Oklahoma's Beneficial Use Monitoring Program

2001 Report

Oklahoma Water Resources Board

COST OF PUBLICATION

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EXECUTIVE SUMMARY

Protecting our state's valuable water resources is essential to preserving our state's natural resources as well as maintaining and promoting quality of life for all Oklahomans. Oklahoma's water resources are used for a myriad of activities such as fishing, irrigation, hydropower, boating, swimming, and as public/private water supplies. Water is vital for the continued advancement of this state, both from an economic and recreational standpoint. The National Recreation Lakes Study Commission (NRLSC) has estimated that 32,100 people in Oklahoma are employed in support of activities related to our numerous man-made lakes (reservoirs) that are greater than 1,000 surface acres in size. The NRLSC also estimate that 18,718,000 visitor days are spent on Oklahoma lakes each year and that approximately **$2.2 billion dollars** are contributed **annually** to Oklahoma's economy in connection with recreation in and around our large reservoirs. This dollar figure does not include recreation associated with our smaller municipal or Oklahoma Department of Wildlife lakes, nor does it include recreational activities occurring on our numerous river and stream resources. The Kerr-McClellan Navigation system also brings substantial dollars into the state's economy and supports numerous thriving businesses up and down the navigation channel. In addition, rivers and streams serve as critical sources for water supply and irrigation water. Recreational activities directly or indirectly associated with Oklahoma's rivers and streams contribute on an **annual** basis approximately **$10.7 million dollars** (camping) and **$15.2 million dollars** (hunting/fishing) in 1987 dollars to our economy (Oklahoma Statewide Comprehensive Outdoor Recreation Plan, 1987). This dollar figure has undoubtedly increased substantially in the years since the Oklahoma Comprehensive Outdoor Recreation Plan (SCORP) was completed.

Surface waters are not the only waters of the state that are critical to our economy and quality of life. Oklahoma's numerous groundwater aquifers serve as municipal water supplies and are a key ingredient to our agricultural economy. Without plentiful and high quality groundwater to meet our irrigation and municipal water supply demands, Oklahoma would not be the state it is today. Groundwater serves as the primary water supply for approximately three-hundred (300) Oklahoma cities and towns and comprises 60% of the total water used (Oklahoma Comprehensive Water Plan, 1997). Groundwater resources also meet approximately 90% of the state's irrigation needs and are vital to supporting the state's **$6.1 billion dollar** agricultural industry.

It should be readily apparent to the reader at this point that our water (lakes, streams, groundwater, and wetlands) is vital to our state economy and the continued well being of our people. It is therefore essential that Oklahoma protect and manage its water resources to ensure that they continue to serve the state's citizens well, far into the foreseeable future. That is why this report is so important. It is critical that scientifically defensible data be collected and analyzed following procedures outlined in the Use Support Assessment Protocols (USAP). If data are to be analyzed following protocols other than those outlined in the USAP, then the party or parties doing show must be prepared to defend the legitimacy of their efforts. The foundation of all of these efforts must be the Oklahoma Water Quality Standards (OWQS) and the beneficial uses they prescribe for all waters. If a designated beneficial use is impaired threatened, or otherwise compromised, we must take efforts to mitigate or restore the quality of our waters in order to continue to provide the citizens of Oklahoma with a plentiful supply of good clean water.

The State of Oklahoma has historically had numerous monitoring programs conducted by several state and federal agencies. In general, each environmental agency conducts its own program with nominal integration 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, OWQS process, lake trophic status determination, water quality impacts from nonpoint and point source pollution, stream flow measurements, document success of best management practices, etc.). Information of this type is specific to each individual project's data quality objectives (DQOs) and is often limited to a very small geographic area. This Beneficial Use Monitoring Program (BUMP) brings water quality management full circle. From the promulgation of OWQS, to permitting and enforcement of permits stemming from OWQS established criteria, to non-point source controls - all water quality management activities must work in concert to restore, protect and maintain designated beneficial uses. Indeed, it is the universal yardstick by which we may document success.

With this as background, it is little wonder that the Oklahoma legislature recognized the importance of this program and funded the Oklahoma Water Resources Board (OWRB) to address this critical issue. Although this inaugural report will of necessity be written prior to collecting enough data to draw many conclusions for streams, it will contain extensive lake data. As the program matures, the BUMP is sure to become one of the most important documents published annually in Oklahoma.

