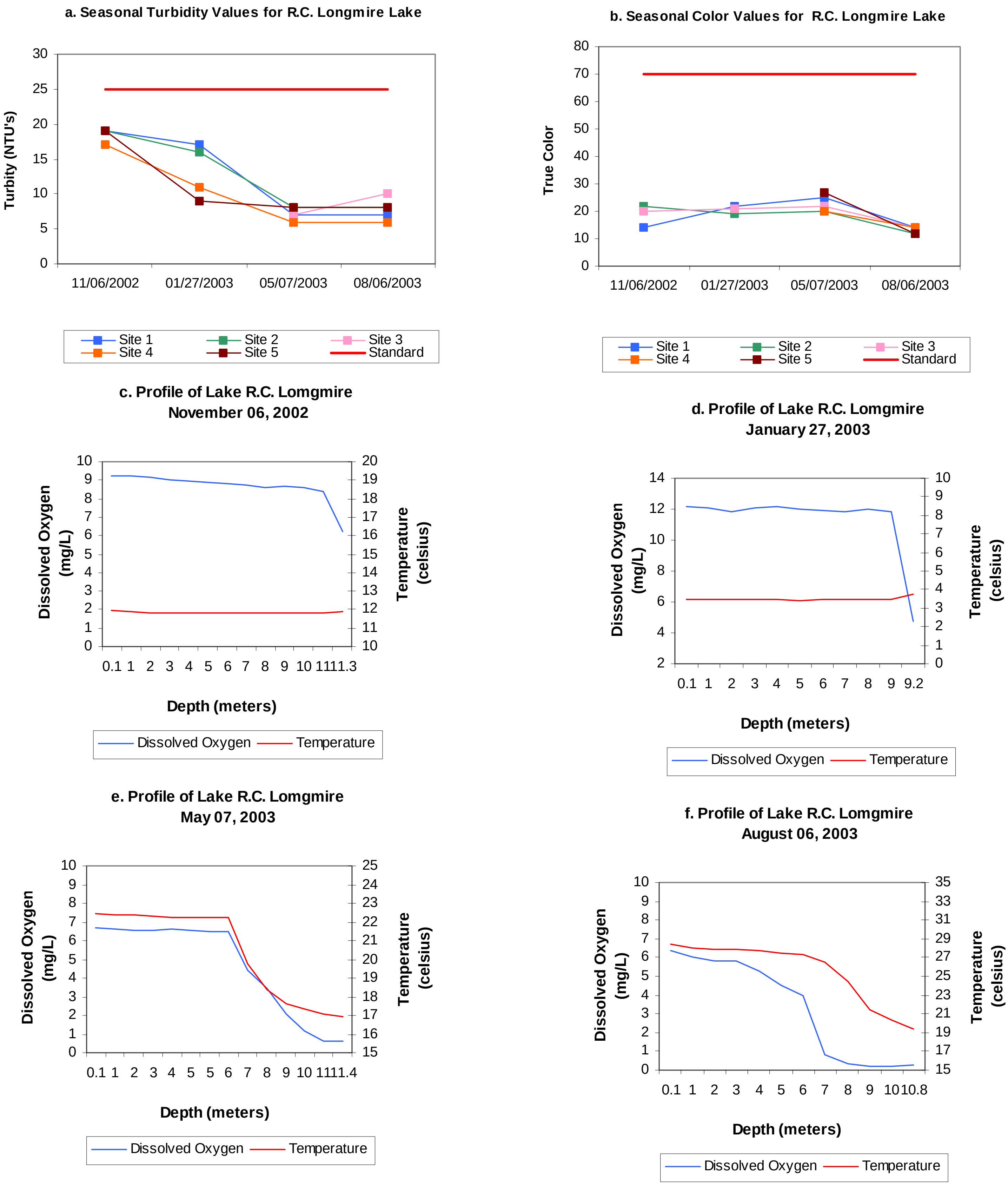
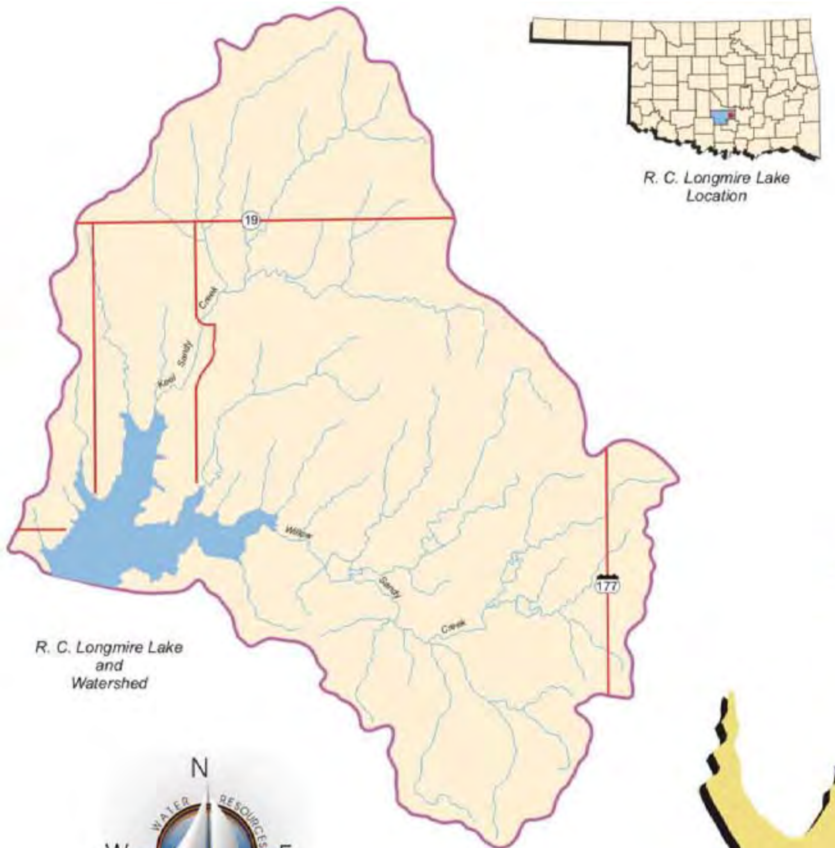


Figure 180a-175f. Graphical representation of data results for R.C. Longmire Lake.

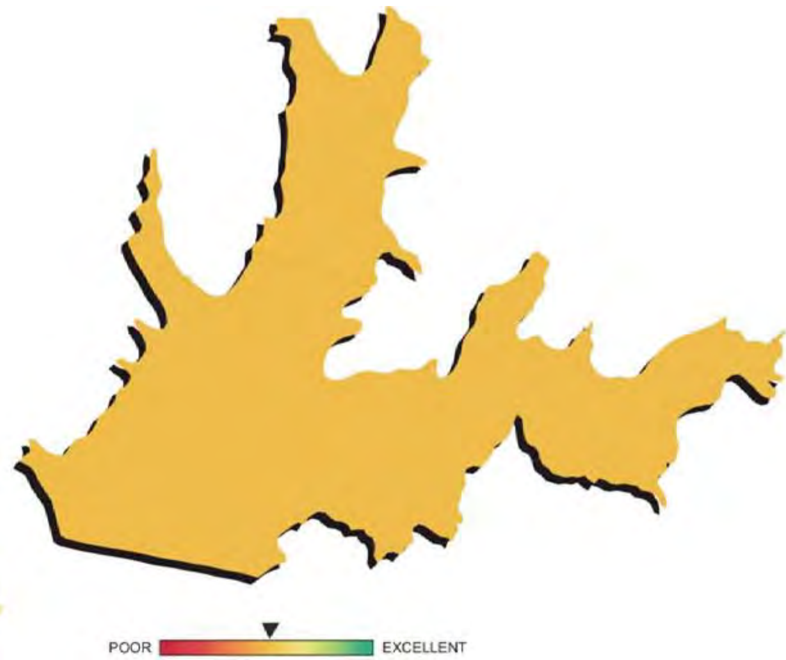


R. C. Longmire Lake
and
Watershed

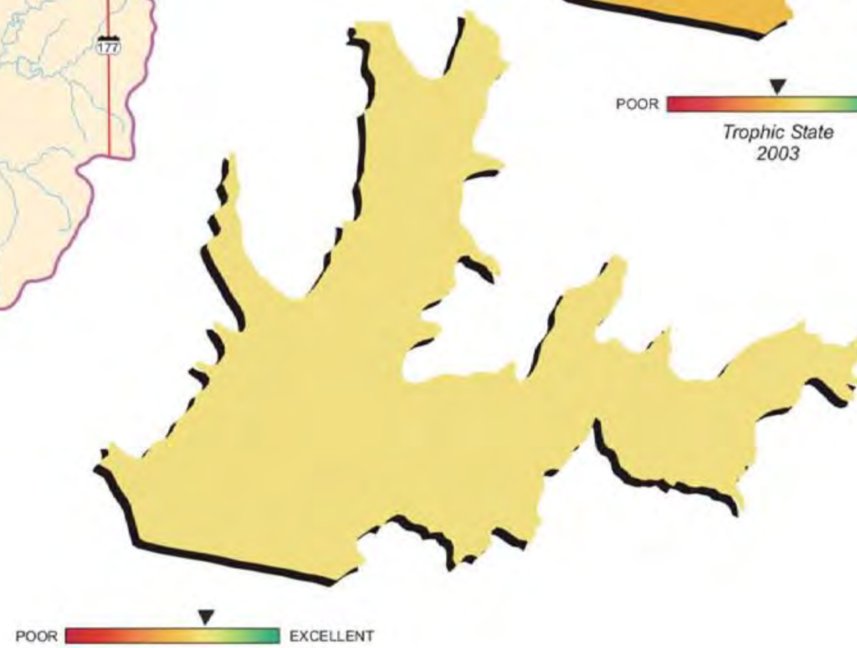
R. C. Longmire Lake
Location

N
W E
S

Lake Data	
Owner	City of Pauls Valley
County	Garvin
Constructed in	1989
Surface Area	745 acres
Volume	14,424 acre/feet
Shoreline Length	12 miles
Mean Depth	19.36
Watershed Area	29 square miles



Trophic State
2003



Turbidity
2003

Plate 81 - Lake Water Quality for
R. C. Longmire Lake

Robert S. Kerr Reservoir

Robert S. Kerr Reservoir was sampled for four quarters, from October 2002 through July 2003. 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 40 NTU (Plate 82), true color was 43 units and average secchi disk depth was 48 centimeters. Based on these three parameters, water clarity at R.S. Kerr Reservoir was fairly poor. Results are similar to those reported in 2000, 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 55 (Plate 82), indicating the lake was eutrophic, with high levels of primary productivity and conditions. This value is similar to the one calculated in 2000 (TSI=53), indicating the no significant increase or decrease in productivity has occurred since the lake was last evaluated. The TSI values were primarily eutrophic throughout the sample year although sites 1 and 2 were mesotrophic in the spring (See Figure 181). Seasonal turbidity values are displayed in Figure 182a. Turbidity values were well above the Oklahoma Water Quality Standard (OWQS) of 25 NTU in the first three quarters, but below the standard 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 OWQS (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. True color varied seasonally with the highest values reported in the fall and the lowest during the winter (Figure 182b). Applying the same default protocol, the Aesthetics beneficial use is partially supported with 12% of the values exceeding the OWQS of 70-units for true color.

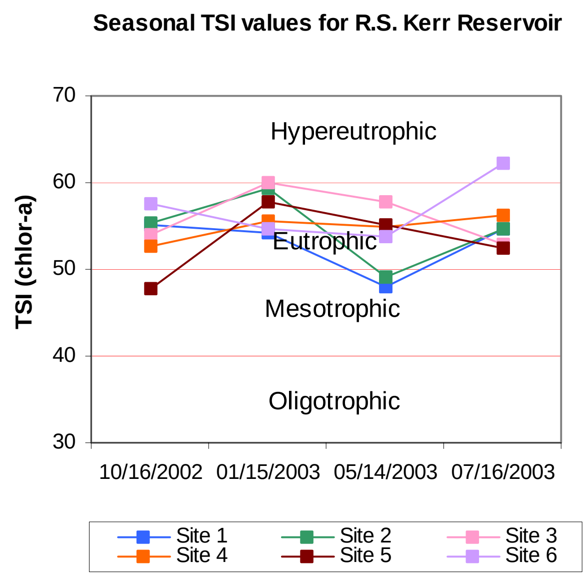


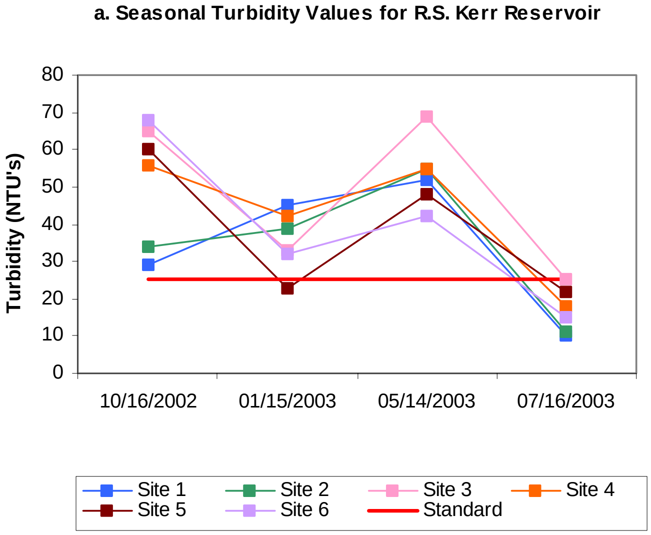
Figure 181. TSI values for R.S. Kerr Reservoir**.**

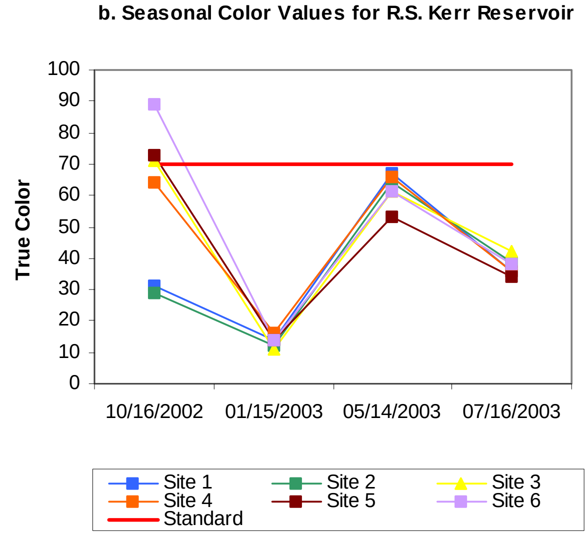
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values ranged from 0.32 parts per thousand (ppt) in the summer to 1.09 ppt in the winter. This is higher than the average range of values reported for most Oklahoma reservoirs. Specific conductance ranged from 624.4 to 2033 mS/cm, indicating 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 7.14 to 8.57 during the study period. According to USAP (OAC 785:46-15-5), pH v values are exceeding standards if they fall outside the 6.5 to 9 range, for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. 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 357 mV in the summer to 651 mV in the fall, indicating reducing conditions were not present during the study period. The lake was not stratified during any of the sampling intervals and was well mixed (Figure 182c-177f). The only instance where dissolved oxygen (D.O.) fell below 2.0 mg/L occurred at site 2 in the summer quarter. R.S. Kerr Reservoir 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 2002-2003 found the Agriculture beneficial use to be fully supported based on numerical criteria for these parameters located in OAC 785:45 – Appendix F.

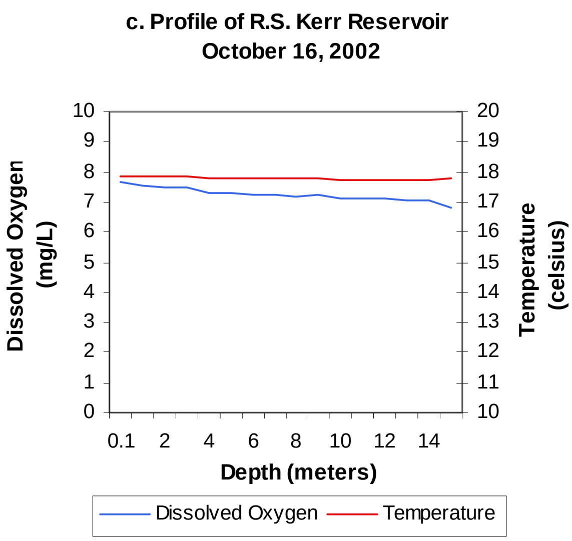
Bacteriological samples were also collected to assess the Primary Body Contact Recreation (PBCR) beneficial use. Samples were collected at five sites for *E.coli*, fecal coliform, and enterococci during the recreation season of May through September. The PBCR beneficial use is considered fully supported

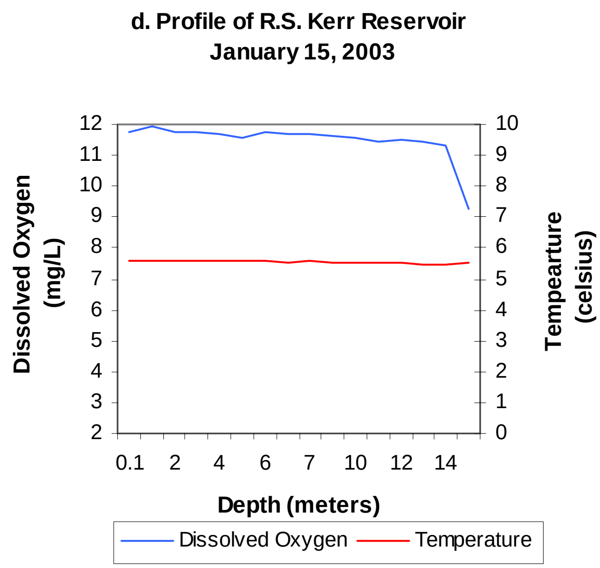
Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.01 mg/L at the surface and 1.05 mg/L at the lake bottom. The TN at the surface ranged from 0.62 mg/L to 1.71 mg/L. The highest surface total nitrogen was reported in the fall and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.109 mg/L and 0.126 mg/L at the lake bottom. The surface TP ranged from 0.070 mg/L to 0.157 mg/L. The highest surface TP was reported in the spring and the lowest values were seen during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was approximately 9:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

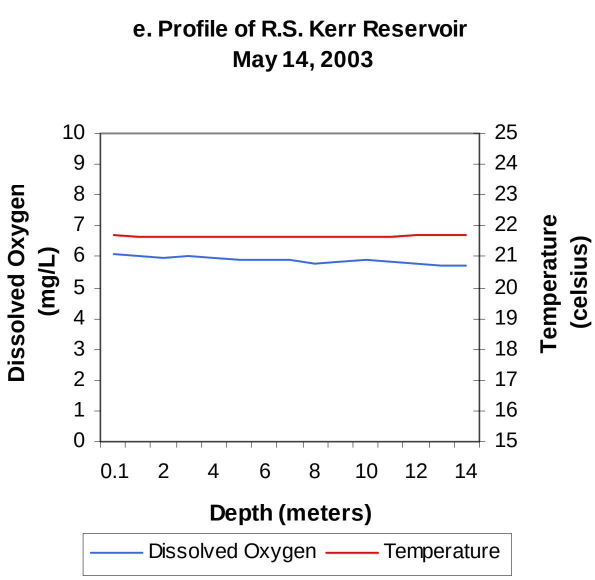
In summary, Robert S. Kerr Reservoir was classified as eutrophic with high primary productivity and nutrient conditions. This is similar to the value in 2000 (TSI=53), indicating no significant increase or decrease in productivity has occurred since the last evaluation. Water clarity was poor based on 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 based on high turbidity. The Aesthetics beneficial use is supported based on its trophic status, but partially supporting based on high true color values reported in the fall quarter. The Oklahoma Department of Environmental Quality (ODEQ) sampled the fish community in 2002 as part of the Toxics and Reservoirs program and none of the fish tissue samples exceeded the screening level or low consumption advisory for metals toxicity. The Fish Consumption beneficial use is considered supported. The United States Army Corps of Engineers (USACE) constructed Robert S. Kerr Reservoir in 1971 for navigation, hydroelectrical and recreation purposes. The lake is located in both Sequoyah and Leflore Counties approximately 8 miles south of Sallisaw.











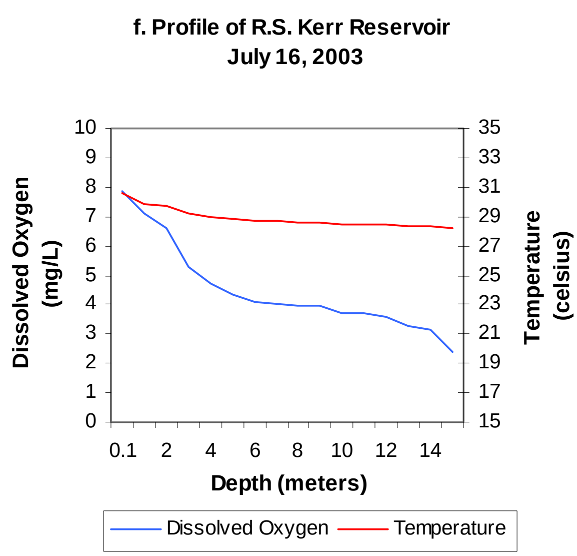
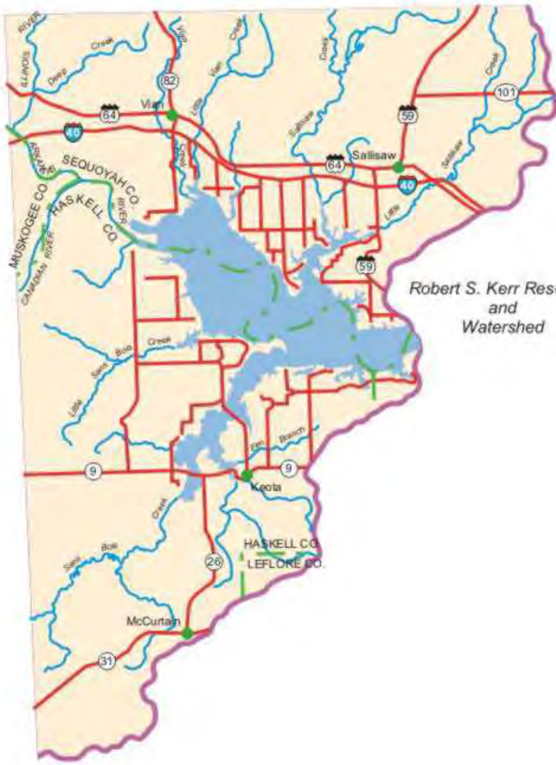
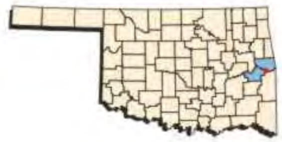
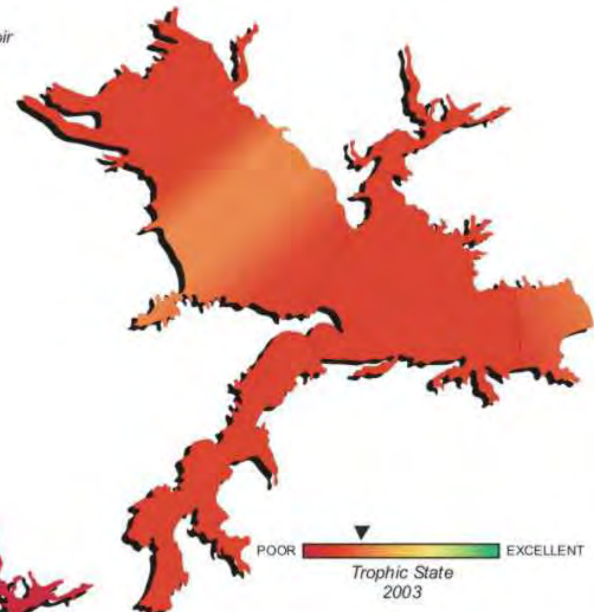
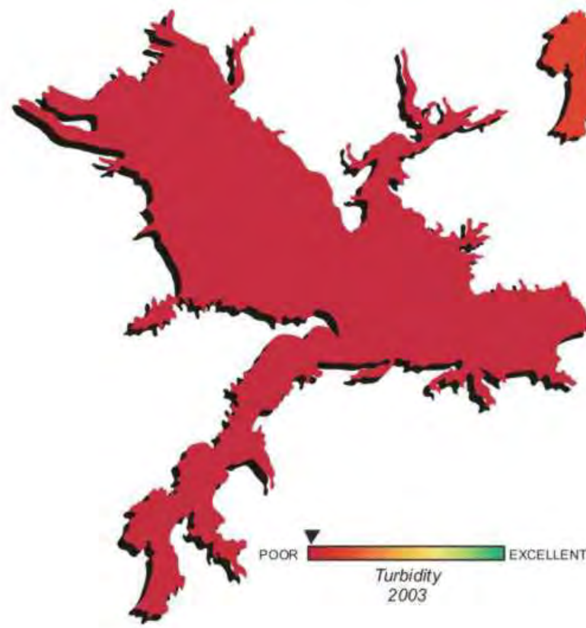


Figure 182a-177f. Graphical representation of data results for R.S. Kerr Reservoir.









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 82 - Lake Water Quality for

Robert S. Kerr Reservoir

Rock Creek Reservoir

Rock Creek Reservoir was sampled for four quarters, from November 2002 through August 2003. 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 9 NTU (Plate 83), true color was 16 units, and secchi disk depth was 90 centimeters. Based on these three parameters, Rock Creek Reservoir had good water clarity. Water clarity was even better than reported in 2000, with secchi disk depth twice as high as 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 average TSI was 50 (Plate 83), indicating the lake was eutrophic, with high levels of productivity and nutrient rich conditions. This value is similar to the TSI in 2000 (TSI=55), and in the same trophic category, indicating no significant increase or decrease over time. The TSI values varied seasonally from eutrophic in the fall and spring to mesotrophic in the winter and summer (see Figure 183). Seasonal turbidity values are displayed in Figure 184a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) 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 OWQS (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 2003. True color values were below the aesthetics OWQS of 70 units at all sites throughout the year (Figure 184b). Applying the same default protocol, the lake is supporting the Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values ranged from 0.09 parts per thousand (ppt) to 0.14 ppt. This is within the average range of values reported for most Oklahoma reservoirs. Specific conductance ranged from 191.7 to 293.1 mS/cm, indicating low 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 7.09 to 8.64 during the study period. According to

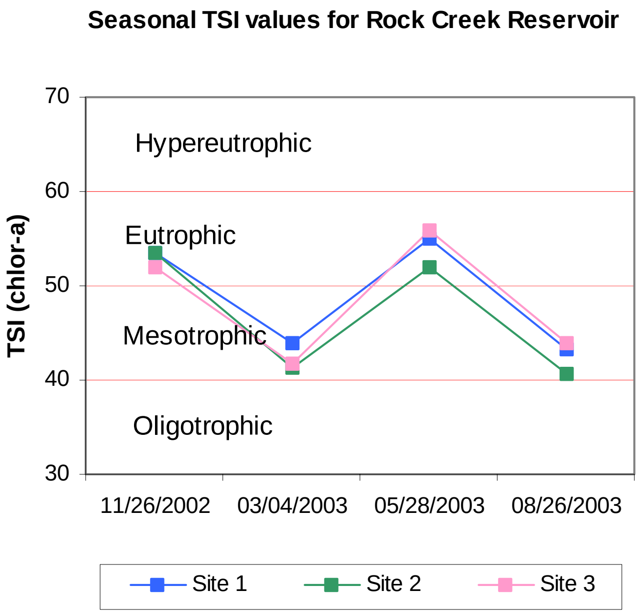


Figure 183. TSI values for Rock Creek Reservoir.

USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting it the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. 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 348 mV in the winter to 527 mV in the summer, indicating reducing conditions were not present during the study period. The lake was not stratified during the fall and winter quarters and the lake was well mixed with dissolved oxygen values generally above 8.0 mg/L (Figure 184c-179d). The lake was thermally stratified and anoxic conditions were present in both spring and summer quarters. In the spring the lake was stratified between 6 and 7 meters at which point dissolved oxygen (D.O.) fell below 2.0 mg/L for 36% of the water column (Figure 184e). During the summer the thermocline occurred higher in the water column (between 2 and 3 meters), falling below 2.0 mg/L from 4 meters to the lake bottom of 9.1 meters at site 1 (Figure 184f). 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 36% of the D.O. values in the spring and 64% 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.50 mg/L at the surface and 0.54 mg/L at the lake bottom. The TN at the surface ranged from 0.34 mg/L to 0.66 mg/L. The highest surface total nitrogen was reported in the summer and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.016 mg/L and 0.023 mg/L at the lake bottom. The surface TP ranged from 0.009 mg/L to 0.030 mg/L. Similar to TN, the lowest surface TP was reported in the fall but the highest values were reported during the spring quarter. The nitrogen to phosphorus ratio (TN:TP) was 31:1 for sample year 2002-2003. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Rock Creek Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. This is consistent with the 2000 evaluation, indicating no significant change in productivity has occurred over time. Water clarity was good 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 the spring and summer quarters. The Aesthetic beneficial use is fully supported by both trophic status and collected true color values. Rock Creek Reservoir is located in Carter County and serves as a recreational reservoir for the City of Ardmore.

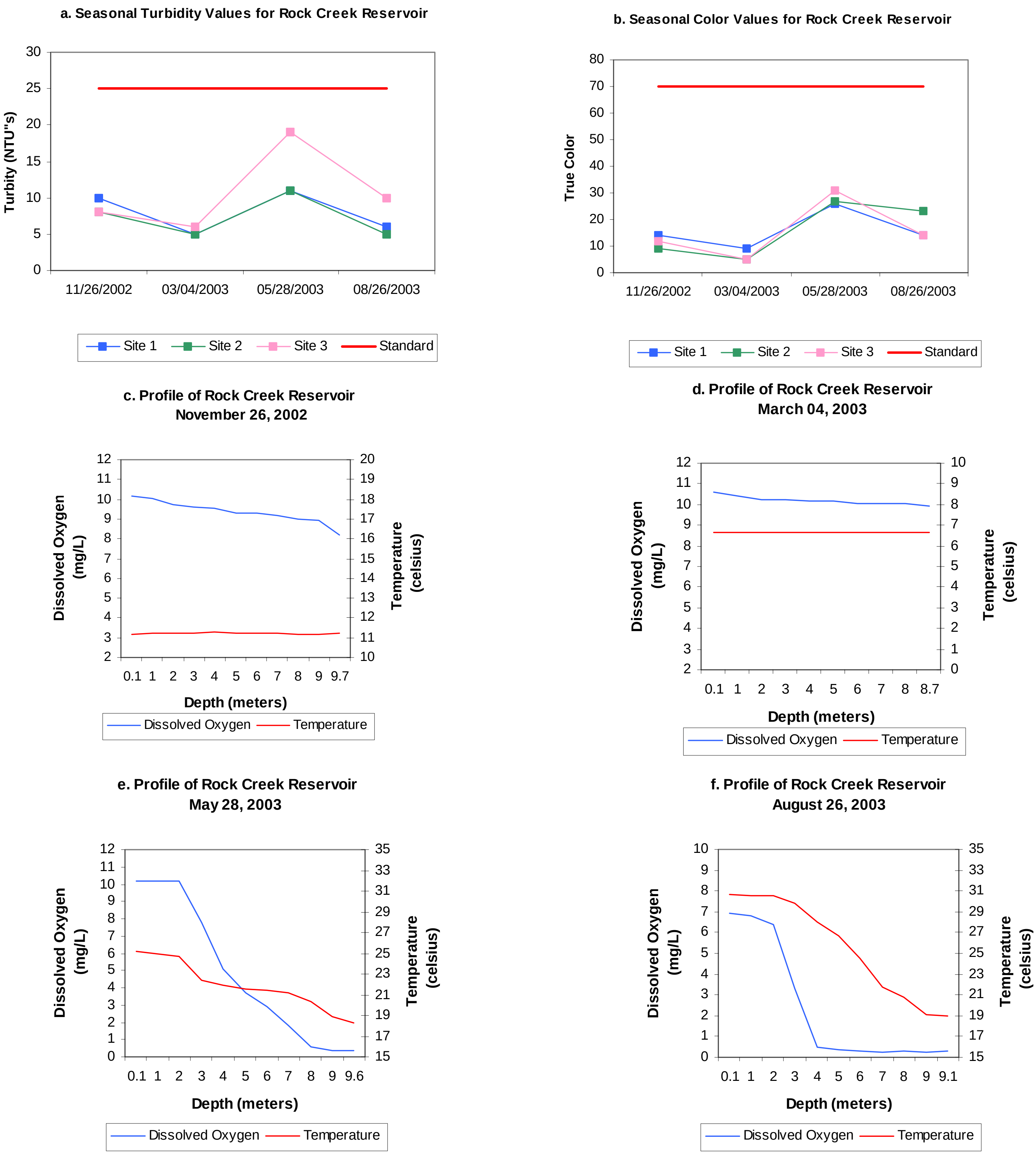
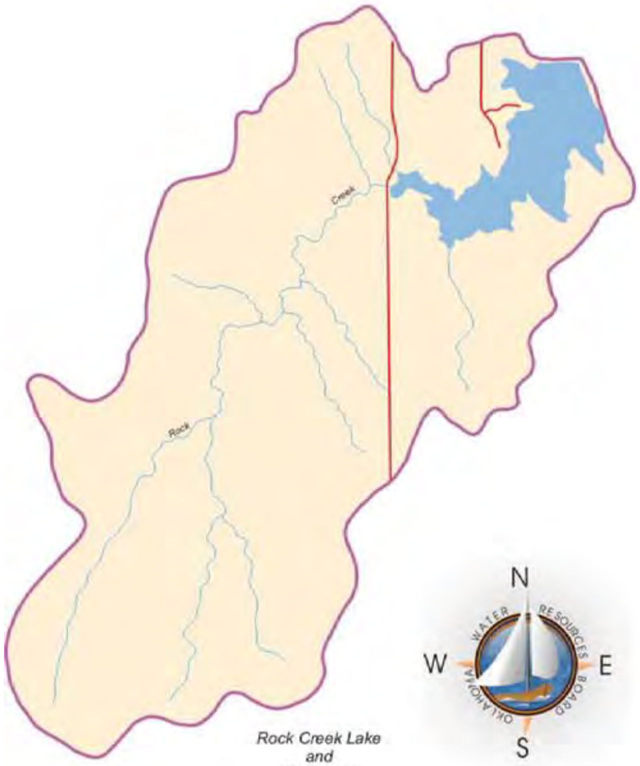


Figure 184a-179f. Graphical representation of data results for Rock Creek Reservoir.

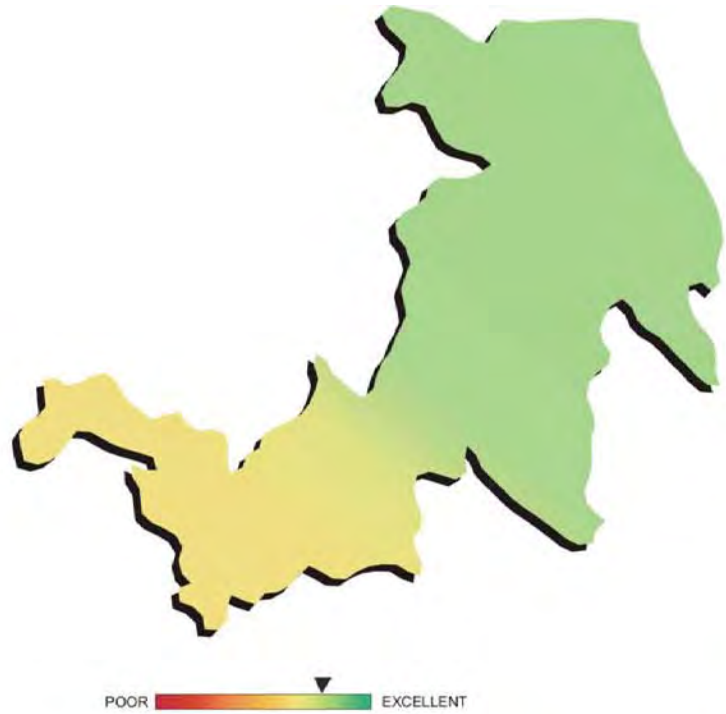
Rock Creek Lake
Location



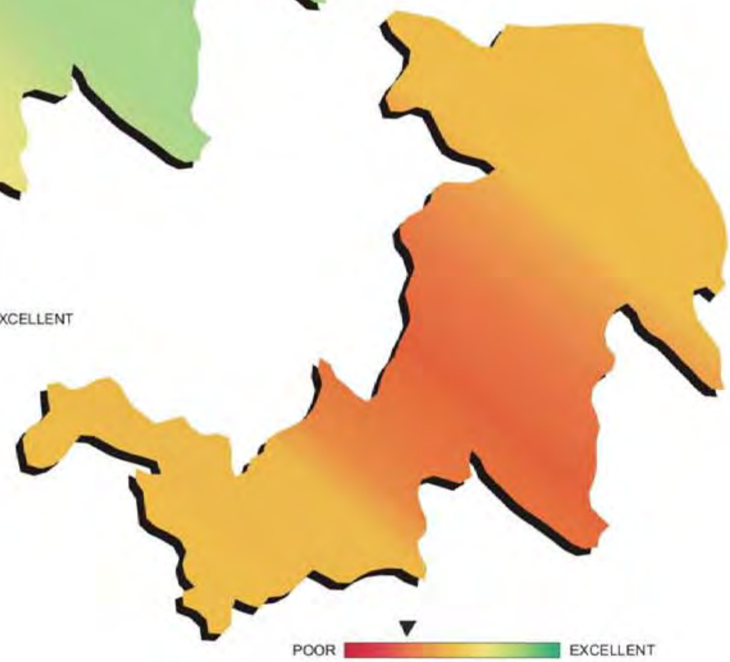
Rock Creek Lake
and
Watershed

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



Turbidity
2003



Trophic State
2003

Plate 83 - Lake Water Quality for
Rock Creek Reservoir

Rocky (Hobart) Lake

Rocky Lake (347 surface acres) was sampled for three quarters, from March 2001 through August 2001. Several attempts were made in the fall quarter to sample the lake, however, due to drought conditions; the lake level was too low to launch a boat until late in the winter quarter. Water quality samples were collected at 3 sites to represent the riverine, transition, and lacustrine zones of the reservoir in the winter, spring, and summer. Although there are only 3 sites designated for Rocky Lake, an extra sample was collected in the winter. 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 37 NTU, true color was 114 units, and secchi disk depth was 30 centimeters in 2001. Based on these three parameters, Rocky Lake had poor water clarity in comparison to other Oklahoma reservoirs. Water clarity was similar in the summer of 1997, although based on only three samples. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters plus the additional site in the winter (n=10). The average TSI was 66, classifying the lake as hypereutrophic, indicative of excessive levels of productivity and nutrients. This value is very similar to the one calculated in 1997 (TSI=67) indicating little or no change in trophic status over time. The TSI values were eutrophic in the spring, but hypereutrophic at all sites the other two seasons. A minimum of 20 samples is required to make beneficial use determinations in lakes greater than 250 surface acres and therefore not enough data was collected on this reservoir to make beneficial use determinations based on Oklahoma Administrative Code (OAC) 785:45-15-4. All turbidity values, except for two sites in the winter, were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU. 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 OWQS (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. No beneficial use determination can be made because the minimum data requirements were not met. All of the true color values were above the numeric criteria of 70 units in the spring and summer, but below the standard in the winter. The minimum data requirements were not met, therefore, the Aesthetics beneficial use is considered fully supported.

Please refer to the “Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report” for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency’s web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Lake Sahoma

Lake Sahoma was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional samples were collected at the lake surface at sites 4 and 5 for the purpose of chlorophyll-a and nephelometric turbidity analysis in order to meet minimum data requirements. 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 22 NTU (Plate 84), true color was 82 units, and secchi disk depth was 46 centimeters in 2001-2002. Water clarity was average to fair based on secchi disk depth, turbidity, and true color values. 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 56 (Plate 84), indicating the lake was eutrophic, with high levels of productivity and nutrient rich conditions. The TSI values were consistent throughout the four quarters with TSI calculations ranging from lower eutrophy to upper eutrophy with one hypereutrophic value calculated at site 2 in the summer (see Figure 185). Turbidity values per site varied based upon site location, with sites in the upper end of the reservoir consistently exceeding the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 186a). 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 OWQS (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 40% of the collected turbidity values exceeding the criteria, Lake Sahoma is not supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 186b. With 58% of the true color values above the Aesthetics OWQS of 70 units, data strongly suggests the lake is not supporting its Aesthetics beneficial use (see Figure 186b). Although 58% of samples in were above the 70-unit standard, no listing could be made due to insufficient data to make a definitive beneficial use determination.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites in 2001-2002. Salinity ranged from 0.03 parts per thousand (ppt) in the summer quarter to 0.07 ppt in the winter, indicating low salt content and below the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 85.2 mS/cm in the summer to 161.8 mS/cm in the winter, 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 6.62 units in the summer to 7.97 units in the winter quarter. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. All

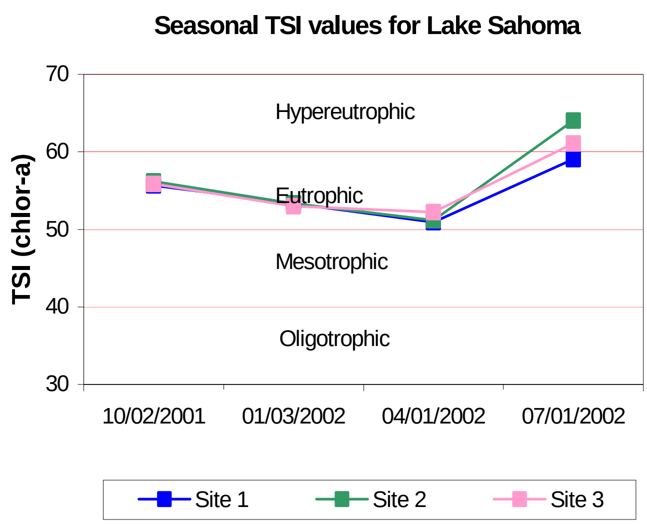


Figure 185. TSI values for Lake Sahoma.

collected pH values were within the acceptable range, so Lake Sahoma is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 49 mV to 525 mV, indicating reducing conditions were not present during the sampling events to any appreciable degrees. The lake was not thermally stratified in the fall, winter or spring quarters and was well mixed with dissolved oxygen (D.O.) concentrations remaining above 3.5 mg/L throughout the water column and generally above 4.6 mg/L (see Figure 186c-181e). In the summer quarter, the lake was strongly thermally stratified between 2 and 3 meters at site 1 near the dam. Extending from the 2-meter depth to the lake bottom at 8.9 meters, D.O. values were less than 1.5 mg/L (see Figure 186f). 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 not supported at Lake Sahoma because approximately 80% of the water column was anoxic during the summer sampling event. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.67 mg/L at the lake surface. The TN at the surface ranged from 0.49 mg/L to 1.00 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the winter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.045 mg/L at the lake surface. The surface TP ranged from 0.030 mg/L to 0.068 mg/L. The highest surface TP value was reported in the summer and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 15:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Sahoma was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Lake Sahoma was classified as eutrophic, indicating high primary productivity and nutrient rich conditions (Plate 84). The lake was fully supporting its Aesthetics beneficial use based on its trophic status (for nutrients) and support for true color could not be definitively made though data strongly supports the supposition that it would not support based on true color. Sahoma was fully supporting its FWP beneficial use based on pH and not supporting the beneficial use based on nephelometric turbidity and D.O. concentrations. 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.

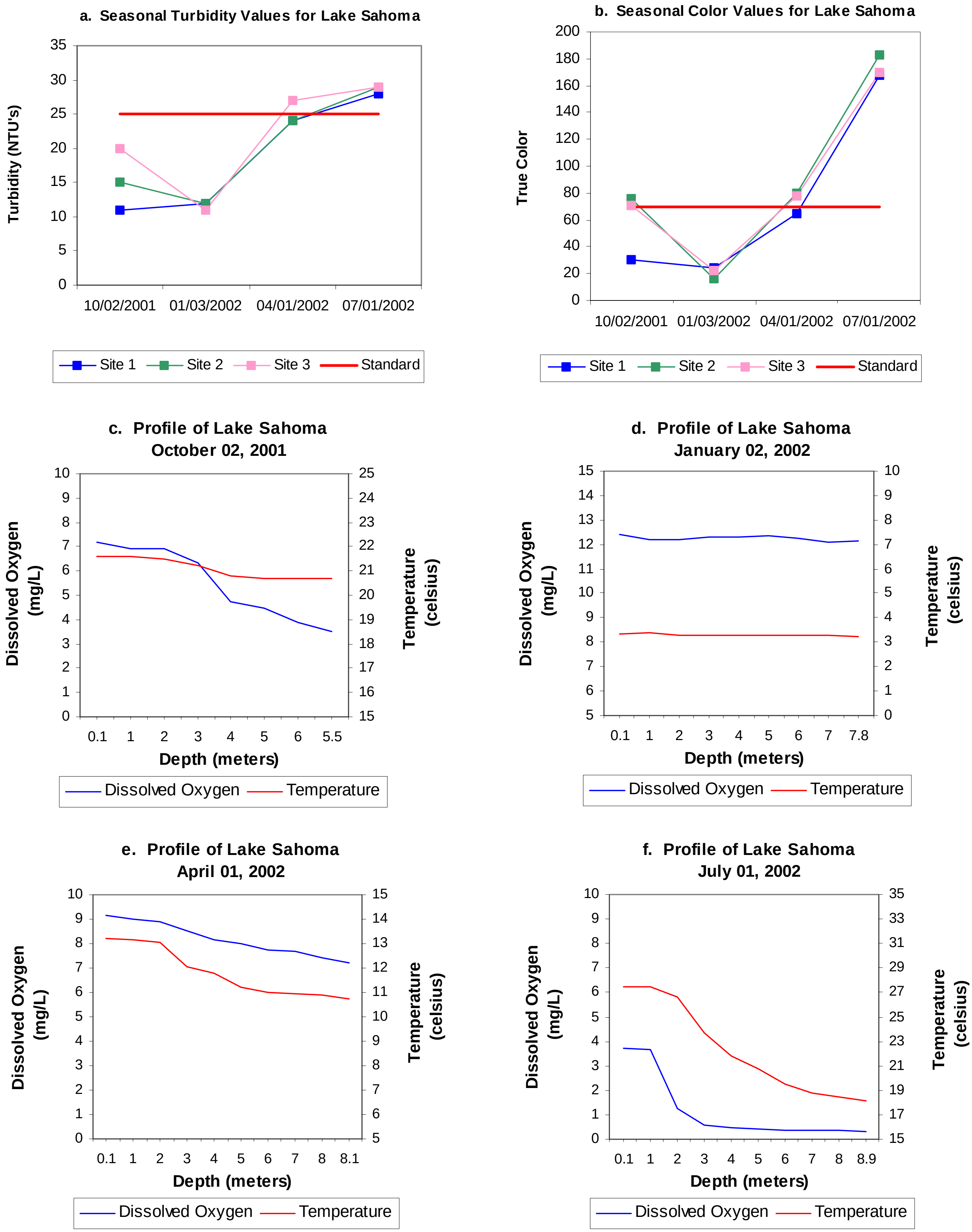
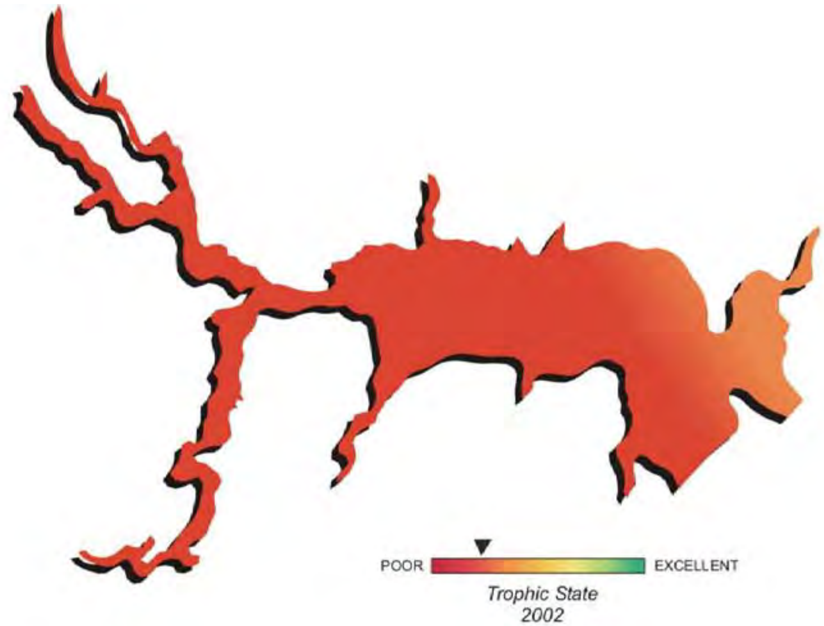


Figure 186a181f. Graphical representation of data results for Lake Sahoma.