This document interprets current lake and stream data collected 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. In addition, this document also interprets data collected on our groundwater resources (specifically the Cimmaron Terrace) as part of a small demonstration project to show what type of work can be conducted given additional financial resources to monitor grounwaters of the state.

The overall program goal of the BUMP is as follows:

Overall Monitoring Program Goal: The goal of the 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 between 100 and 150 stations on a monthly basis. These sites are segregated into two discrete types of monitoring activities. The first monitoring activity is focusing on fixed station monitoring on rivers and streams and the second monitoring activity focuses on a number of sample stations whose location rotate on an annual basis. The two monitoring components are explained on the following pages.

  - **Fixed Station Monitoring on Rivers & Streams** - Fixed station monitoring is based largely upon the sixty-seven (67) United States Geological Survey 8-digit hydrologic unit code (HUC) basins present in Oklahoma. In general, at least one (1) sample station was located in all of the HUC watersheds with the exception of some of the smaller HUC watersheds adjacent to the state line or in a HUC that does not contain a free flowing stream at some point during the year. After consultation with the other state environmental agencies and over time the OWRB has identified one hundred thirteen (113) fixed stations of which one hundred (100 are currently being monitored.

- **Rotating Station Monitoring on Rivers & Streams** - Sampling is occurring at forty-five (45) stations for numerous water quality variables. Over the life of the BUMP, rotational sampling has occurred on one hundred ninety (190) 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** - Efforts in connection with this task are occurring on a limited basis this fiscal year due to monetary constraints. The OWRB will cooperate with the USGS, or other agencies involved in collecting flow data, to establish long-term flow monitoring stations in the future in a coordinated and cooperative fashion.

- **Fixed Station Lakes Monitoring** - Quarterly sampling (approximately once every 90 days) of approximately 35 lakes per annum has been the monitoring plan for the BUMP Lakes program since the onset of BUMP. 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, and additional sites are added as needed. With continued stable funding, the program is moving forward such that quarterly sampling (approximately once every 90 days) of 50-60 lakes will occur in 2001/2002 (See Figure 5) at which point repeat sampling will occur.

- **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) program.

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

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 hyper-eutrophic (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, with sampling scheduled to be completed in the spring of 1999. For this reason, the OWRB was able to roll the existing lake sample program into the BUMP.

For streams, no such comprehensive, statewide sampling effort was ongoing at the time the BUMP was funded. Because of this, the OWRB required a number of months to re-allocate staff and implement a monitoring regime on streams. In addition, OWRB staff greatly desired input from the other environmental agencies on the placement of stream monitoring stations. The existence of a previous statewide stream monitoring network greatly aided in sample site selection. This historical ambient trend stream-monitoring network existed from 1975 until 1993 and was implemented by the Oklahoma State Health Department. Although this program did not evaluate sample results through comparison with the OWQS criteria or determine use support, it did provide a locational framework upon which to build. The historical sampling network sampled streams on a monthly basis from 1975-1986 and on a semi-annual basis from 1987-1993. Based upon the historical program and input from other agencies, the OWRB has established an ambient monitoring network of 99 active permanent stations and 45-82 rotational sites. The rotational sites will be evaluated each year to determine if any should be dropped and others added. The Water Resources Board relies heavily on the other state and federal agencies for input into this process. With continued funding it is the desire of BUMP staff to increase the number of permanent sites to 120 to more effectively monitor our stream resources. In addition, staff with the OWRB work closely with the other state environmental agencies to avoid duplication of sampling effort (i.e. the Oklahoma Conservation Commision rotating and data gaps sampling initiatives), except on a very limited basis for quality assurance purposes. A very small number of sites that are duplicative in nature do allow for the comparison of results between sampling programs to ensure that sampling protocols and the Use Support Assessment Protocols (USAP - described below) are working effectively and that decisions on support status are being made in a consistent manner.