Sahoma Lake Location

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



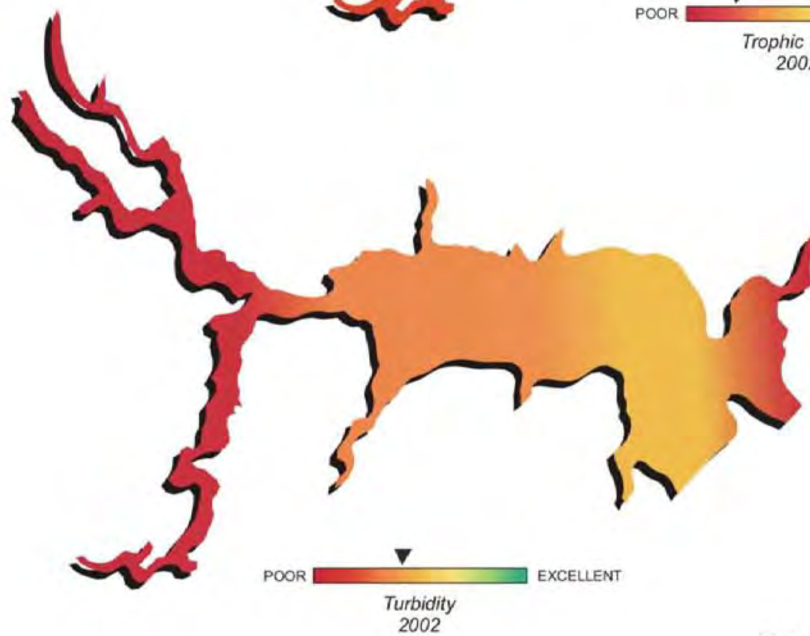


Plate 84 - Lake Water Quality for
Sahoma Lake

Sardis Lake

Sardis Lake was sampled for four quarters, from November 2002 through August 2003. 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 13 NTU (Plate 85), true color was 32 units, and average secchi disk depth was 94 centimeters. Based on these three parameters, Sardis Lake had good water clarity, similar to that reported in 2000. 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 45 (Plate 85), classifying the lake as mesotrophic, with moderate primary productivity and nutrient conditions. This is very similar to the value calculated in 2000 (TSI=47), indicating no significant change in productivity has occurred. The TSI values were primarily mesotrophic throughout the year and the TSI of 45 seems to accurately represent conditions at Sardis Lake. The only time collected values were not mesotrophic was in the summer when 4 out of the 5 sites were oligotrophic (see Figure 187). Seasonal turbidity values are displayed in Figure 188a. In general, turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, the only exception being site 2, which was recorded at 25 NTU in the winter. 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 OWQS (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 at or below the standard, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported for sample year 2003. Seasonal true color values are displayed in Figure 188b. True color followed the same pattern as turbidity with all values below the OWQS of 70, except for site 2, which had a value of 80 units reported in the winter quarter. Applying the same default protocol, the Aesthetics beneficial use is fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values were 0.00 parts per thousand (ppt) at all sites throughout the study period. This is much lower than the average range of values reported for most Oklahoma reservoirs. Specific conductance ranged from 17.7 to 37.9 mS/cm, indicating extremely low concentrations of electrical current conducting compounds (salts) were present in the lake, consistent with the salinity readings. In general pH values were neutral with values ranging from 6.23 to 7.69 during the study period.

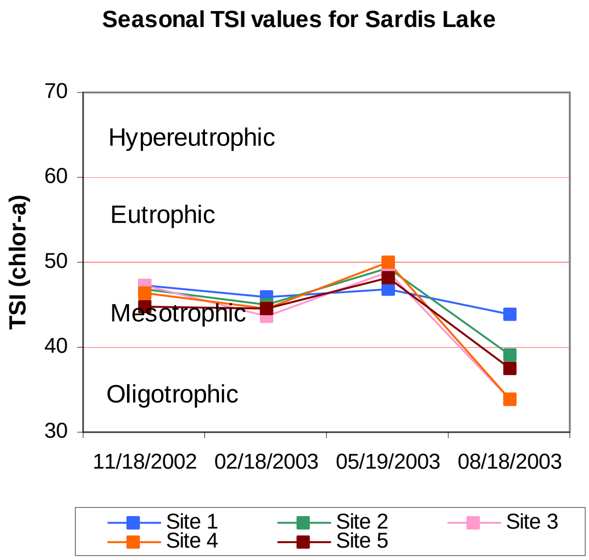


Figure 187. TSI values for Sardis Lake.

According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With only 6.4% of the recorded values less than 6.5 the lake is considered supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 440 mV to 581 mV, indicating the absence of reducing conditions during the sample year. The lake was not stratified during the first three sampling quarters and the lake was well mixed (Figure 188c-183e). The lake was thermally stratified and anoxic conditions were present during the summer. In the summer the lake was stratified between 9 and 10 meters at which point dissolved oxygen (D.O.) fell below 2.0 mg/L for 44% of the water column (Figure 188f). 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.27 mg/L at the surface and 0.24 mg/L at the lake bottom. The TN at the surface ranged from 0.05 mg/L to 0.56 mg/L. The highest surface total nitrogen was reported in the summer and the lowest in the winter. The lake-wide total phosphorus (TP) average was 0.018 mg/L and 0.022 mg/L at the lake bottom. The surface TP ranged from 0.010 mg/L to 0.039 mg/L. The lowest surface TP was reported in the fall but the highest values were reported during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 15:1 for sample year 2002-2003. This value is greater 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 2003, consistent with results from the 2000 evaluation. Water clarity was good based on true color, turbidity, and secchi disk depth. The FWP beneficial use is supported by both turbidity and pH, but only partially supporting the use with anoxic conditions present for 44% of the water column during the summer. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color values. In 1999, a bathymetric survey was conducted at Sardis Lake (Figure 189) 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 Kathy Koon 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.

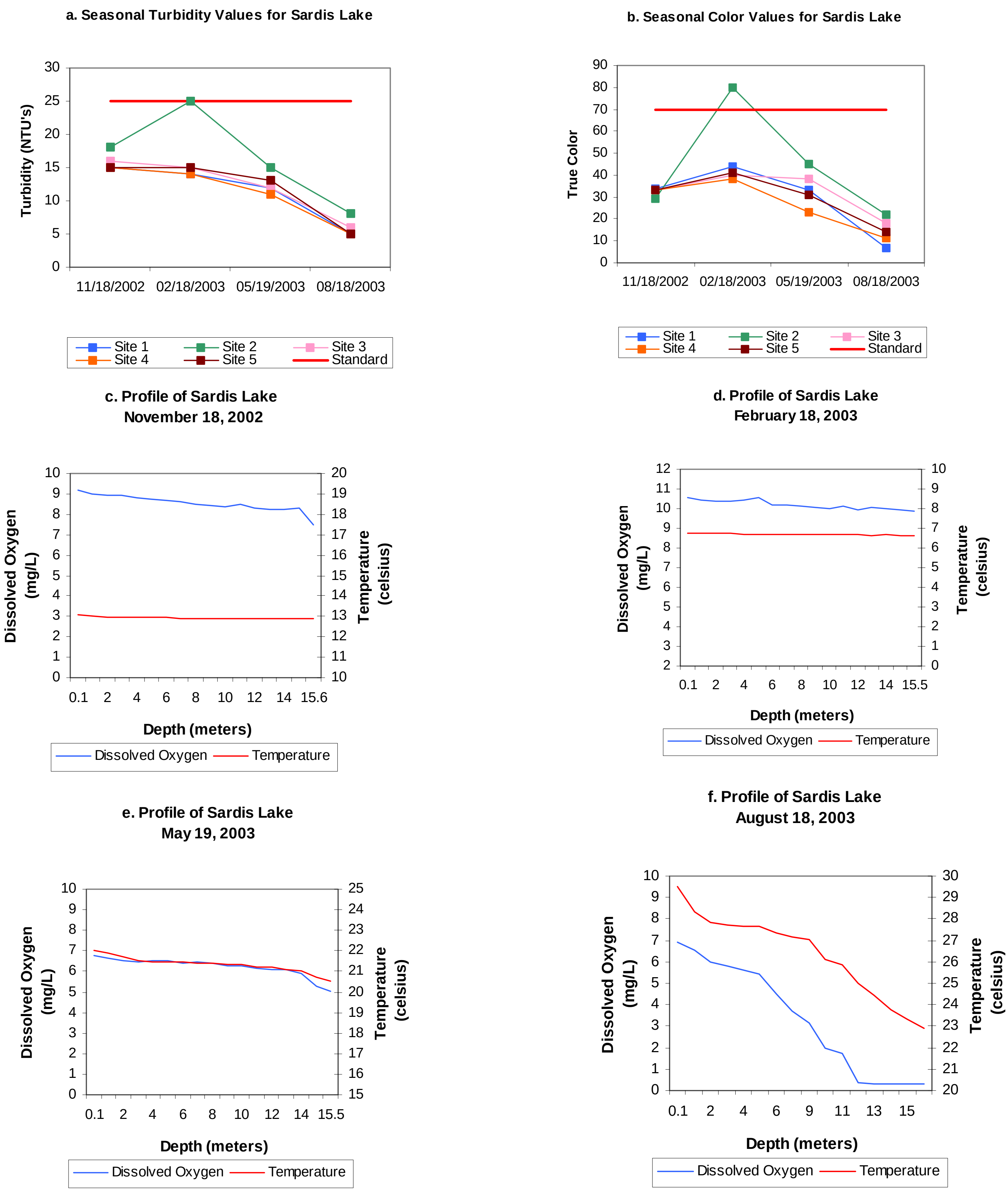
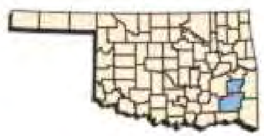
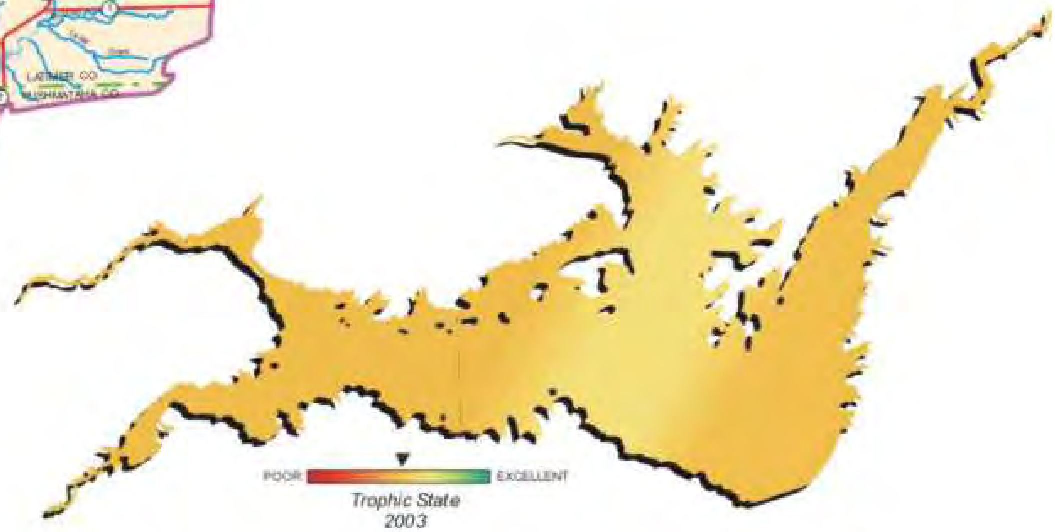
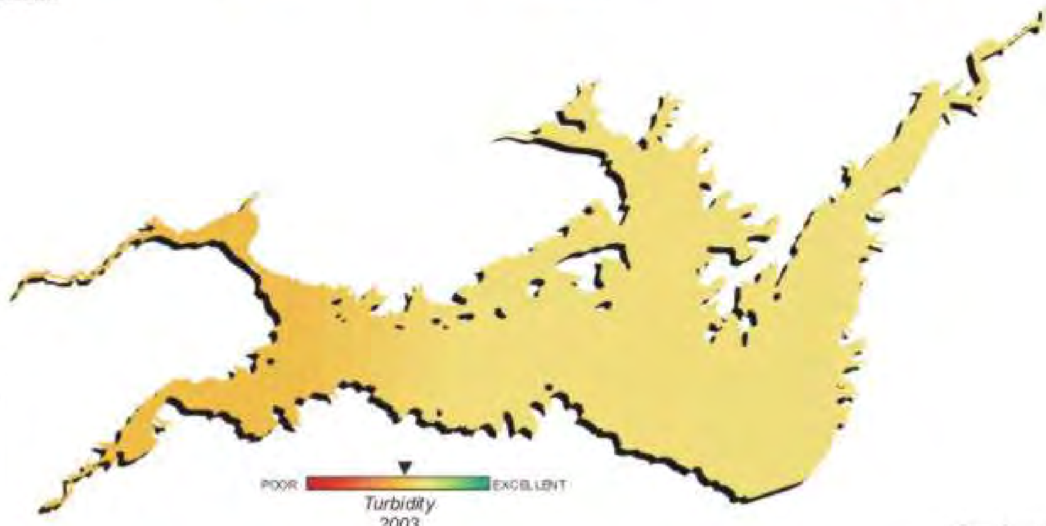


Figure 188a-183f. Graphical representation of data results for Sardis Lake.







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 85 - Lake Water Quality for
Sardis Lake

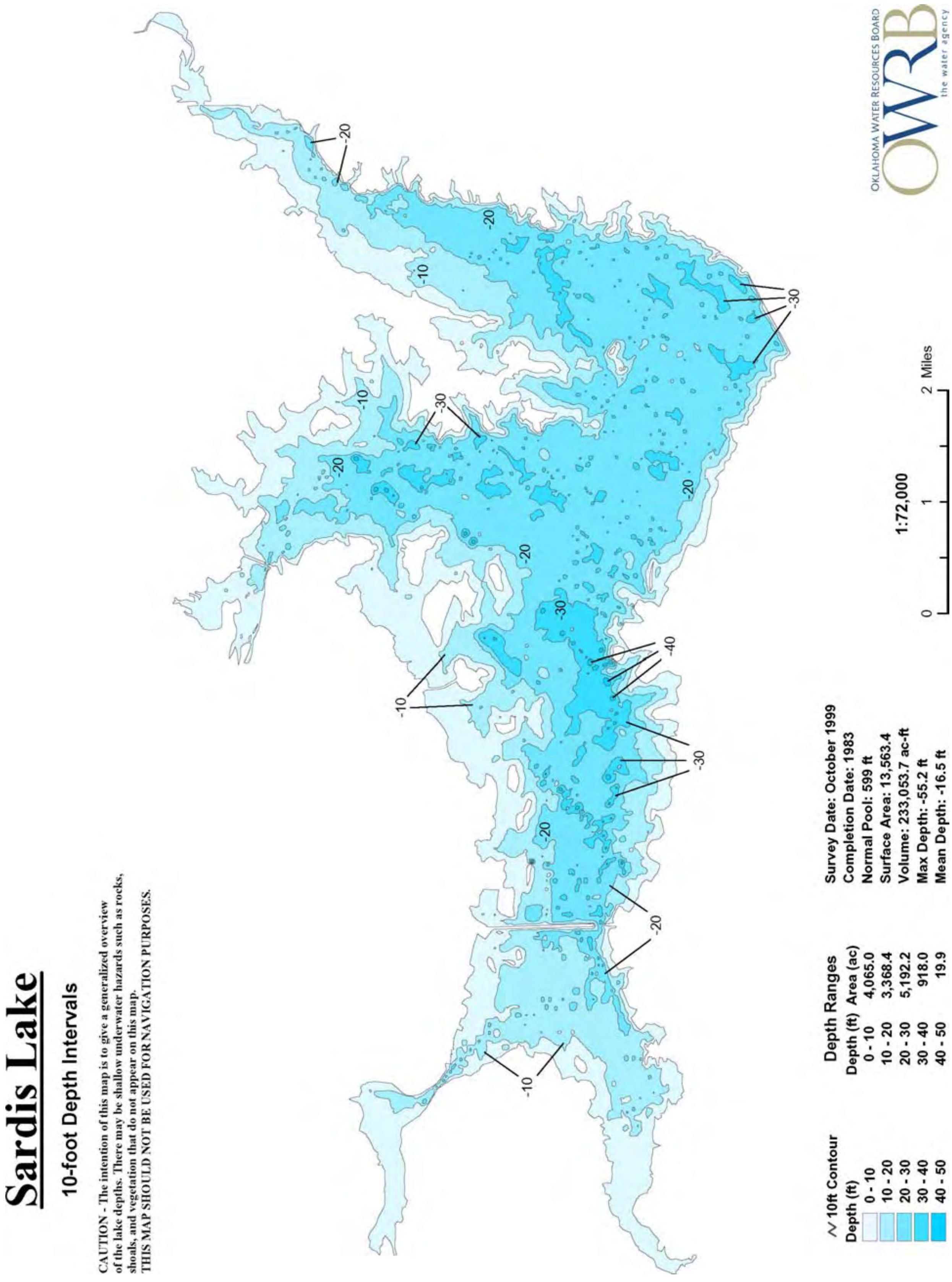


Figure 189. Bathymetric Map of Sardis Lake.

Shawnee Twin Lake # 1

Shawnee Twin Lake # 1 was sampled for four quarters, from November 2001 through August 2002. 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 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 (Plate 86), true color was 33 units, and secchi disk depth was 94 centimeters in 2001-2002. Based on these three parameters, Shawnee Twin Lake # 1 had excellent water clarity. 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 86), indicating the lake was mesotrophic, with moderate levels of primary productivity and nutrient conditions. The TSI values varied from mesotrophic in the fall, spring and summer quarters to oligotrophic in the winter quarter (see Figure 190). Turbidity values were all well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 191a). 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 OWQS (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 values below the criteria the lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 191b. True color values were below the aesthetics OWQS of 70 units at all sites with the exception of site 4 in the summer quarter (see Figure 191b). With only 5% of the collected samples above the numerical criteria for true color, the lake is fully supporting its Aesthetics beneficial use related to true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five (5) sample sites in 2001-2002. Salinity ranged from 0.08 parts per thousand (ppt) in the fall and spring quarters to 0.13 ppt in the summer, indicating low salt content and values were well within the expected range of salinity concentrations reported for most Oklahoma lakes. Specific conductance ranged from 183.2 mS/cm in the fall to 264.0 mS/cm in the summer quarter, 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 in the summer to 8.08 units in the spring quarter. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. With all recorded values within the allowable range, the lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 50 mV to 523 mV indicating that reducing conditions were not present during any of the sampling events. The lake was not thermally stratified in the fall, winter or spring

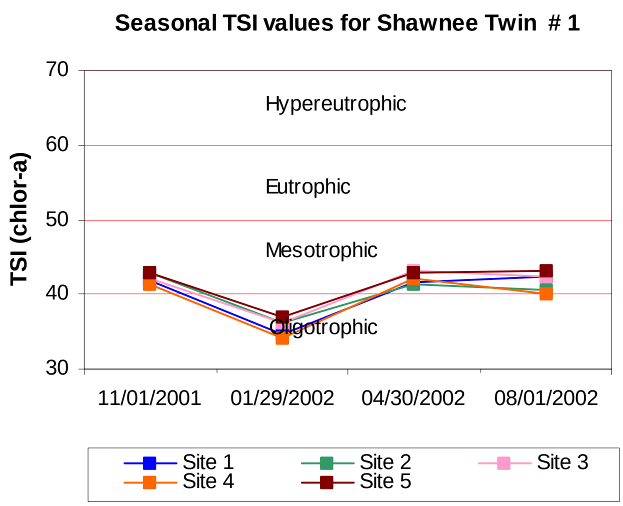


Figure 190. TSI values for Shawnee Twin Lake # 1.

quarters and dissolved oxygen (D.O.) concentrations were above 7.5mg/L throughout the water column (see Figure 191c-186e). In the summer, the lake was strongly thermally stratified between 7 and 8 meters below the surface at site 1 near the dam. Below 7 meters at site 1 and extending to the lake bottom at 12.6 meters D.O. concentrations were below 1.0 mg/L (see Figure 191f). 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 Shawnee Twin Lake # 1 because only 47% of the water column at site 1 had a D.O. of less than 2.0 mg/L. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.36 mg/L at the lake surface. The TN at the surface ranged from 0.17 mg/L to 0.45 mg/L. The highest surface TN value was reported in the summer and the lowest was in the spring quarter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.014 mg/L at the lake surface. The surface TP ranged from 0.009 mg/L to 0.22 mg/L. The highest surface TP value was reported in the fall and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 26:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Shawnee Twin Lake # 1 was also sampled for metals at five sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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, indicating moderate primary productivity and nutrient conditions (Plate 86). The lake was fully supporting its Aesthetics beneficial use based on the trophic status (nutrients) and true color. The lake was fully supporting its FWP beneficial use for nephelometric turbidity, pH, and D.O. at the time of sampling. In general, the water quality condition of the lake was excellent based on Water Resources Board sampling with no water quality concerns detected. 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.

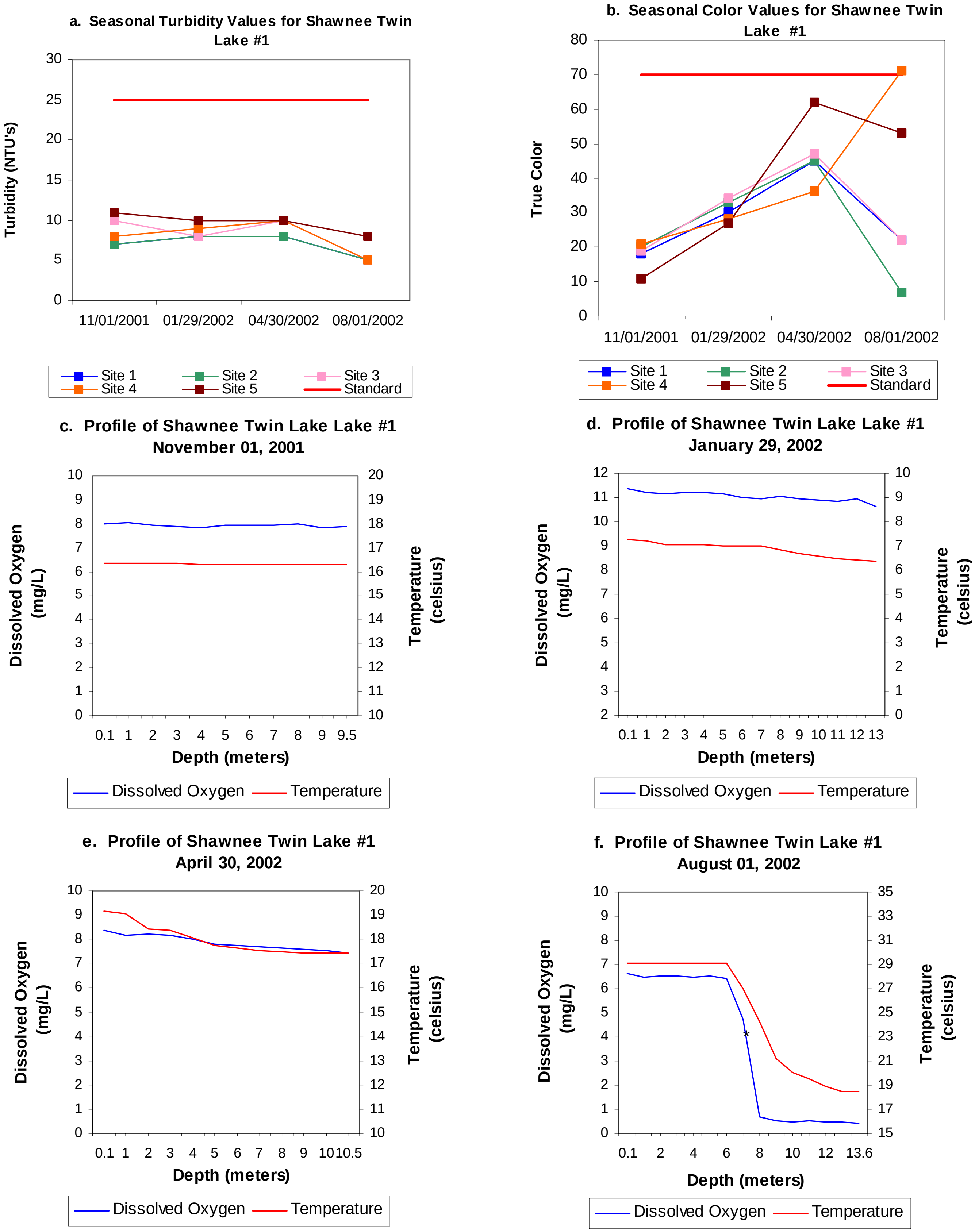
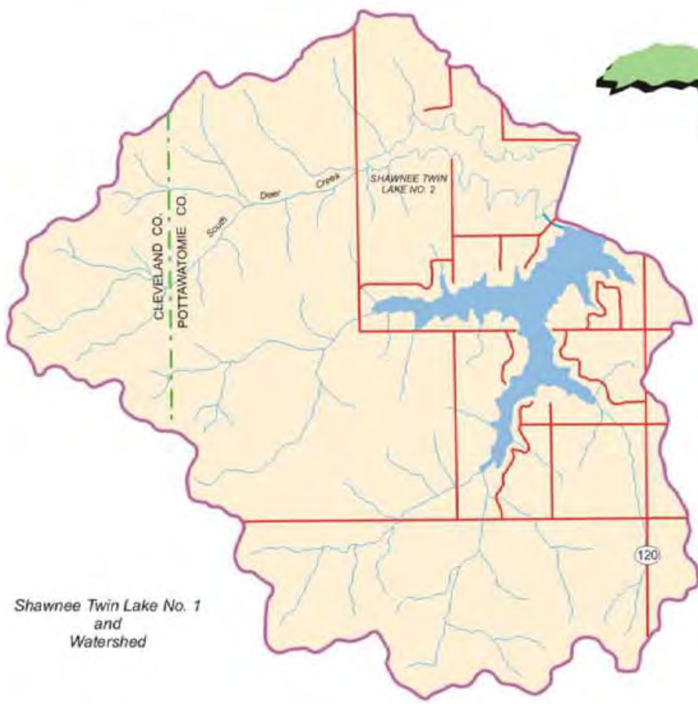
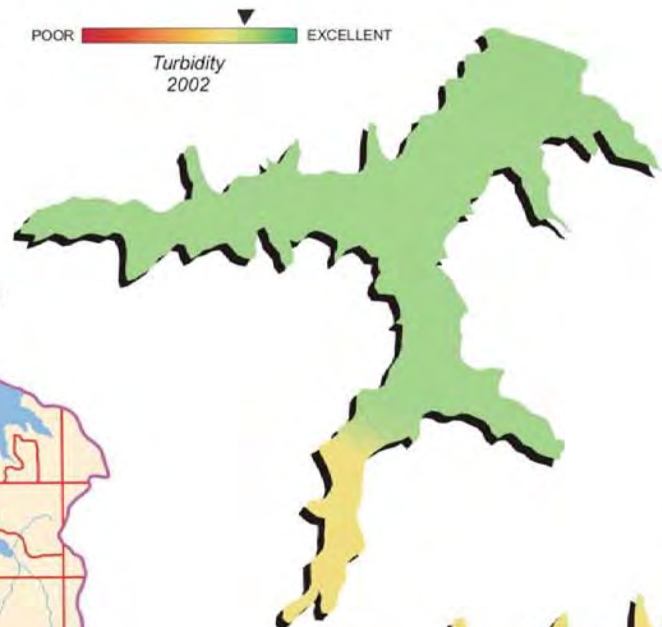
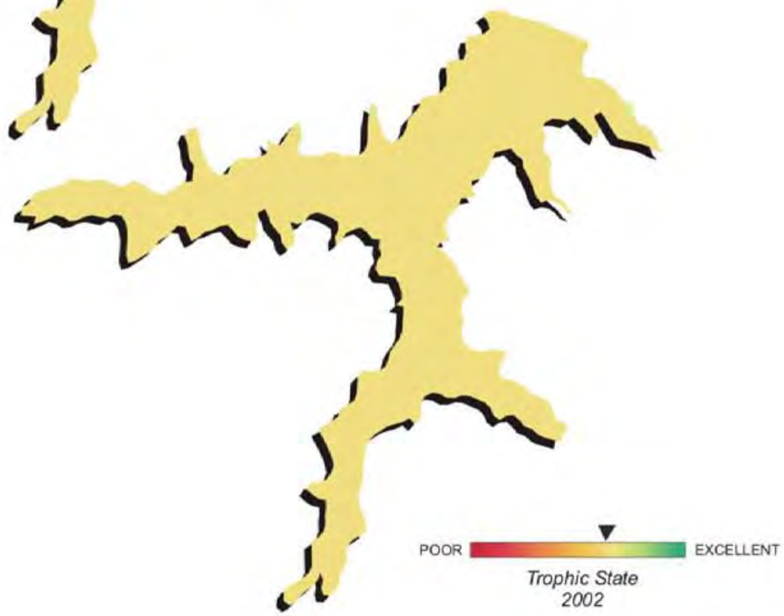


Figure 191a-186f. Graphical representation of data results for Shawnee Twin Lake # 1.







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 86 - Lake Water Quality for

Shawnee Twin Lake No. 1

Shawnee Twin Lake # 2

Shawnee Twin Lake # 2 was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at four (4) sites to represent the riverine, transition, and lacustrine zones of the reservoir as well as any major lake arms. In addition, a sample was collected at the lake surface at site 5 for the purpose of assessing chlorophyll-a and nephelometric turbidity concentrations. 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 10 NTU (Plate 87), true color was 32 units, and secchi disk depth was 80 centimeters in 2001-2002. Based on these three parameters, Shawnee Twin Lake # 2 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 42 (Plate 87), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. The TSI values varied seasonally and were upper mesotrophic in the fall, oligotrophic in the winter and spring quarters and oligo-mesotrophic in the summer quarter (see Figure 192). All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 193a). 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 OWQS (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. Shawnee Twin Lake #2 was fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity readings. Seasonal true color values are displayed in Figure 193b. All of the true color values were well below the Aesthetics numeric criteria of 70 units, however the use could not be definitively assessed due to insufficient data. Collected data does strongly support the supposition that the Aesthetics beneficial use is fully supported for true color.

Vertical profiles for dissolved oxygen; pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all four (4) sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.11 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 165.6 mS/cm reported in the fall quarter to 224.9 mS/cm in the summer, indicating that low to moderate levels of electrical conducting compounds (salts) were present in the lake system. In general, pH values were neutral, ranging from 7.08 to 8.09 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 should be listed as not supporting beneficial uses. 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 beneficial uses. The lake was fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox)

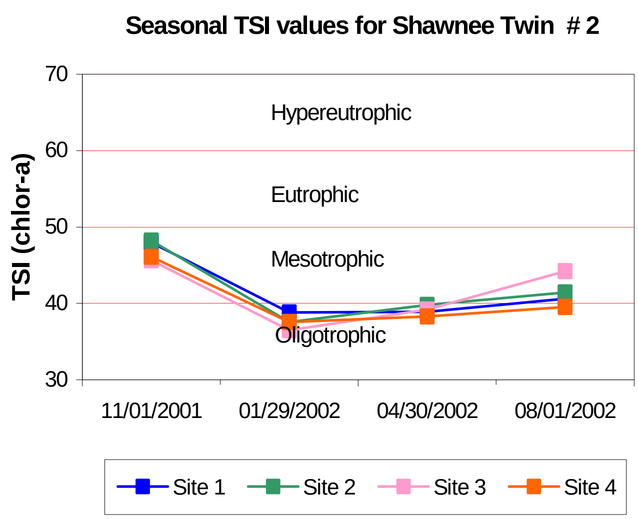


Figure 192. TSI values for Shawnee Twin Lake # 2.

ranged from 59 mV at the sediment-water interface in the summer to 498 mV recorded in the fall quarter near the sediment-water interface at site 1. 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, winter, or spring quarters and dissolved oxygen (D.O.) readings were above 5.1 mg/L throughout the water column (see Figure 193c-188e). In the summer, the lake was strongly thermally stratified between the 5 and 6-meter depth. Below 5 meters, D.O. values were less than 2.0 mg/L and remained so all the way to the lake bottom at 7.8 meters (see Figure 193f). 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 Shawnee Twin Lake # 2 with only 33% of the water column with D.O. values less than 2.0 mg/L. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.36 mg/L at the lake surface. The TN at the surface ranged from 0.16 mg/L in the spring quarter to 1.07 mg/L in the winter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.015 mg/L at the lake surface. The surface TP ranged from 0.008 mg/L in the fall to 0.27 mg/L in the summer quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 24:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Shawnee Twin Lake # 2 was also sampled for metals at four sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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 # 2 was classified as mesotrophic, indicative of moderate primary productivity and nutrients. The lake was fully supporting its Aesthetics beneficial use based on trophic status for nutrients (Plate 87). Collected true color values strongly support the supposition that the lake would also support the Aesthetics beneficial use for true color. The lake was fully supporting the FWP beneficial use based on nephelometric turbidity, pH, and D.O. concentrations. Much like its sister lake (Shawnee Twin Lake # 1) the water quality of this reservoir was excellent during the sample period with no water quality concerns detected. Shawnee Twin Lake # 2 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.

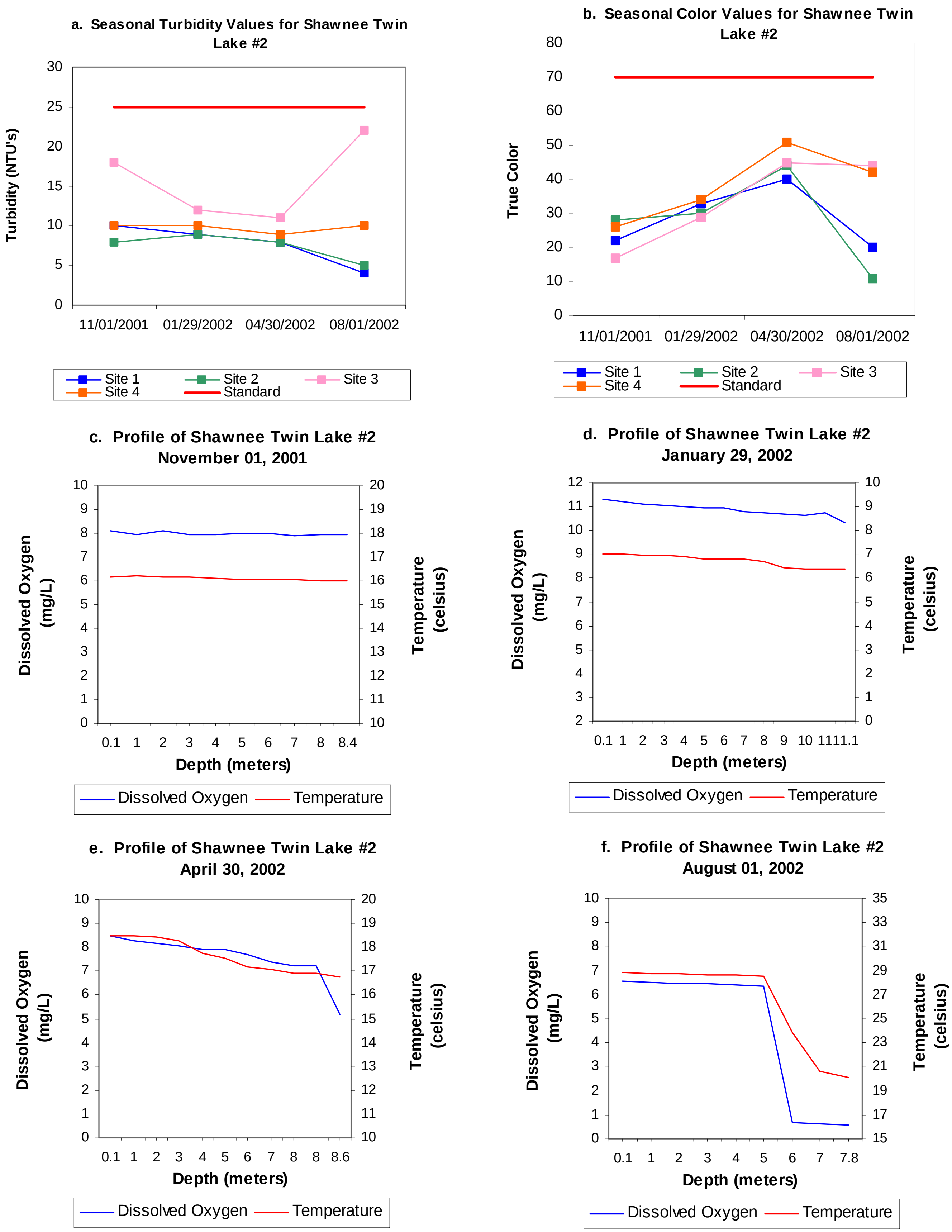


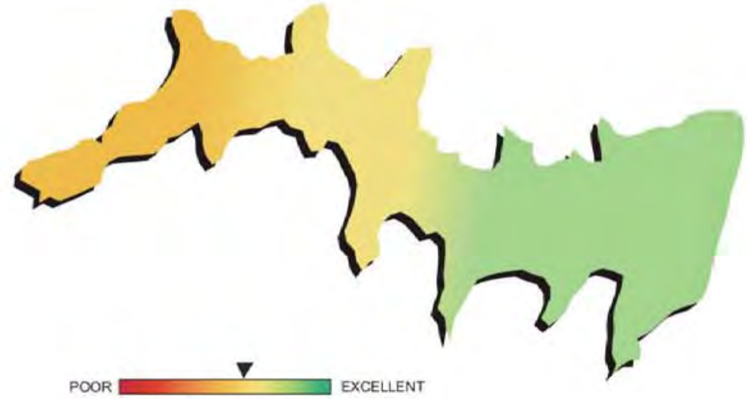
Figure 193a-188f. Graphical representation of data results for Shawnee Twin Lake # 2.

Shawnee Twin Lake No. 2
Location

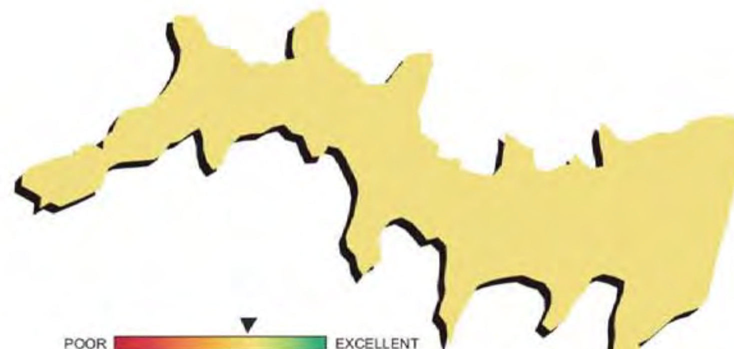
Shawnee Twin Lake No. 2
and
Watershed

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



Turbidity
2002



Trophic State
2002

Plate 87 - Lake Water Quality for
Shawnee Twin Lake No. 2

Shell Lake

Shell Lake was sampled for four quarters, from October 2001 through July 2002. 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. Additional samples were collected at sites 4 and 5 at the lake surface for the purpose of looking at chlorophyll-a and nephelometric turbidity concentrations. The lake-wide annual turbidity value was 10 NTU (Plate 88), true color was 26 units, and secchi disk depth was 85 centimeters in 2001-2002. 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 51 (Plate 88), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions. The TSI values varied seasonally from mesotrophic in the winter and spring quarters, to lower eutrophy in the winter, to upper eutrophy in the summer quarter (see Figure 194). All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 195a). 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 OWQS (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 average of 10 NTU seems to accurately represent the conditions at this lake and Shell Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 195b. All of the true color values were below the numeric criteria of 70 units in 2001-2002, although a beneficial use assessment for Aesthetics could not be made due to insufficient data. Collected data strongly supports the supposition that the Aesthetics use would be fully supporting it sufficient data were available.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.04 parts per thousand (ppt) to 0.07 ppt, indicating low salt content and were well within the expected range of salinity values reported for most Oklahoma lakes if not less. Specific conductance ranged from 100.3 mS/cm in the spring quarter to 144.6 mS/cm in the winter, 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 6.57 units to 8.28 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 should be listed as not supporting beneficial uses. 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 beneficial uses. None of the collected pH values fell outside the

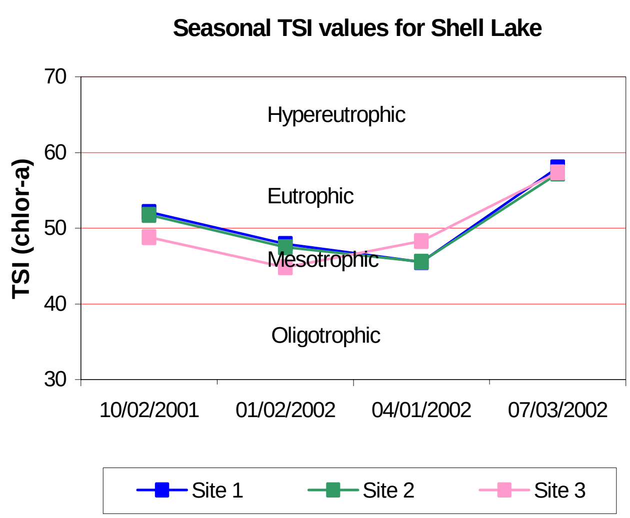


Figure 194. TSI values for Shell Lake.

acceptable range, so Shell Lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 41 mV at the sediment-water interface in the summer to 520 mV in the winter quarter. Redox readings indicated that reducing conditions were not present in the reservoir to any appreciable degree during any of the sampling events. The lake was not thermally stratified in the fall, winter or spring quarters and dissolved oxygen (D.O.) values were above 3.0 mg/L throughout the water column and were generally above 6.0 mg/L except near the lake bottom (see Figure 195c-190e). In the summer, the lake was very strongly thermally stratified between 3 and 4 meters below the surface, at which point D.O. values were less than 1.0 mg/L from the 4-meter depth to the lake bottom at 13.7 meters (see Figure 195f). 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 not supporting at Shell Lake as 73% of the water column was anoxic at site 1 in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.67 mg/L at the lake surface. The TN at the surface ranged from 0.49 mg/L to 1.00 mg/L. The highest surface TN value was reported in the summer quarter and the lowest was in the winter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.045 mg/L at the lake surface. The surface TP ranged from 0.030 mg/L to 0.068 mg/L. The highest surface TP value was reported in the summer and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 15:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Shell Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Shell Lake was eutrophic in 2001-2002, indicative of high primary productivity and nutrient rich conditions (Plate 88). Water clarity is very good at this lake. Shell Lake was fully supporting its Aesthetics beneficial use based on its nutrient status and use support for true color could not be determined due to insufficient data. True color data collected strongly supports the supposition that the lake would be supporting the Aesthetics use for true color. The FWP beneficial use was fully supported for turbidity and pH, but was not supported for D.O. because 73% of the water column was anoxic. Shell Lake 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.

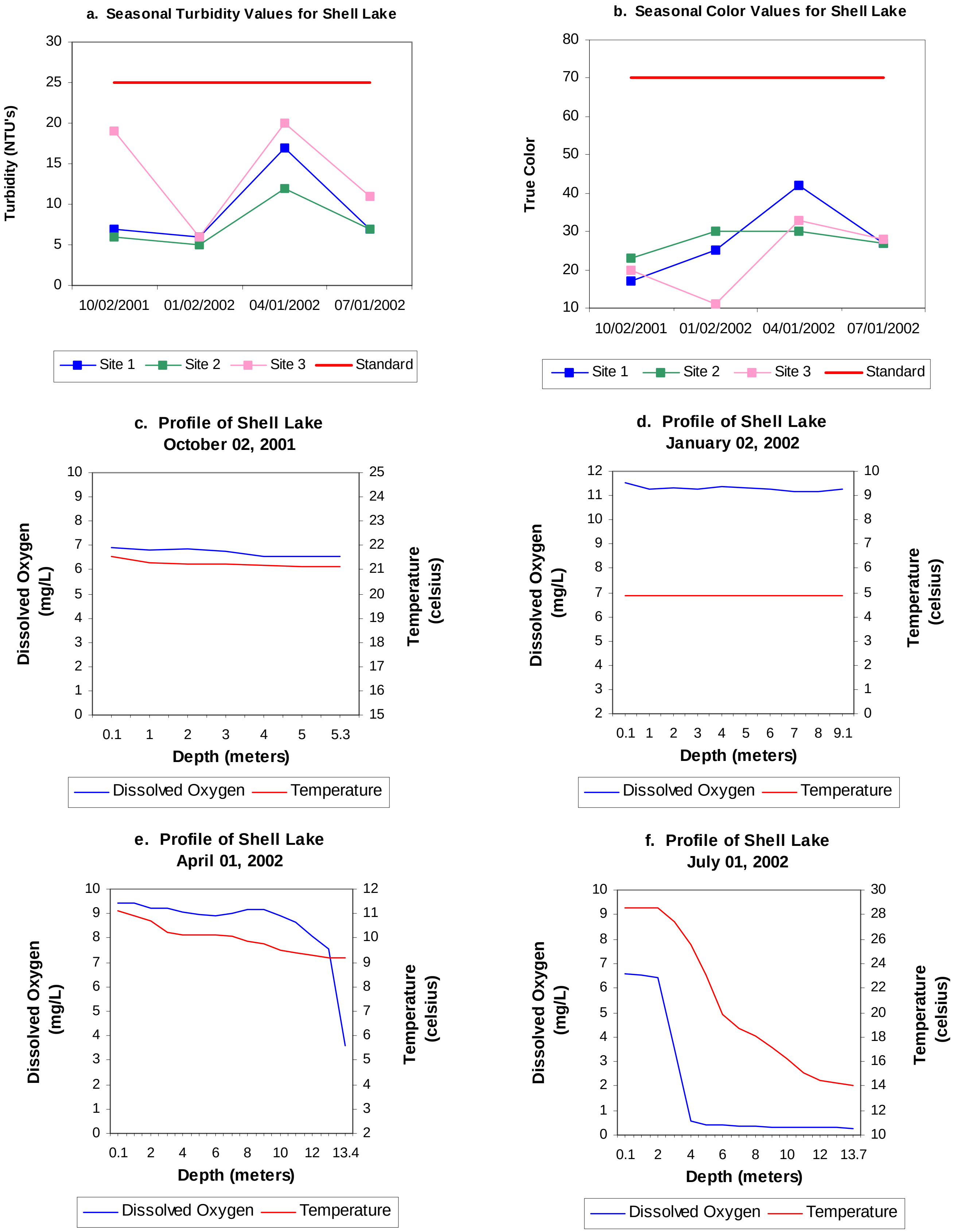


Figure 195a-190f. Graphical representation of data results for Shell Lake.

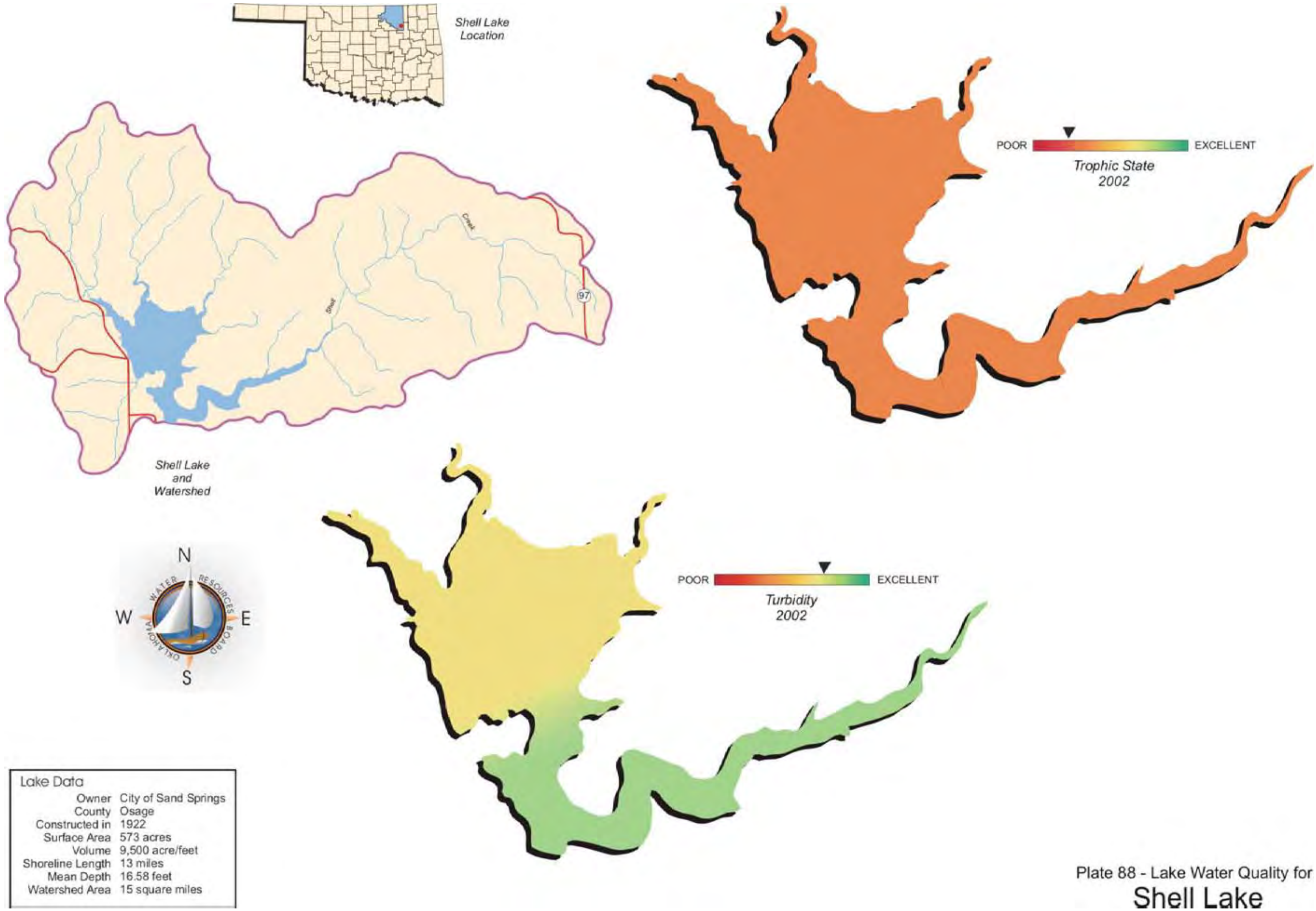


Plate 88 - Lake Water Quality for
Shell Lake

Skiatook Lake

Skiatook Lake was sampled for four quarters, from October 2002 through July 2003. 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 89), true color was 34 units, and average secchi disk depth was 137 centimeters. Based on these three parameters Skiatook Lake had excellent water clarity in 2002-2003, even better than reported in sample year 2000. 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 45 (Plate 89), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions. This value is slightly lower than the TSI calculated in 2000 (TSI=50), although in the same trophic category, and is likely a more accurate depiction of productivity as it is based on data collected year round versus the growing season. The TSI values varied by site and season throughout the sample year (Figure 196) with values spanning three trophic categories. In the fall and winter values were primarily mesotrophic with sites 4 and 5 falling in the eutrophic category. In the spring and summer quarters TSI values were split with half of the values being oligotrophic and the other half mesotrophic. The only exception was site 4, which was eutrophic in the summer (Figure 196). Seasonal turbidity values are displayed in Figure 197a. Turbidity values were below the Oklahoma Water Quality Standard (OWQS) 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 OWQS (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% of the samples exceeding the standard, the Fish and Wildlife Propagation (FWP) beneficial use is considered supported for sample year 2003. Seasonal true color values are displayed in Figure 197b. True color followed the same pattern as turbidity with all values below the OWQS of 70, except for sites 4 and 5, which had a values of 250 and 133 units, respectively reported in the spring quarter. Applying the same default protocol, the Aesthetics beneficial use is fully supported.

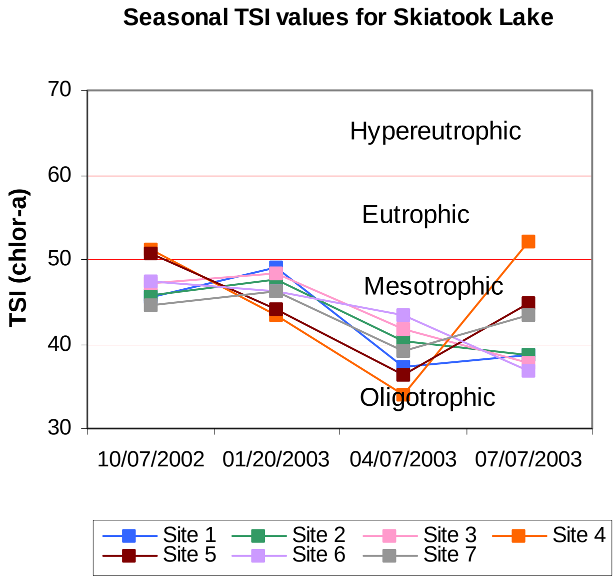


Figure 196. TSI values for Skiatook Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites in 2002-2003. Salinity values ranged from 0.09 parts per thousand (ppt) to 0.23 ppt during the study period. This is within the average range of values reported for most Oklahoma reservoirs. Specific conductance ranged from 197.6 to 282.4 mS/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 6.59 to 8.18 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. 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 71 mV in the fall to 526 mV in the spring, generally indicating the absence of reducing conditions. 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 197d-192e). 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 1,2, 3 and 4 at which point D.O. fell below 2.0 mg/L for the rest of the water column (Figure 197c-192f). 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. 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.48 mg/L at the surface and 0.53 mg/L at the lake bottom. The TN at the surface ranged from 0.13 mg/L to 1.42 mg/L. The highest surface total nitrogen was reported in the spring and the lowest in the fall. The lake-wide total phosphorus (TP) average was 0.016 mg/L and 0.013 mg/L at the lake bottom. The surface TP ranged from 0.005 mg/L to 0.111 mg/L. Similar to TN, the highest surface TP was reported in the spring and the lowest values were reported during the fall quarter. The nitrogen to phosphorus ratio (TN:TP) was 31:1 for sample year 2002-2003. This value is greater 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. These results are similar to those reported in 2000, indicating no significant increase or decrease in productivity has occurred. Water clarity was excellent in 2003, even better than reported in 2000 with secchi disk depth readings showing the biggest increase. 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. 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 Skiatook.

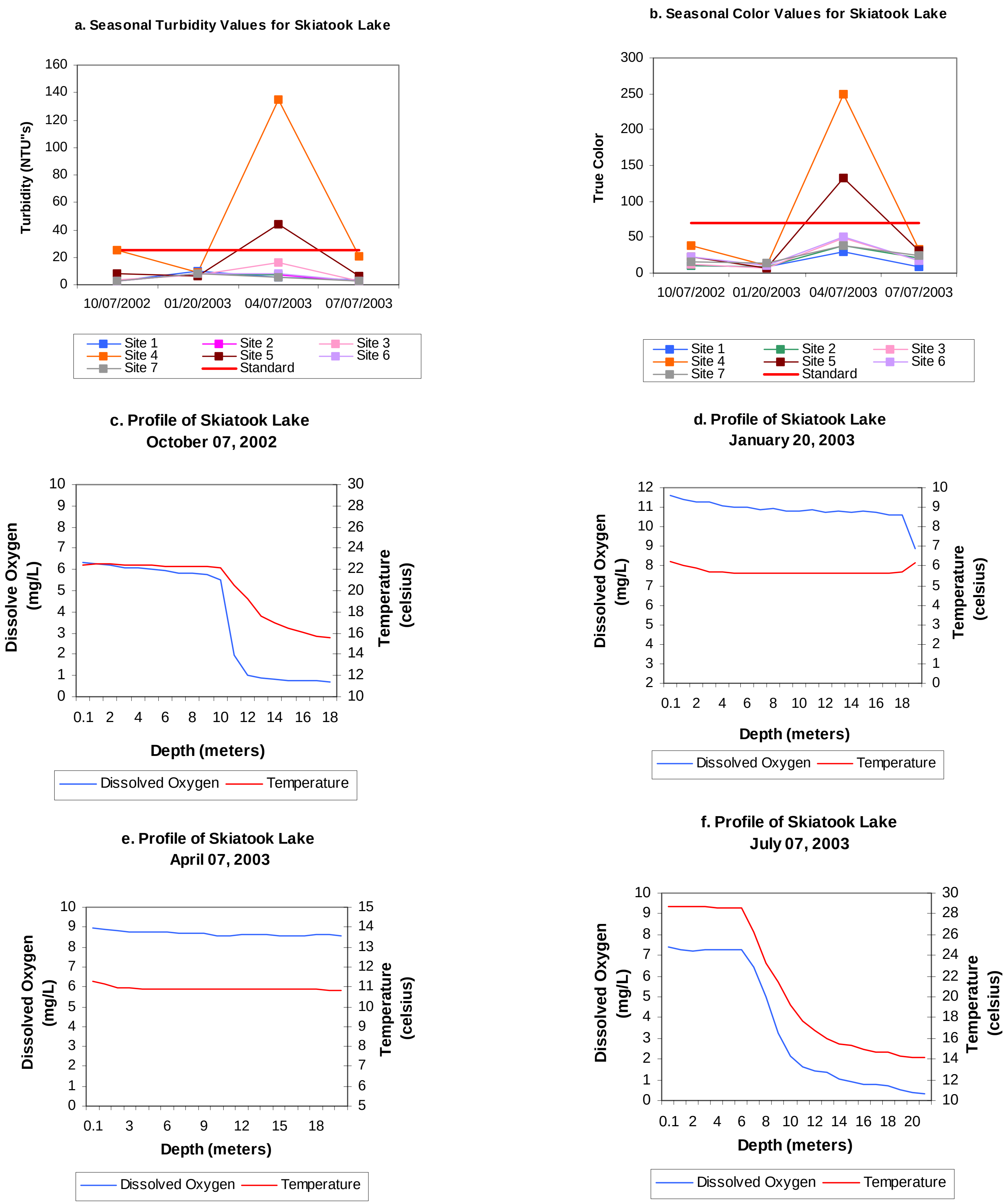
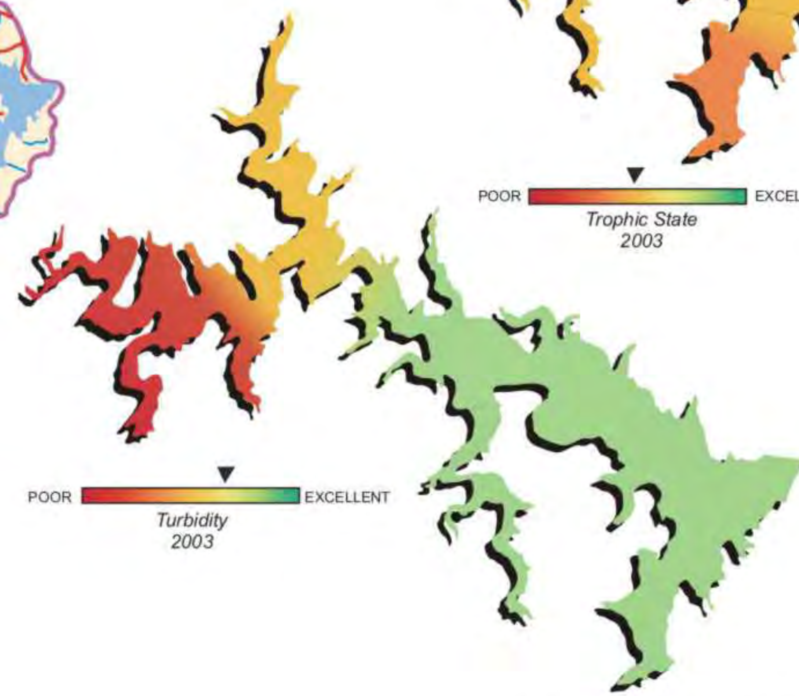


Figure 197a-192f. Graphical representation of data results for Skiatook Lake.

Skiatook Lake
and
Watershed

Skiatook Lake
Location

Trophic State
2003



Turbidity
2003

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 89 - Lake Water Quality for
Skiatook Lake

Sooner Reservoir

Sooner Reservoir was sampled for four quarters, from October 2002 through July 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative of a lake larger than 250 surface acres. 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 9 NTU (Plate 90), true color was 12 units, and average secchi disk depth was 126 centimeters. Based on these three parameters, Skiatook Lake had excellent water clarity in 2002-2003. These results are similar to those in 2000, 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 90), 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 2000 (TSI=48), indicating no change in productivity has occurred since the last evaluation. The TSI values varied seasonally ranging from eutrophic in the fall to mesotrophic in the winter and summer and oligotrophic in the spring (see Figure 198). Seasonal turbidity per site is displayed in Figure 199a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. A spike in turbidity occurred at site 3 in the spring, but it was still below the standard with a reported value of 24 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 OWQS (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 2003. Seasonal true color values are displayed in Figure 199b. All of the true color values were below the numeric criteria of 70 units, however a beneficial use assessment for Aesthetics could not be made due the minimum data requirements of 20 samples for lakes greater than 250 surface acres not being met. Available data strongly suggests that the Aesthetics use would be fully supporting if sufficient data were available.

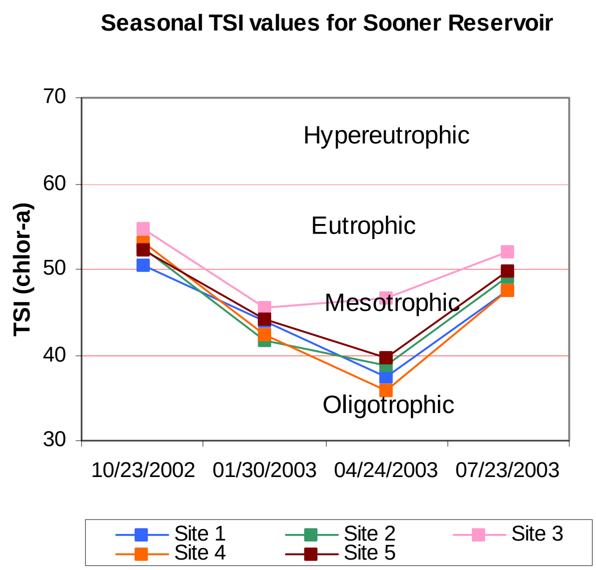


Figure 198. TSI values for Sooner Reservoir.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.98 parts per thousand (ppt) to 0.106 ppt during the study period. This is much higher than the average range of values reported for most Oklahoma reservoirs. Specific conductance ranged from 1836 to 1969 mS/cm, 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 7.31 to 8.38 during the study period. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. 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 257 mV to 674 mV, indicating the absence of reducing conditions. During the fall, winter, and spring quarters the lake was well mixed with dissolved oxygen generally above 7.0 mg/L (Figure 199c-194e). Thermal stratification was evident and anoxic conditions were present below the thermocline in the summer (Figure 199f). The lake was stratified between 10 and 11 meters with dissolved oxygen (D.O.) concentrations below 2.0 mg/L for approximately 54% 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. Sooner Reservoir is considered partially supporting its FWP beneficial use with 54% 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.41 mg/L at the surface and 0.49 mg/L at the lake bottom. The TN at the surface ranged from 0.29 mg/L to 0.59 mg/L. The highest surface total nitrogen was reported in the spring and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.020 mg/L at the surface and 0.021 mg/L at the lake bottom. The surface TP ranged from 0.014 mg/L to 0.026 mg/L. Similar to TN, the highest surface TP was reported in the spring and the lowest values were reported during the winter quarter. The nitrogen to phosphorus ratio (TN:TP) was 21:1 for sample year 2002-2003. This value is greater 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 condition. This is same as the 2000 evaluation (TSI=48), therefore no change in productivity has occurred over time. Water clarity was excellent in 2002-2003, based on true color, turbidity and secchi disk depth. The FWP beneficial use is supported based on turbidity and pH, but only partially supported due to the presence of anoxic condition in the summer. The lake is supporting the Aesthetics beneficial use based on its trophic status. Although 100% of the collected true color values were below the standard of 70 units, a use determination cannot be made due to minimum data requirements not being met. Sooner Reservoir, located in Pawnee County, is owned and operated by the Oklahoma Gas and Electric Company (OG&E) as a cooling reservoir.

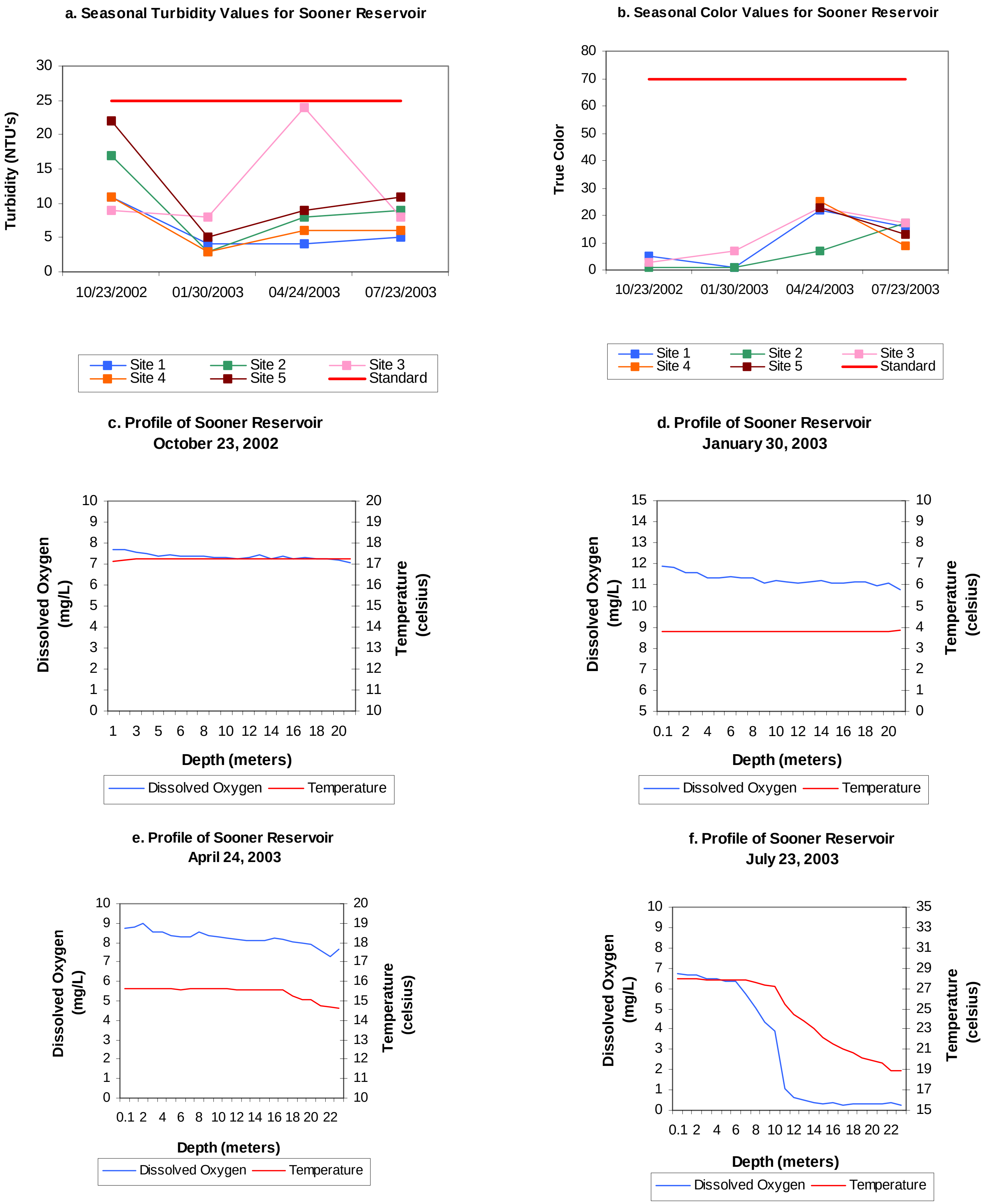
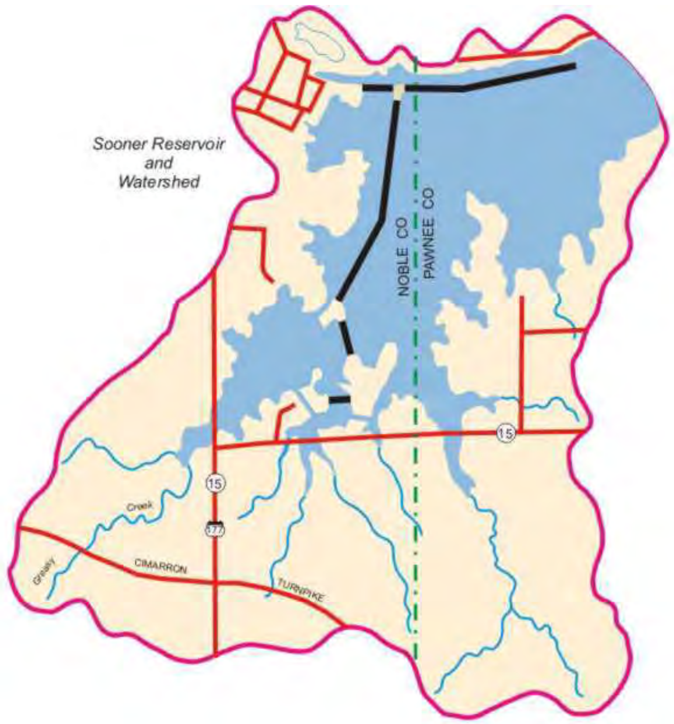
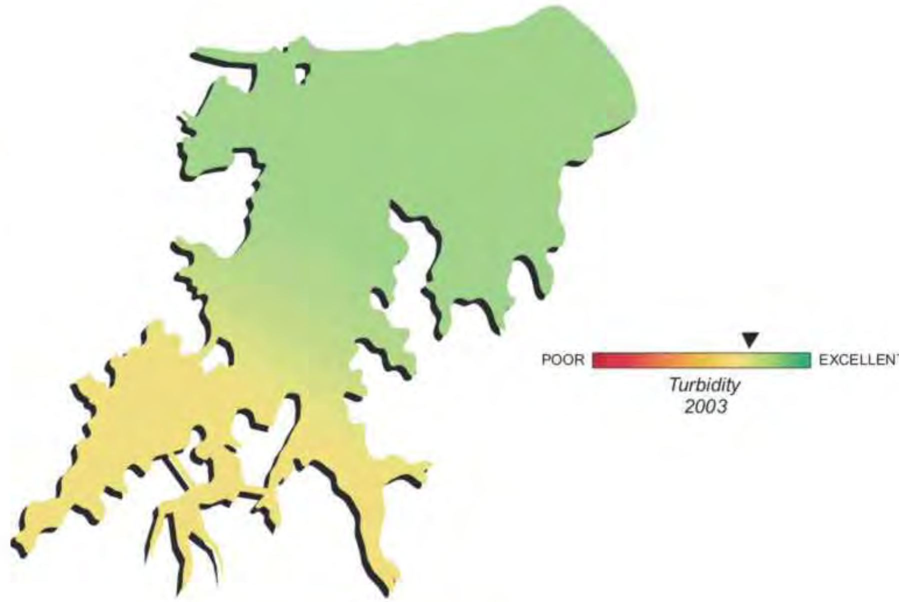
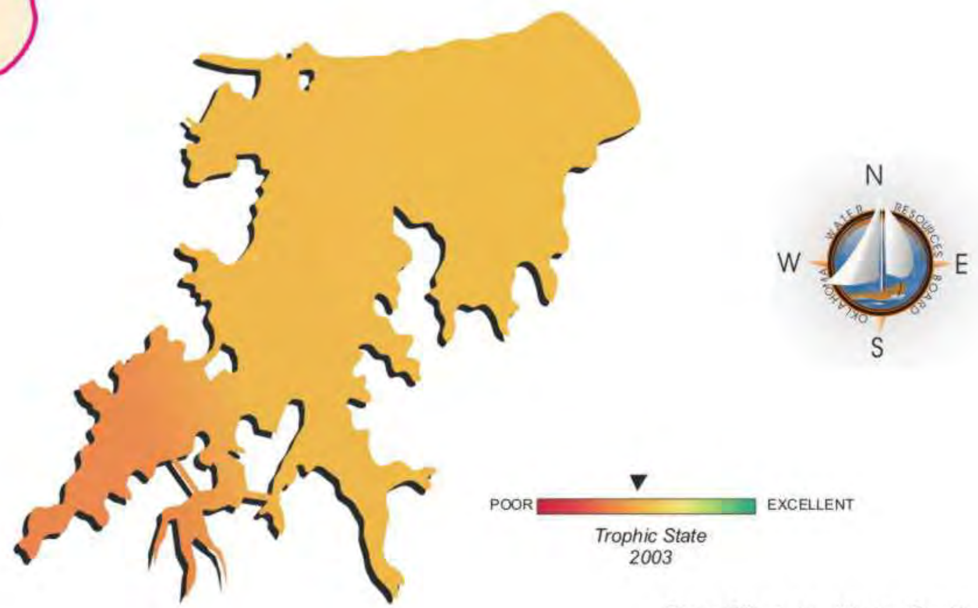


Figure 199a-194f. Graphical representation of data results for Sooner Reservoir.







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 90 - Lake Water Quality for
Sooner Reservoir

Spavinaw Lake

Spavinaw Lake was sampled for four quarters, from October 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer, to represent the riverine, transition, and lacustrine zones of the lake. Additional sites were added to ensure the sample size was representative for lakes greater than 250 surface acres in size. 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 91), true color was 9 units, and secchi disk depth was 124 centimeters. Based on these three parameters water clarity at Eucha Lake was excellent in sample year 2002-2003. 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 91), indicating the lake was eutrophic, indicative of moderate primary productivity and nutrient levels in sample year 2002-2003. The TSI values were primarily eutrophic with the exception of site 1, which was mesotrophic in both fall and winter quarters (Figure 200). These results differ from historical data collection efforts on the lake, which found the lake to be at the upper end of eutrophy in 1999 (TSI=58). The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient impaired. A nutrient impairment study should be conducted to determine if uses are impaired. Seasonal turbidity values are displayed in Figure 201a. Turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and ranged from a low of 3 NTU to a maximum of 20 NTU. 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 OWQS of 70 units and are displayed in Figure 201b. Due to the minimum data requirements not being met assessment of the Aesthetics beneficial use based on true color could not be made, however the available data suggests that it would be supporting.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.07 parts per thousand (ppt) to 0.30 ppt, which is within the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 165.1 mS/cm to 304.4 mS/cm, indicative of low to moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.96 to 8 .30, representing a neutral to slightly alkaline system. According to USAP (OAC 785:46-15-5), pH values are exceeding standards

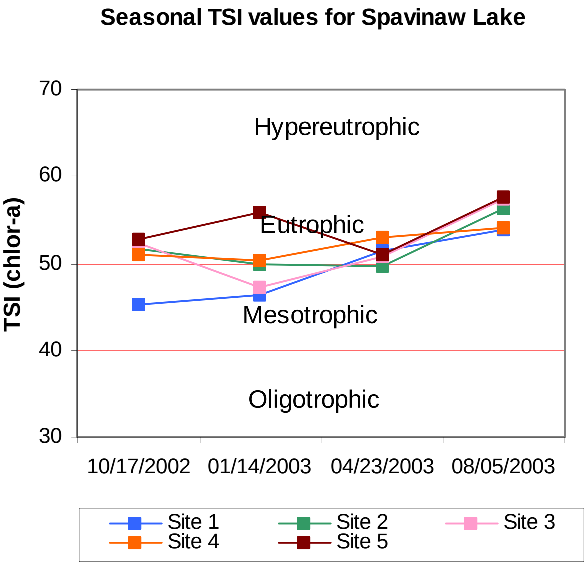


Figure 200. TSI values for Spavinaw Lake.

if they fall outside the 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. 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 87 mV in the hypolimnion in the summer to 590 mV in the fall 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. The lake was not stratified in the fall and winter and the water column was well mixed with dissolved oxygen (D.O.) values generally above 5.0 mg/L (see Figure 201c-196d). In the spring, the stratification was only observed at site 1, with D.O. only falling below 2.0 mg/L near the sediment-water interface (Figure 201e). Thermal stratification was evident and anoxic conditions were present throughout the lake in the summer (Figure 201f). During the summer sampling interval, stratification occurred between 6 and 7 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 30 to 59% 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.37 mg/L at the surface and 1.01 mg/L at the lake bottom. Surface TN ranged from 0.18 mg/L to 0.71 mg/L with the highest values recorded in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.022mg/L at the surface and 0.197 mg/L at the lake bottom. Similar to total nitrogen, surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.015 mg/L to 0.030 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 17:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Spavinaw Lake was classified as eutrophic, with high primary productivity and nutrient levels in 2002-2003. These results differ from historical data collection efforts on the lake, which found the lake to be hypereutrophic in 1999 (TSI=58). The lake is currently listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) 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 trophic status however a beneficial use determination cannot be made for true color because the minimum data requirements were not met. 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 197) 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 Kathy Koon at (405) 530-8800.

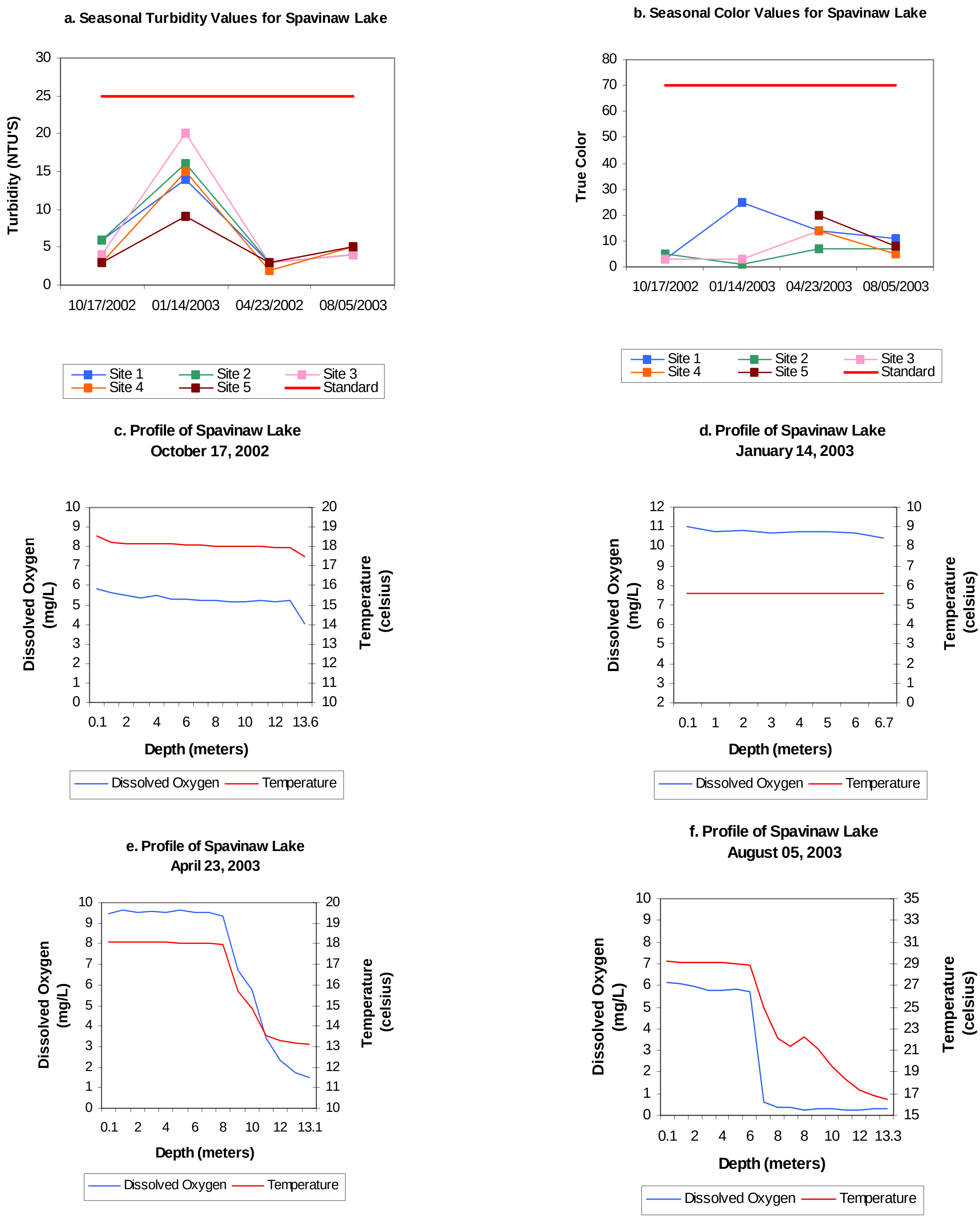


Figure 201a-196f. Graphical representation of data results for Spavinaw Lake.

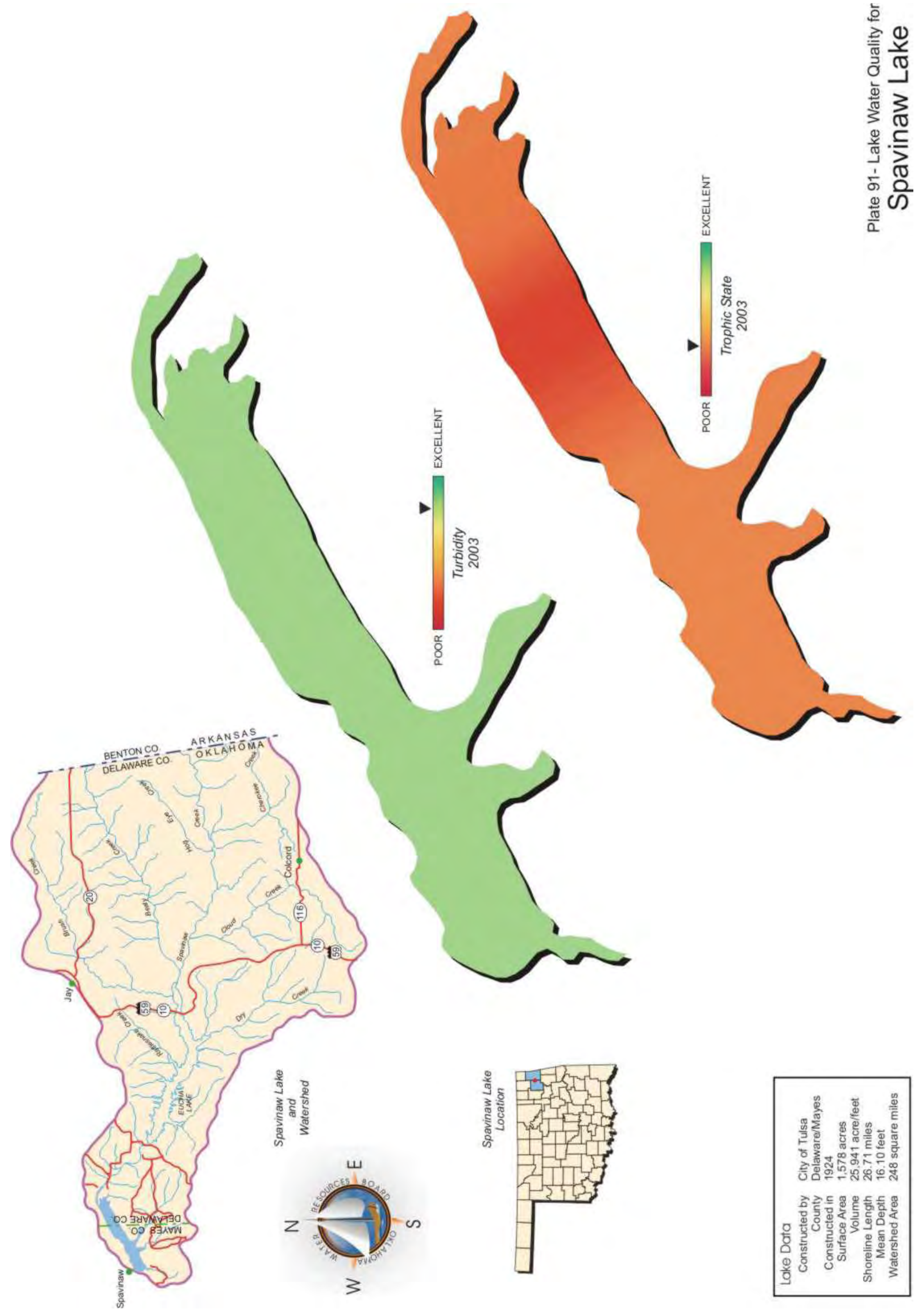


Plate 91 - Lake Water Quality for
Spavinaw Lake
Turbidity
2003
POOR
EXCELLENT
Trophic State
2003
POOR
EXCELLENT
Spavinaw Lake and Watershed
ARKANSAS
OKLAHOMA
BENTON CO.
DELAWARE CO.
MAYES CO.
Colcord
Jay
Spavinaw
N
E
S
W
Spavinaw Lake Location
Lake Data
Constructed by City of Tulsa
County Delaware/Mayes
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

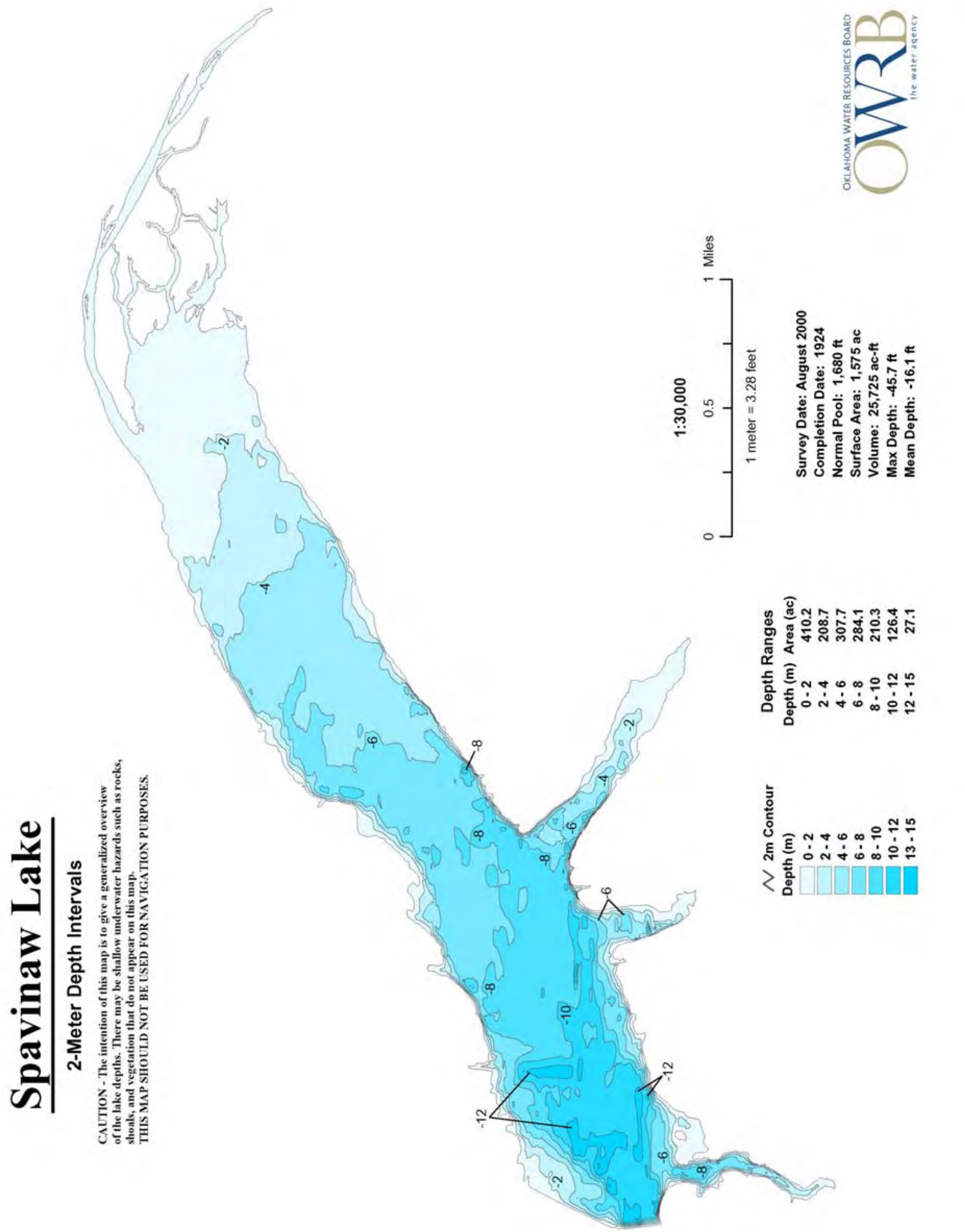


Figure 202. Bathymetric Map of Spavinaw Lake.

Sportsman Lake

Sportsman Lake was sampled for four quarters, from November 2001 through August 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional samples were collected at sites 4 and 5 at the lake surface for the determination of chlorophyll-a and nephelometric turbidity concentrations. 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 8 NTU (Plate 92), true color was 32 units, and secchi disk depth was 102 centimeters in 2001-2002. 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 41 (Plate 92), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrient conditions. The TSI values varied seasonally from oligotrophic in the winter and spring quarter to lower mesotrophy in the fall and summer quarters (see Figure 203). Sportsman Lake was on the border between oligotrophy and mesotrophy. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 204a). The lake-wide annual turbidity average of 8 NTU seems to accurately represent the conditions at this 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 OWQS (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. Sportsman Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to nephelometric turbidity. Seasonal true color values are displayed in Figure 204b. All of the true color values were below the Aesthetics numeric criteria of 70 units in 2001-2002, however, a definitive determination of the use support could not be made due to lack of sufficient data. Recorded data does strongly support the supposition that the lake would be supporting its Aesthetics beneficial use for true color.