The OWRB has developed Use Support Assessment Protocols, commonly referred to as USAP, for lakes and streams. The USAP developed 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 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 was 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 35 lakes was used for this report. Also, data for two lakes, Oologah Lake and Texoma Lake, was supplied by USACOE during this sample year. In the future, it is the intention of the BUMP to increase the number of lakes sampled annually to between 50 and 60 lakes. A sampling regime of this nature will allow staff to collect information on approximately 100 to 120 of the largest lakes in Oklahoma every other year. For the current sample year, data was collected from the fall of 2000 through the fall of 2001. The results of the BUMP Lakes sample year 2000 are summarized below. As shown in Figure 1, a small percentage (9%) of lakes sampled was determined to have serious water quality concerns, classified 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". About half the lakes sampled, 45%, in 2001 were classified as eutrophic, high primary productivity and nutrient rich conditions. A eutrophic lake also has the potential for beneficial use impairments, though the potential is less than in 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 in 2001, forty percent (40%) were classified as mesotrophic reservoirs. 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 these reservoirs are very turbid waters, have poor water clarity with light inhibiting lake productivity. Only one of the 37 lakes sampled in 2001 was classified as oligotrophic. In this case, Lake Henryetta is classified as oligotrophic because it is an extremely turbid and highly colored lake, limiting productivity and high nutrient concentrations. This type of lake system is technically considered "dystrophic", meaning the lake is not oligotrophic based on low nutrient and productivity levels, but due to the high content of humic organic matter (Wetzel 1983). Based on the results for trophic state index

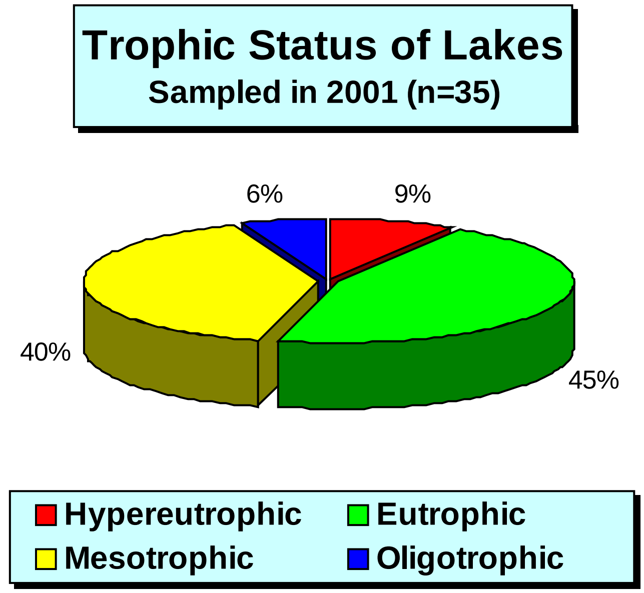


Figure 1. Trophic Status of Lakes Sampled in 2001.

calculations, the majority of the waters sampled are exhibiting high to excessive levels of primary productivity and nutrient rich conditions. A higher number of lakes sampled in 2000 were classified as hypereutrophic, the upper end of eutrophication, but the number and percentage of lakes classified as eutrophic was basically the same as in 2000.

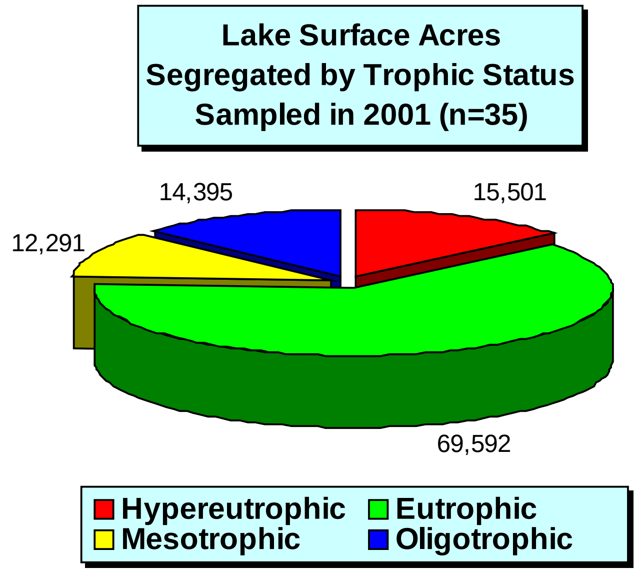


Figure 2. Lakes surface acres segregated by trophic state.