Vertical profiles for dissolved oxygen, pH, temperature; specific conductance, oxidation-reduction potential, and salinity were recorded at all three water chemistry sample sites. The salinity values ranged from 0.11 parts per thousand (ppt) to 0.15 ppt, indicating moderate salt content and were within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 225.7 mS/cm in the spring quarter to 317.5 mS/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 6.72 to 7.94 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 should be listed as not supporting beneficial uses. 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 beneficial uses. Sportsman was fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 48 mV at the sediment-water interface in the summer to 400 mV in the fall quarter. Redox

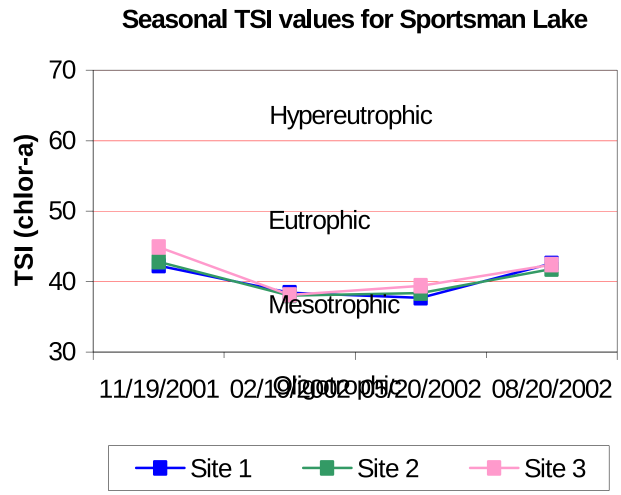


Figure 203. TSI values for Sportsman Lake.

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 8.8 mg/L throughout the water column (see Figure 204c-199d). In the spring, the lake was strongly thermally stratified at several 1-meter intervals, the first one between 6 and 7 meters at site 1 and again between 7 and 8 meters at site 1 (see Figure 204e). 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 9.2 meters (see Figure 204e). In the summer, the lake was once again 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 9.2 meters (see Figure 204f). From the 5-meter depth to the lake bottom at 9.2 meters the water temperature dropped over 10° Celsius, which is a large temperature difference in a lake this shallow. 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 27% 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 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.52 mg/L at the lake surface. The TN at the surface ranged from 0.23 mg/L to 1.69 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 for sample year 2001-2002 was 0.030 mg/L at the lake surface. The surface TP ranged from 0.014 mg/L to 0.063 mg/L. The highest surface TP value was reported in the fall and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 17:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Sportsman Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use based on metal (toxic) compounds in the water column.

In summary, Sportsman Lake was mesotrophic, indicative of moderate to low primary productivity and nutrient conditions (Plate 92). Water clarity was excellent at this lake. Sportsman Lake was fully supporting its Aesthetics beneficial use based on its trophic state and true color data strongly supports the supposition that it would be fully supporting for that parameter as well. The FWP beneficial use was fully supporting for nephelometric turbidity, pH and D.O. in the water column. There were no water quality concerns associated with the lake and it is one of the nicer small municipal lakes in Oklahoma. 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. This lake should be managed and maintained to protect its excellent water quality.

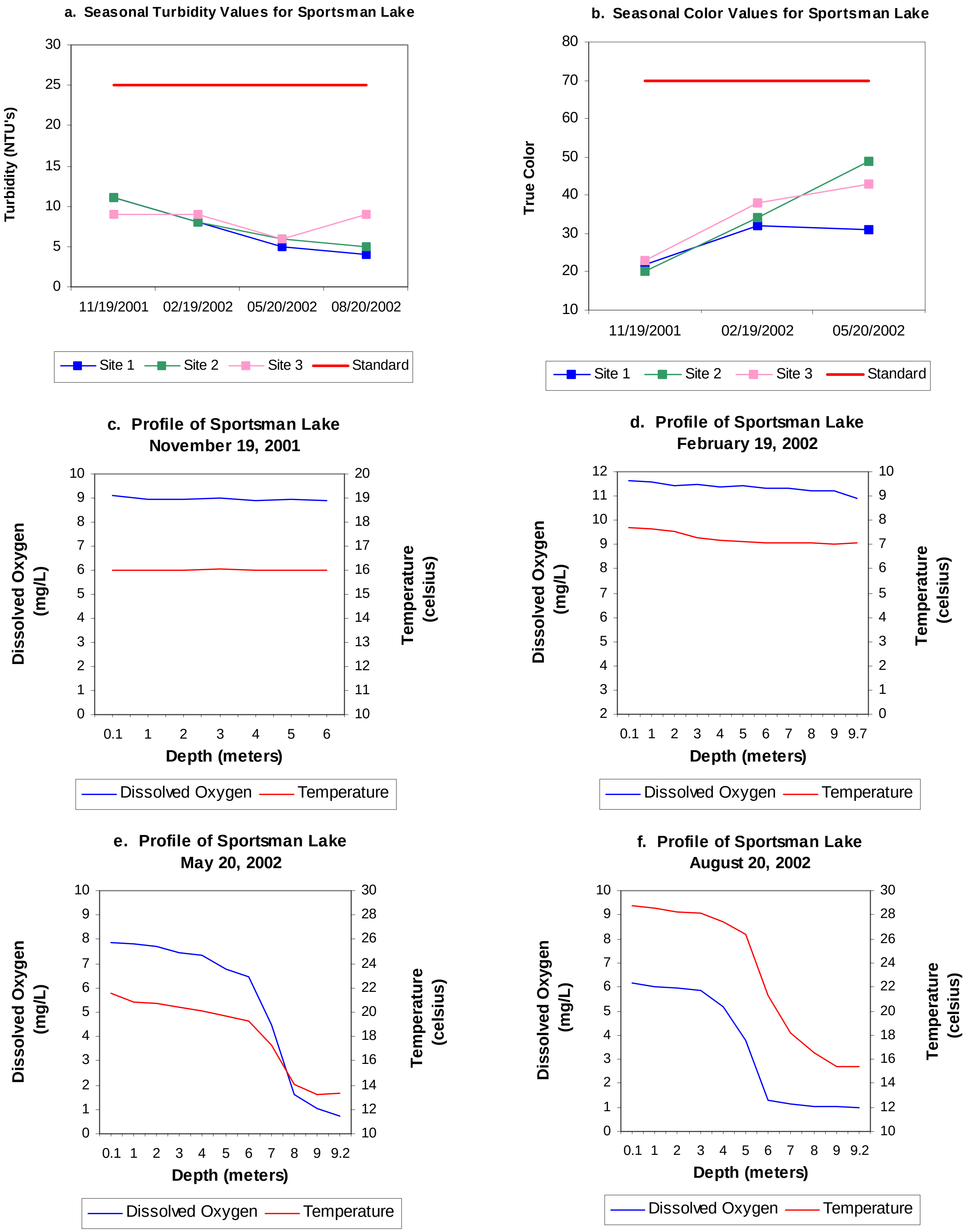


Figure 204a-199f. Graphical representation of data results for Sportsman Lake.

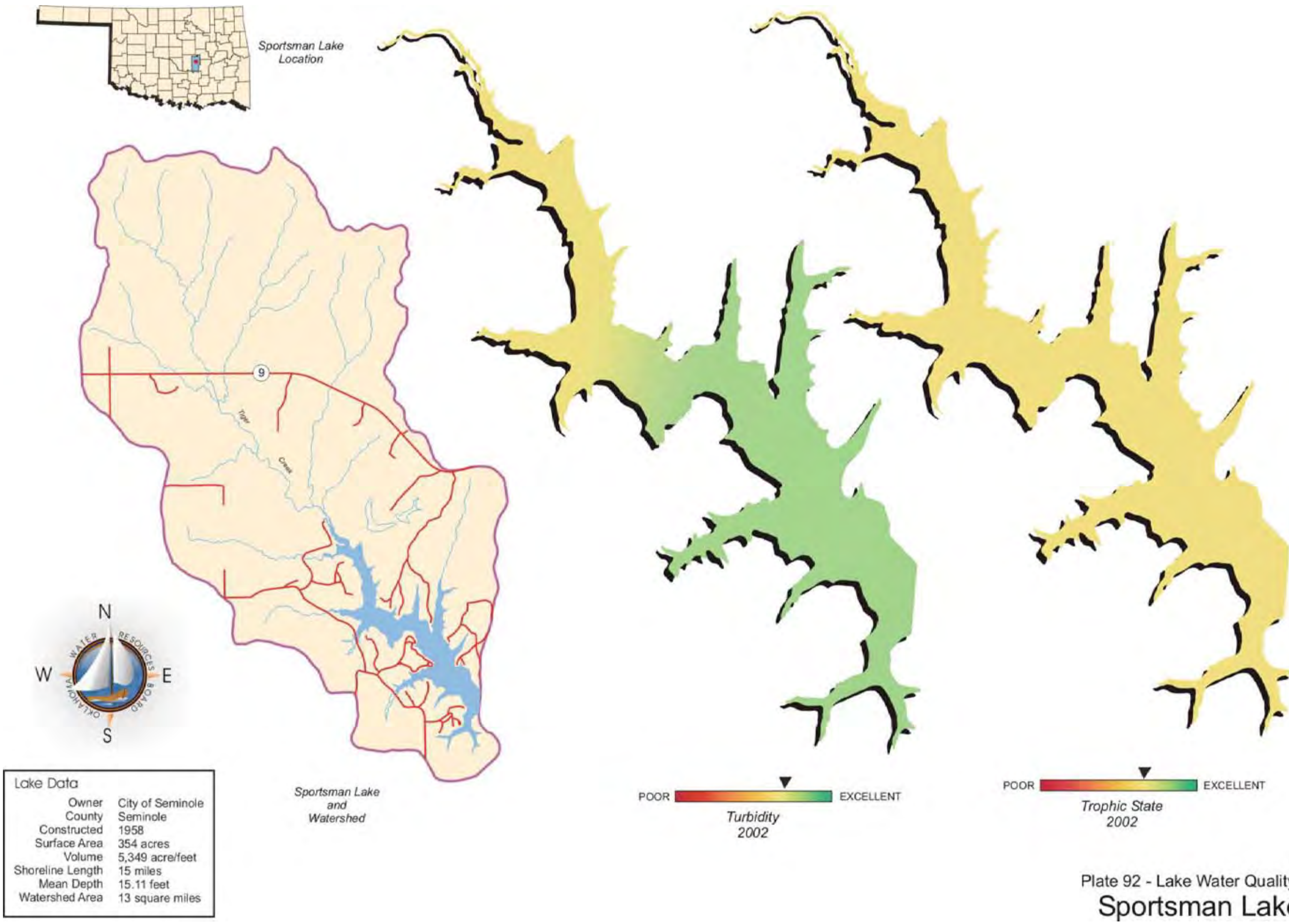


Plate 92 - Lake Water Quality for
Sportsman Lake

Lake Stanley Draper

Lake Stanley Draper was sampled for four quarters, from October 2001 through July 2002. 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 and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 32 NTU (Plate 93), true color was 109 units, and secchi disk depth was 46 centimeters in 2001-2002. The water clarity of the reservoir was poor based on the three water quality parameters mentioned above. 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 93), classifying the lake as oligotrophic, indicative of low levels of primary productivity and nutrient. This value is no doubt due in large part to the high levels of inorganic turbidity present in the water column limiting the amount of light available for use by the biotic community. The TSI values varied seasonally, from oligotrophic at in the fall and winter quarters to lower mesotrophy in the spring and summer quarters (see Figure 205). Almost all turbidity values were above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 206a). The lake-wide annual turbidity average of 32 NTU seems to accurately represent the conditions at this 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 OWQS (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 water column turbidity concentrations exceeding the criteria, the lake is not supporting its Fish & Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 206b. Almost all of the true color values were above the numeric criteria of 70 units in 2001-2002 and with 65% of the values exceeding the criteria the lake is not supporting its Aesthetics beneficial use.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.05 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most Oklahoma lakes if not slightly lower. Specific conductance ranged from 53.7 mS/cm in the fall to 114.1 mS/cm in the summer 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 6.74 units to 8.06 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 should be listed as not supporting beneficial uses. 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 beneficial uses. Lake Stanley Draper was fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox)

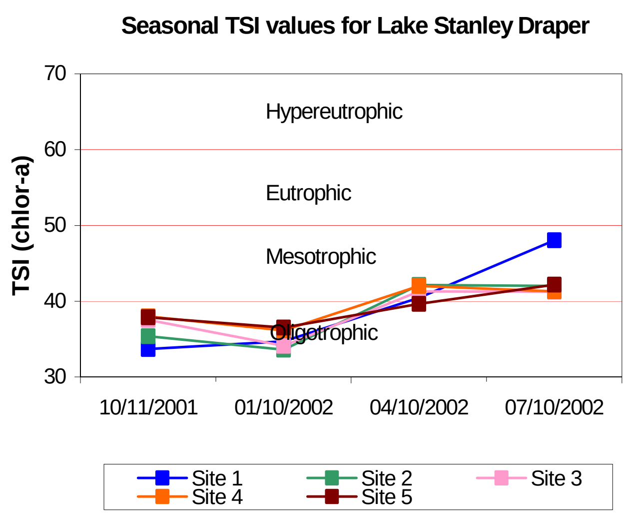


Figure 205. TSI values for Lake Stanley Draper.

ranged from 213 mV at the sediment-water interface in the spring quarter to 643 mV in the fall. Redox readings indicated that reducing conditions were not present in the reservoir at any point during the sample events. The lake was thermally stratified in the fall quarter between 20 and 21 meters below the lake surface and dissolved oxygen (D.O.) readings in the bottom 3 meters of the reservoir were less than 2.0 mg/L at site 1 (see Figure 206c). The lake was not thermally stratified in either the winter or spring quarters and D.O. values were above 9.5 mg/L throughout the water column (see Figure 206d-201e). In the summer quarter, the lake was thermally stratified at several depths with the first stratification located between 7 and 8 meters below the lake surface and another one between 9 and 10 and a third one 11 and 12 meters. However, D.O. concentrations never fell below 2.7 mg/L at any point in the lake water column (see Figure 206f). 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. The FWP beneficial use is considered fully supported at Lake Stanley Draper as only 12% of the water column was anoxic at site 1 in the summer and only 8% in the fall quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.51 mg/L at the lake surface. The TN at the surface ranged from 0.35 mg/L to 0.75 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the fall. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.026 mg/L at the lake surface. The surface TP ranged from 0.018 mg/L to 0.039 mg/L. The highest surface TP value was reported in the spring and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 19:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Stanley Draper was sampled for metals at five sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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. The lake is fully supporting its Fish Consumption beneficial use.

In summary, Lake Stanley Draper was oligotrophic, indicative of low primary productivity (Plate 93). Water clarity was poor at this lake and no doubt light limitation played a major role in mitigating the productivity of the lake. The lake was not supporting its FWP beneficial use for turbidity, but was fully supporting based on D.O. and pH values. The lake was fully supporting its Aesthetics use based on its trophic state, but was not supporting based on true color. 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. 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 207) was generated to determine current storage capacity and identify areas of extreme sedimentaion. For more information on bathymetric mapping visit our website at www.owrb.state.ok.us or contact Kathy Koon at (405) 530-8800.

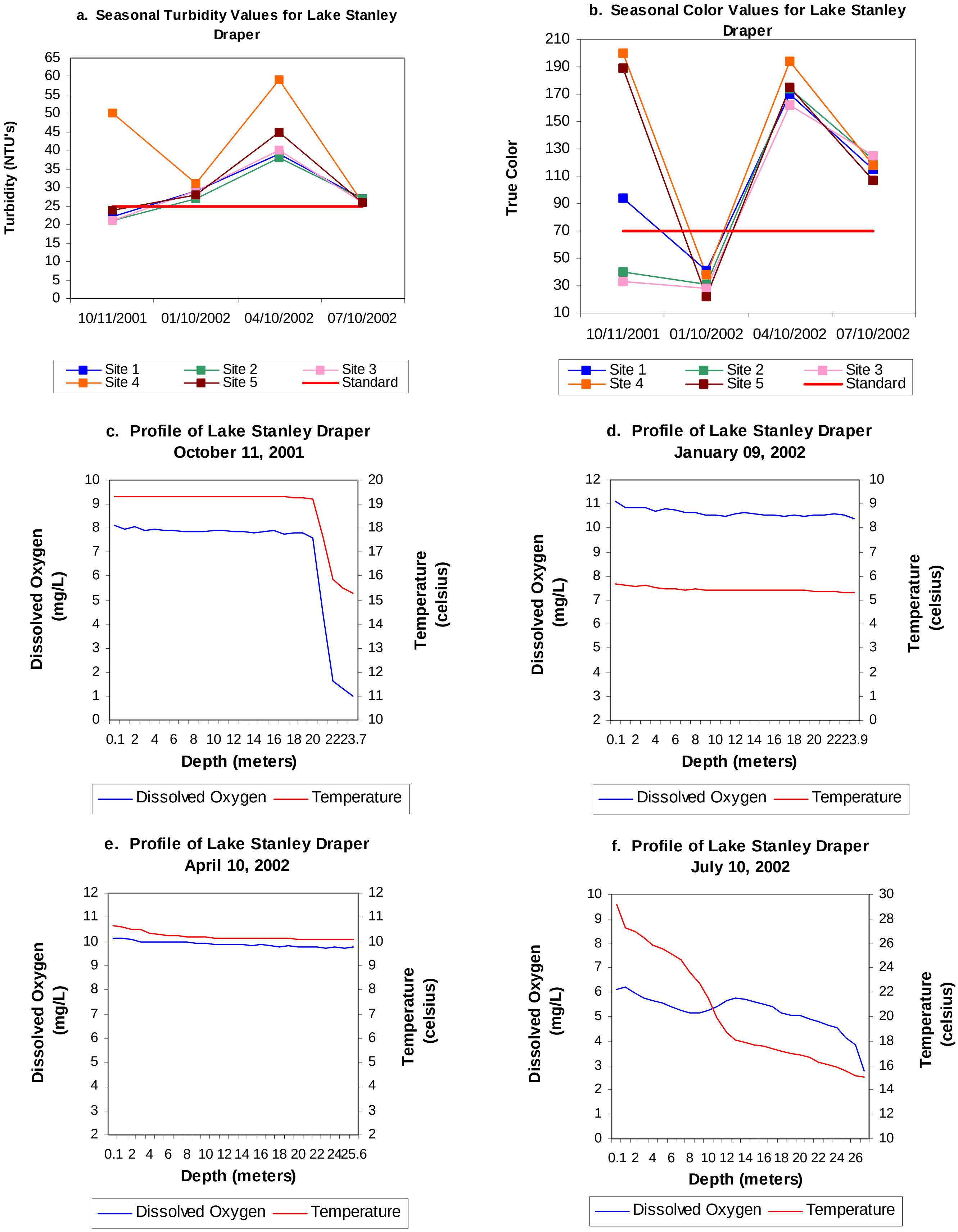


Figure 206a-201f. Graphical representation of data results for Lake Stanley Draper.

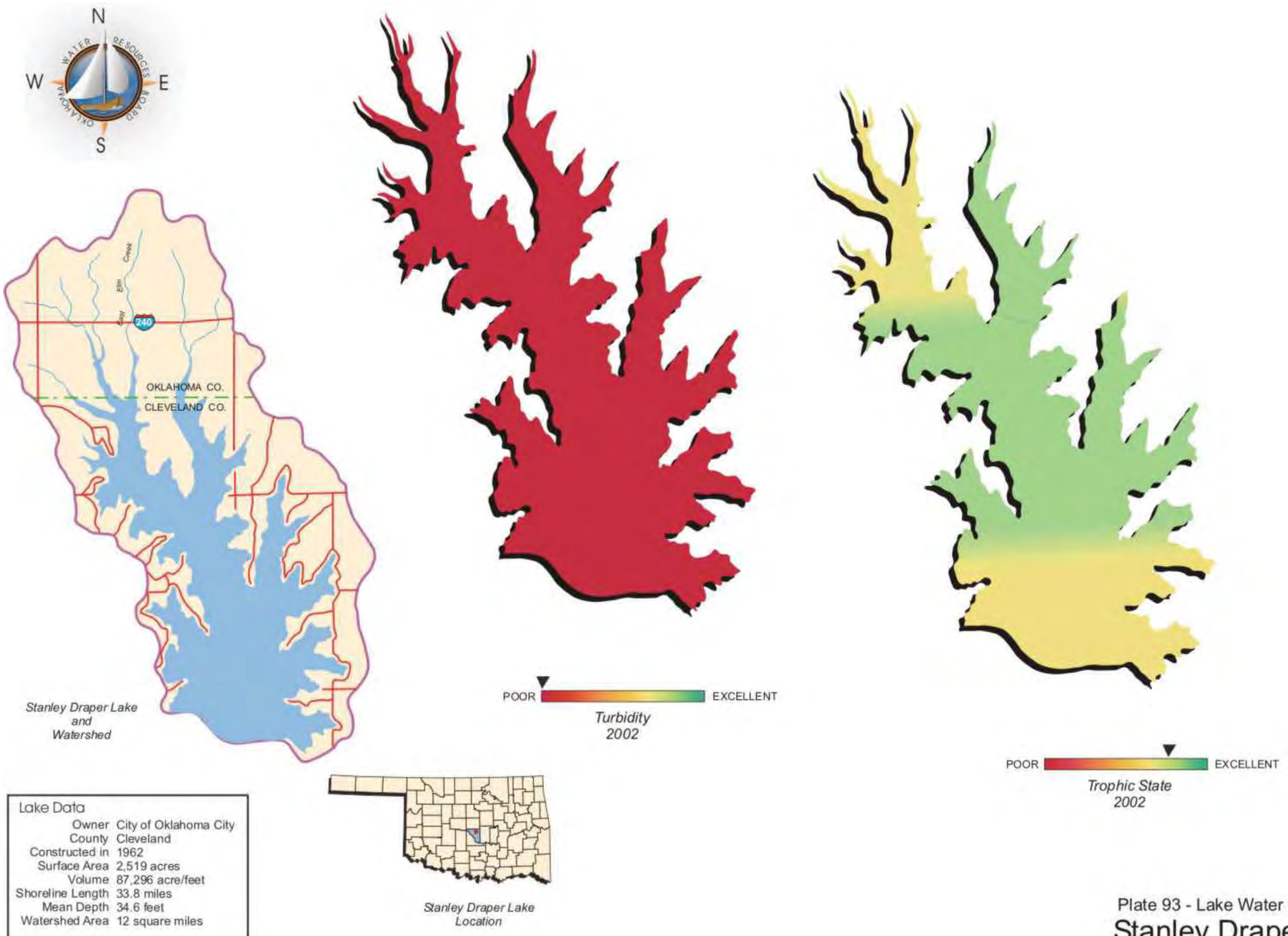


Plate 93 - Lake Water Quality for
Stanley Draper Lake

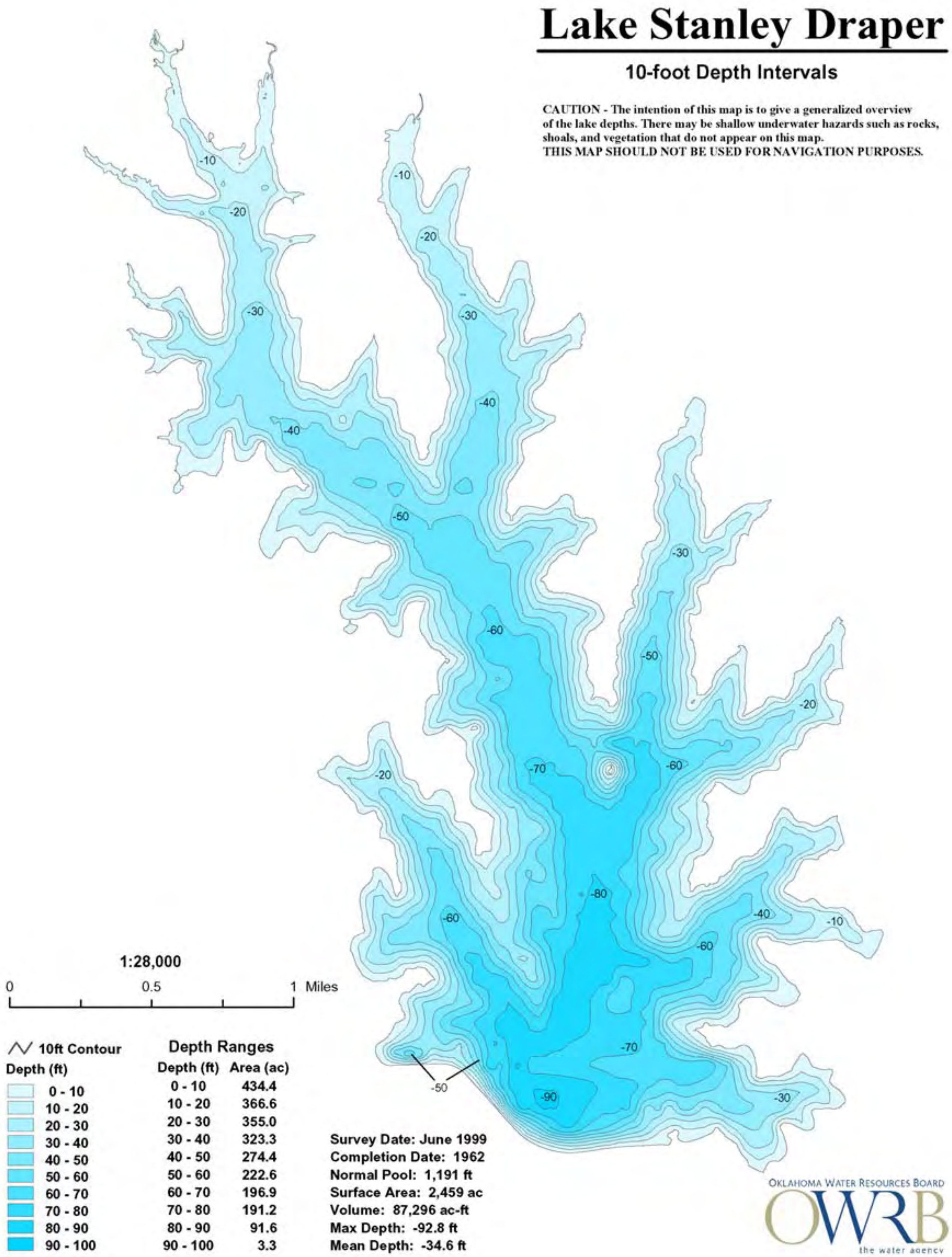


Figure 207. Bathymetric map of Lake Stanley Draper.

Stilwell City Lake

Stilwell City Lake (188 surface acres) was sampled for four quarters, from December 2000 through August 2001. Several attempts were made to sample the lake in the fall; however, the lake level was too low to launch a boat until the very end of the fall quarter. 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. A minimum of 10 samples is required to make beneficial use determinations in lakes less than 250 surface acres based on the Use Support Assessment Protocols (USAP) outlined in Oklahoma Administrative Code (OAC) 785:45-15-4. The lake-wide annual turbidity value was 4 NTU, true color was 26 units, and secchi disk depth was 168 centimeters 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=10). The average TSI was 58, classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions. This value is similar to the one calculated in 1998 (TSI=56) indicating little or no change in trophic status over time. The TSI values varied seasonally in 2001, from oligotrophic at two sites in the spring to hypereutrophic at all sites in the winter. The peak in chlorophyll-a at all sites was in the winter, which is uncommon in most lakes, placing the TSI in the hypereutrophic category for this quarter. This seasonal variability demonstrates the need to collect data year-round during all seasons to accurately represent the trophic conditions at Stilwell City Lake. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU. The lake-wide annual turbidity average of 4 NTU seems to accurately represent the conditions at this lake. All of the true color values were below the numeric criteria of 70 units in 2001, although an increasing trend from the fall to summer season was evident. Currently, the Aesthetics beneficial use is considered fully supported.

Please refer to the “Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report” for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency’s web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Stroud Lake

Stroud Lake (188 surface acres) was sampled for four quarters, from October 2001 through July 2002. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sample were collected at the lake surface at sites 4 and 5 solely for the analysis of chlorophyll-a and nephelometric turbidity. 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 9 NTU (Plate 94), true color was 23 units, and secchi disk depth was 105 centimeters in. Based on the three parameters just mentioned the lake had excellent water clarity when compared 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=20). The average TSI was 43 (Plate 94), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. The TSI values varied somewhat seasonally with the lake being oligotrophic in the winter quarter and basically mesotrophic for the other three quarters sampled (see Figure 208). All turbidity values collected were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 209a). 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 OWQS (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 209b. All of the true color values were below the Aesthetics numeric criteria of 70 units, however a beneficial use determination could not be definitively made due to insufficient data. Collected information does strongly support the supposition that the lake would fully support its Aesthetics use for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.05 parts per thousand (ppt) to 0.09 ppt, indicating low salt content and readings were well within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 0.127.3 mS/cm in the fall quarter to 190.6 mS/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 6.98 to 8.07 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 should be listed as not supporting beneficial uses. 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 beneficial uses. The lake is fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 51 mV at the sediment-water interface in the summer to 556 mV in the winter quarter. Redox readings indicated that reducing conditions were not present in the reservoir to

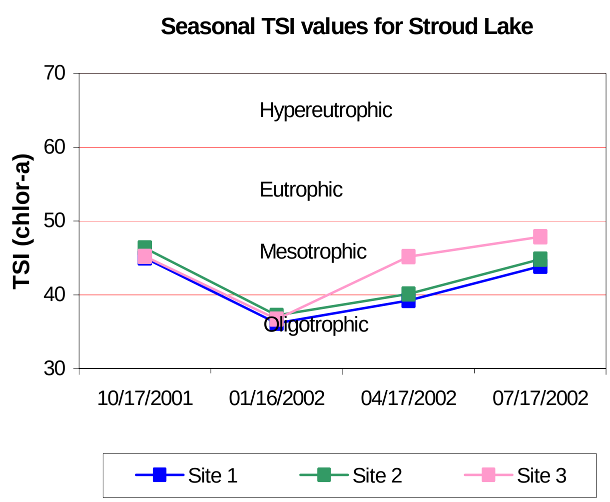


Figure 208. TSI values for Stroud Lake.

any appreciable extent during sampling events in 2001-2002. The lake was not thermally stratified in the fall, winter or spring quarters and dissolved oxygen (D.O.) values were above 5.7 mg/L throughout the water column in all 3 quarters (see Figure 209c-203e). In the summer quarter, the lake was thermally stratified between 4 and 5 meters below the lake surface and again between 5 and 6 meters. Water column D.O. values were less than 2.0 mg/L from 4 meters in depth to the lake bottom at 12.4 meters (see Figure 209f). 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 not supported at Stroud Lake as 71% of the water column was anoxic at site 1 in the summer. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.40 mg/L at the lake surface. The TN at the surface ranged from 0.22 mg/L to 0.69 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was also recorded in the fall. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.021 mg/L at the lake surface. The surface TP ranged from 0.011 mg/L to 0.069 mg/L. The highest surface TP value was reported in the summer and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 19:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Stroud Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Stroud Lake was mesotrophic, indicative of moderate primary productivity and nutrient conditions (Plate 94). Water clarity was excellent at this lake. The lake was fully supporting its Aesthetics beneficial use based on its trophic state and data strongly supports the supposition that it would have supported for true color had sufficient data been available. The lake was also fully supporting its FWP beneficial use based on nephelometric turbidity and pH. However, the lake was not supporting its FWP beneficial use based on low D.O. values in the water column. 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. Other than the occurrence of low D.O. in the water column, the lake is one of the nicer small municipal lakes in Oklahoma.

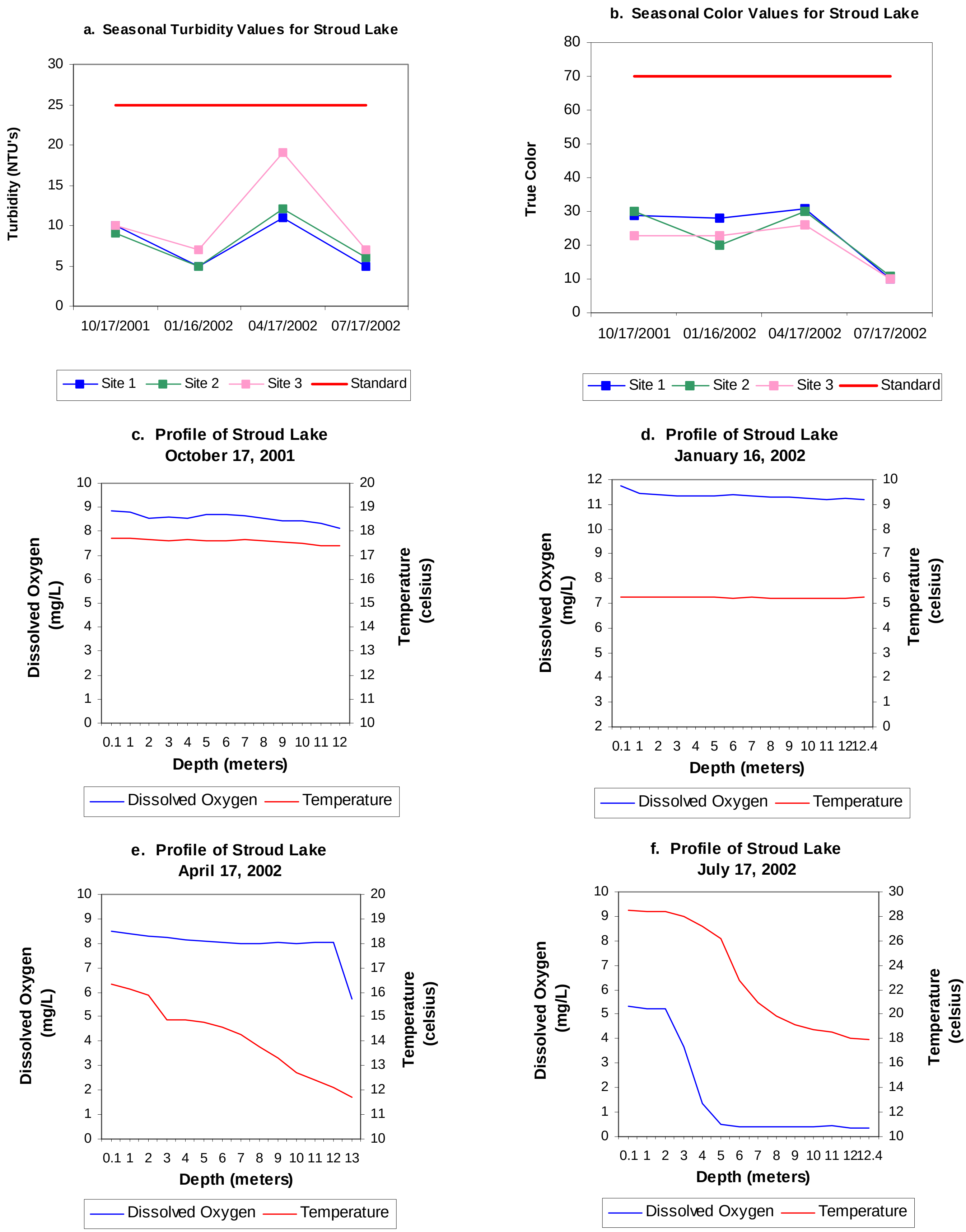
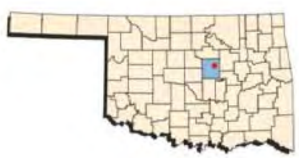


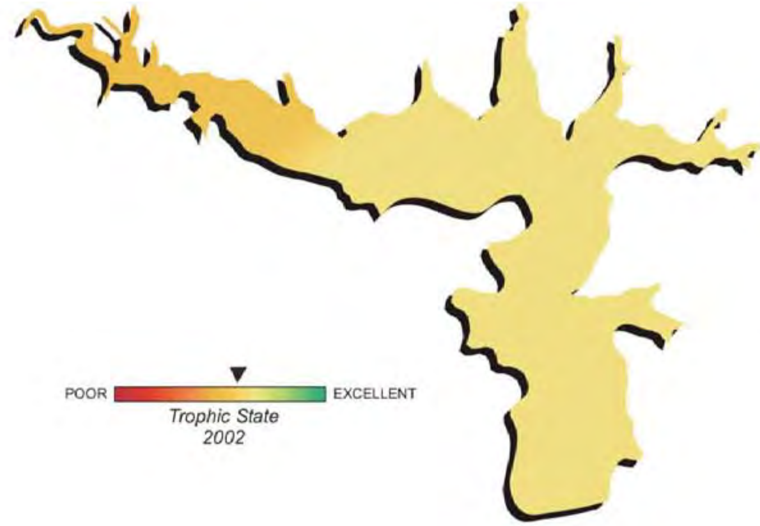
Figure 209a-203f. Graphical representation of data results for Stroud Lake.

Stroud Lake and Watershed



Stroud Lake Location

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



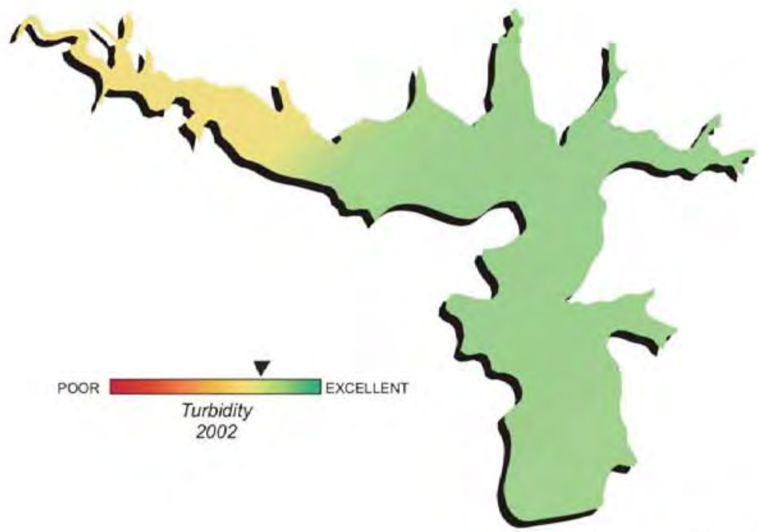


Plate 94 - Lake Water Quality for

Stroud Lake

Talawanda Lake No.1

Talawanda Lake No.1 was sampled for four quarters, from October 2002 through July 2003. 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 4 NTU (Plate 95), true color was 18 units, and secchi disk depth was 190 centimeters. Based on these three parameters, Talawanda Lake No.1 had excellent water clarity, very similar to values 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 average TSI was 45 (Plate 95), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. This value is exactly the same as the one calculated in 2001 (TSI=45) indicating no change in trophic status has occurred over time. All TSI values were in the mesotrophic category in 2003 and are displayed in Figure 210. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU and are displayed in Figure 211a. The Fish and Wildlife Propagation (FWP) beneficial use is considered fully supported based on turbidity. All of the true color values were well below the numeric criteria of 70 units in 2003. Currently, the Aesthetics beneficial use is considered fully supported.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.09 ppt, which is lower than the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 60.7 mS/cm to 195.7 mS/cm, indicative of low levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.24 to 7.43, representing a neutral to slightly acidic system. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. With 10% the collected values less than 6.5, the lake should be listed as partially supporting beneficial uses. The low pH values recorded at Talawanda Lake No.1 may be due to natural conditions, and will be listed as “provisionally partially supporting”* the FWP. Oxidation-reduction potentials (ORP) ranged from 144 mV to 551 mV indicating reducing conditions were not present at this reservoir in sample year 2002-2003. In the fall, the lake was

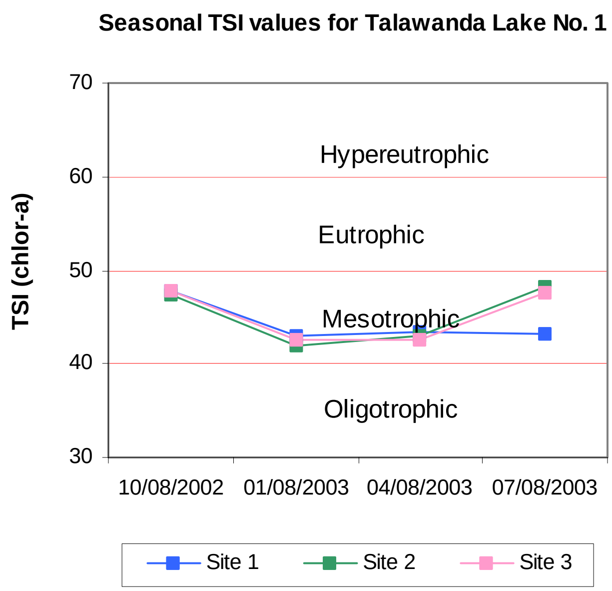


Figure 210. TSI values for Talawanda Lake No.1

stratified at site 1 between 4 and 5 meters at which point dissolved oxygen (D.O.) dropped below 2.0 mg/L to the lake bottom of 7.8 meters. In the winter quarter the water column was well mixed with dissolved oxygen (D.O.) values generally above 8.0 mg/L (see Figure 211d). In the spring, the lake was weakly stratified, only approaching 2.0 mg/L near the sediment-water interface (Figure 211e). Thermal stratification w s evident and anoxic conditions were present throughout the lake in the summer. Stratification occurred between 3 and 4 meters, accounting for 50 to 60 % of the water column to be anoxic (Figure 211f). 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 and fall. 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OQWS for these parameters. The lake-wide total nitrogen (TN) average was 0.43 mg/L at the surface and 0.94 mg/L at the lake bottom. Surface TN ranged from 0.26 mg/L to 0.58 mg/L with the highest values recorded in the fall quarter and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.013mg/L at the surface and 0.024 mg/L at the lake bottom. The surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.007 mg/L to 0.016 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 34:1 for sample year 2003. This value 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 2003. 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 supported based on turbidity, but partially supported based on dissolved oxygen values. Low pH values recorded at Talawanda Lake No.1 may be due to natural conditions, and will be listed as "provisionally partially supporting"* the FWP. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color values. Talawanda Lake No. 1, owned by the City of McAlester, was constructed in 1902 for the purpose of recreation.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

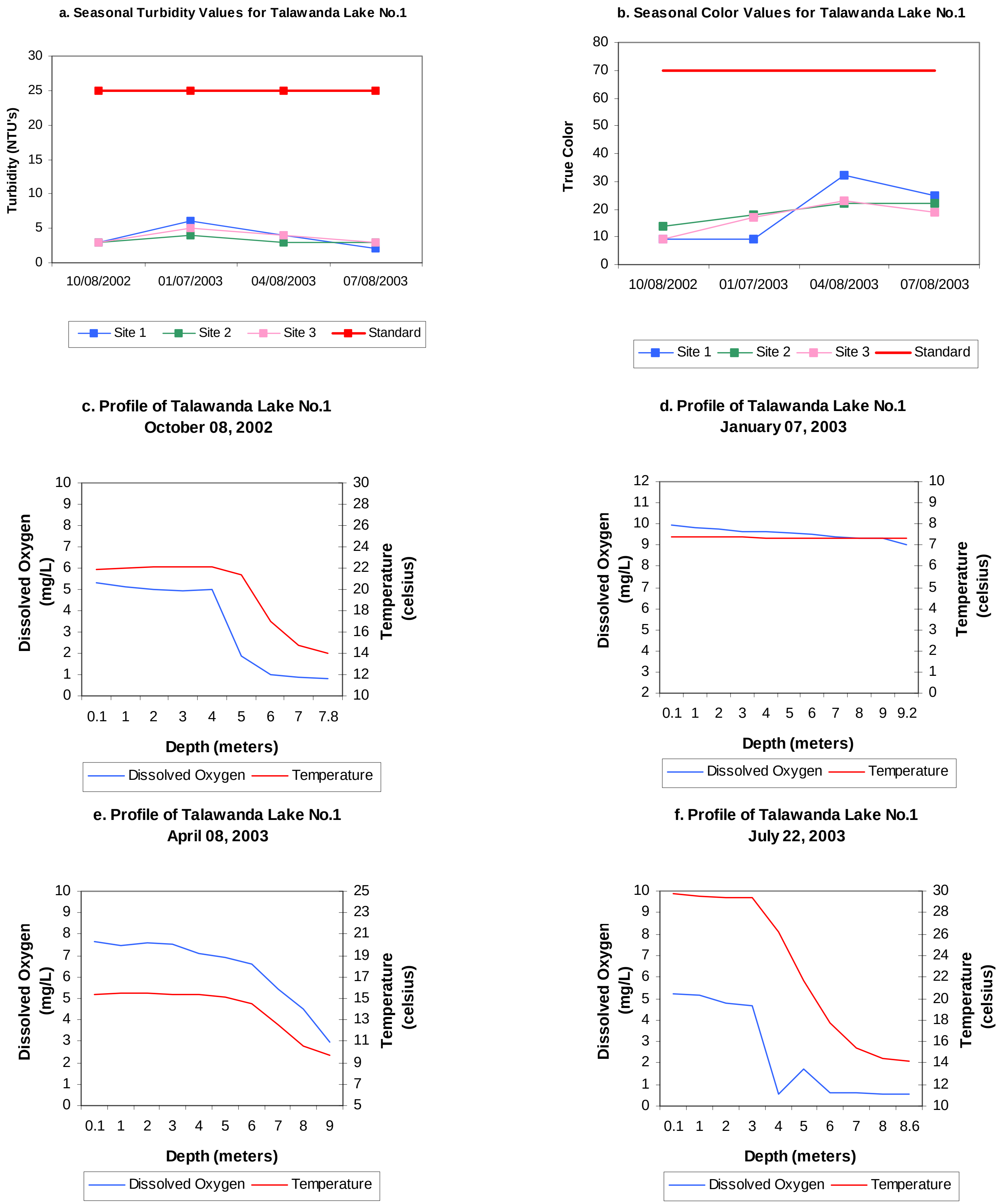
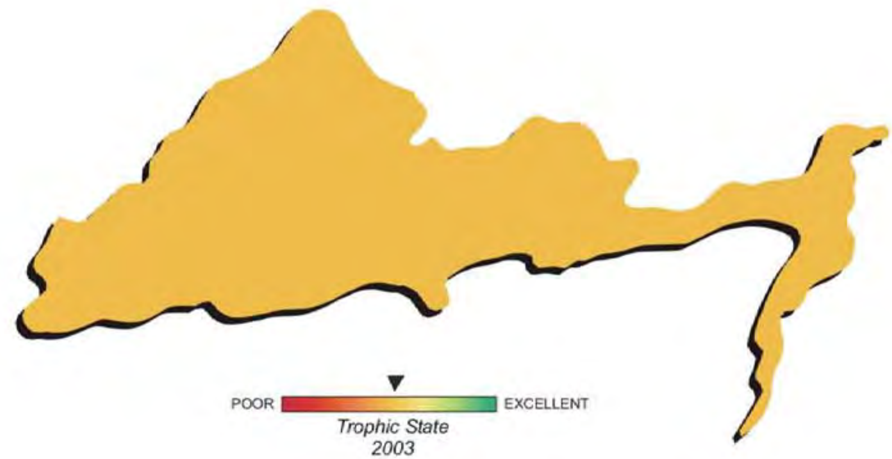


Figure 211a-205f. Graphical representation of data results for Talawanda Lake No.1

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



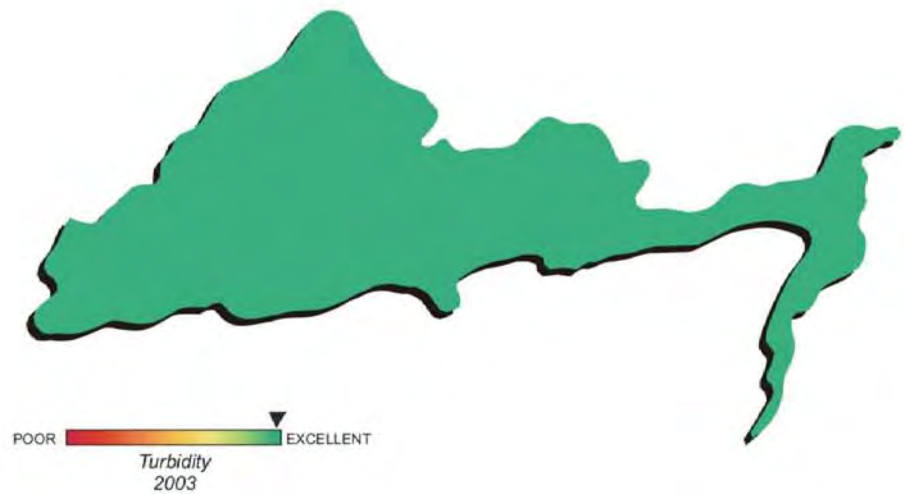


Plate 95 - Lake Water Quality for

Talawanda Lake No. 1

Talawanda Lake No. 2

Talawanda Lake No. 2 was sampled for four quarters, from October 2002 through July 2003. 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 6 NTU (Plate 96), true color was 12 units, and secchi disk depth was 162 centimeters. Based on these three parameters, Talawanda Lake No. 2 had excellent water clarity, similar to the values reported 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 average TSI was 39 (Plate 96), classifying the lake as oligotrophic, indicative of low levels of primary productivity and nutrients. This value is similar to the one calculated in 2001 (TSI=40) indicating no significant increase or decrease in productivity has occurred since the 2001 evaluation. TSI values were primarily oligotrophic with all sites in the mesotrophic category in the winter sampling quarter (Figure 212). The TSI of 39 seems to accurately represent conditions at Talawanda Lake No. 2. Seasonal turbidly values are displayed in Figure 213a. All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU, therefore meeting the Fish and Wildlife Propagation (FWP) beneficial use in regards to turbidity. The lake-wide annual turbidity average of 6 NTU seems to accurately represent the conditions at this lake. All of the true color values were well below the numeric criteria of 70 units in 2003 and are displayed in Figure 213b. The Aesthetics beneficial use is considered fully supported based on true color values.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.05 ppt, which is lower than the range of values observed in Oklahoma reservoirs. Specific conductance ranged from 60.3 mS/cm to 125.8 mS/cm, indicative of extremely low levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 6.48 to 7.76, representing a slightly acidic to neutral system. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. With approximately 2% of the collected values less than 6.5, the lake is supporting the FWP

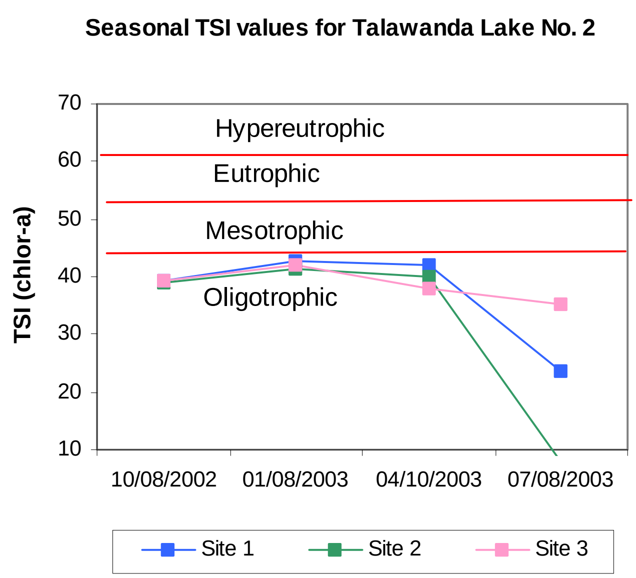


Figure 212. TSI values for Talawanda Lake No.2

beneficial use. The low pH values recorded at Talawanda Lake No.2 only occurred in the summer quarter and may be due to natural conditions. Oxidation-reduction potentials (ORP) ranged from 161 mV to 503 mV indicating reducing conditions were not present at this reservoir in sample year 2002-2003. In the fall, the lake was stratified at site 1 between 8 and 9 meters at which point dissolved oxygen (D.O.) dropped below 2.0 mg/L to the lake bottom of 13.2 meters (Figure 213c). 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 213d-207e). Thermal stratification was evident and anoxic conditions were present throughout the lake in the summer. Stratification occurred between 6 and 7 meters, with 36 to 54 % 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. Talawanda Lake No.2 is considered to be partially supporting the FWP beneficial use based on anoxic conditions present in the summer and fall. 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.18 mg/L at the surface and 0.38 mg/L at the lake bottom. Surface TN ranged from 0.05 mg/L to 0.32 mg/L with the highest values recorded in the fall quarter and the lowest in the summer. The lake-wide total phosphorus (TP) average was 0.011mg/L at the surface and 0.022 mg/L at the lake bottom. The surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.005 mg/L to 0.018 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 17:1 for sample year 2003. This value 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 in sample year 2003. 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 supported based on turbidity and pH, but partially supporting based on dissolved oxygen values. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color values. Talawanda Lake No. 2, owned by the City of McAlester, serves as a water supply and recreational reservoir.

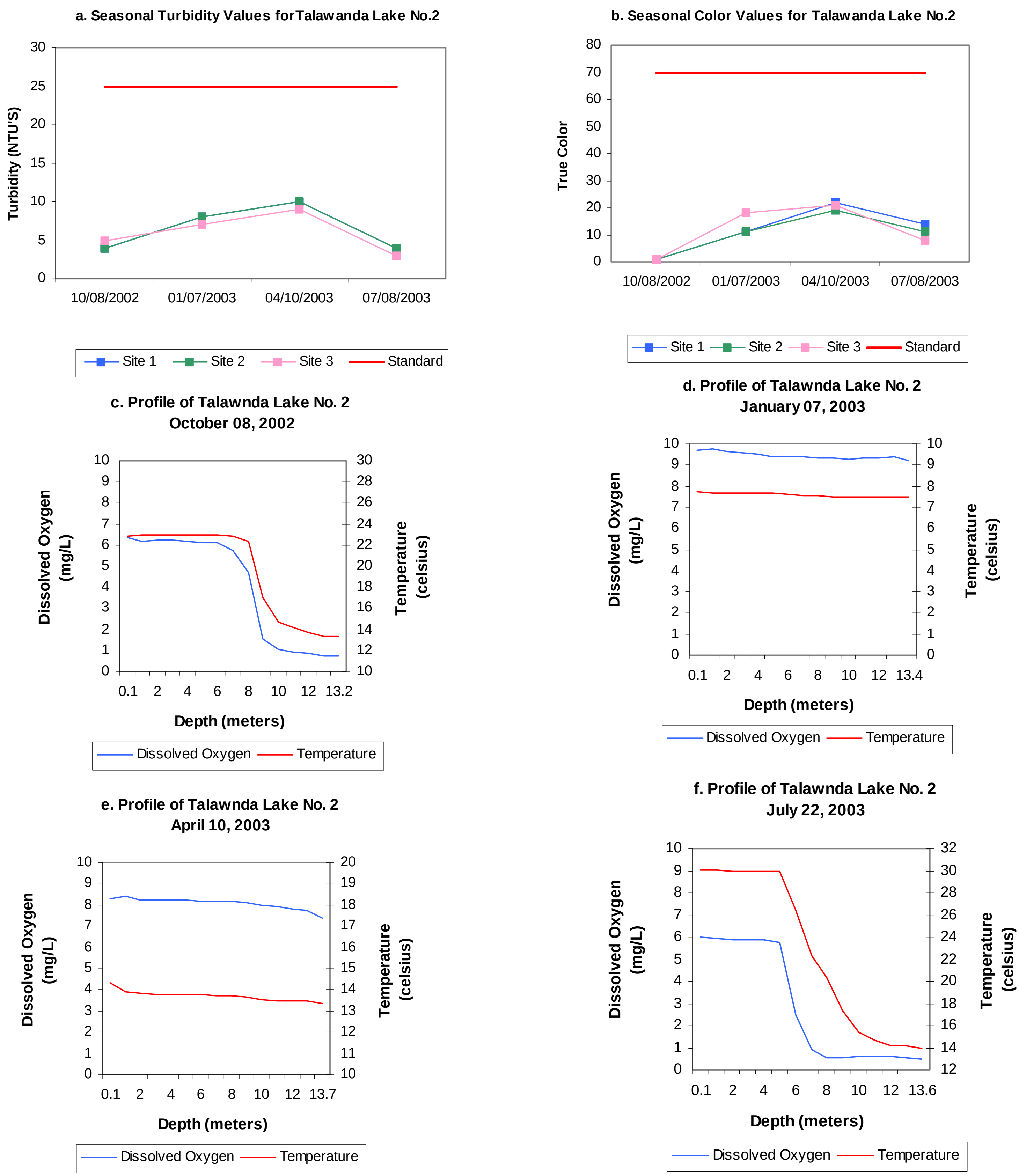
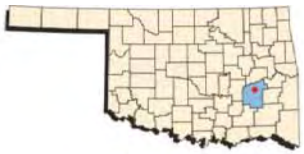


Figure 213a-207f Graphical representation of data results for Talawanda Lake No.2

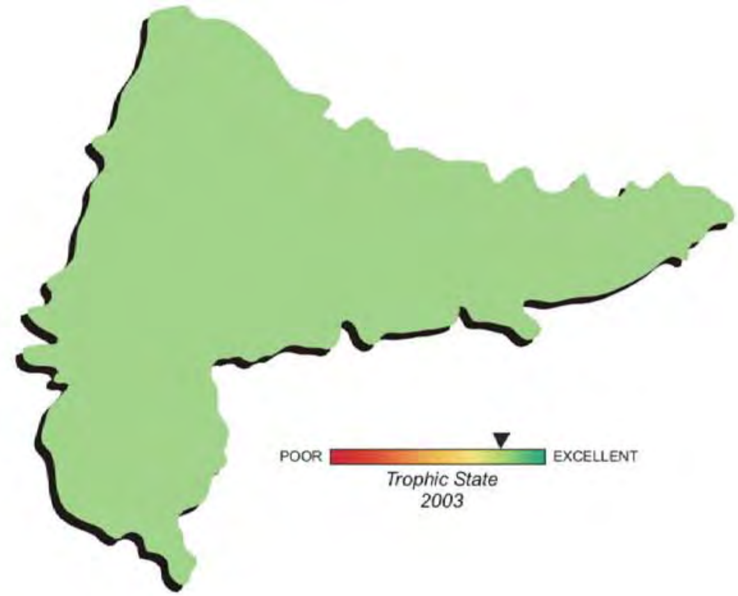


Talawanda Lake No. 2
Location

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



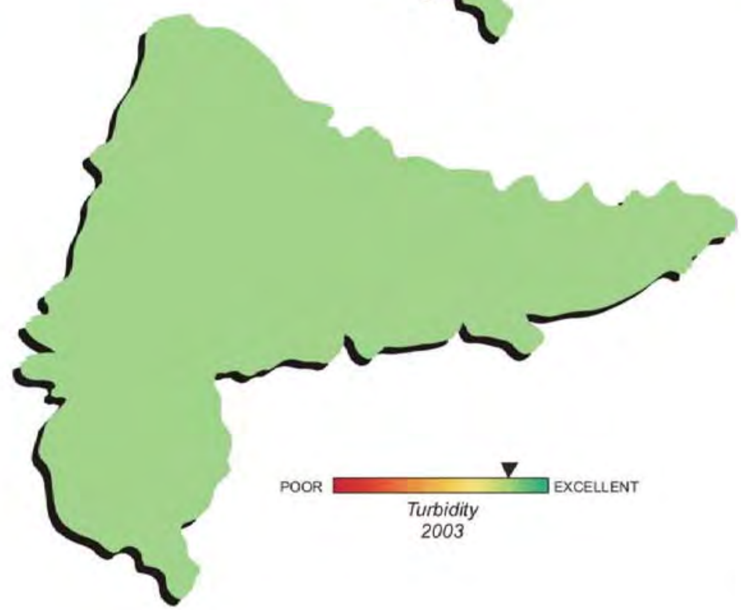


Plate 96 - Lake Water Quality for
Talawanda Lake No. 2

Taylor Lake

Taylor Lake was sampled for four quarters, from November 2002 through August 2003. 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 17 NTU (Plate 97), true color was 21 units, and average secchi disk depth was 47 centimeters. Based on these three parameters, Taylor Lake had average water clarity in 2002-2003. 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 62 (Plate 97), classifying the lake as hypereutrophic, indicative of excessive primary productivity and nutrient levels. This value is similar to the one calculated in 2000 (TSI=65) indicating no significant increase or decrease in productivity has occurred since the 2001 evaluation. TSI values were fairly consistent with values ranging from upper eutrophic in the winter to hypereutrophic the remainder of the year (Figure 214). Currently, the lake listed as a Nutrient Limited Watershed (NLW) in the Oklahoma Water Quality Standards (OWQS) and is considered nutrient threatened and a nutrient impairment study should be conducted to determine if uses are impaired. Seasonal turbidity values are displayed in Figure 215a. Turbidity values ranged from a low of 7 NTU to a maximum of 33 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 (OWQS) 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 Taylor Lake with 33% of the values above the turbidity standard of 25 NTU. Seasonal true color values were all well below the OWQS of 70 and are displayed in Figure 215b. Applying the same default protocol, the Aesthetics beneficial use is fully supported based on true color values.

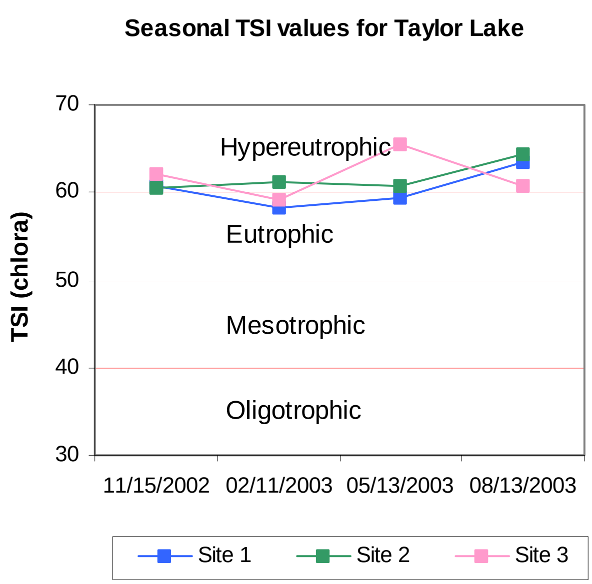


Figure 214. TSI values for Taylor Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.24 parts per thousand (ppt) to 0.31 ppt, which is within the range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 476.6 mS/cm to 614.7 mS/cm, indicative of moderate levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 7.10 to 8.52, 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 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. 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 386 mV to 460 mV indicating the absence of reducing conditions in sample year 2002-2003. The lake was not stratified during the fall, winter, or spring sampling quarters and the water column was well mixed (see Figure 215c-209e). In the summer, thermal stratification was evident and anoxic conditions were present (Figure 215f). 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 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 1.11 mg/L at the surface and 1.11 mg/L at the lake bottom. Surface TN ranged from 0.67 mg/L to 1.47 mg/L with the highest values recorded in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.128mg/L at the surface and 0.142 mg/L at the lake bottom. The surface TP was highest in the summer quarter and lowest in the fall with values ranging from 0.047 mg/L to 0.204 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 9:1 for sample year 2003. This value 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 2002-2003. The calculated TSI was similar to that in 2000 (TSI=65), 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, partially supporting based on dissolved oxygen, but not supporting based on turbidity with 33% of the values exceeding the OWQS of 25 NTU. The Aesthetics beneficial use is supported based on its true color, but not supporting based on its trophic status. Currently, the lake is listed as a Nutrient Limited Watershed (NLW) and a nutrient impairment study should be conducted to determine if uses are threatened. Taylor Lake is leased to the City of Marlow and serves as a flood control, water supply, and recreational reservoir.

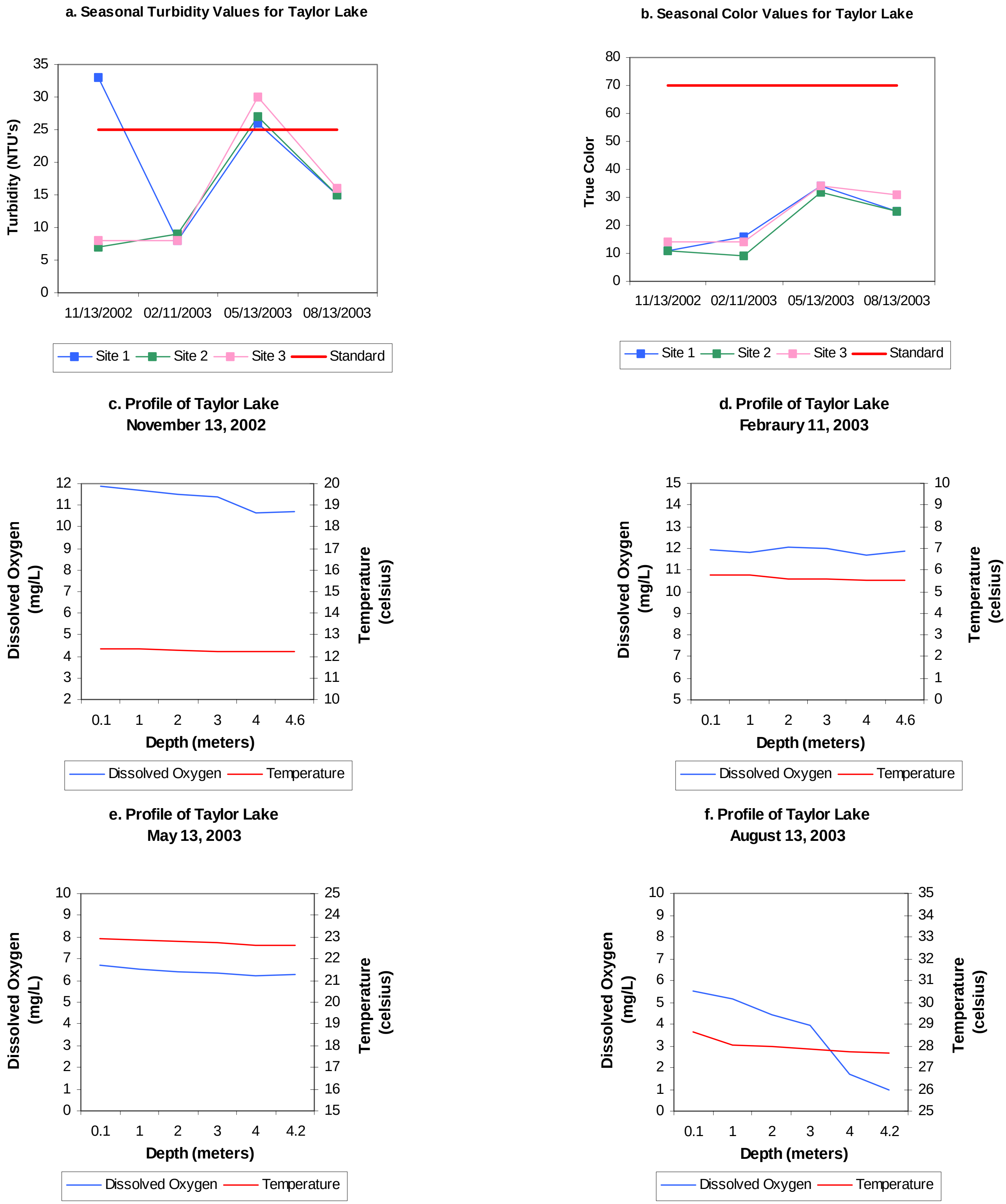


Figure 215a-209. Graphical representation of data results for Taylor Lake.

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 97 - Lake Water Quality for

Taylor Lake

Tecumseh Lake

Tecumseh Lake was sampled for four quarters, from November 2001 through August 2002. 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 86 NTU (Plate 98), true color was 161 units, and secchi disk depth was 17 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 four quarters (n=12). The average TSI was 51 (Plate 98), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. TSI values for this lake varied seasonally from mesotrophy in the fall and spring, to meso-eutrophic in the summer quarter, to middle eutrophy in the winter (see Figure 216). Unlike the vast majority of Oklahoma reservoirs, Tecumseh Lake was most productive in the winter, which is not commonly seen. This no doubt correlates with the fact that turbidity readings in the winter were generally 30% lower than the summer quarter and 50% lower than the readings seen in the fall and spring. 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 (OWQS) of 25 NTU (see Figure 217a). 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 OWQS (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. Tecumseh Lake is not meeting its Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 217b. With 83% of the true color values well above the numeric criteria of 70 units, the lake is not supporting its Aesthetics beneficial use based on true color values.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. Salinity values ranged from 0.09 parts per thousand (ppt) to 0.16 ppt, indicating low to moderate salt content compared to most Oklahoma lakes. Specific conductance ranged from 197.7 mS/cm in the fall to 329.6 mS/cm in the summer quarter, indicating minimal to moderate 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 7.44 to 8.34 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 should be listed as not supporting beneficial uses. 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 beneficial uses. Tecumseh Lake is fully supporting its FWP beneficial use based on pH.

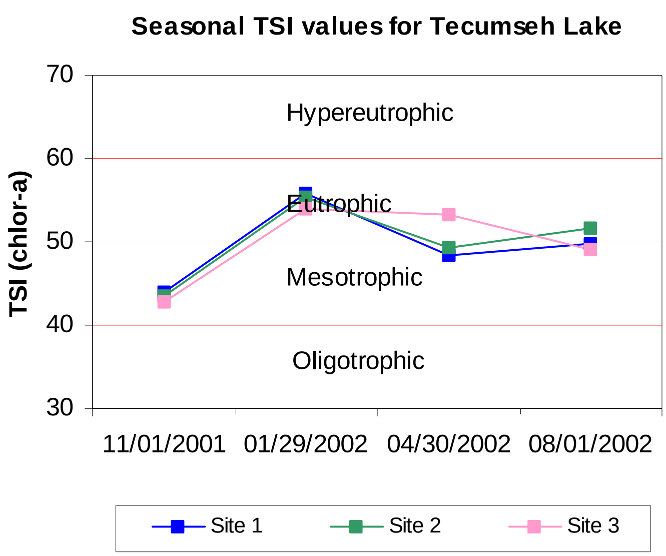


Figure 216. TSI values for Tecumseh Lake

Oxidation-reduction potentials (redox) ranged from 202 mV at the sediment-water interface in the spring quarter to 628 mV in the fall. Redox readings indicated that reducing conditions were not present in the reservoir at any point during the any of the sampling events. 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 throughout the water column (see Figure 217c-211e). In the summer, the lake was thermally stratified at the bottom of the lake and D.O. was below 1.5 mg/L at the bottom of the lake (see Figure 217f). In a lake as shallow as Tecumseh, thermal stratification is generally not encountered due to wind mixing of the water column. 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 Tecumseh Lake as only 20% of the water column had D.O. concentrations less than 2.0 mg/L. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.61 mg/L at the lake surface. The TN at the surface ranged from 0.43 mg/L to 0.95. 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 for sample year 2001-2002 was 0.085 mg/L at the lake surface. The surface TP ranged from 0.042 mg/L to 0.135 mg/L. The highest surface TP value was reported in the fall and the lowest was in the winter quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 7:1 for sample year 2001-2002. This value is equal to 7:1, meaning that the limiting nutrient could not be determined or phosphorus and nitrogen are co-limiting (Wetzel, 1983).

Tecumseh Lake was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Tecumseh Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 98). Water clarity was extremely poor at this lake, which seemed to be serving a useful purpose in limiting the amount of light available to the system, thus limiting productivity. With increasing clarity in this lake, it is quite likely that it would become upper eutrophic to hypereutrophic in nature Tecumseh Lake is not supporting its FWP beneficial use based on nephelometric turbidity and is fully supporting the use for D.O. and pH. The lake is fully supporting its Aesthetics beneficial use based on its trophic state, but is not supporting based on true color readings. 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.

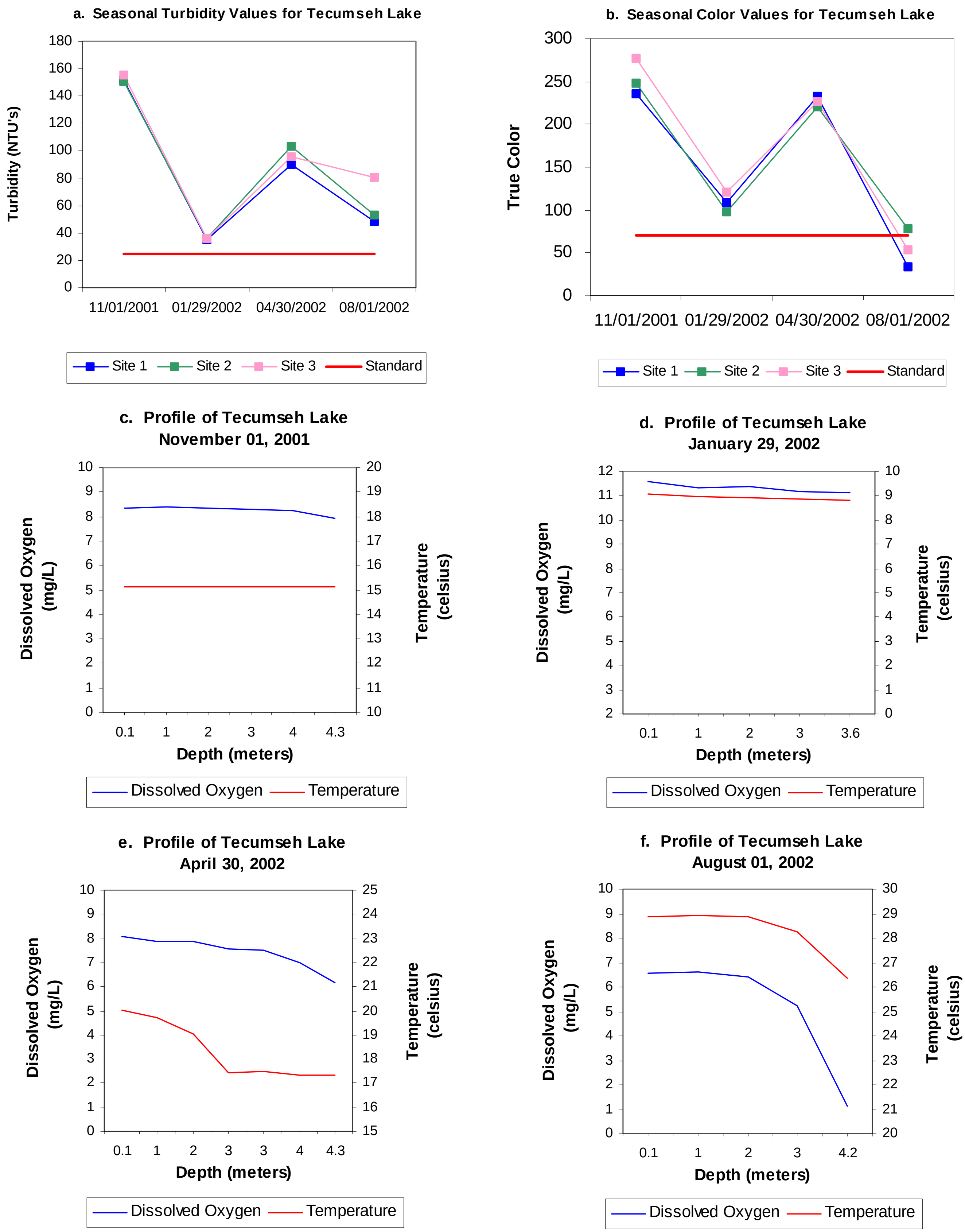


Figure 217a-211f. Graphical representation of data results for Tecumseh Lake.

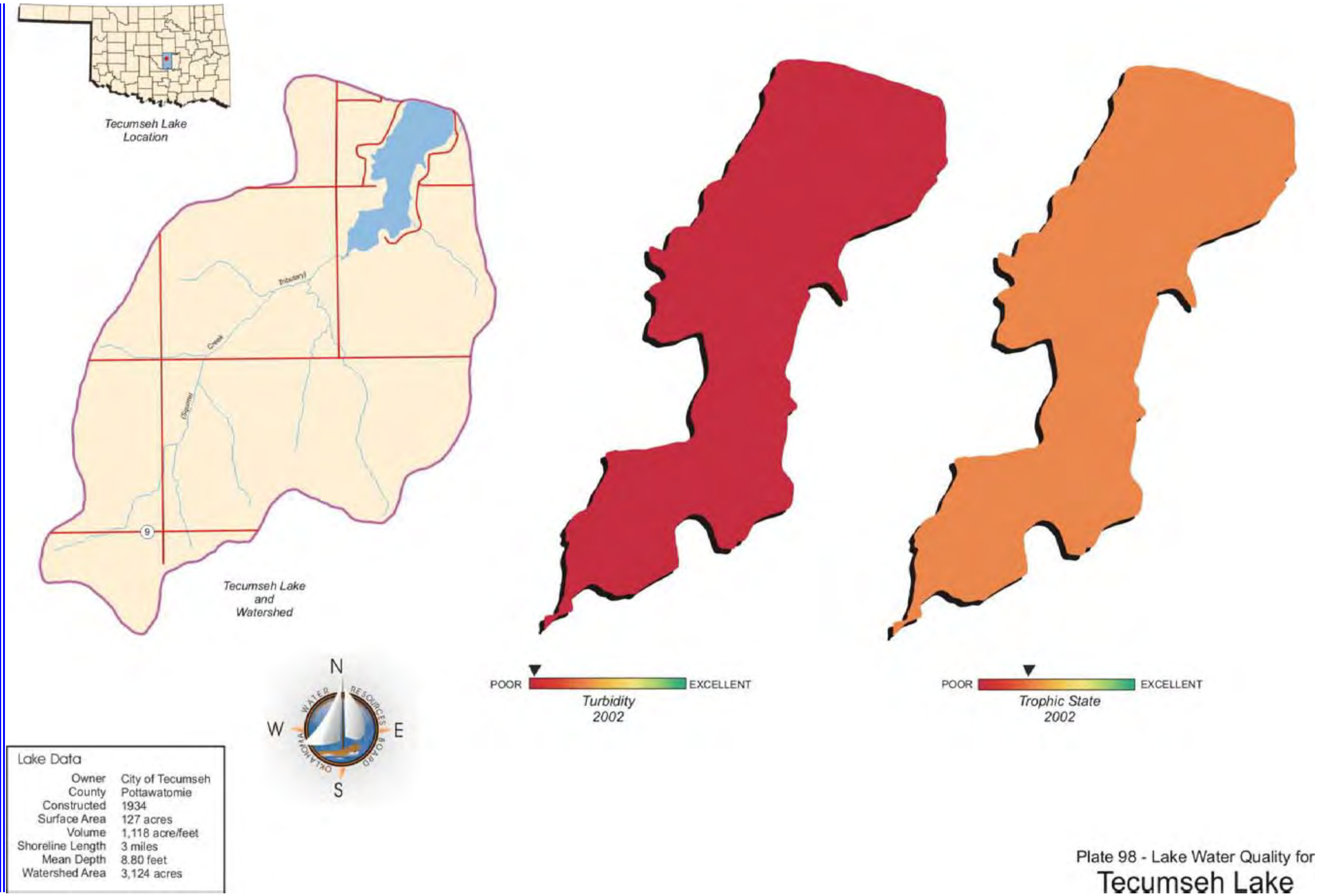


Plate 98 - Lake Water Quality for
Tecumseh Lake

Tenkiller Ferry Lake

Tenkiller Ferry Lake was sampled for four quarters, from October 2001 through July 2002. 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 and 0.5 meters from the lake bottom at sample site 1. The lake-wide annual turbidity value was 10 NTU (Plate 99), true color was 23 units, and secchi disk depth was 107 centimeters. Based on these three parameters, Tenkiller Ferry Lake had excellent water clarity when compared 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=28). The average TSI was 56 (Plate 99), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrients. TSI values varied from season to season and from site to site. Closer to the dam area TSI values were generally mesotrophic in the fall and winter, bordering on eutrophic in the spring and summer. As you moved up the lake values were generally eutrophic in the fall, mesotrophic in the winter and eutrophic to hypereutrophic in the spring and summer. At the upper end of the lake TSI values were generally eutrophic or hypereutrophic year round (see Figure 218). All turbidity values were well below the Oklahoma Water Quality Standard (OWQS) of 25 NTU with the exception of site 5 in the fall which was 26 NTU (see Figure 219a). 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 OWQS (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. Tenkiller Lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use as it relates to turbidity. Seasonal true color values are displayed in Figure 219b. All of the true color values were well below the numeric criteria of 70 units and the Aesthetics beneficial use is considered fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all seven sample sites. Salinity values ranged from 0.02 parts per thousand (ppt) to 0.13 ppt, indicating low to moderate salt content compared to most Oklahoma lakes. Salinity values varied based on the site location with higher salinity occurring in the upper end of the lake. Specific conductance ranged from 119.1 mS/cm in the spring quarter to 277.3 mS/cm in the summer, 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 6.84 to 8.58 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 should be listed as not supporting beneficial uses. 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 beneficial uses. All pH values were within the acceptable range so Lake Tenkiller is

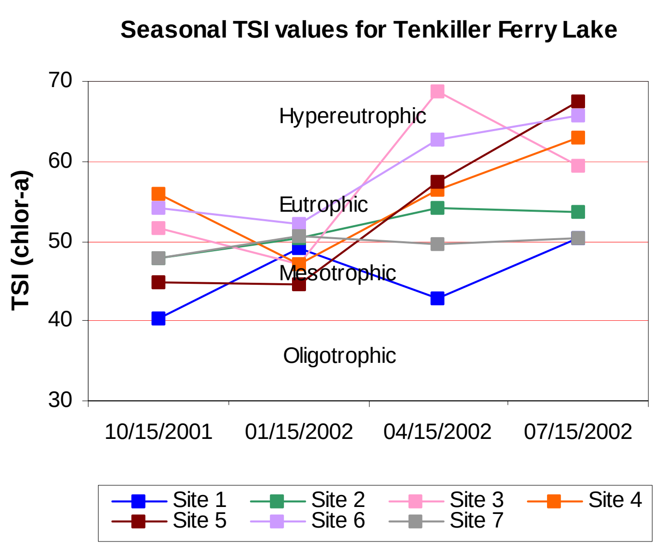


Figure 218. TSI values for Tenkiller Ferry Lake.

fully supporting its FWP beneficial use based on pH. Oxidation-reduction potentials (redox) ranged from 81 mV at the sediment-water interface in the summer quarter at site 1 to 614 mV in the winter. Redox readings indicated that reducing conditions were not present in the reservoir to any appreciable degree at any point during Water Resources Board sampling events. The lake was not thermally stratified in the winter or spring quarters and dissolved oxygen (D.O.) concentration fell below 4.2 mg/L throughout the water column and readings were generally above 6.0 mg/L in the majority of the water column (Figure 219d-213e). The lake was thermally stratified in the fall quarter between 21 and 22 meters below the lake surface and D.O. values were below 2.0 mg/L from the 22 meter depth to the lake bottom at 31.5 meters at site 1 (Figure 219d). In the summer, the lake was strongly thermally stratified at several discrete 1-meter intervals, the first between 6 and 7 meters with the water temperature dropping from 29.11° Celsius at 6 meters to 21.9° Celsius at 11 meters. From the 8-meter depth to the lake bottom at 38.4 meters D.O. values were all less than 2.0 mg/L (see Figure 219f). 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 not supported at Tenkiller Ferry Lake as 80% of the water column was anoxic in the summer. In the fall quarter 30% of the water column was anoxic which was not sufficient to result in a partially supporting or not supporting designation. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 1.28 mg/L at the lake surface, which is a very high value to have as a lake average. The TN at the surface ranged from 0.47 mg/L to 2.91 mg/L, which is a very high nitrogen concentration to have in a lake at the surface. The highest value was in the winter quarter and the lowest value was in the fall. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.063 mg/L at the lake surface. The surface TP ranged from 0.006 mg/L to 0.156 mg/L. The highest surface TP value was reported in the fall and the lowest was also reported in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 20:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Tenkiller Ferry Lake was also sampled for metals at seven sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column. 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, Tenkiller Ferry Lake was classified as eutrophic, indicative of high primary productivity and nutrient levels (Plate 99). Water clarity was excellent at this lake primarily due to the absence of inorganic turbidity levels that are commonly seen in Oklahoma reservoirs. The lake was fully supporting its Aesthetics beneficial use based on trophic status and true color values. A Total Maximum Daily Load (TMDL) is currently being developed for the lake to mitigate the effects of nutrients to the system. A high level of total nitrogen in the lake was documented which should be mitigated. Tenkiller Ferry Lake was supporting its FWP beneficial use based on nephelometric turbidity and pH. The lake was not supporting its FWP beneficial use based on low D.O. concentrations in 80% of the water column. The very low D.O. values seen in the summer time in the lake are a cause for serious concern. Any time 80% of the water column has D.O. less than 2.0 mg/L you have a serious problem that should be further addressed. 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.

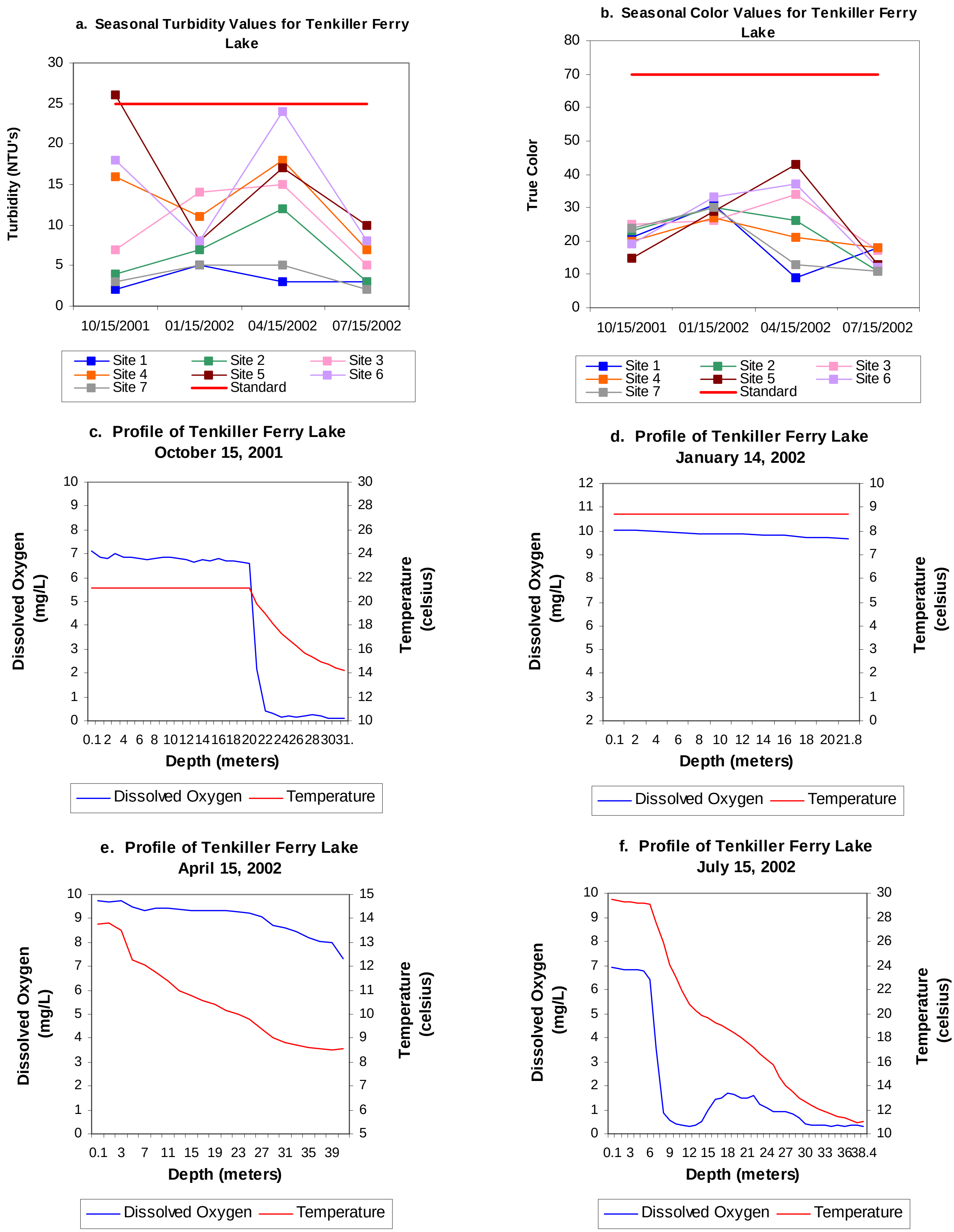
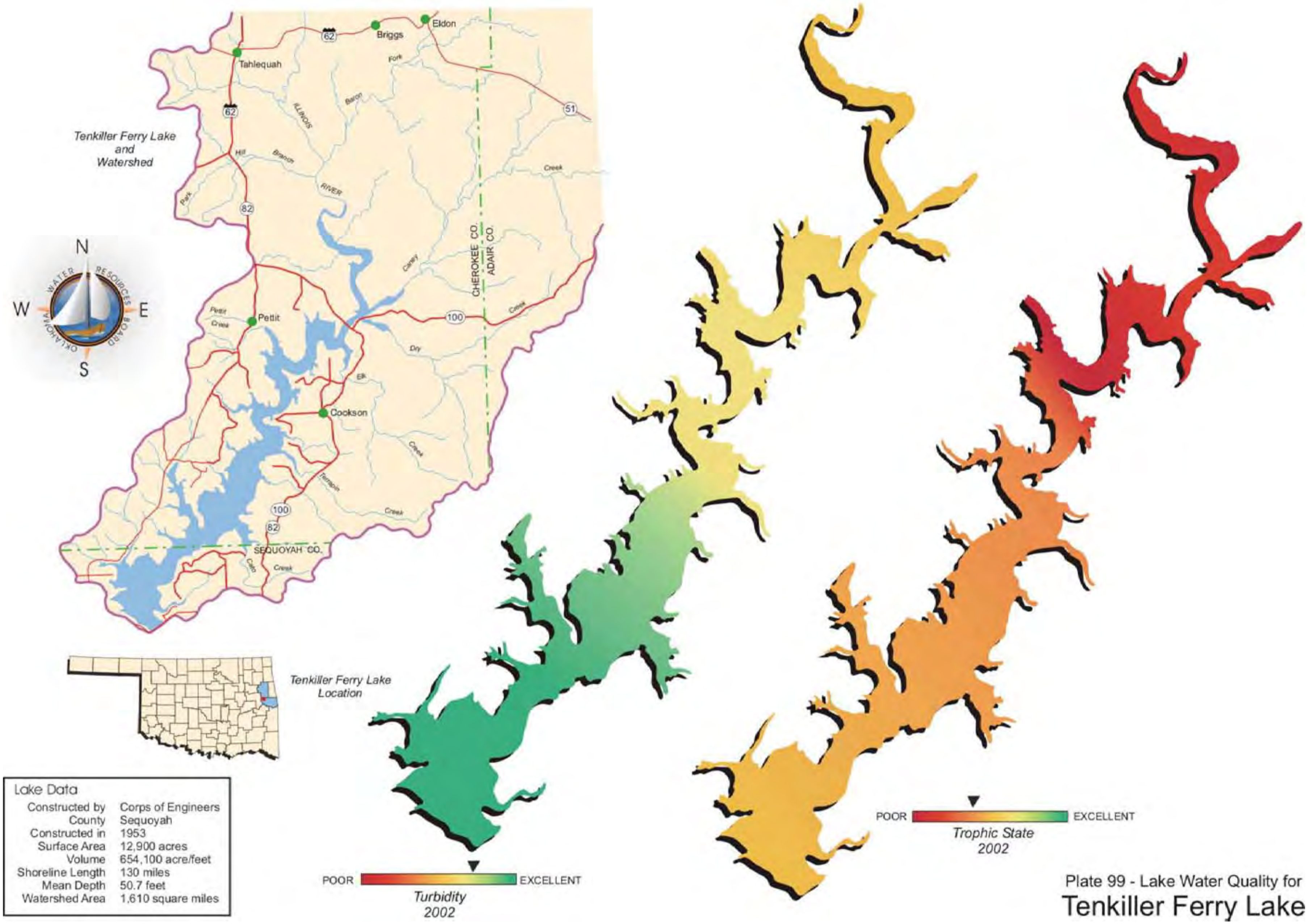


Figure 219a-213f. Graphical representation of data results for Tenkiller Ferry Lake.


Tenkiller Ferry Lake
and
Watershed
Tahlequah
Briggs
Eldon
Pettit
Cookson
CHEROKEE CO.
ADAIR CO.
SEQUOYAH CO.
ILLINOIS
RIVER
N
S
E
W
WATER RESOURCES BOARD
OKLAHOMA
Tenkiller Ferry Lake
Location
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
POOR
EXCELLENT
Turbidity
2002
POOR
EXCELLENT
Trophic State
2002
Plate 99 - Lake Water Quality for
Tenkiller Ferry Lake

Lake Texoma

Lake Texoma was sampled for four quarters, from October 2002 through July 2003. 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 10 NTU (Plate 100), true color was 16 units, and secchi disk depth was 115 centimeters. Based on these three parameters, Lake Texoma had excellent 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 54 (Plate 100), classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient conditions. This is similar to the TSI from 2000 (TSI=57), indicating no significant increase or decrease in productivity has occurred since the last evaluation. TSI values varied from season to season and from site to site. In the fall and winter, values spanned all four trophic categories (see Figure 220). Sites 8-13 (Red River arm) were generally eutrophic to hypereutrophic throughout the sample year. Closer to the dam area, TSI values were generally mesotrophic in the fall, winter, and spring. In the summer quarter, sites were divided between the eutrophic and hypereutrophic categories. Seasonal turbidity values ranged from a low of 2 NTU to a maximum of 42 NTU and are displayed in Figure 221a. 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 OWQS (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 10% of the collected turbidity values exceeding the standard. Seasonal true color values are displayed in Figure 221b. All of the true color values were well below the numeric criteria of 70 units and the Aesthetics beneficial use is considered fully supported.

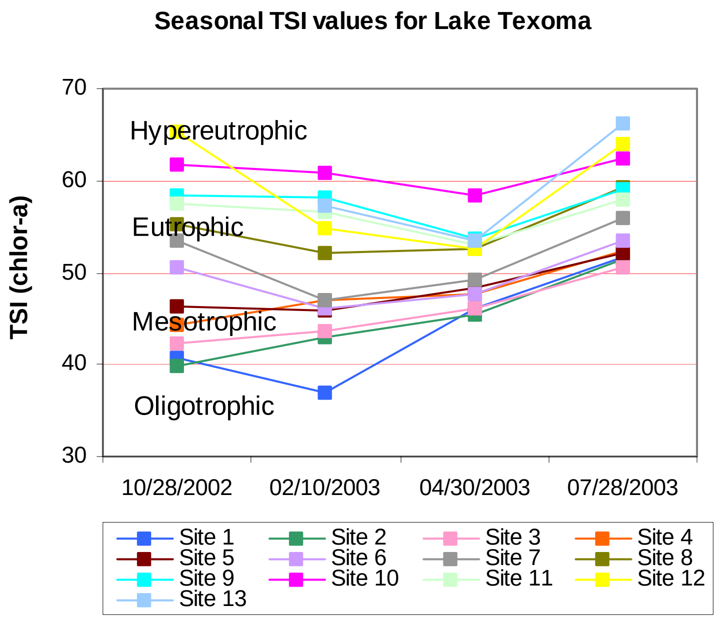


Figure 220. TSI values for Lake Texoma.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.50 parts per thousand (ppt) at site 4 (Washita River arm) to 1.67 ppt at site 11 (Red River arm), which is higher than the range of values recorded in

Oklahoma reservoirs. Specific conductance ranged from 959.5 mS/cm to 3086 mS/cm, 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 6.71 to 8.34, 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 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. 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 22 mV in the hypolimnion during the fall to 634 mV in the winter. Reducing conditions were not present at this reservoir with values above generally 100 mV except for a couple of values recorded at the lake bottom at the sediment-water interface. Stratification was not evident during the fall, winter, or spring sampling quarters and the water column was well mixed (see Figure 221c-215e). In the fall, collected dissolved oxygen (D.O.) values are suspect with all values at site 1 and site 6 at or below 2.0 mg/L while all other sites are generally above 5.0 mg/L. Although the Hydrolab was calibrated before the sample trip the values recorded at these two sites are unusually low and seem questionable. In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline. Stratification occurred between 9 and 10 meters throughout the lake, with 23 to 60% of the water column experiencing anoxic conditions (Figure 221f). 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.55 mg/L at the surface and 0.52 mg/L at the lake bottom. Surface TN ranged from 0.14 mg/L to 1.04 mg/L with the highest values recorded in the summer quarter and lowest in the fall. The lake-wide total phosphorus (TP) average was 0.035mg/L at the surface and 0.055 mg/L at the lake bottom. The surface TP ranged from 0.015 mg/L to 0.086 mg/L with both high and low values recorded in the summer. The nitrogen to phosphorus ratio (TN:TP) was 16:1 for sample year 2003. This value 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 2002-2003. These results are similar to those of 2000 (TSI=57), indicating no significant increase or decrease in productivity has occurred over time. Water clarity was excellent 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 true color values. 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.

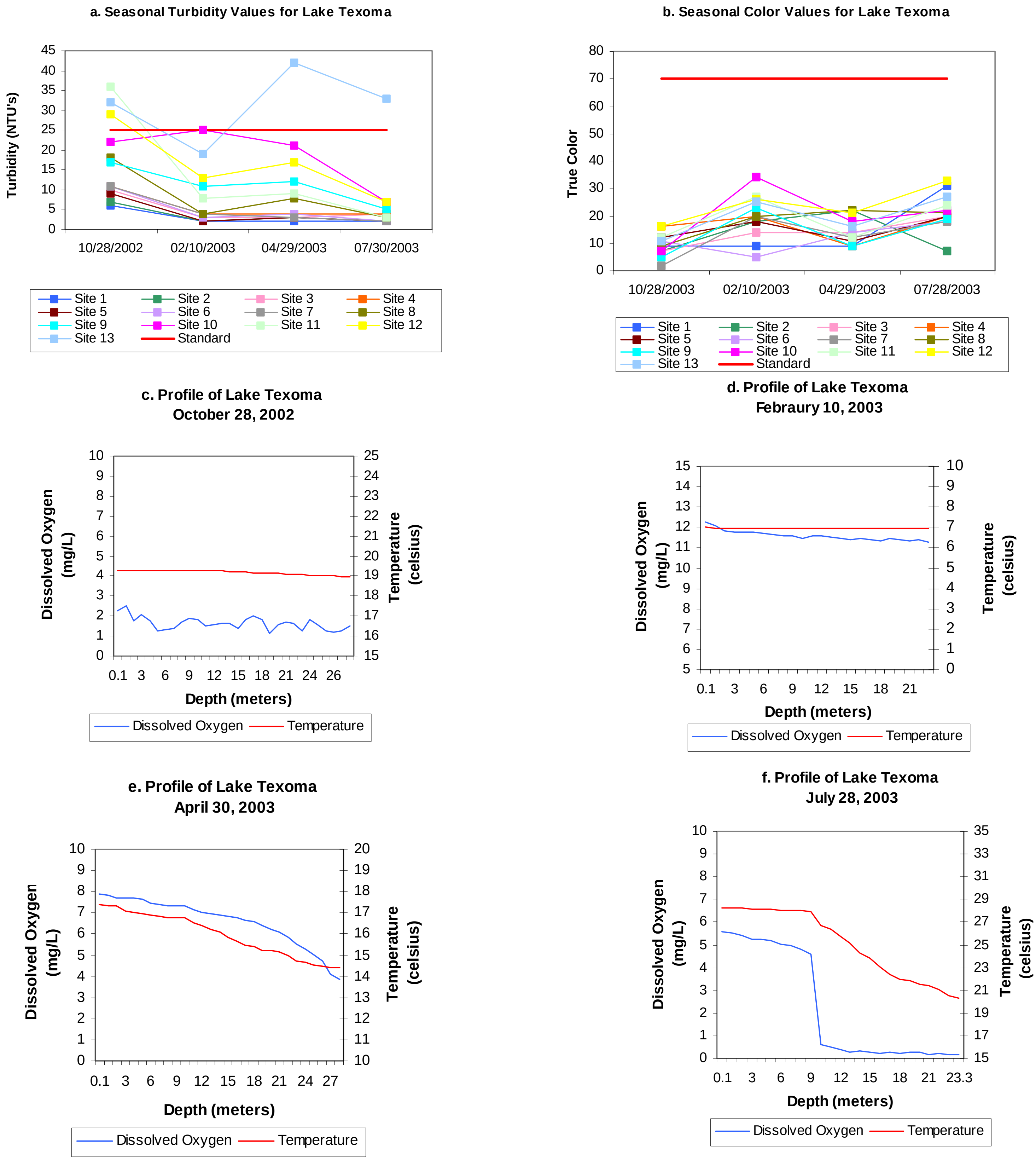
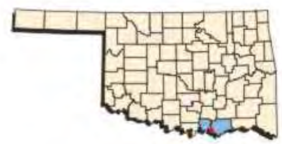
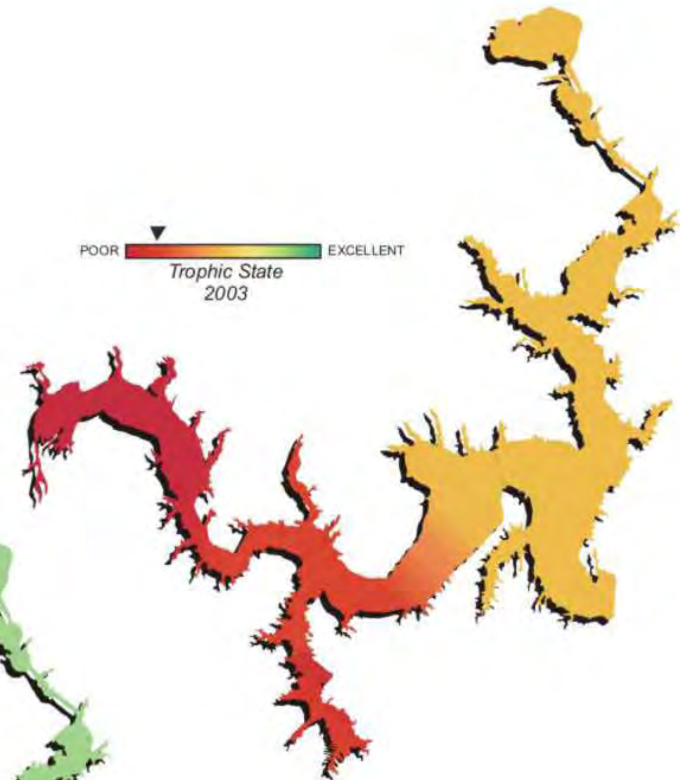
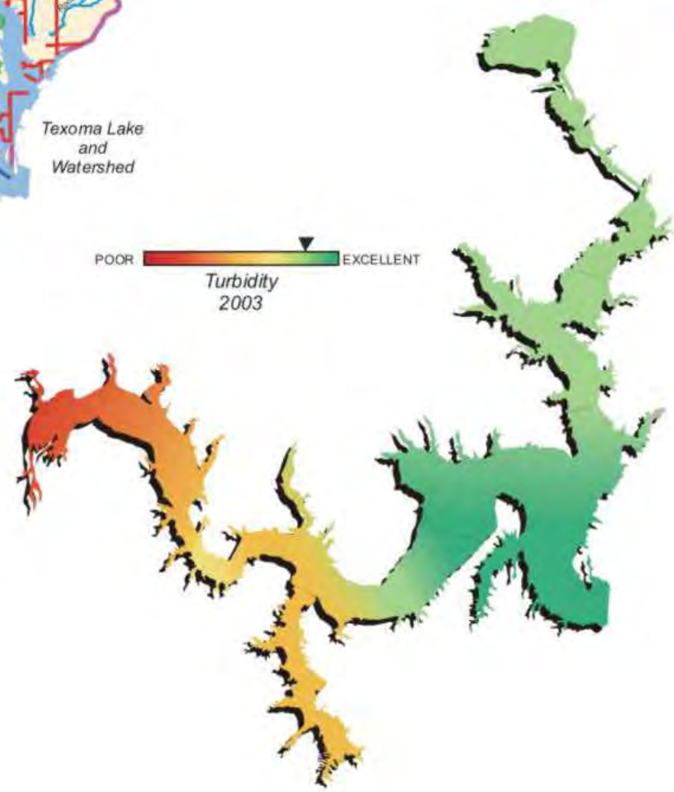


Figure 221a-215f. Graphical representation of data results for Lake Texoma.

Texoma Lake
and
Watershed


Texoma Lake
Location





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 100 - Lake Water Quality for
Texoma Lake

Lake Thunderbird

Lake Thunderbird was sampled for four quarters, from November 2000 through July 2001. Water quality samples were collected at 7 sites to represent the riverine, transitional, and lacustrine zones and 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 lake-wide annual turbidity value was 19 NTU, true color was 51 units, and secchi disk depth was 59 centimeters in 2001. Based on these three parameters, Lake Thunderbird had average water clarity, similar to water clarity in the summer of 1998. 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 56, classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is less than the TSI in 1998 (TSI=60), based on seven summer values, although in the same trophic category. The TSI values were primarily eutrophic throughout the year (50% of samples) at all sites although the TSI at several sites was mesotrophic in the fall and spring (sites 1, 2, and 4) or hypereutrophic in the summer (sites 6 and 7). As expected, the chlorophyll-a concentration was generally lower at the dam site and lacustrine area 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). Only four of the 28 turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU; however, this constitutes a listing as partially supporting the Fish & Wildlife Propagation (FWP) beneficial use as 14% 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 OWQS (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 in the fall were above the standard as well as one site in the winter, constituting 29% of samples in 2001. Greater than 25% of the true color values exceeded the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is considered not supported. 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 2001 a bathymetric survey (Figure 222) 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 Kathy Koon at (405) 530-8800.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

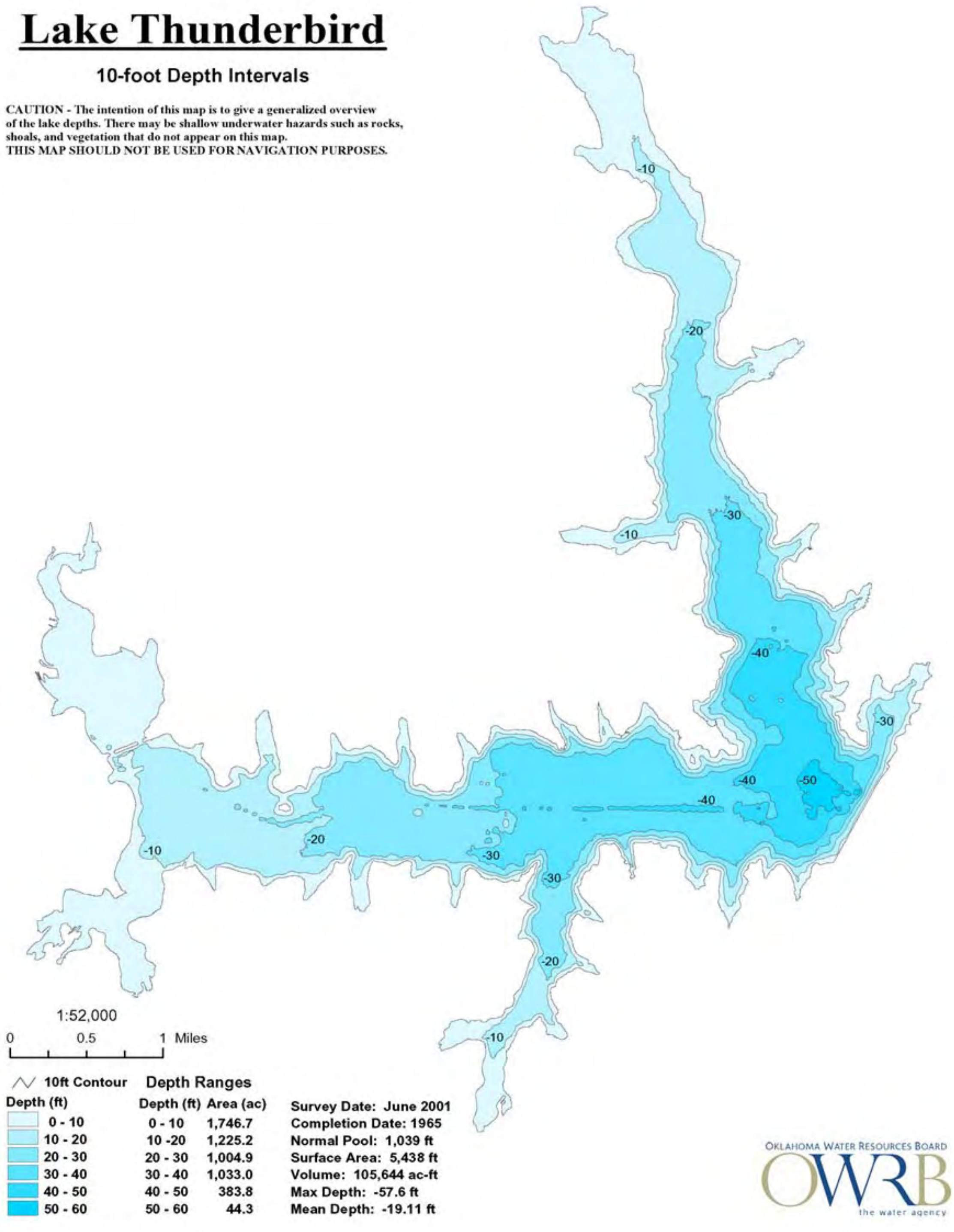


Figure 222. Bathymetric map of Lake Thunderbird.

Tom Steed Reservoir

Tom Steed Reservoir was sampled for four quarters, from October 2002 through June 2003. Water quality samples were collected from three (3) sites in the fall and winter and from five (5) sites in the summer and spring to represent the riverine, transition, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for a lake greater than 250 surface acres. 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 52 NTU (Plate 101), true color was 36 units, and average secchi disk depth was 43 centimeters. Based on these three parameters Tom Steed Reservoir had average to poor water clarity in sample year 2003. 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 52 (Plate 101), indicating the lake was eutrophic with high primary productivity and nutrient conditions. This is similar to the TSI in 2000 (TSI=56), indicating no significant increase or decrease in productivity has occurred since the last evaluation. The TSI values were eutrophic in the fall, winter, and summer quarters and mesotrophic in the winter (Figure 223). The only exceptions being sites, 4 and 5, which were classified, as oligotrophic in the winter quarter. Seasonal turbidity values are displayed in Figure 224a. Turbidity values ranged from a low of 25 NTU to a maximum of 62 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 (OWQS) 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; however due to an accident in the lab there is not enough data to make an assessment. Seasonal true color values are displayed in Figure 224b. All color values were well below the aesthetics OWQS of 70 units. Appling the same default protocol the Aesthetics beneficial use is considered fully supported.

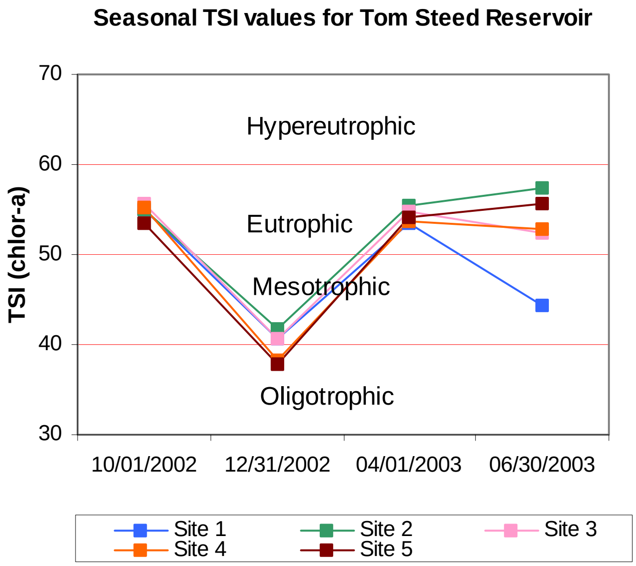


Figure 223. TSI values for Tom Steed Reservoir.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation- reduction potential, and salinity were recorded at all five sample sites. Salinity values ranged from 0.42 parts per thousand (ppt) to 0.52 ppt for this sample year. Specific conductance ranged from 807.6 to 986.8 mS/cm, which is higher than most Oklahoma reservoirs. These values indicate moderate to high levels of electrical current conducting compounds (salts) in the lake, consistent with higher salinity concentrations. The pH values at Tom Steed Reservoir were slightly acidic, ranging from 4.97 in the winter to 8.43 in the spring. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for 25% of the values and should be listed as not supporting the FWP beneficial use. If 10 to 25% of the pH values fall outside the 6.5 to 9 range the lake is considered partially supporting. With 25% of the values recorded being less than 6.5 the lake, should be listed as not supporting based on pH. The low pH values recorded primarily in the winter at Tom Steed Reservoir may be due to natural conditions and will be listed as "provisionally not supporting"* the FWP. Oxidation-reduction potentials ranged from 367 mV in the fall to 562 mV in the spring, indicating the absence of reducing conditions in sample year 2002-2003. Due to the shallow nature of the lake thermal stratification was not present during any of the sampling quarters and the water column was well mixed with dissolved oxygen (D.O.) values generally above 6 mg/L (see Figure 224c-217f). 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 2002-2003 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 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. The PBCR beneficial use is considered fully supported

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.65 mg/L at the surface and 0.64 mg/L at the lake bottom. Surface TN ranged from 0.42 mg/L to 1.02 mg/L with the highest values recorded in the summer quarter and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.059 mg/L at the surface and 0.057 mg/L at the lake bottom. The surface TP ranged from 0.015 mg/L to 0.086 mg/L with the highest values recorded in the summer and lowest values recorded in the winter. The nitrogen to phosphorus ratio (TN:TP) was 11:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Tom Steed Reservoir was classified as eutrophic, indicative of high primary productivity and nutrient conditions. This is consistent with data collection efforts in sample year 2000 (TSI=56) indicating no change in trophic status has occurred over time. Water clarity was fair to poor based on turbidity, true color, and secchi disk depth in 2003. The lake is supporting the FWP beneficial use based on dissolved oxygen, however a use determination based on turbidity could not be made due to insufficient data. Although the minimum data requirements of 20 samples for lakes greater than 250 surface was not met, the collected data suggests that the FWP would not be supported with 100% of the collected values exceeding the OWQS of 25 NTU. Low pH values recorded in the winter may be due to natural causes and therefore the lake will be listed as "provisionally not supporting"* the FWP. The lake is supporting the Aesthetics beneficial use based on its trophic status and true color values. The Bureau of Reclamation constructed Tom Steed Reservoir for municipal and industrial water supply, flood control, and fish and wildlife purposes.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

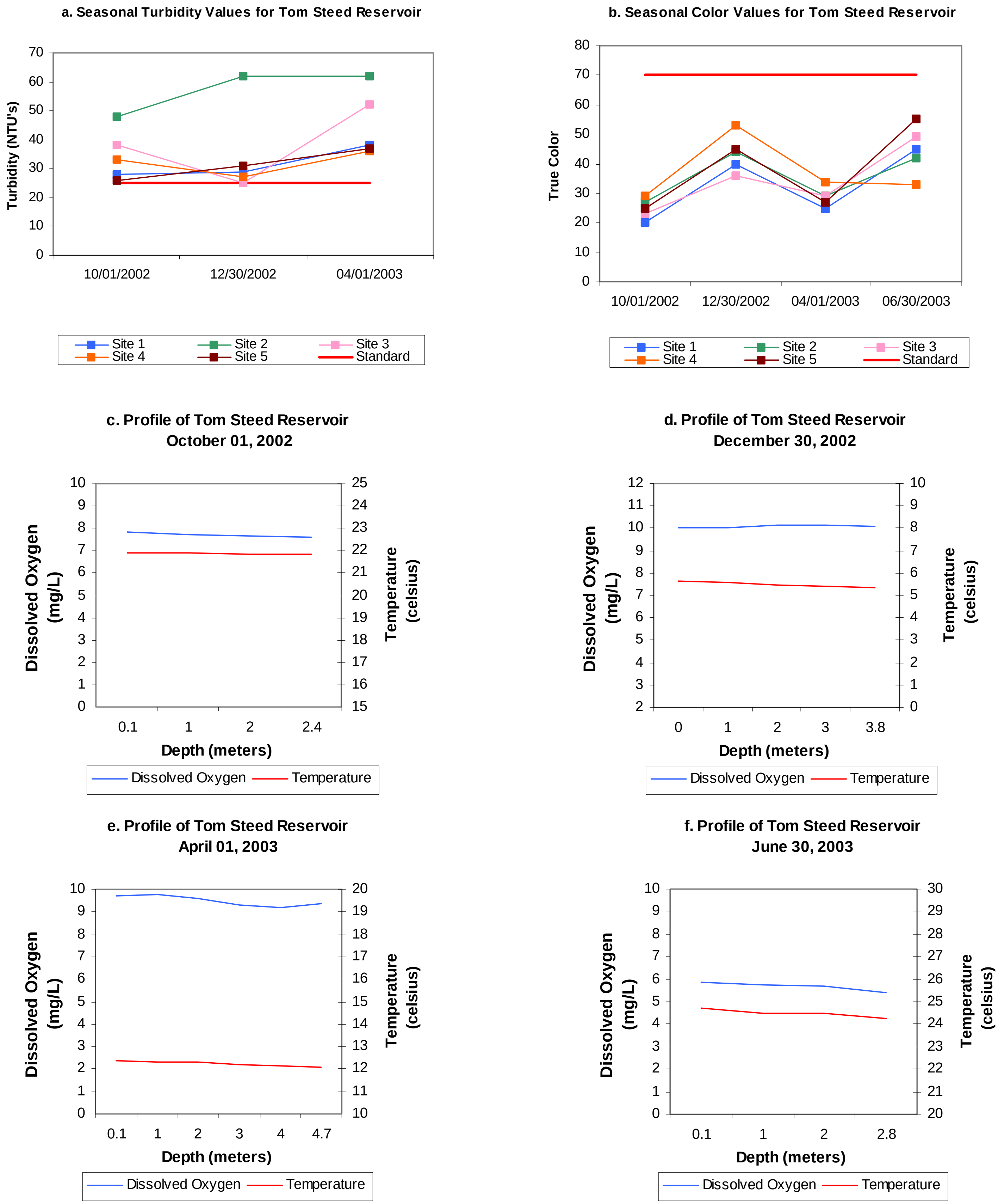
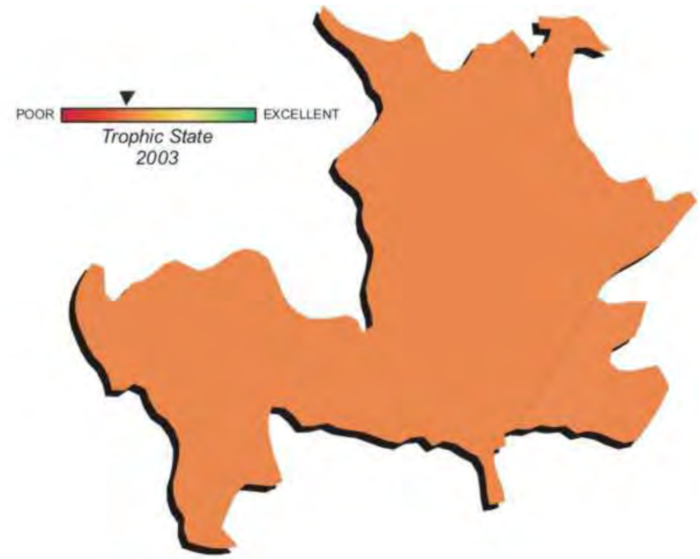
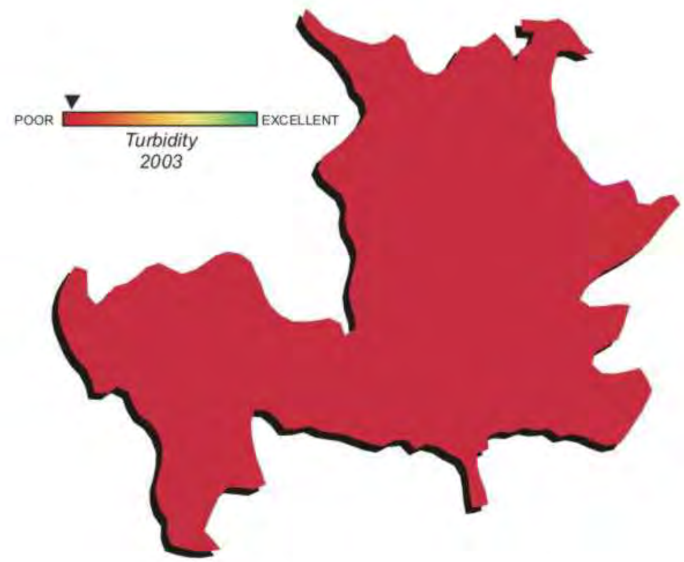


Figure 224a-217f. Graphical representation of data results for Tom Steed Reservoir.





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 101 - Lake Water Quality for

Tom Steed Reservoir

Lake Vanderwork

Lake Vanderwork was sampled for four quarters, from October 2001 through July 2002. 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 10 NTU (Plate 102), true color was 32 units, and secchi disk depth was 61 centimeters in 2001-2002. 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 63 (Plate 102), classifying the lake as hypereutrophic, indicative of excessive levels of productivity and nutrient rich conditions. The TSI values varied seasonally with the winter quarter characterized by eutrophic conditions and the fall and spring characterized by hypereutrophic conditions and the summer quarter was a mixture of the two depending where the site was located in the lake (see Figure 225). Findings were in agreement with historical data collection efforts that resulted in the lake being listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW) meaning that the lake is threatened due to nutrients and should be very intensively studied to determine if the Aesthetics beneficial use is partially supporting or not supporting. All turbidity values were below the OWQS of 25 NTU (see Figure 226a). 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 OWQS (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. Vanderwork Lake is fully supporting its Fish and Wildlife Propagation (FWP) beneficial use based on nephelometric turbidity. Seasonal true color values are displayed in Figure 226b. 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 conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Lake salinity values ranged from 0.57 parts per thousand (ppt) in the fall to 1.04 ppt at in the spring quarter. Values were much 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 conductance values were also greatly elevated above the expected range for Oklahoma reservoirs, coinciding with the very high salinity concentrations. Values ranged from 1079 mS/cm in the fall quarter to 1946 mS/cm at site 1 in the spring, indicating that high levels of electrical conducting compounds (salts) were present in the lake system. Oxidation-reduction potentials (redox) ranged from -86 mV at the sediment-water interface in the summer to 471 mV in the fall, indicating reducing conditions were present in the lake in the summer quarter with the possibility of nutrient release from the lake sediments. The pH values were neutral to slightly alkaline with values ranging from 6.96 units in the summer quarter to 8.39 also recorded in the summer quarter. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5

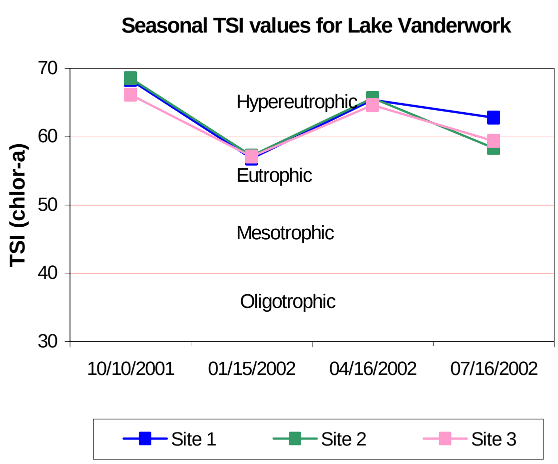


Figure 225. TSI values for Lake Vanderwork.

to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. None of the collected pH values were outside the acceptable range, so the lake is fully supporting its FWP beneficial use based on pH. Thermal stratification was not evident in the fall or winter quarters and dissolved oxygen (D.O.) values were above 6.0 mg/L throughout the water column (see Figure 226c-219d). In the spring the lake was strongly thermally stratified between 4 and 5 meters below the lake surface, however D.O. concentrations remained above 2.4 mg/L throughout the water column (see Figure 226e). In the summer, the lake was again thermally stratified with stratification occurring between 3 and 4 meters below the lake surface. Unlike the spring quarter, D.O. concentrations below 3 meters were all less than 2.0 mg/L extending to the lake bottom at 8.8 meters at site 1 (see Figure 226f). 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 Lake Vanderwork as 60% of the water column was anoxic in the summer. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 1.30 mg/L at the lake surface. The TN at the surface ranged from 0.93 mg/L to 1.67 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the summer. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.041 mg/L at the lake surface. The surface TP ranged from 0.007 mg/L to 0.63 mg/L. The highest surface TP value was reported in the fall and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 31:1 for sample year 2001-2002. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Vanderwork was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use based on metal (toxic) compounds in the water column.

In summary, Lake Vanderwork was classified as hypereutrophic, indicative of excessive primary productivity and nutrient rich conditions (Plate 102). The lake is currently listed in the OWQS as a NLW indicating that the Aesthetics beneficial use is threatened by nutrients. Sampling confirmed this finding and the lake should be monitored intensively to determine if it is partially supporting or not supporting the use. Vanderwork is fully supporting its Aesthetics use based on true color. The FWP beneficial use is fully supported based on nephelometric turbidity and pH, however the use is partially supporting based on D.O. concentrations in the water column. 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.

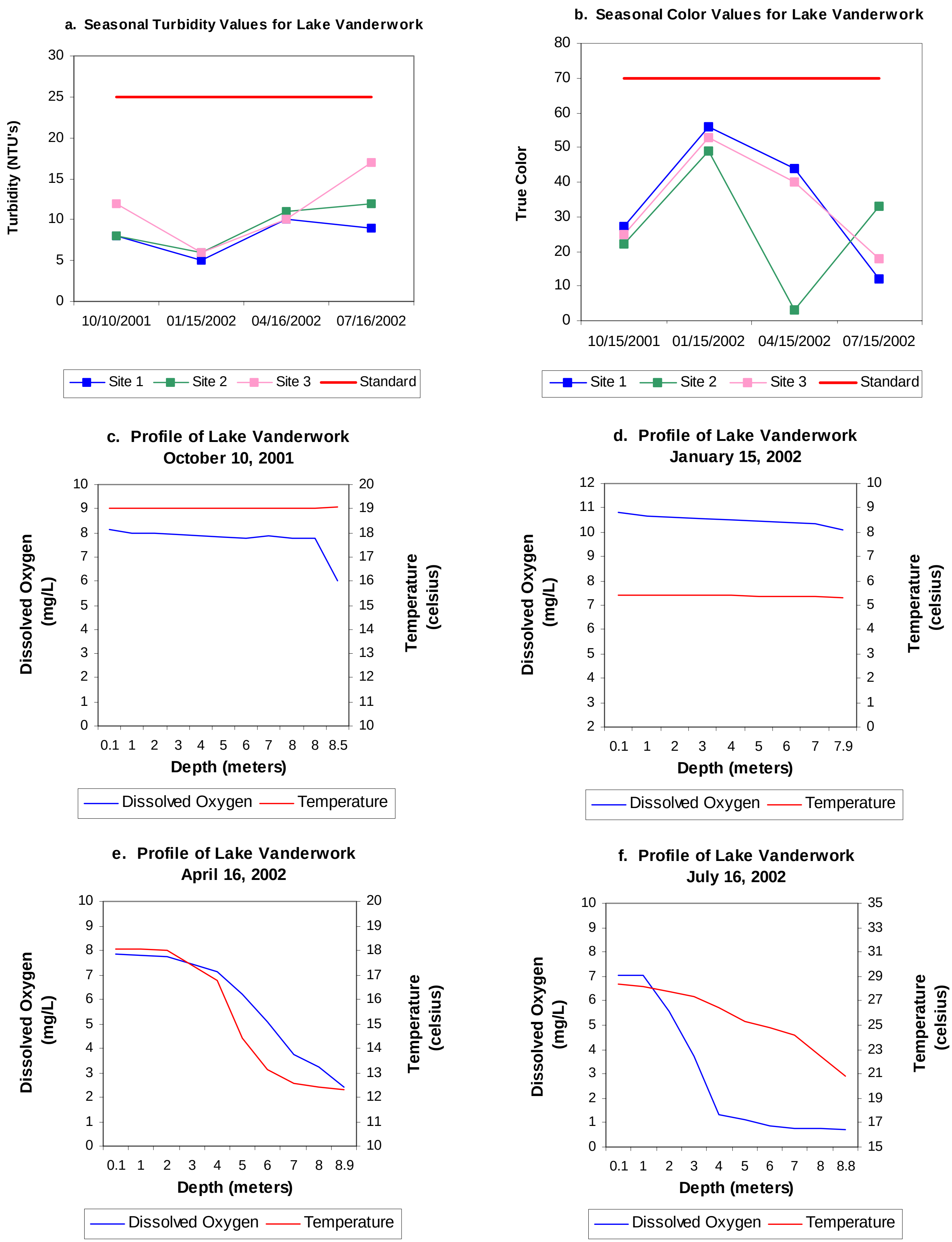
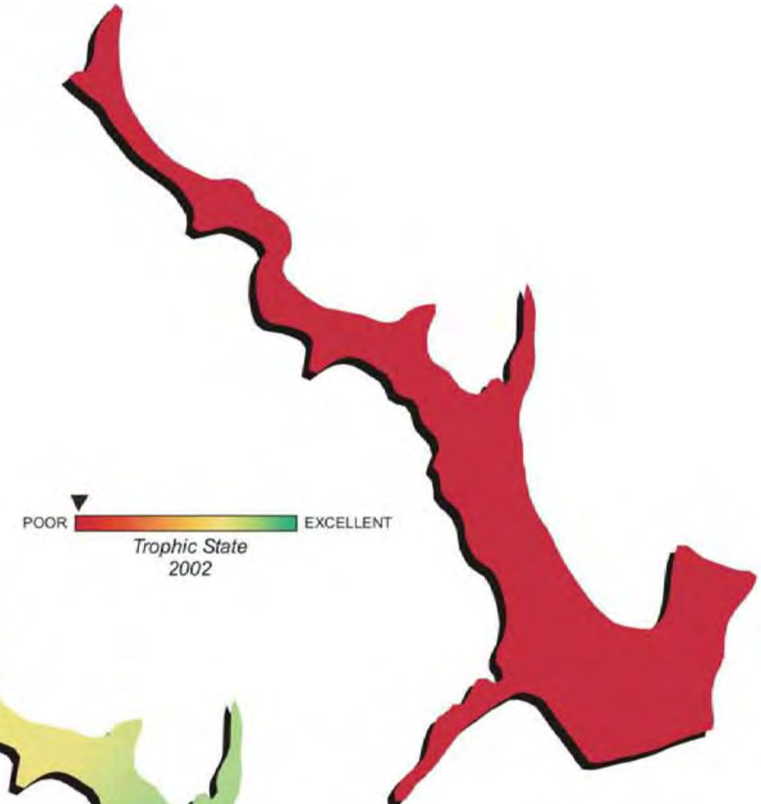
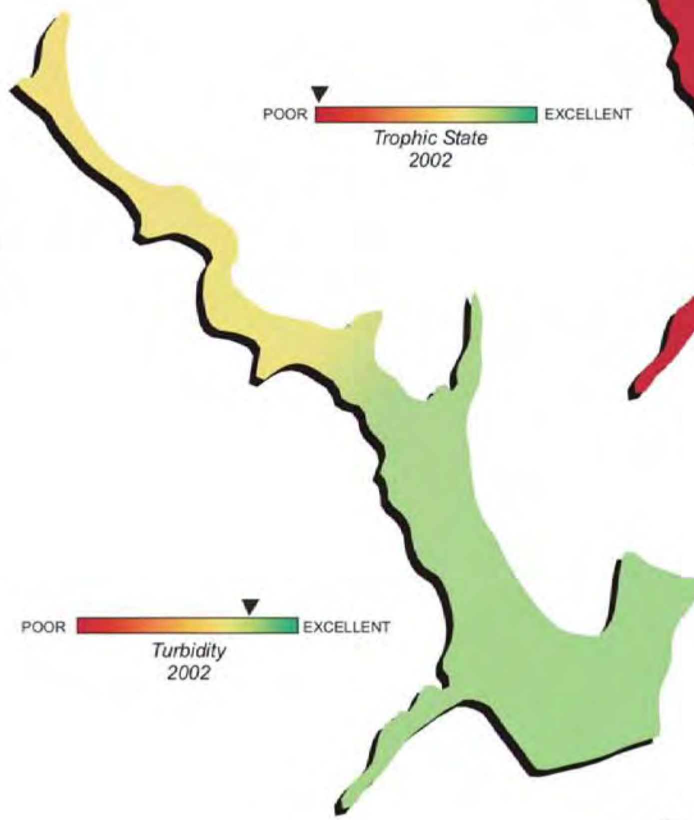


Figure 226a-2197f. Graphical representation of data results for Lake Vanderwork.





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 102 - Lake Water Quality for
Vanderwork Lake

Lake Vincent

Lake Vincent was sampled for four quarters, from October 2002 through July 2003. 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 11 NTU (Plate 103), true color was 15 units, and secchi disk depth was 109 centimeters. Based on these three parameters, Lake Vincent had excellent 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 42 (Plate 103), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. This is similar to results in 2000 (TSI=48), indicating no significant increase or decrease in productivity has occurred over time. The TSI values were primarily mesotrophic throughout the year except in the spring when values for all sites were in the oligotrophic category (see Figure 227). The TSI of 42 seems to accurately represent conditions at Lake Vincent. Seasonal turbidity values are displayed in Figure 228a. 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 not supported if ≥25% of the samples exceed the screening level prescribed in the OWQS (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% of the collected values above the OWQS 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. All true color values were less than the Aesthetics criteria of 70 units, therefore, the use is considered fully supported (Figure 228b).

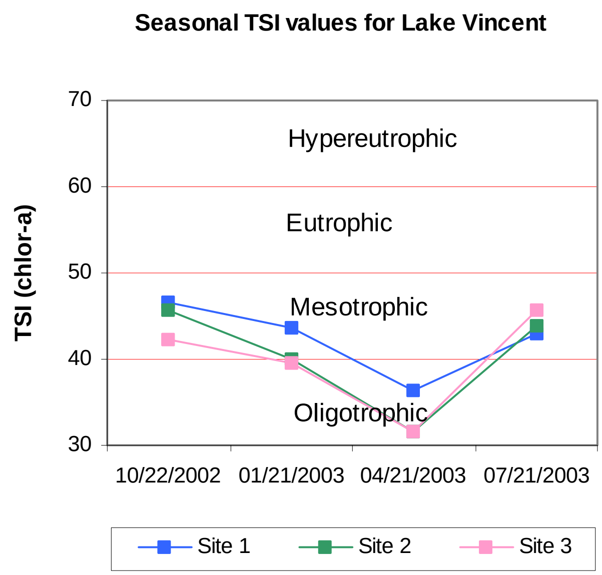


Figure 227. TSI values for Lake Vincent.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.38 parts per thousand (ppt) to 0.42 ppt, which is higher than the average range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 736.6 mS/cm to 801.4 mS/cm, indicative of moderate to high levels of current conducting ions (salts) in the lake system. The recorded values for pH ranged from 7.16 to 8.33, 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 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. 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 38 mV in the hypolimnion in the summer to 609 mV in the fall. In general, reducing conditions were not present with recorded values above 100 mV, except in the hypolimnion at site 1 during the summer. The lake was not stratified during the fall, winter, or spring sampling quarters and the water column was well mixed (see Figure 228c-221e). 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 up to 58% of the water column experiencing anoxic conditions (Figure 228f). 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 58% 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.46 mg/L at the surface and 0.62 mg/L at the lake bottom. Surface TN ranged from 0.12 mg/L to 0.69 mg/L with the highest values recorded in the winter quarter and lowest in the summer. The lake-wide total phosphorus (TP) average was 0.020 mg/L at the surface and 0.031 mg/L at the lake bottom. The surface TP was highest in the fall quarter and lowest in the spring with values ranging from 0.013 mg/L to 0.029 mg/L. The nitrogen to phosphorus ratio (TN:TP) was 23:1 for sample year 2003. This value 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. This is consistent with past data collection efforts in 2000 (TSI=48), indicating that no significant increase or decrease in productivity has occurred over time. Water clarity was excellent 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 the summer. The Aesthetics beneficial use is fully supported based on its trophic status and true color values. Lake Vincent is located in Ellis County and is utilized for recreation.

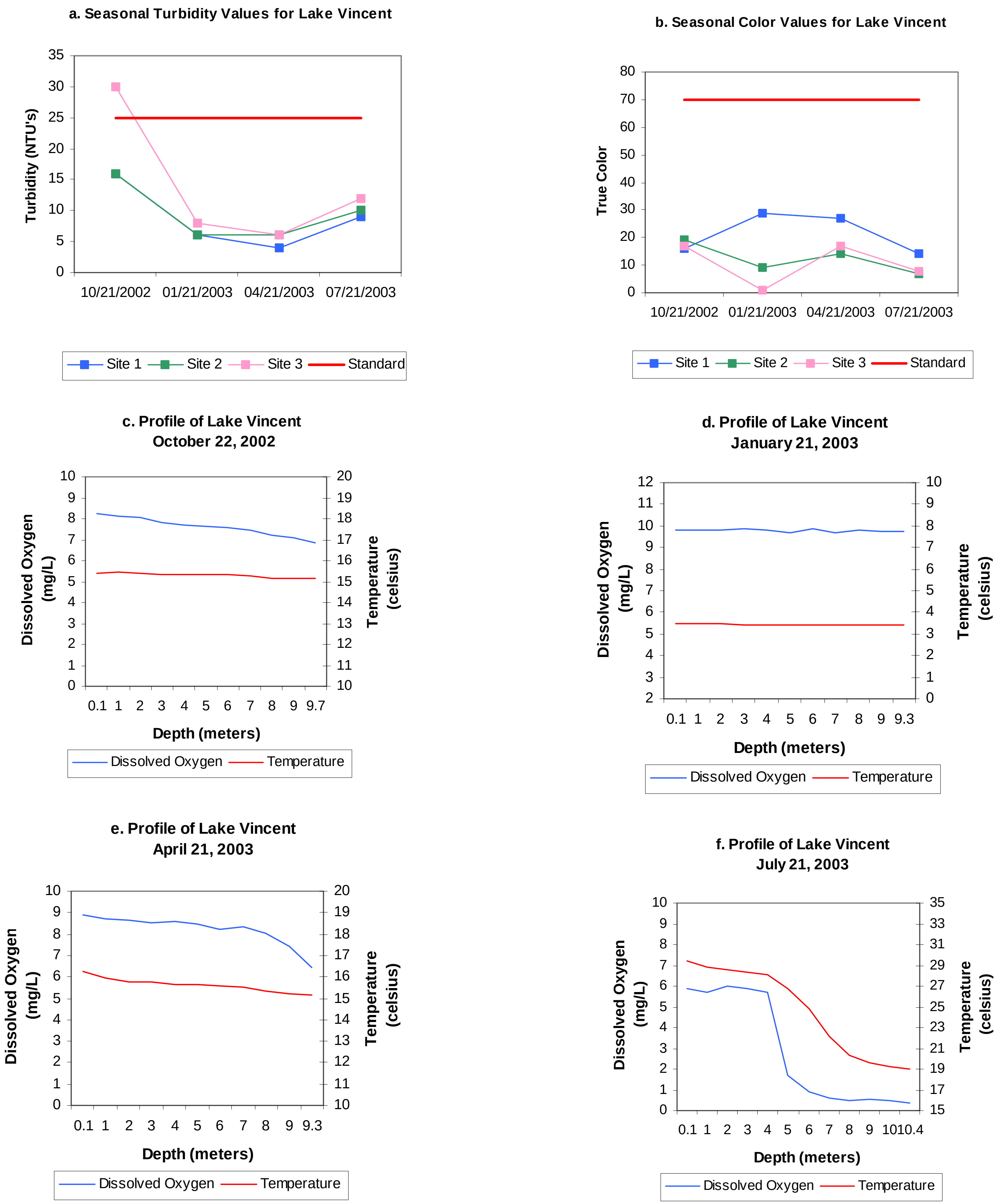


Figure 228a-221f. Graphical representation of data results for Lake Vincent.

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 103 - Lake Water Quality for
Lake Vincent

W.R. Holway Reservoir

W.R. Holway Reservoir was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected from three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transition, and lacustrine zone of the reservoir. Additional sites were added to ensure sample size was representative for lakes larger than 250 surface acres. 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 104), true color was 16 units, and average secchi disk depth was 151 centimeters. Based on theses three parameters, W.R. Holway Reservoir had excellent water clarity, similar to that in 2000. 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 104), classifying the lake as mesotrophic, bordering eutrophic, with moderate levels of productivity and nutrient conditions. This is lower than results in 2000 (TSI=57), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. The TSI values were fairly consistent and ranged from mesotrophic in the first three quarters to eutrophic in the summer (see Figure 229). Seasonal turbidity values are displayed in Figure 230a. Turbidity values ranged from a low of 3 NTU to a maximum of 13 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 OWQS (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 OWQS 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 230b. All true color values were less than the Aesthetics criteria of 70 units, however the minimum data requirements (20 samples) were not met and a use determination cannot be made at this time.

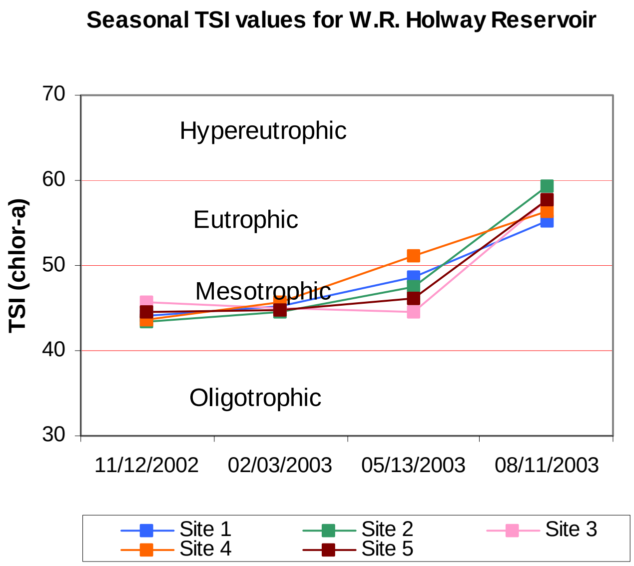


Figure 229. TSI values for W.R. Holway Reservoir**.**

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.11 parts per thousand (ppt) to 0.22 ppt in sample year 2002-2003. This is within the average the range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 230 mS/cm to 436.9 mS/cm, indicating the presence of low levels of current conducting ions (salts) in the lake system. The pH values ranged from 6.38 in the summer to 9.22 in the spring. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. The pH values that were outside the range only occurred at site 4, near the dam site, and only constituted 0.9 % of the total collected values therefore the lake is supporting the FWP beneficial use based on pH. Oxidation-reduction potentials (ORP) ranged from 274 mV to 505 mV, indicating reducing conditions were not present at this reservoir in sample year 2002-2003. In the fall and winter quarters the water column was well mixed with dissolved oxygen (D.O.) values generally above 7.0 mg/L (Figure 230c-223d). The only exception to this occurred at site 1 where a value of 2.16 mg/L was recorded at the lake bottom, near the sediment-water interface. In the spring, the lake was weakly stratified however dissolved oxygen remained above 4.0 mg/L throughout the water column (Figure 230e). 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 21 to 38% of the water column experiencing anoxic conditions (Figure 230f). 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 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.46 mg/L at the surface and 0.59 mg/L at the lake bottom. Surface TN ranged from 0.30 mg/L to 0.62 mg/L with the highest values recorded in the summer quarter and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.047 mg/L at the surface and 0.062 mg/L at the lake bottom. The surface TP was highest in the fall quarter and lowest in the summer with values ranging from 0.039 mg/L to 0.082 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2003. This value 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 2002-2003. The current TSI is slightly lower than that of 2000 (TSI=57), although in the same trophic category, it is likely a more accurate depiction of productivity as it is based on data collected year round instead of growing season only. 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, but is partially supported due to the presence of anoxic conditions in the summer quarter. The Aesthetics beneficial use is supported based on its trophic status, however minimum data requirements were not met for true color and a use determination cannot be made. W.R. Holway Reservoir is owned by the Grand River Dam Authority (GRDA) and serves as a water supply, hydroelectric, and recreational reservoir.

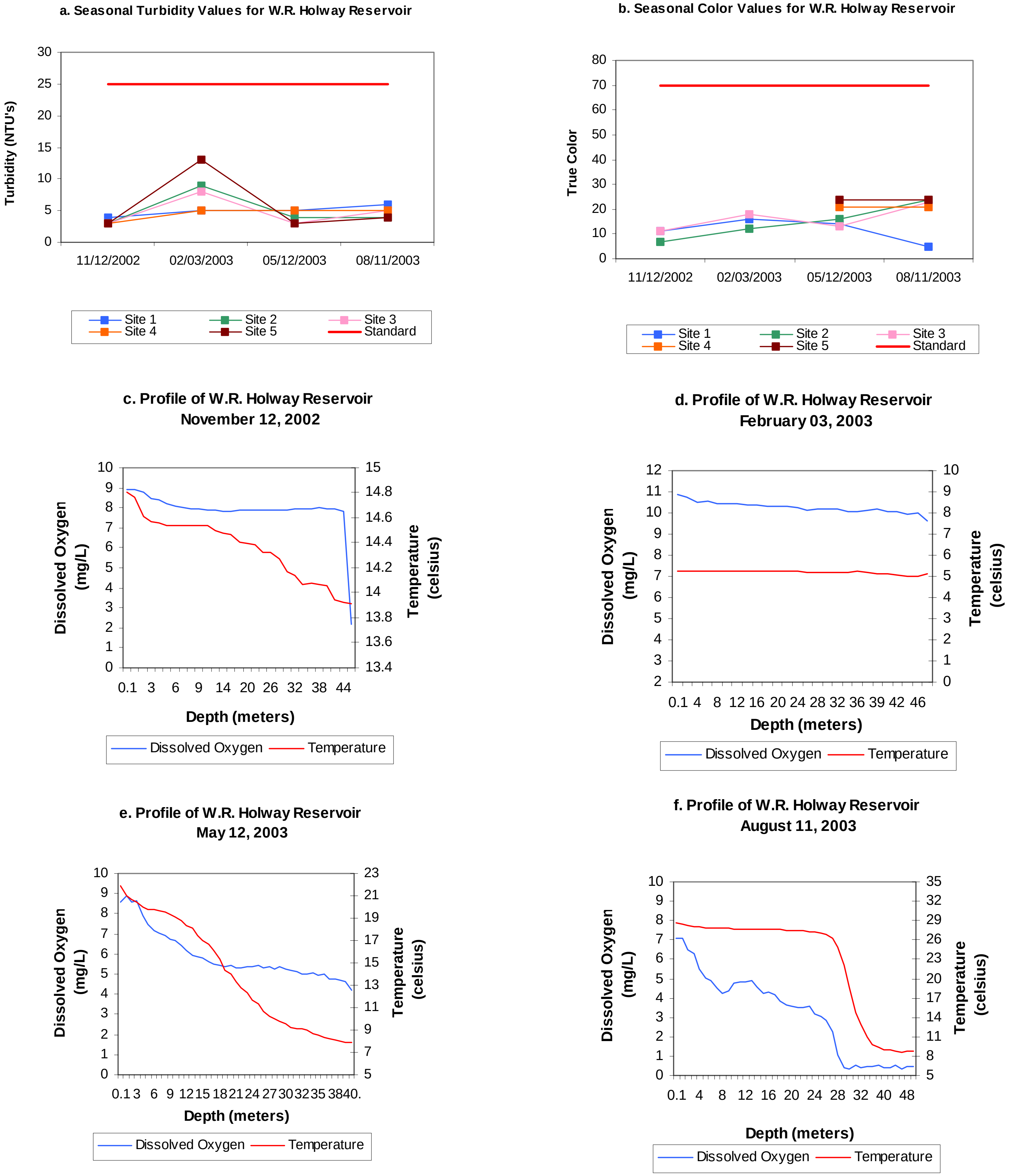
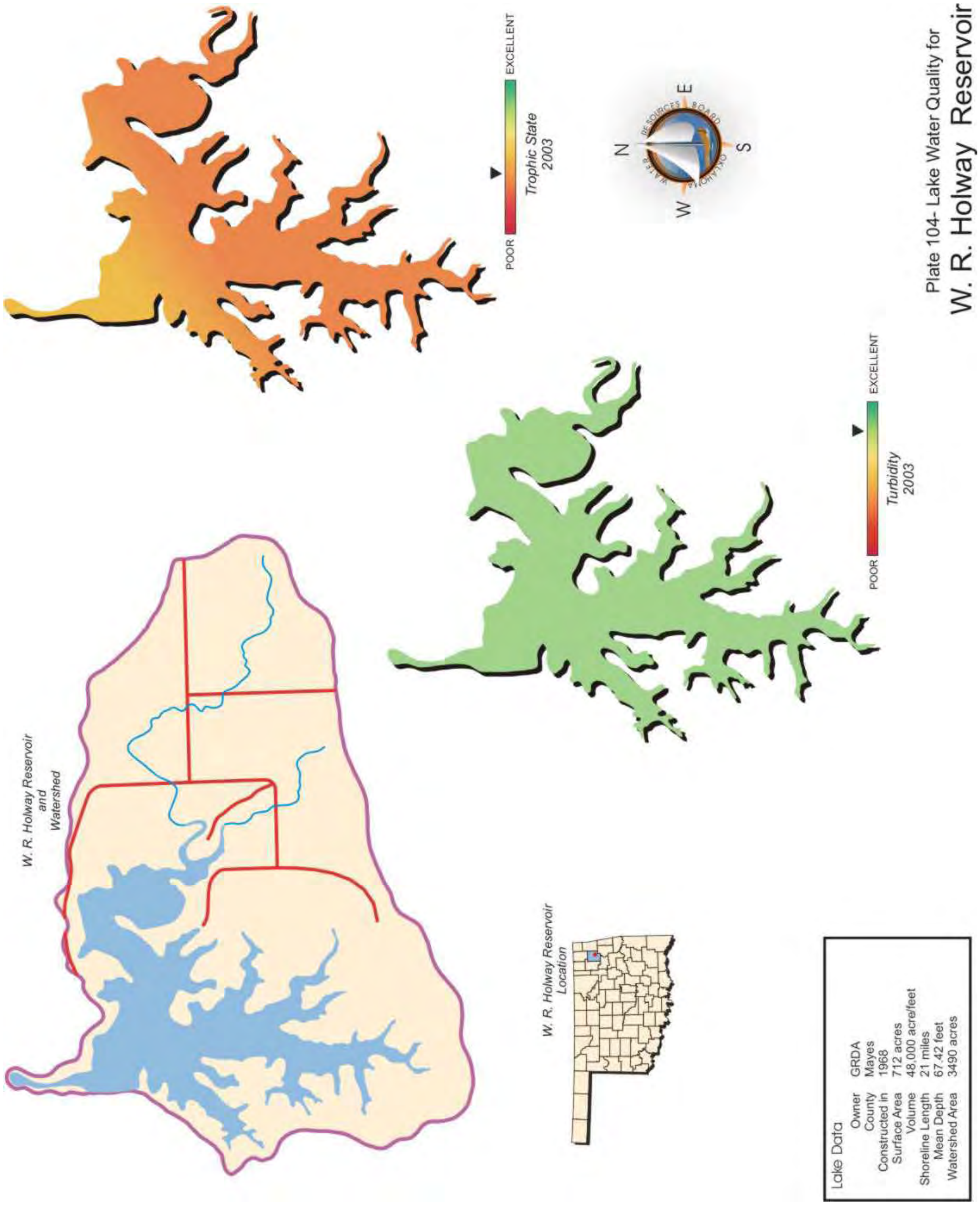


Figure 230a-223f. Graphical representation of data results for W.R. Holway Reservoir.


W. R. Holway Reservoir and Watershed
W. R. Holway Reservoir Location
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
POOR
Turbidity 2003
EXCELLENT
POOR
Trophic State 2003
EXCELLENT
N
E
S
W
Plate 104- Lake Water Quality for
W. R. Holway Reservoir

Waurika Lake

Waurika Lake was sampled for four quarters, from November 2002 through August 2003. 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 30 NTU (Plate 105), true color was 28 units, and average secchi disk depth was 48 centimeters. Based on these three parameters, Waurika Lake had average water clarity in 2002-2003. 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 105), classifying the lake as eutrophic, with high levels of primary productivity and nutrient conditions. This is lower than results in 2000 (TSI=61), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. The TSI values were primarily eutrophic with values ranging from mesotrophic (sites 4 and 5) in the winter to hypereutrophic (sites 2 and 3) in the summer (see Figure 231). Turbidity values ranged from a low of 6 NTU to a maximum of 75 NTU with higher values reported at sites 4 and 5 in the upper end of the reservoir (Figure 232a). 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 OWQS (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 40% of the values exceeding the OWQS of 25 NTU, Waurika Lake is not supporting its Fish and Wildlife Propagation (FWP) beneficial use in regards to turbidity. Seasonal true color values are displayed in Figure 232b. All true color values were less than the Aesthetics criteria of 70 units, therefore the beneficial use is considered supported.

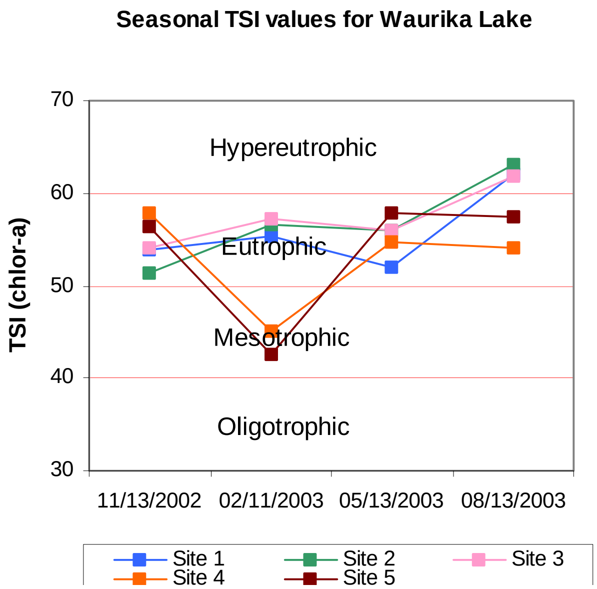


Figure 231. TSI values for Waurika Lake.

In 2003, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.26 parts per thousand (ppt) to 0.34 ppt in sample year 2002-2003. This is slightly higher than the average range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 518.7 mS/cm to 596.2 mS/cm, indicating the presence moderate levels of current conducting ions (salts) in the lake system. The pH values ranged from 7.14 to 8.47 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 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. 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 214 mV to 664 mV, indicating reducing conditions were not present at this reservoir in sample year 2002-2003. In the fall and winter quarters stratification was not evident and the water column was well mixed with dissolved oxygen (D.O.) values generally above 7.0 mg/L (Figure 232c-225d). In the spring, the lake was stratified at several 1-meter intervals at site 1, however dissolved oxygen only dropped below 2.0 mg/L near the lake bottom of 14.8 meters (Figure 232e). In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline, at both sites 1 and 2 (Figure 232f). 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 33 to 43% of the water column less than 2.0 mg/L in the summer, Waurika Lake 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.75 mg/L at the surface and 0.87 mg/L at the lake bottom. Surface TN ranged from 0.43 mg/L to 1.08 mg/L with the highest values recorded in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.072 mg/L at the surface and 0.135 mg/L at the lake bottom. The surface TP was highest in the summer quarter and lowest values were reported in both spring and summer with values ranging from 0.045 mg/L to 0.150 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 10:1 for sample year 2003. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983).

In summary, Waurika Lake was classified as eutrophic, indicative of high primary productivity and nutrient conditions in 2002-2003. This classification differs from 2000 (TSI=61), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. 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, partially supported based on dissolved oxygen, but not supported based on turbidity. The lake is supporting the Aesthetics beneficial use based on its trophic status and reported true color values. 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.

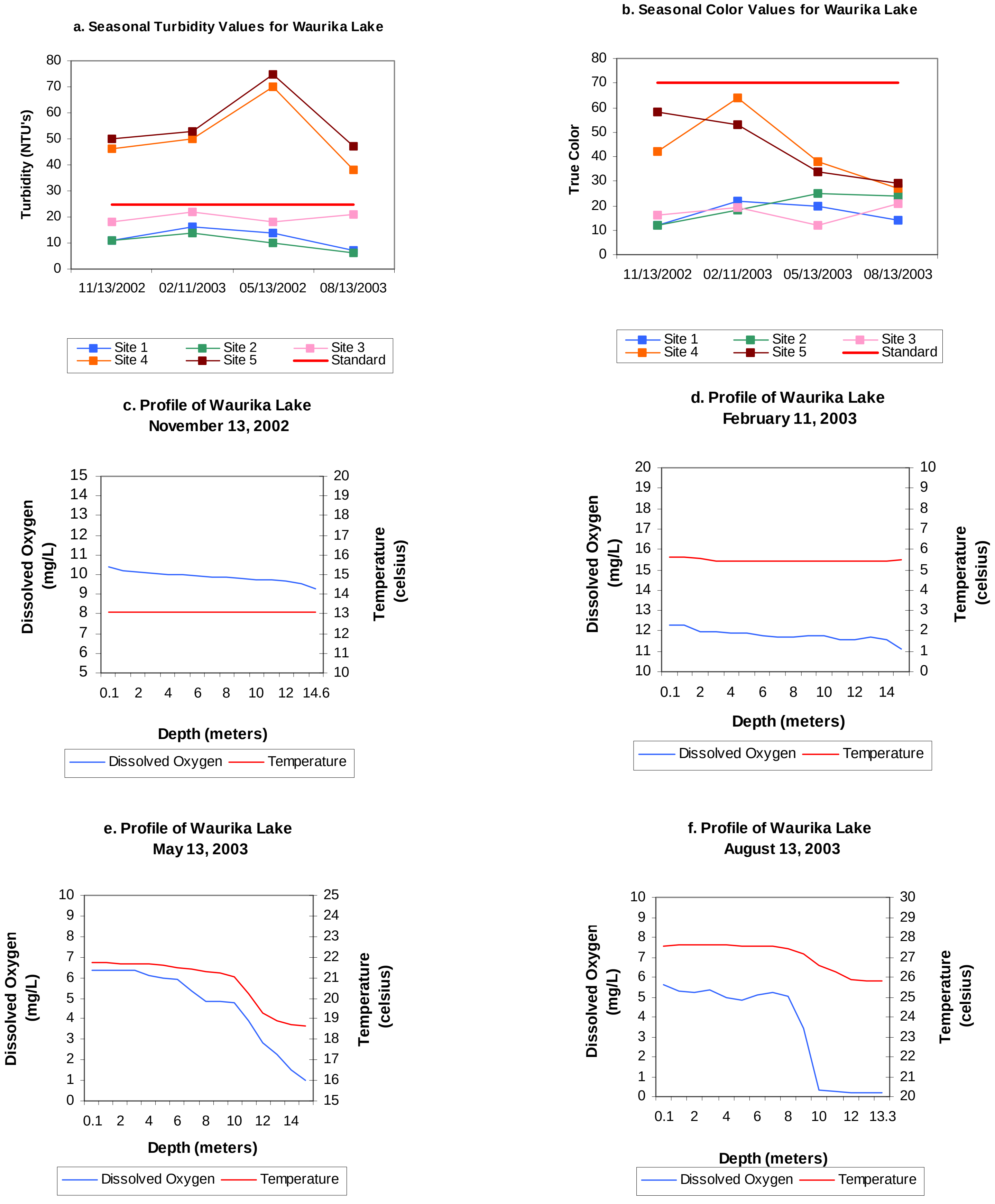
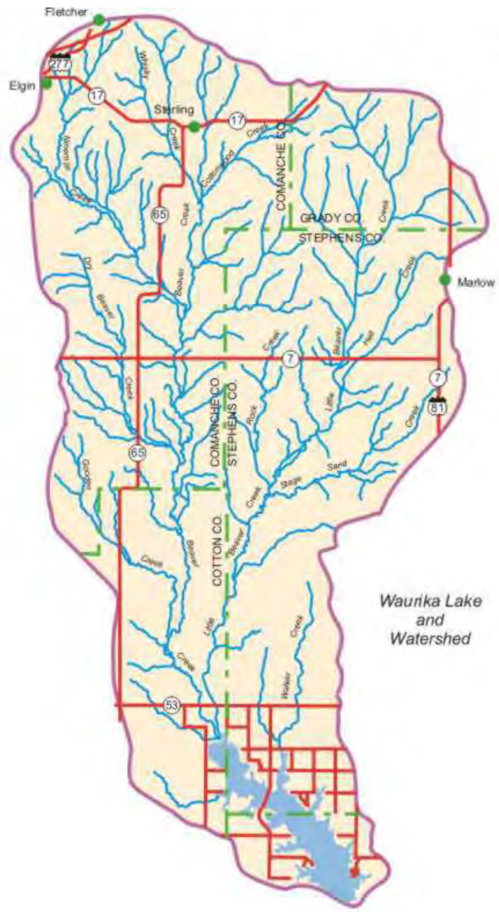
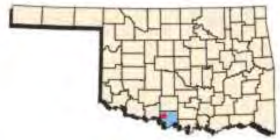


Figure 232a-223f. Graphical representation of data results for Waurika Lake.



Waurika Lake
and
Watershed



Waurika Lake
Location

Trophic State
2003

Turbidity
2003

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 105 - Lake Water Quality for
Waurika Lake

Lake Waxhoma

Lake Waxhoma was sampled for four seasons extending from October 2001 through July 2002. 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 lake-wide annual turbidity value was 7 NTU (Plate 106), true color was 30 units, and secchi disk depth was 121 centimeters. Based on these three parameters, Lake Waxhoma had excellent water clarity. 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 106), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI varied seasonally with the lakes being mesotrophic in the fall and summer quarters and oligotrophic in the winter. During the spring quarter the lake was hypereutrophic. Two data points collected in the spring were central to the lake being classified as eutrophic as they were easily many orders of magnitude greater than values seen for the rest of the year (see Figure 233). None of the nephelometric turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 234a). 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 OWQS (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 Waxhoma is fully supporting Fish & Wildlife Propagation (FWP) beneficial use based on turbidity. Seasonal true color values are displayed in Figure 234b. All true color values were below the Aesthetics OWQS and beneficial use is fully supported.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Lake salinity values ranged from 0.07 parts per thousand (ppt) in the fall, winter, spring and summer to 0.11 ppt also recorded in the summer quarter. Salinity readings were within the range of expected values for Oklahoma lakes if not very slightly elevated, and reflected the presence of moderate amounts of chlorides or other salts in the lake. Specific conductance values were also well within the range of values recorded in Oklahoma reservoirs, if not slightly lower. Values ranged from 0.153.1 mS/cm recorded in the spring quarter to 225.2 mS/cm in the summer, indicating that moderate to low levels of electrical conducting compounds (salts) were present in the lake. Oxidation-reduction potentials (redox) ranged from 16 mV at the sediment-water interface in the summer to 550 mV in the winter. Redox showed that reducing conditions were not present in the lake with the exception of site 1 in the summer when reducing conditions were present. The pH values were neutral to slightly alkaline with values ranging from 6.33 to 8.00 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 should be listed as not supporting beneficial uses. If 10 to 25% of the pH values

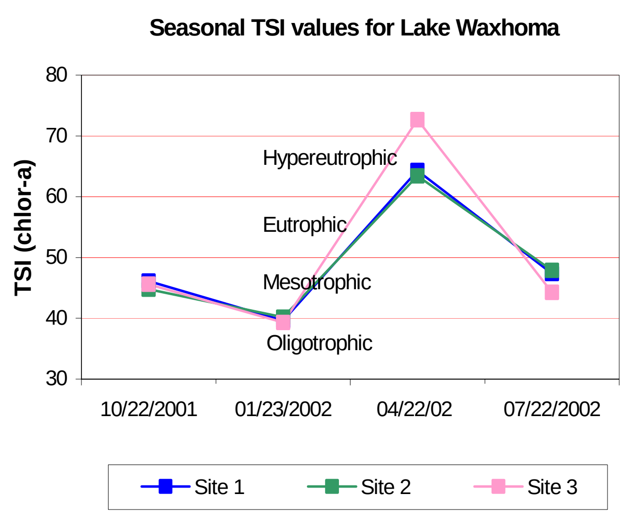


Figure 233. TSI values for Lake Waxhoma.

fall outside the 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. Lake Waxhoma is provisionally partially supporting* its FWP beneficial use for pH as 10% of the collected data fell outside the allowable range. Thermal stratification was not evident in the lake in the fall or winter quarters and dissolved oxygen (D.O.) values were above 5.8 mg/L throughout the water column at all sites (see Figure 234c-227d). In the spring quarter the lake was thermally stratified between 3 and 4 meters below the lake surface, however D.O. values were above 4.88 mg/L throughout the water column at all sites (see Figure 234e). The lake was also strongly thermally stratified in the summer quarter between 3 and 4 meters below the lake surface where the water temperature dropped almost 7° Celsius over 1 meter. From the 4-meter depth at site 1 to the lake bottom at 11.1 meters, all recorded D.O. values were less than 2.0 mg/L (see Figure 234f). 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 not supported at Lake Waxhoma as 75% of the water column had D.O. values less than 2.0 mg/L. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.55 mg/L at the lake surface. The TN at the surface ranged from 0.30 mg/L to 1.14 mg/L. The highest surface TN value was reported in the fall quarter and the lowest was in the spring. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.018 mg/L at the lake surface. The surface TP ranged from 0.013 mg/L to 0.028 mg/L. The highest surface TP value was reported in the spring and the lowest was in the fall and winter quarters. The nitrogen to phosphorus ratio (TN: TP) was approximately 30:1 for sample year 2001-2002. This value is higher than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Lake Waxhoma was also sampled for metals at three sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Lake Waxhoma was classified as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions (Plate 106). The lake was fully supporting its Aesthetics beneficial use based on its trophic status and true color values. The lake was fully supporting its FWP beneficial use for nephelometric turbidity. The FWP beneficial use was partially supported based on pH was not supporting based on D.O. values less than 2.0 mg/L. With the exception of the D.O. concerns in the lake, Waxhoma is one of the nicer small municipal lakes in Oklahoma. Its excellent water clarity actually promotes some of the water quality problems observed. Lake Waxhoma 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.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the “other than by natural causes” clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

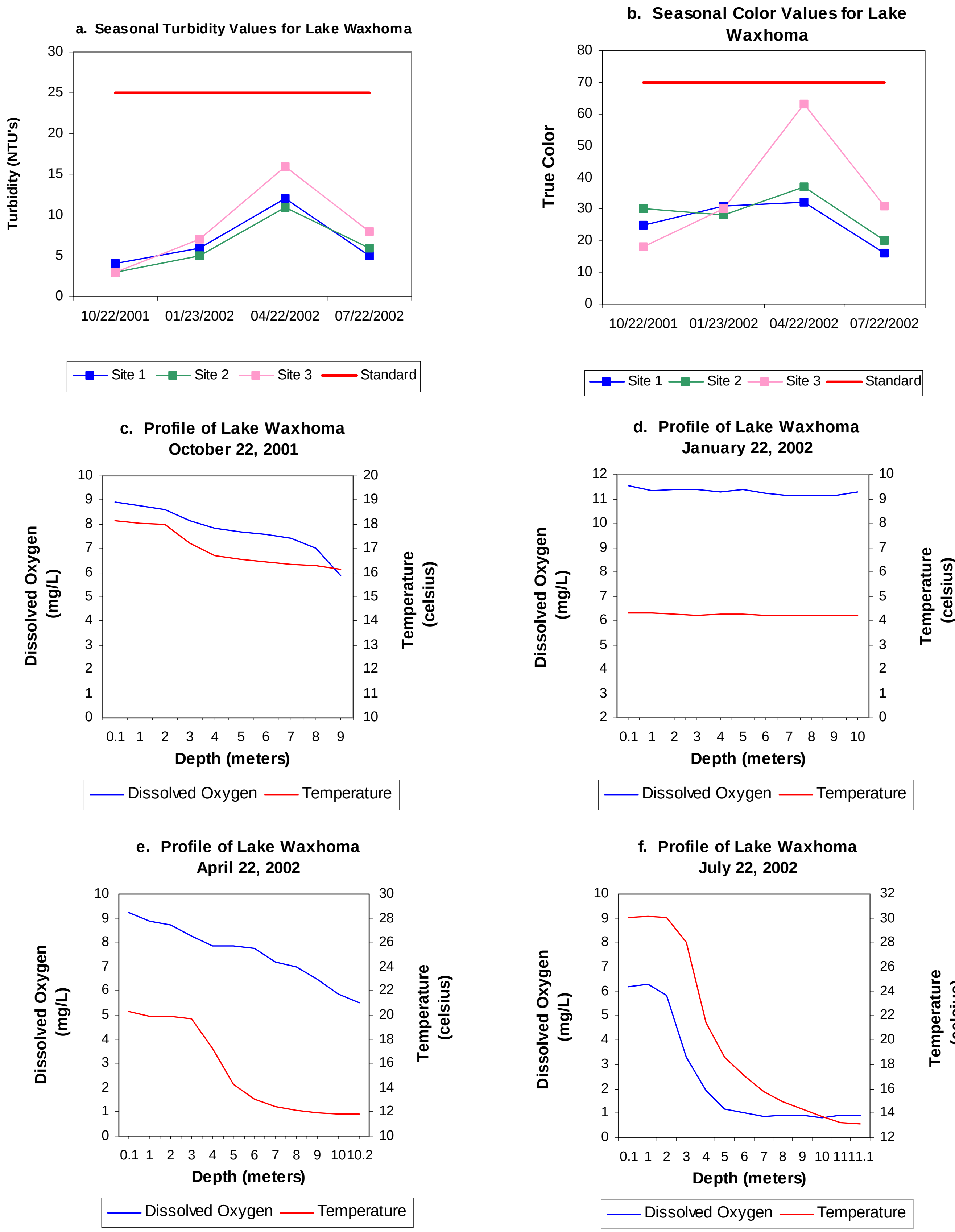
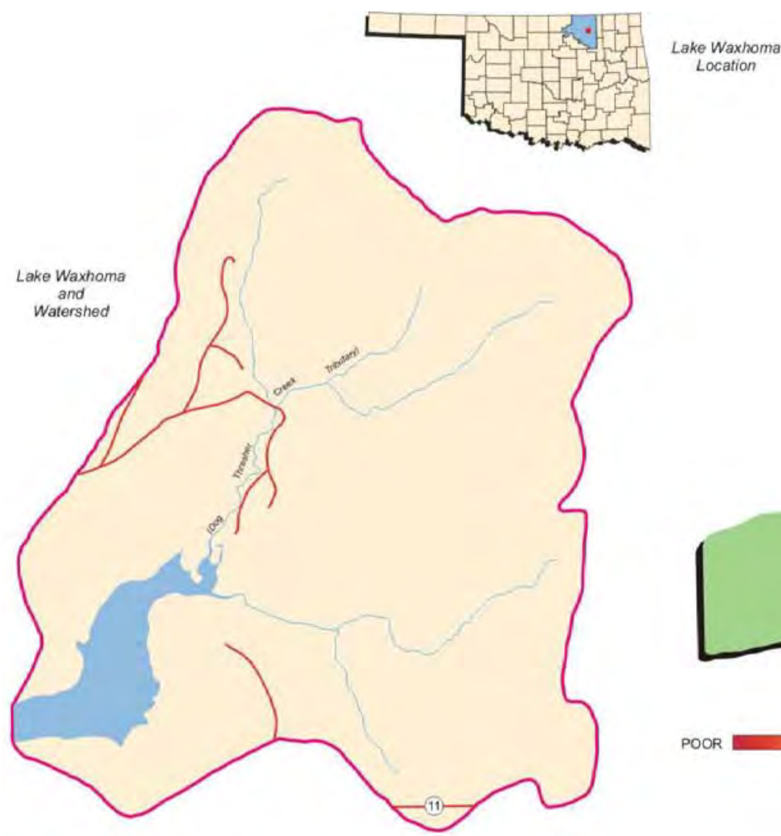
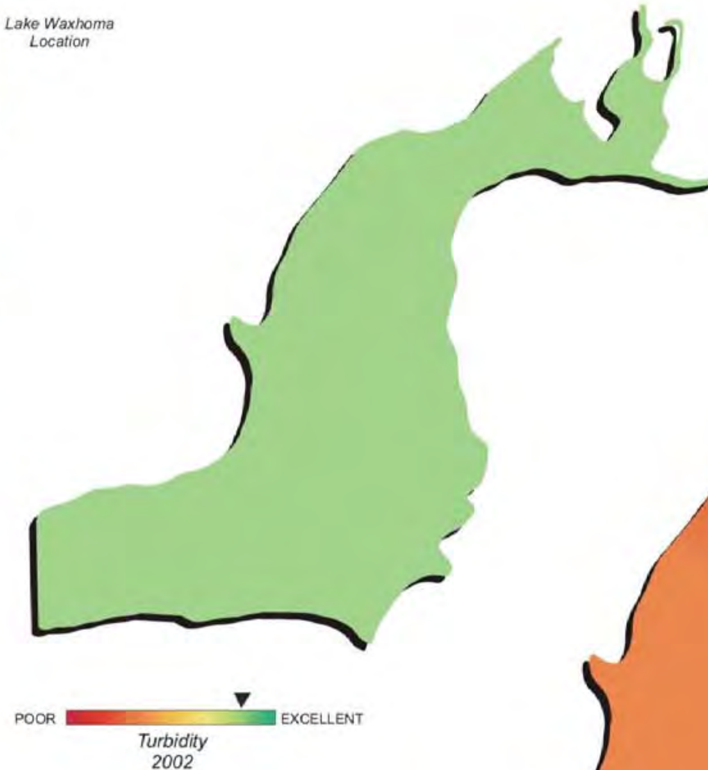
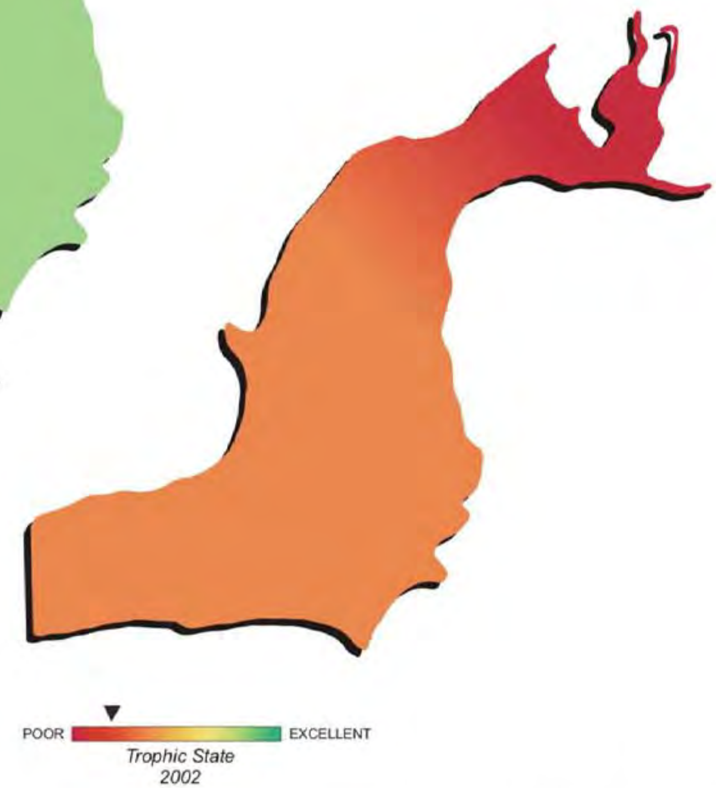


Figure 234a-227f. Graphical representation of data results for Lake Waxhoma.







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 106 - Lake Water Quality for

Lake Waxhoma

Lake Wayne Wallace

Lake Wayne Wallace was sampled for four quarters, from November 2002 through August 2003. 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 13 NTU (Plate 107), true color was 58 units, and average secchi disk depth was 105 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 44 (Plate 107), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrient conditions. This classification differs from 2000 (TSI=56), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. The TSI values were fairly consistent ranging from mesotrophic in the first three sampling quarters to oligotrophic at sites 2 and 3 the summer (see Figure 235). Seasonal turbidity values are displayed in Figure 236a. All turbidity values were below the Oklahoma Water Quality Standard (OWQS) 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 OWQS (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 236b. Of the twelve true color values collected, five (42%) were above the OWQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered not supported.

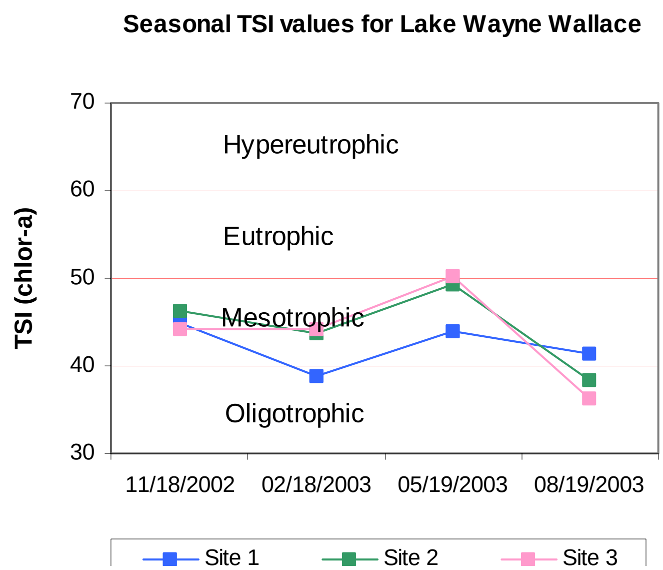


Figure 235. TSI values for Lake Wayne Wallace.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, 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 2002-2003. This is lower than the average the range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 21.3 mS/cm to 71.1 mS/cm, indicating the presence low levels of current conducting ions (salts or chlorides) in the lake system. The pH values ranged from 5.92 to 7.05 representing a slightly acidic to neutral system. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. With approximately 39% of the values recorded being less than 6.5 the lake should be listed as not supporting based on pH. The low pH values recorded primarily in the spring at Lake Wayne Wallace may be due to natural conditions as slightly acidic conditions are also seen in other lakes in this region of the state, and will be listed as "provisionally not supporting"***** the FWP. Oxidation-reduction potentials (ORP) ranged from 313 mV to 552 mV, indicating reducing conditions were not present at this reservoir in sample year 2002-2003. During the fall and winter sampling intervals stratification was not evident and the water column was well mixed with dissolved oxygen (D.O.) values generally above 7.0 mg/L (Figure 236c-229d). In the spring, the lake was stratified at several 1-meter intervals at site 1, however dissolved oxygen never dropped below 2.0 mg/L (Figure 236e). In the summer, thermal stratification was evident and anoxic conditions were present below the thermocline, at both sites 1 and 2 (Figure 236f). 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 56 to 69% of the water less than 2.0 mg/L in the summer, Lake Wayne Wallace is considered partially supporting the FWP beneficial use and 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. The Agriculture beneficial use was 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.64 mg/L at the surface and 0.65 mg/L at the lake bottom. Surface TN ranged from 0.31 mg/L to 2.18 mg/L with the highest values recorded in the spring quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.021 mg/L at the surface and 0.080 mg/L at the lake bottom. The surface TP was highest in the spring quarter but the lowest value was reported in the summer with values ranging from 0.014 mg/L to 0.030 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 29:1 for sample year 2003. This value 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 2002-2003. This classification differs from 2000 (TSI=56), however the current calculation is based on data collected year round versus growing season only and is likely a more accurate depiction of productivity within the lake. 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 39% of the pH values less than 6.5 the lake will be listed as "provisionally not supporting"***** the FWP. The Aesthetics beneficial use is considered supported in regards to trophic status and true color. Lake Wayne Wallace, located in Latimer County is owned by the State of Oklahoma and is utilized for flood control and recreation purposes.

***** Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the "other than by natural causes" clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

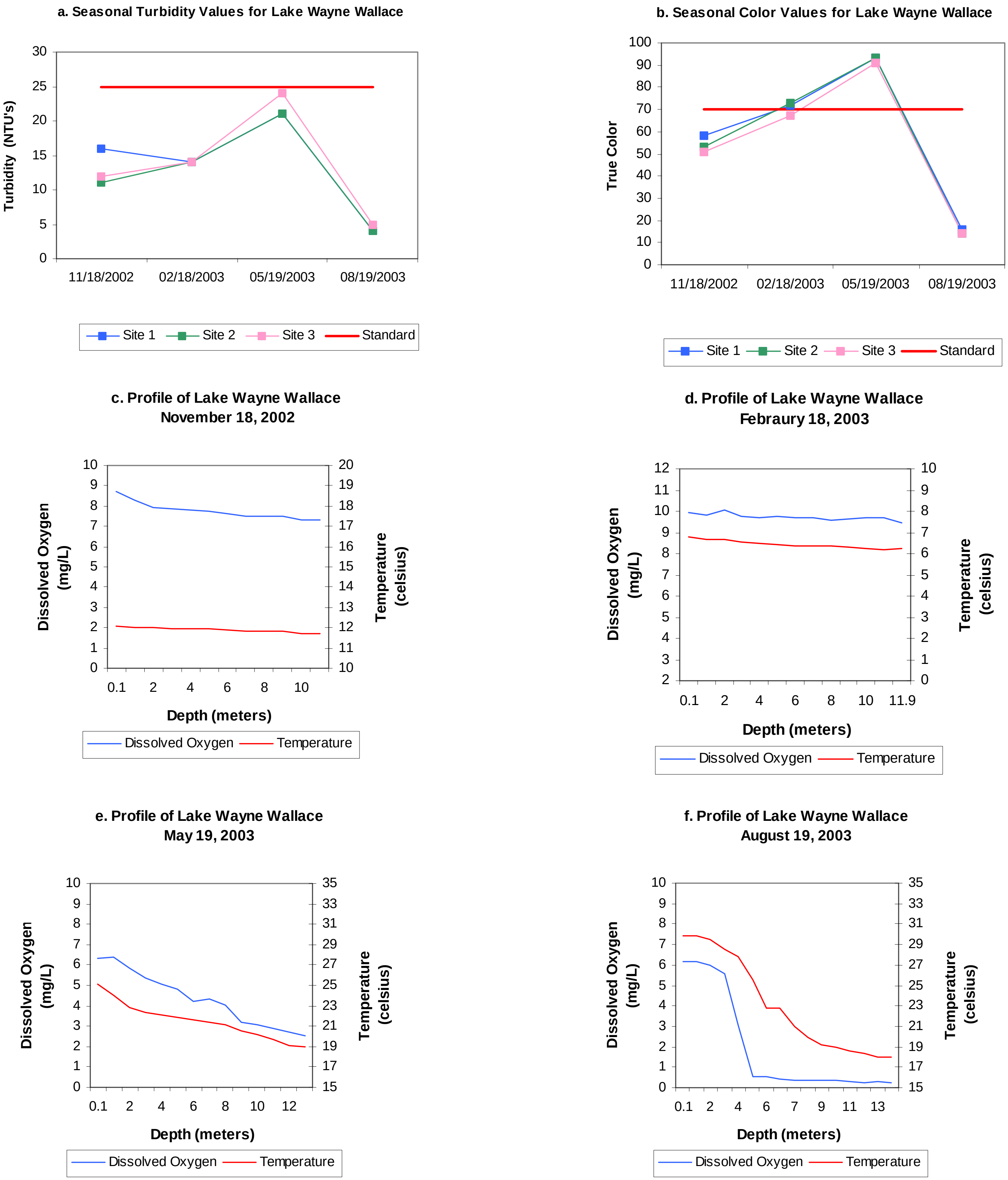
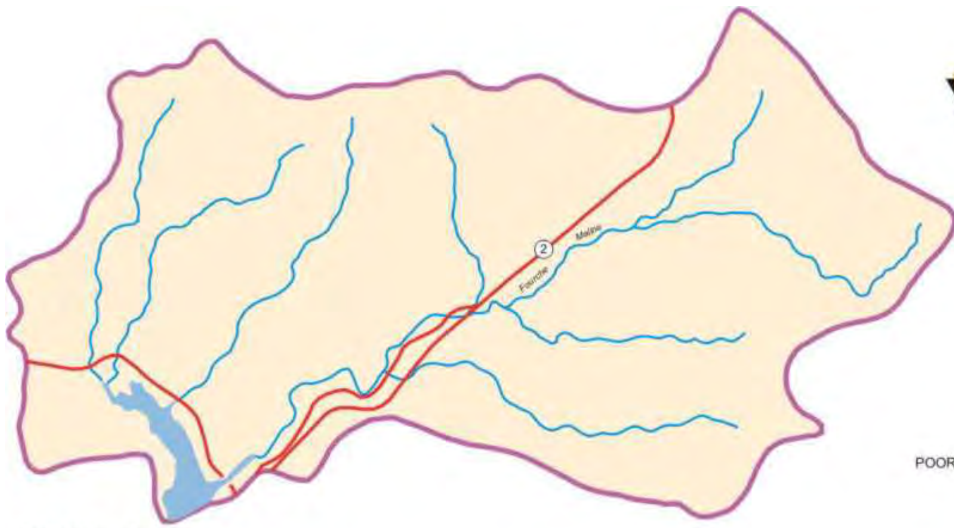
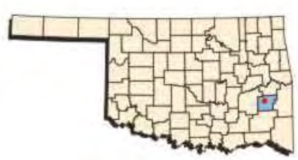


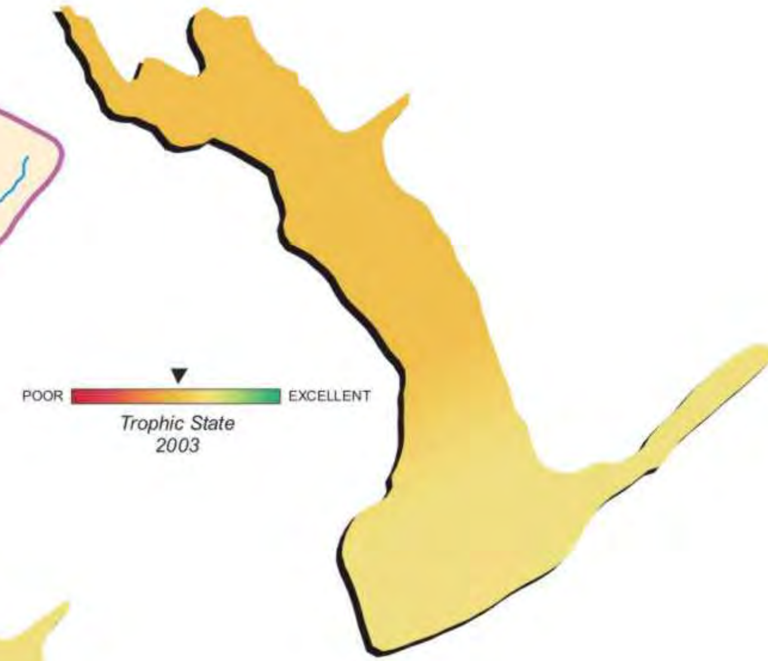
Figure 236a-229f. Graphical representation of data results for Lake Wayne Wallace.

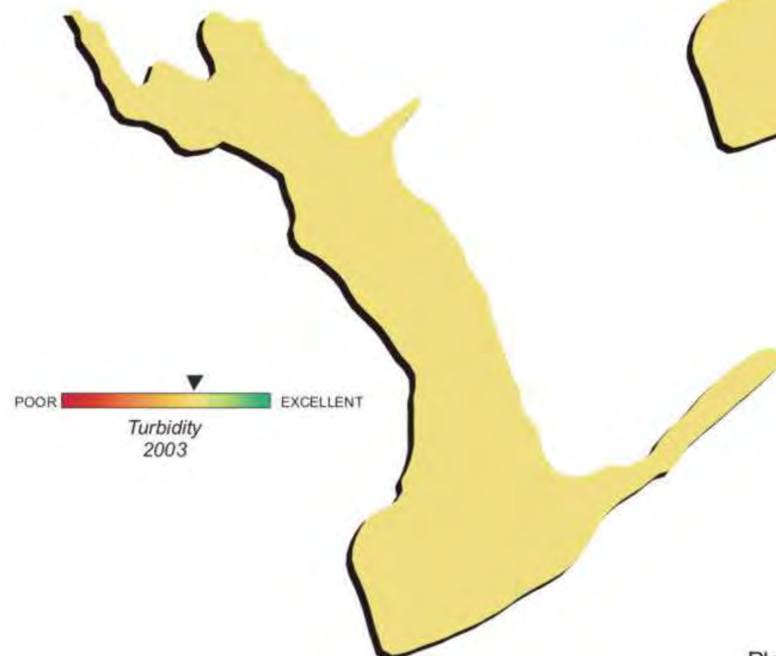


Lake Wayne Wallace
and
Watershed



Lake Wayne Wallace
Location





N
W
E
S

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 107 - Lake Water Quality for
Lake Wayne Wallace

Webbers Falls Reservoir

Webbers Falls Reservoir was sampled from October 2000 through July 2001. Water quality samples were collected at six 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 lake-wide annual turbidity value was 18 NTU, true color was 47 units, and secchi disk depth was 57 centimeters in 2001. Based on these three parameters, Webbers Falls Reservoir had average water clarity, similar to water clarity in the summer of 1997 and certainly reflective in the summer of 2001. 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 57, classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is less than the TSI in 1997 (TSI=61), based on four summer values. The TSI values were primarily eutrophic throughout the year (67% of samples) at all sites although the TSI at several sites was hypereutrophic in the fall and summer (sites 1, 4, and 6) or oligotrophic at one site in the winter and summer (sites 1 and 3, respectively). 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. Six of the 24 turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU; however, although 25% of the samples were above the standard, the lake was listed as partially supporting the 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 OWQS (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 standard of 25 NTU except in the spring, when turbidity values at all 6 sites were above the criteria probably due to seasonal rain events. All true color values throughout the year were below the standard, with the exception of sites 3 and 5 in the fall. Currently, the Aesthetics beneficial use is considered fully supported. 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.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Wes Watkins (North Deer Creek) Reservoir

Wes Watkins (North Deer Creek) Reservoir was sampled four seasons extending from October 2001 through July 2002. Water quality samples were collected at four (4) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. An additional sample was collected at site 5 at the lake surface for the determination of nephelometric turbidity and chlorophyll-a analysis. 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 15 NTU (Plate 108), true color was 38 units, and secchi disk depth was 73 centimeters in 2001-2002. Based on these three parameters, Wes Watkins (North Deer Creek) Reservoir had average to good water clarity. 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 108), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values fluctuated based on season and site location, but in general the lake was mesotrophic in the spring quarter and eutrophic during the other three quarters (see Figure 237). Only one of the 20 turbidity values exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 238a). 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 OWQS (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 standard of 25 NTU except in the fall, when a turbidity value of 27 NTU was recorded at site 1, so with only 5% of the values exceeding the criteria; the lake is fully supporting its Fish & Wildlife Propagation (FWP) beneficial use. Seasonal true color values are displayed in Figure 238b. All true color values throughout the year were below the Aesthetics criteria of 70 units, however the use could not be definitively assessed due to insufficient data. Collected data does strongly support the supposition that the lake would be fully supporting the Aesthetics use if minimum data requirements were met.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Lake salinity values ranged from 0.05 parts per thousand (ppt) in the fall to 0.11 ppt in the summer, well within the range of expected values for Oklahoma lakes, reflecting moderate levels of chlorides or other salts in the lake. Specific conductance values were within the range of expected values recorded in Oklahoma reservoirs. Values ranged from 114.9 mS/cm in the fall quarter to 230.5 mS/cm in the summer quarter, indicating that moderate levels of electrical conducting compounds (salts) were present in the lake. Oxidation-reduction potentials ranged from 36 mV at the sediment-water interface in the summer to 506 mV in the fall, indicating that slightly reducing conditions were present in the summer quarter, but were not present for the rest of the year. The pH values were neutral to slightly alkaline with values ranging from 6.73 units to 8.45 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the

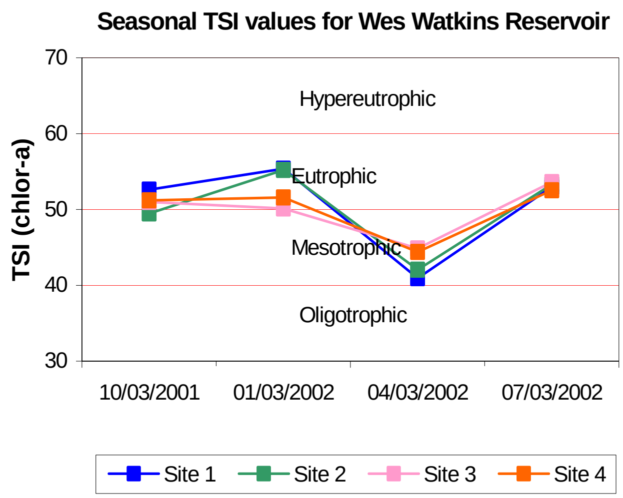


Figure 237. TSI values for Wes Watkins Reservoir.

6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. With all 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 238c-231e). However, dissolved oxygen (D.O.) values in the fall were below 1.0 mg/L in the fall quarter at site 1. Generally the water column was fairly well oxygenated and mixed with D.O. values in the winter and spring staying well above 8.0 mg/L and even in the fall levels were generally above 4.0 mg/L in the bulk of the water column (see Figure 238a-231e). In the summer quarter the lake was very strongly thermally stratified between 4 and 5 meters below the lake surface. From the 5 meters depth to the lake bottom at 8 meters at site 1, D.O. values were all less than 1.0 mg/L (see Figure 238f). 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 fully supported at Wes Watkins (North Deer Creek) Reservoir with only 22% of the water column with D.O. values less than 2.0 mg/L in the fall quarter and 44% in the summer quarter. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.75 mg/L at the lake surface. The TN at the surface ranged from 0.49 mg/L to 1.09 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 year 2001-2002 was 0.029 mg/L at the lake surface. The surface TP ranged from 0.021 mg/L to 0.035 mg/L. The highest surface TP value was reported in the winter and the lowest was in the fall quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 25:1 for sample year 2001-2002. This value is higher than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Wes Watkins Reservoir was also sampled for metals at four sites during the spring quarter in 2002. Use support assessment for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use based on metal (toxic) 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 108). The lake was fully supporting its Aesthetics beneficial use based on its trophic state and data strongly supports the supposition that it would be fully supporting for true color if sufficient data had been available. With only 5% of the water column exceeding the turbidity criteria the lake is fully supporting its FWP beneficial use for nephelometric turbidity and all of the pH values were within the acceptable range so it was fully supporting for pH. The FWP beneficial use was also fully supported for D.O. based on collected data.

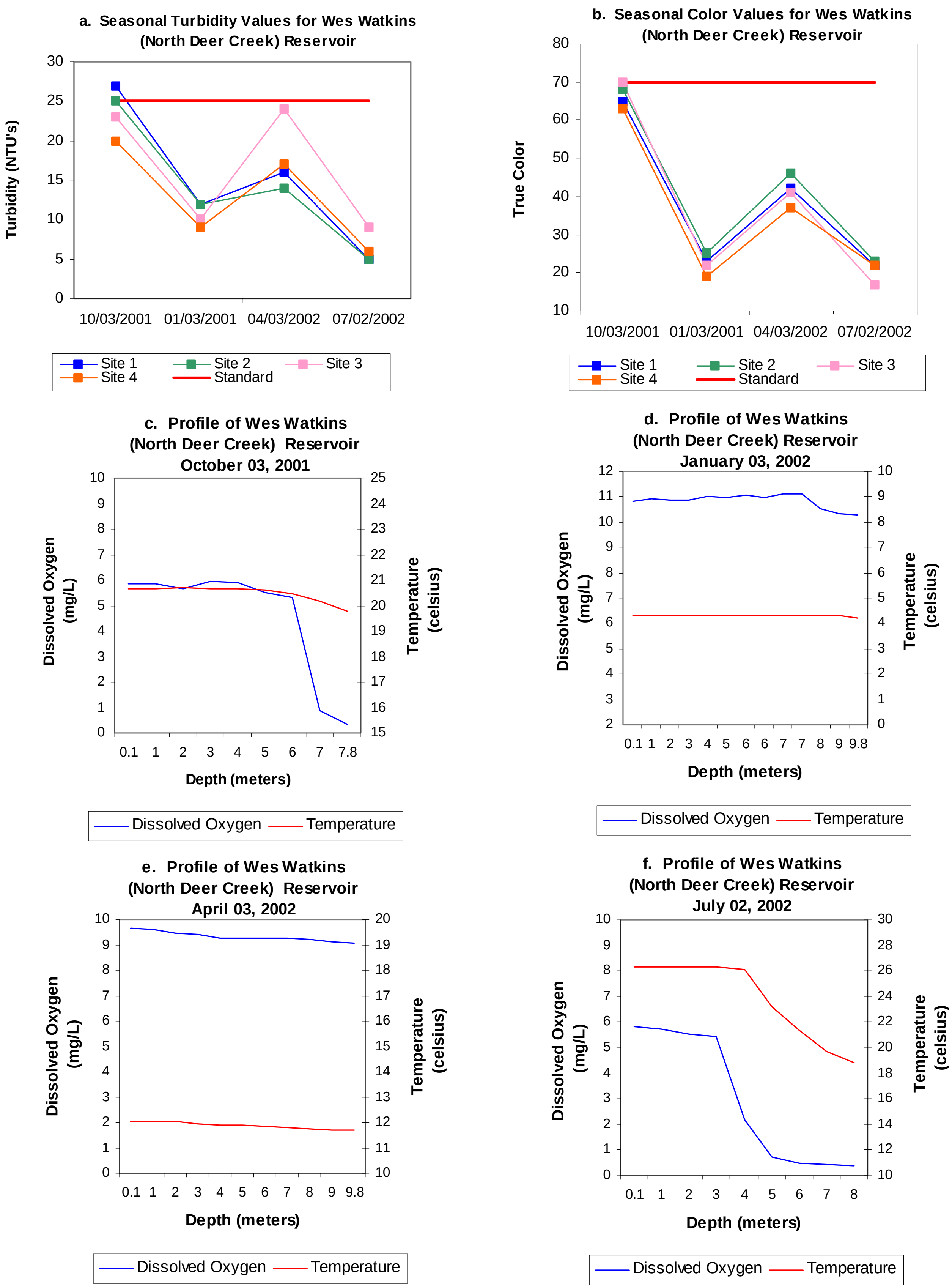
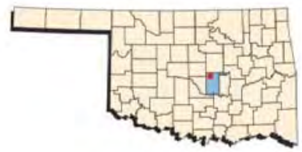


Figure 238a-231f. Graphical representation of data results for Wes Watkins (North Deer Creek) Reservoir.

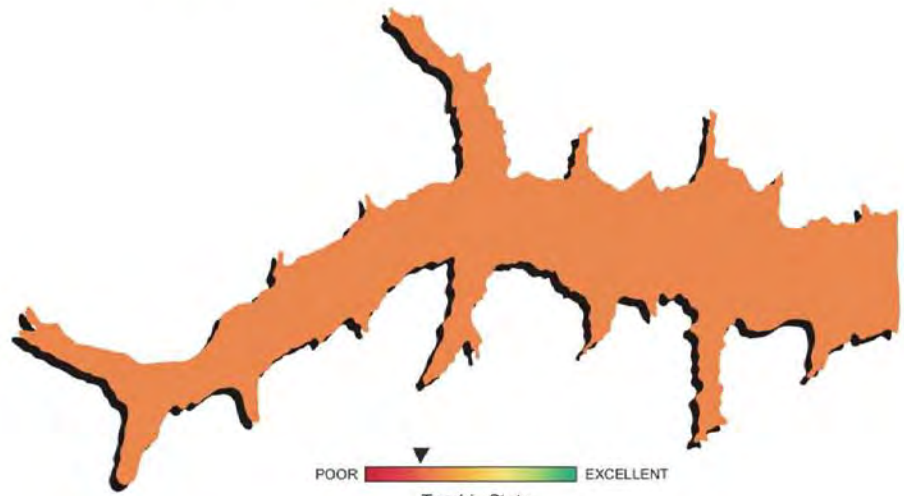


Wes Watkins Lake
Location

North Deer Creek Lake
and
Watershed

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

Turbidity
2002



Trophic State
2002

Plate 108 - Lake Water Quality for
Wes Watkins Reservoir

Wetumka Lake

Wetumka Lake (169 surface acres) was sampled for four quarters, from October 2000 through July 2001. 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. A minimum of 10 samples is required to make beneficial use determinations in lakes less than 250 surface acres specified in the Use Support Assessment Protocols (USAP) outlined Oklahoma Administrative Code (OAC) 785:45-15-4. The lake-wide annual turbidity value was 15 NTU, true color was 44 units, and secchi disk depth was 82 centimeters in 2001. Based on these three parameters, Wetumka Lake had good water clarity, similar to previous values although clarity was better in the summer of 1998. The trophic state index (TSI), using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=10). The average TSI was 52, classifying the lake as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions. This value is much higher than the one calculated in 1998 (TSI=43); although the seasonal variability in 2001 also indicates the summer is the less productive season. Obviously, sampling Wetumka Lake in only one season, like the historical summer sampling regime, is not representative of lake trophic conditions. TSI values ranged from mesotrophic/oligotrophic in the summer to eutrophic bordering hypereutrophic in the winter. The peak in chlorophyll-a at all sites in the winter is uncommon in most lakes, but also occurred at several other lakes across this state in 2001. Turbidity values varied from below the Oklahoma Water Quality Standard (OWQS) of 25 NTU in the fall, winter, and summer at all sites to above the standard at all sites in the spring. 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 OWQS (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 samples collected in 2001 were above the standard, the lake is listed as partially supporting the Fish & Wildlife Propagation (FWP) beneficial use as the spike in turbidity in the spring was probably due to seasonal rain events. True color values were below the aesthetics OWQS of 70 throughout the year, except at site 1 in the spring quarter. Currently, the Aesthetics beneficial use is considered fully supported.

Please refer to the "Beneficial Use Monitoring Program (BUMP) 2001 Draft Final Report" for a more intensive discussion of monitoring results on this lake. The report may be accessed via the Agency's web page at http://www.owrb.state.ok.us/reports/Bump/Bump1.html or you may contact the Water Resources Board for a copy of the 2001 BUMP Final Report on CD. The OWRB may be reached at (405) 530-8800 (ask for Nikki Cole) or at the following address;

Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK. 73118
Attn: Nikki Cole

Wewoka Lake

Wewoka Lake was sampled from October 2001 through July 2002 comprising four seasons. Water quality samples were collected at three (3) sites to represent the riverine, transitional, and lacustrine zones of the reservoir. In addition, samples were collected at the lake surface at sites 4 and 5 for the purpose of looking at nephelometric turbidity and chlorophyll-a concentrations. 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 25 NTU (Plate 109), true color was 72 units, and secchi disk depth was 49 centimeters. Based on these three parameters, Wewoka Lake had fair to poor water clarity, similar to water clarity. A trophic state index, 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 109), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. The TSI values for the lake was fairly consistent from season to season and were primarily eutrophic throughout the year, the exception being in the winter quarter when the lake was classified as mesotrophic (see Figure 239). Of the 20 turbidity values generated, 30% of them exceeded the Oklahoma Water Quality Standard (OWQS) of 25 NTU (see Figure 240a). 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 OWQS (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 not supporting its Fish & Wildlife Propagation (FWP) beneficial use for nephelometric turbidity. Seasonal true color values are displayed in Figure 240b. Of the true color values collected, 42% exceeded the Aesthetics numerical criteria of 70 units. However, a use support determination could not be made due to insufficient data. Available information strongly suggests that the lake would not be supporting its Aesthetics use for true color.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Lake salinity values ranged from 0.05 parts per thousand (ppt) in the fall, winter and spring quarters to 0.10 ppt in the summer. Data was consistent with the range of expected values for Oklahoma lakes, reflecting moderate amounts of chlorides or other salts in the lake. Specific conductance values were also consistent with the expected range of values recorded in Oklahoma reservoirs, if not somewhat lower. Values ranged from 120.4 mS/cm in the spring quarter to 221.3 mS/cm in the summer quarter near the lake bottom, indicating that low to moderate levels of electrical conducting compounds (salts) were present in the lake. Oxidation-reduction potentials (redox) ranged from 29 mV at the sediment-water interface in the summer to 504 mV in the fall quarter, indicating reducing conditions were not present. The pH values were neutral with values ranging from 6.85 units to 7.84 units. According to USAP (OAC 785:46-15-5),

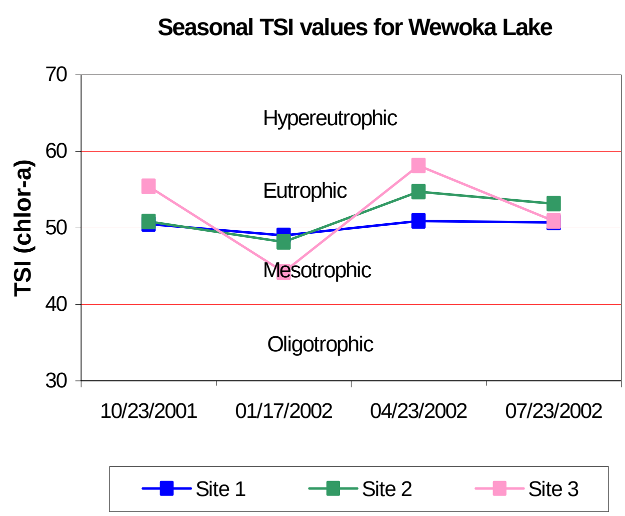


Figure 239. TSI values for Wewoka Lake.

pH values are exceeding standards if they fall outside the 6.5 to 9.0 range 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 6.5 to 9.0 range, the lake should be listed as partially supporting beneficial uses. Wewoka Lake pH values were all within the acceptable range so the FWP beneficial use is fully supported. Thermal stratification was not evident in the fall or winter quarters and dissolved oxygen (D.O.) values never fell below 6.4 mg/L in the water column at any site (see Figure 240c-233d). In the spring quarter, the lake was thermally stratified between 5 and 6 meters below the surface. However, D.O. values were above 2.6 mg/L throughout the water column at all sites and were generally above 5.4 mg/L (see Figure 240e). In the summer quarter, the lake was strongly thermally stratified between 4 and 5 meters below the surface. From 4 meters to the lake bottom at 7.6 meters, D.O. values were below 1.1 mg/L at site 1 (see Figure 240f). 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 fully supported at Wewoka Lake because 44% of the water column was less than 2.0 mg/L in the summer. The lake was sampled for total dissolved solids, chlorides and sulfates to assess its Agriculture beneficial use. Sampling in 2001-2002 found the Agriculture beneficial use to be fully supported based on numerical criteria located in OAC 785:45 – Appendix F.

Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001-2002 was 0.54 mg/L at the lake surface. The TN at the surface ranged from 0.27 mg/L to 0.76 mg/L. The highest surface TN value was reported in the spring quarter and the lowest was in the winter. The lake-wide total phosphorus (TP) average for sample year 2001-2002 was 0.042 mg/L at the lake surface. The surface TP ranged from 0.028 mg/L to 0.075 mg/L. The highest surface TP value was reported in the spring and the lowest was in the summer quarter. The nitrogen to phosphorus ratio (TN: TP) was approximately 13:1 for sample year 2001-2002. This value is higher than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

Wewoka Lake was sampled for metals at three sites during the spring of 2002. Use support for metals is made in the same fashion as turbidity and true color. Results of metals sampling showed the lake to be fully supporting its FWP beneficial use and Public and Private Water Supply (PPWS) beneficial use based on metal (toxic) compounds in the water column.

In summary, Wewoka Lake was classified as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions (Plate 109). The lake was fully supporting its Aesthetics beneficial use for trophic status, but insufficient data was available to assess the true color support, though available information strongly suggests it would not be supporting. Wewoka Lake was not supporting its FWP beneficial use for nephelometric turbidity, but was fully supporting the use for pH and D.O. concentrations in the water column. 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.

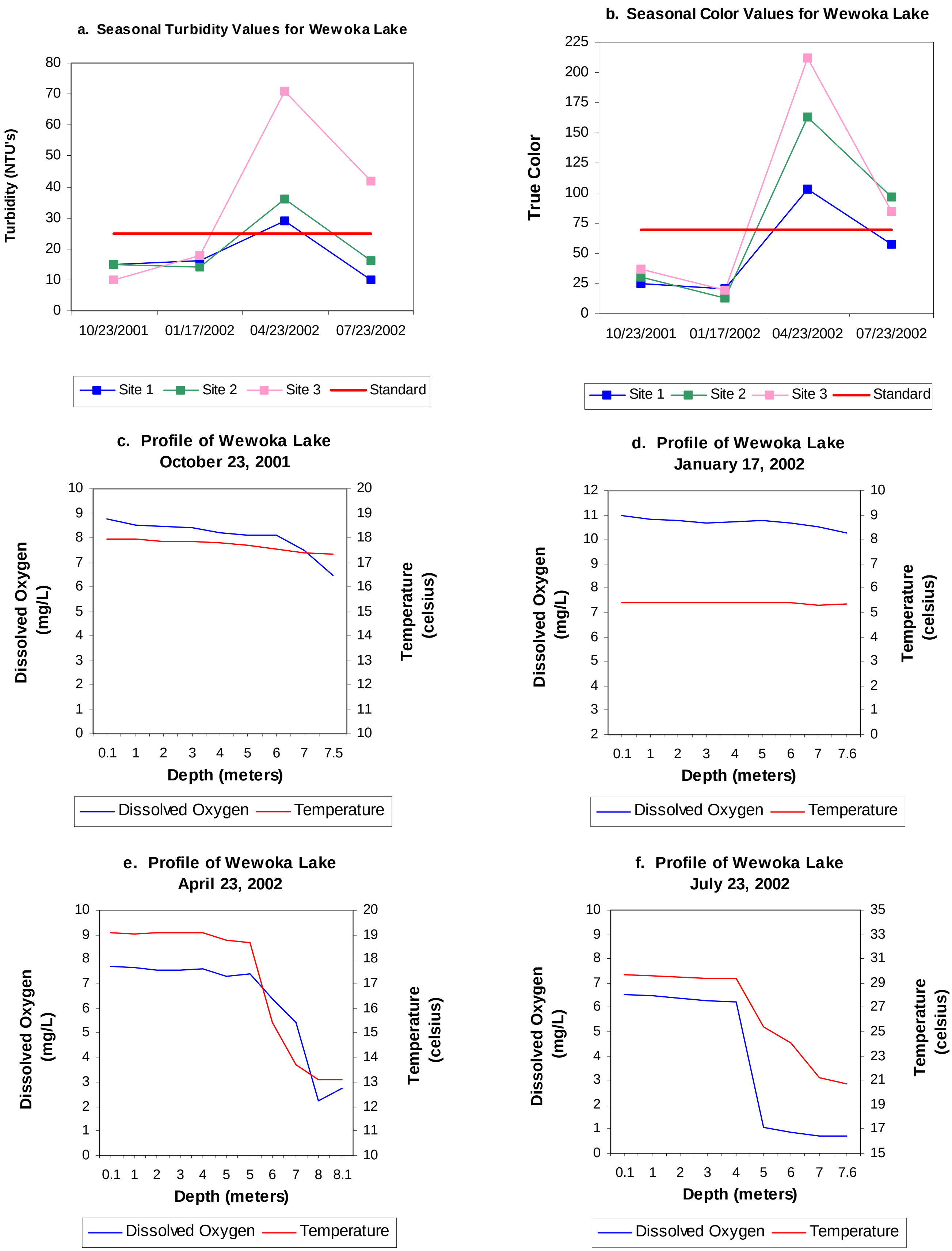


Figure 240a-233f. Graphical representation of data results for Wewoka Lake.

Wewoka Lake
and
Watershed

Wewoka Lake
Location

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
2002

POOR EXCELLENT
Trophic State
2002

Plate 109 - Lake Water Quality for
Wewoka Lake

Wister Lake

Wister Lake was sampled for four quarters, from November 2002 through August 2003. Water quality samples were collected at three (3) sites in the fall and winter and from five (5) sites in the spring and summer to represent the riverine, transitional, and lacustrine zones of the reservoir. Additional sites were added to ensure sample size was representative for a lake greater than 250 surface acres. 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 72 NTU (Plate 110), true color was 177 units, and average secchi disk depth was 26 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 54 (Plate 110), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient conditions. This is similar to 2000 (TSI=59), indicating no significant increase or decrease in productivity has occurred since the 2000 evaluation. The TSI values were fairly consistent ranging from eutrophic in the fall, winter and spring quarters to mesotrophic in the spring. The only exception was site 3, which was classified hypereutrophic in the summer (Figure 241). Wister Lake is listed in the Oklahoma Water Quality Standards (OWQS) as a Nutrient Limited Watershed (NLW) indicating that its Aesthetics use is threatened due to nutrients (based on trophic status). A nutrient impairment study should be conducted to determine if uses are impaired. Seasonal turbidity values are displayed in Figure 242a. Turbidity values ranged from a low of 24 NTU to a maximum of 126 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 OWQS (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 90% 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 242b. All true color values were above the OWQS of 70 units. Applying the same default protocol, the Aesthetics beneficial use is considered not supported based on true color.

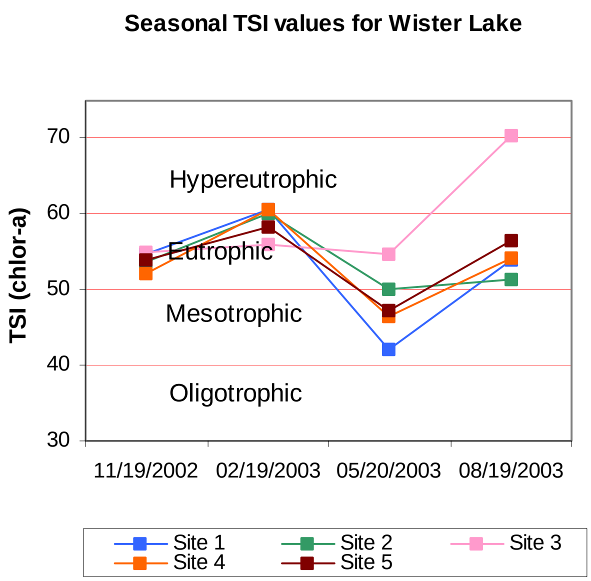


Figure 241. TSI values for Wister Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.01 parts per thousand (ppt) to 0.02 ppt in sample year 2002-2003. This is lower than the average the range of values recorded in Oklahoma reservoirs. Specific conductance ranged from 41.6 mS/cm to 66.1 mS/cm, indicating the presence of low levels of current conducting ions (salts or chlorides) in the lake system. The pH values ranged from 6.04 to 7.49 representing a slightly acidic to neutral system. 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 should be listed as not supporting beneficial uses. 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 beneficial uses. With approximately 58% of the values recorded being less than 6.5 the lake should be listed as not supporting based on pH. The low pH values recorded primarily in the spring and summer months at Wister Lake may be due to natural conditions as slightly acidic conditions are also seen in other lakes in this region of the state, and will be listed as "provisionally not supporting"* the FWP. Oxidation-reduction potentials (ORP) ranged from 455 mV to 574 mV, indicating reducing conditions were not present at this reservoir in sample year 2002-2003. During the fall, winter, and spring sampling intervals, stratification was not evident and the water column was well mixed (Figure 242c-235e). 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 242f). 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 fully supporting the FWP beneficial use with less than 20% 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 2002-2003 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. The PBCR beneficial use is considered fully supported for sample year 2002-2003.

Collected water quality samples were analyzed for nutrients including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average was 0.64 mg/L at the surface and 0.62 mg/L at the lake bottom. Surface TN ranged from 0.05 mg/L to 1.95 mg/L with the highest values recorded in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average was 0.113 mg/L at the surface and 0.184 mg/L at the lake bottom. Similar to TN, the surface TP was highest in the summer quarter and lowest in the winter with values ranging from 0.041 mg/L to 0.182 mg/L. The nitrogen to phosphorus ratio (TN:TP) was approximately 6:1 for sample year 2003. This value is slightly less 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 2000 (TSI=59), 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 (OWQS) and is considered nutrient threatened and a nutrient impairment study should be conducted to determine if uses are impaired. Water clarity was poor based on turbidity, true color and secchi disk depth. The FWP beneficial use is supported based on dissolved oxygen, but not supported based on high turbidity values recorded throughout the year. With 58% of the recorded pH values less than 6.5 the lake will be listed as "provisionally not supporting"* the FWP. The Aesthetics beneficial use is considered supported in regards to trophic status but not supported based on true color values. In 2002, the OWRB conducted a bathymetric survey of Wister Lake () 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 Kathy Koon 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.

* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the “other than by natural causes” clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.

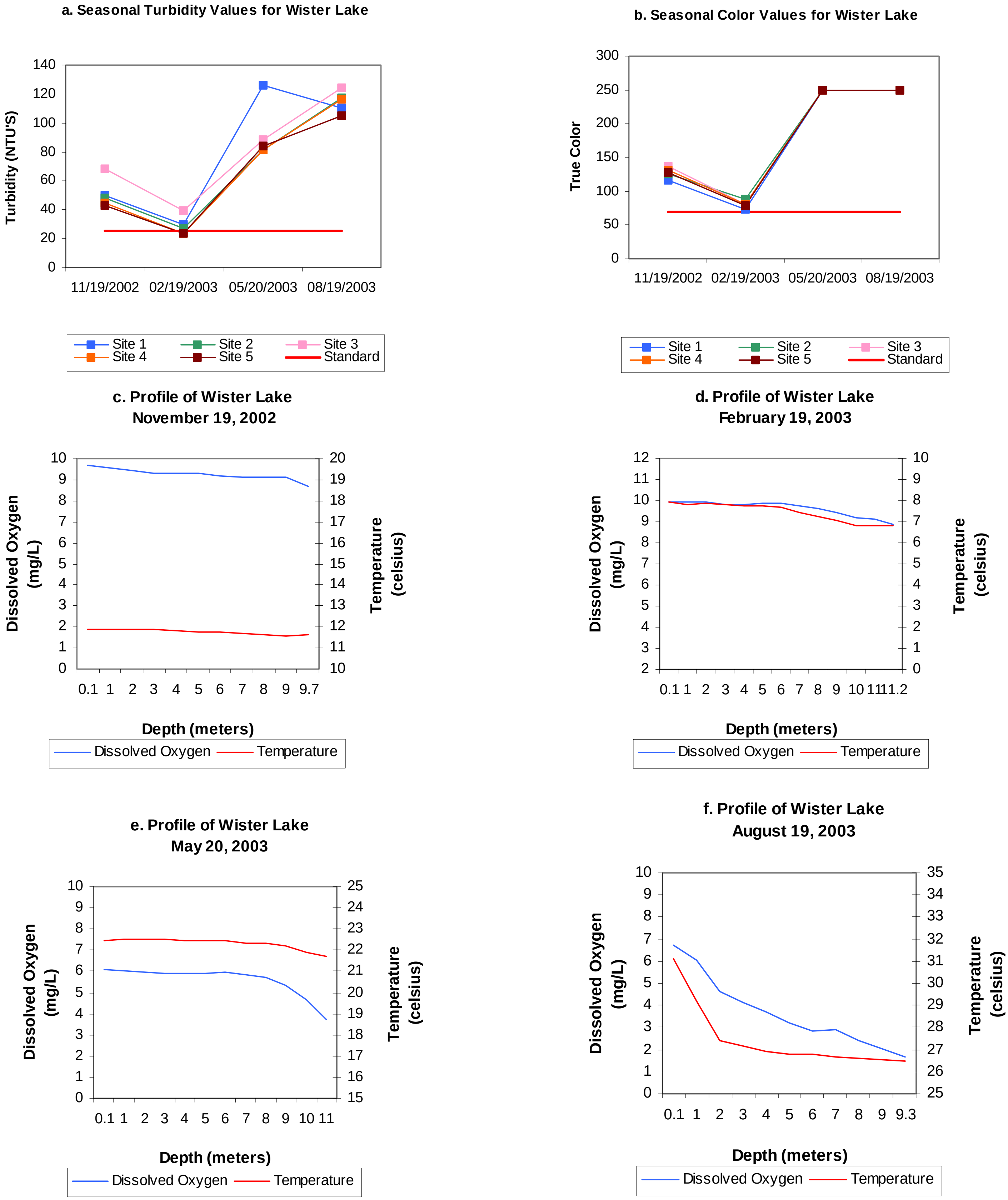


Figure 242a-235f. Graphical representation of data results for Wister Lake.

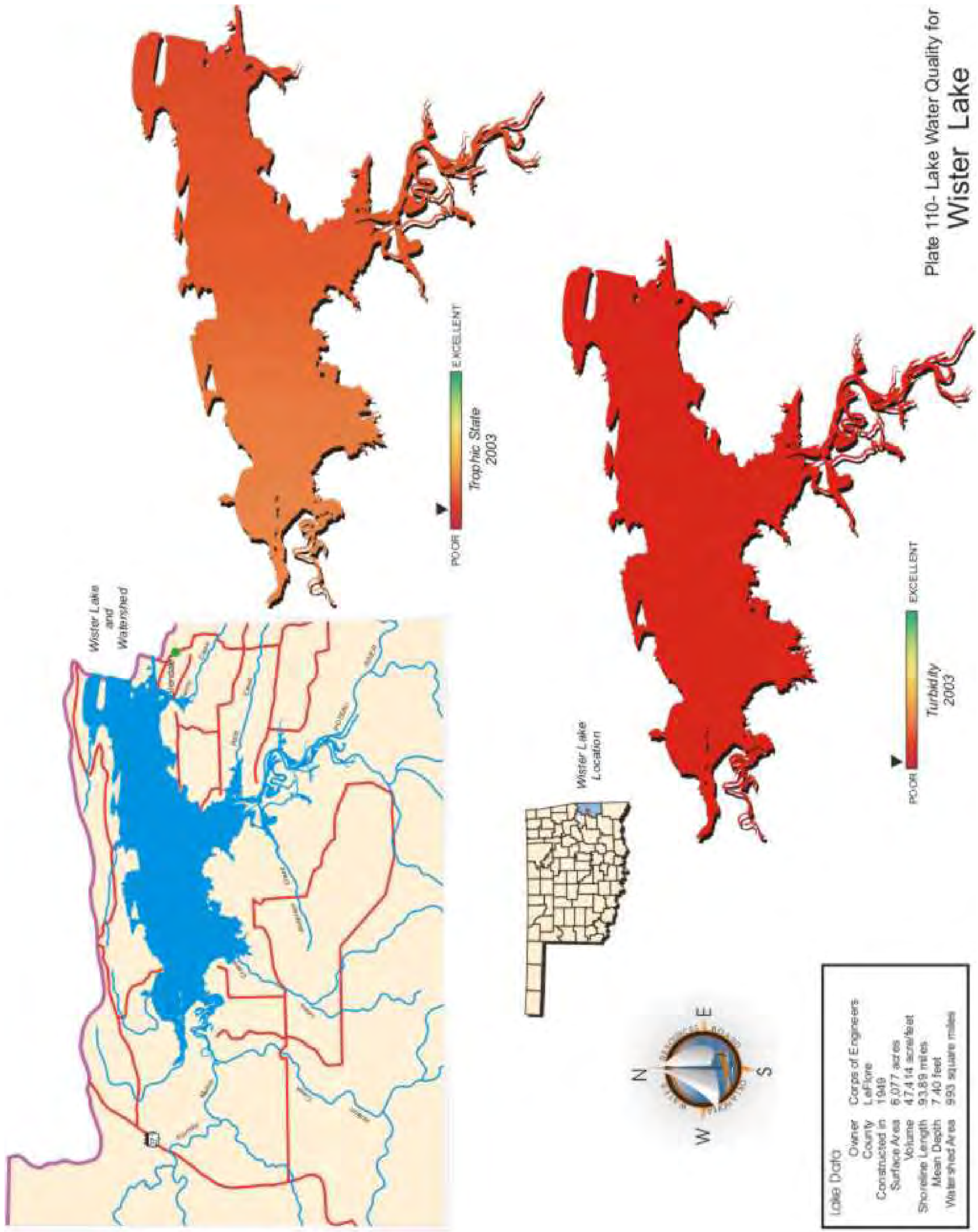


Plate 110- Lake Water Quality for Wister Lake

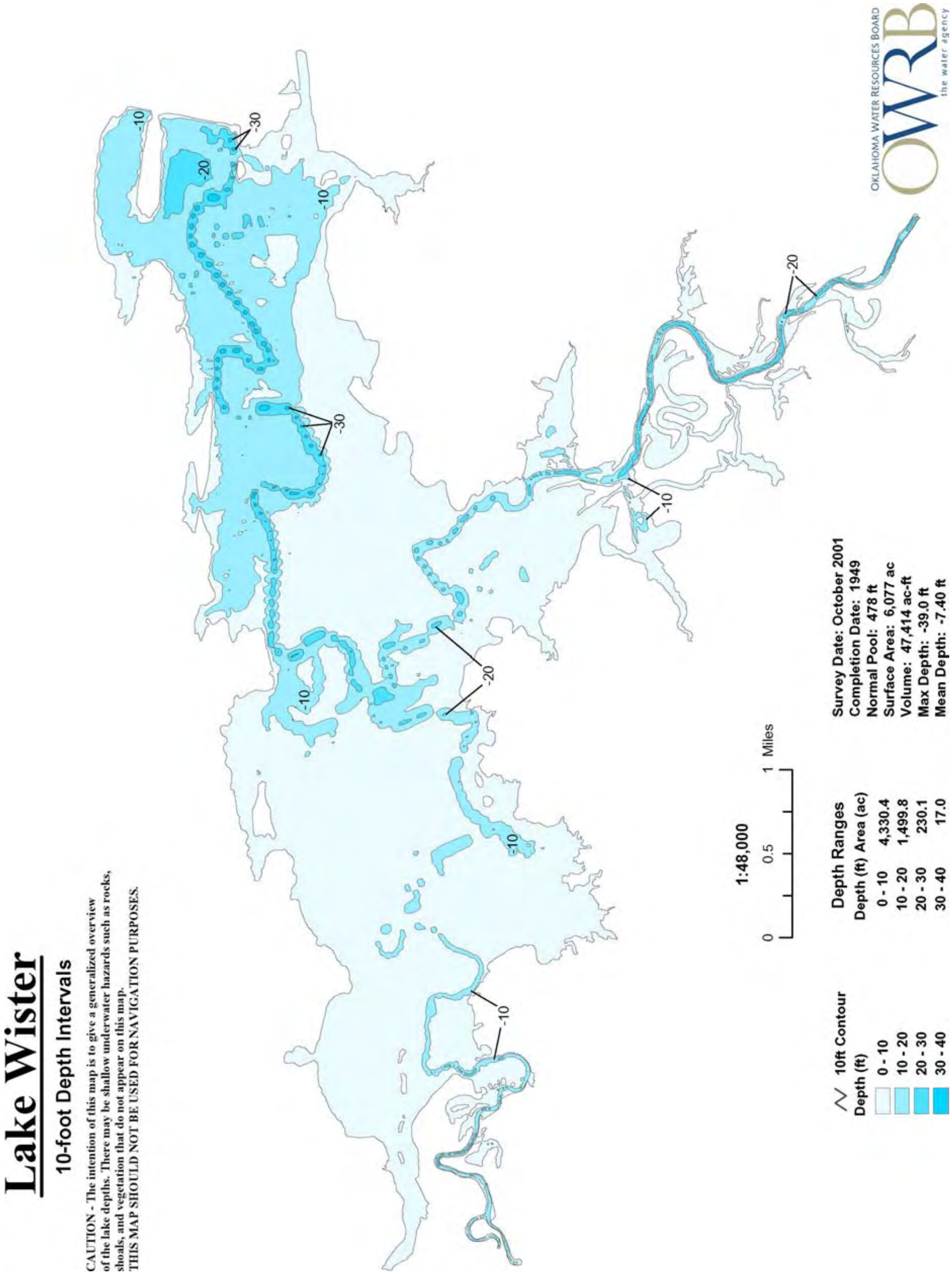


Figure 243. Bathymetric Map of Wister Lake.

BIBLIOGRAPHY

Carlson, R.E. 1977. “A trophic state index for lakes”. Limnology and Oceanography. 22:361-369.

Hounslow, A.W., 1995, Water Quality Data Analysis and Interpretation: Lewis Publishers, Boca Raton, FL.

Mueller, D.K., Hamilton, P.S., Helsel, D.R., Hitt, K.J., and Ruddy, B.C., 1995, Nutrients in Ground Water and Surface Water of the United States--An Analysis of Data Through 1992: U.S. Geological Survey Water-Resources Investigations Report 95-4031, 74 p.

Oklahoma Department of Tourism and Recreation. “Oklahoma Statewide Comprehensive Outdoor Recreation Plan - This Land is Your Land”. 1987. 216pp.

Oklahoma Water Resources Board. “Oklahoma Water Atlas”. May 1990. 360pp.

Oklahoma Water Resources Board. “Update of the Oklahoma Comprehensive Water Plan 1995". February 1997. 148pp.

Oklahoma Water Resources Board. “Use Support Assessment Protocols”. December 2001-20022. OAC 785:46

United States Environmental Protection Agency. “The Lake and Reservoir Restoration Guidance Manual”. August 1990. 326pp.

Wetzel, Robert G. “Limnology – Second Edition”. 1983. 767pp.

INDEX

A

B

C

D

E

F

G

H

J

K

L

M

N

O

P

R

S

T

V

W

APPENDIX A

Oklahoma's Use Support Assessment Protocols

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 <u>or not attained for that waterbody and that the waterbody segment is a water quality limited segment</u>.

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 <u>due to other than naturally occurring conditions</u>, 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 <u>due to other than naturally occurring conditions</u>, 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 <u>and such result is due to other than naturally occurring conditions</u>.

(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)~~ <u>785:45-5-12(f)(6)(D), (E) and (G)</u> 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)~~ <u>785:45-5-12(f)(6)(D), (E) and (G)</u> 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)~~ <u>785:45-5-12(f)(6)(D), (E) and (G)</u> 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)~~<u>(j)</u> **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)~~<u>(k)</u> **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.

<u>(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:</u>

<u>(1) Such subcategory shall be deemed fully supported if the application of Appendix C produces a score of 26 or more.</u>

<u>(2) Such subcategory shall be deemed not supported if the application of Appendix C produces a score of 19 or less.</u>

<u>(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.</u>

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. <u>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.</u>

(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 <u>with criteria for such use</u> listed in ~~785:45-5-10(1) or 785:45-5-10(6)~~ <u>OAC 785:45 Appendix G</u> if the sample concentrations from that waterbody do not exceed the criterion for that substance prescribed in ~~785:45-5-10~~ <u>OAC 785:45 Appendix G</u> 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 <u>with criteria for such use</u> listed in ~~785:45-5-10(1) or 785:45-5-10(6)~~ <u>OAC 785:45 Appendix G</u> if the sample concentrations from that waterbody exceed the criterion for that substance prescribed in ~~785:45-5-10~~ <u>OAC 785:45 Appendix G</u> 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 <u>with criteria for such use</u> listed in ~~785:45-5-10(1) or 785:45-5-10(6)~~ <u>OAC 785:45 Appendix G</u> if the sample concentrations from that waterbody exceed the criterion for that substance prescribed in ~~785:45-5-10~~ <u>OAC 785:45 Appendix G</u> 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~~ <u>OAC 785:45 Appendix G</u>, 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.

<u>(e) **Oil and grease.**</u>

<u>(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.</u>

<u>(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 have been put into effect by an agency with jurisdiction.</u>

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~~ <u>phosphorus</u> 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~~ <u>phosphorus</u> 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~~ <u>phosphorus</u> 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~~ <u>phosphorus</u> 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.