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. Based on trophic status of lakes segregated by lake surface acres, 80% of all surface acres were eutrophic, 10% were mesotrophic and 10% were hypereutrophic, and basically none were oligotrophic (only 450 out of 408,277 total surface acres). The largest reservoirs sampled in 2001 were all classified as eutrophic, including Eufaula (105,500 surface acres), Texoma (88,000), Robert S. Kerr (43,480), and Oologah (29,460). Large reservoirs in the state have larger watersheds and are generally deeper than smaller lakes, which promotes the detection of beneficial use impairments since a larger surface area is available. During stratification, the larger/deeper reservoirs have a greater portion of the water column that becomes anoxic for long periods of time, which also increases the potential for nutrient release from sediments. Therefore, larger reservoirs may meet the requirements listed in USAP to be designated as exceeding the dissolved oxygen criteria for fish and wildlife propagation. With 367,418 out of 408,277 lake surface acres classified as eutrophic or hypereutrophic, 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 nutrient impacts. At this time twelve (12) 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. NLW are lakes with a TSI ≥ 62, based on Carlson’s trophic state classification using chlorophyll-a as the indicator. Lakes sampled as part of the BUMP, their trophic status, and any potential threats or impairments are listed in Table 1.

Table 1. Lakes sampled by the BUMP and their use attainment.

Lake Name	County	Surface Area (Acres)	Volume (Acre/Ft.)	TSI	Year Sampled	Threats or Impairments	Carlson's TSI
American Horse	Blaine	100	2,200	52	2000	D.O. (PS)	Eutrophic
Arbuckle	Murray	2,350	72,400	52	2000		Eutrophic
Arcadia	Oklahoma	1,820	27,520	60	2000		Eutrophic
Ardmore City	Carter	142	600	49	2001	D.O. (PS)	Mesotrophic
Atoka	Atoka	5,700	125,000	43	1999	Turbidity (NS)	Mesotrophic
Bell Cow	Lincoln	1,153		55	1997		Eutrophic
Birch	Osage	1,137	19,200	57	2000	D.O. (PS)	Eutrophic
Bixhoma	Wagoner	110	3,130	59	1999	D.O. (PS)	Eutrophic
Bluestem	Osage	762	17,000	45	1999	Color (NS) D.O. (PS) Turbidity (NS)	Mesotrophic
Boomer	Payne	260	3,200	49	1997		Mesotrophic
Broken Bow	McCurtain	14,200	918,070	40	2001	pH (NS - PL)	Oligotrophic
Brushy Creek	Sequoyah	358	3,258	51	2001	D.O. (PS), pH (PS - PL)	Eutrophic
Burtschi, Louis‡	Grady	180	2,140	62	1997		Hypereutrophic
Canton	Blaine	7,910	111,310	60	1999		Eutrophic
Carl Albert	Latimer	183	2,739	41	2001	D.O. (PS) pH (NS - PL)	Mesotrophic
Carl Blackwell	Payne	3,370	61,500	48	1999	Color (NS) Turbidity (NS)	Mesotrophic
Carter	Marshall	108	990	44	2001		Mesotrophic
Cedar (Mena)	LeFlore	78	1,000	51	2001	D.O. (PS), pH (NS - PL)	Eutrophic
Chandler	Lincoln	129	2,778	46	2001	D.O. (PS)	Mesotrophic
Chickasha‡	Caddo	820	41,080	66	2000		Hypereutrophic
Claremore	Rogers	470	7,900	68	1997	NLW	Hypereutrophic
Clear Creek	Stephens	722	7,710	53	2001		Eutrophic
Cleveland	Pawnee	159	2,200	56	1997		Eutrophic
Clinton	Washita	335	3,980	58	1999		Eutrophic
Coalgate	Coal	352	3,437	44	1997		Mesotrophic
Comanche	Stephens	184	2,500	50	2001	Color (NS), pH (PS - PL) Turbidity (PS)	Mesotrophic
Copan	Washington	4,850	43,400	57	2000		Eutrophic
Crowder	Washita	158	2,094	61	1999	NLW	Hypereutrophic
Cushing	Payne	591	3,304	49	1999	Color (NS),Turbidity (NS)	Mesotrophic
Dave Boyer (Walters)	Cotton	148	861	51	2001	Color (NS) Turbidity (NS)	Eutrophic
Dripping Springs	Okmulgee	1,150	16,200	49	1997		Mesotrophic
Duncan	Stephens	500	7,200	49	2001		Mesotrophic
El Reno	Canadian	170	709	56	2001	Turbidity (PS)	Eutrophic
Elk City	Beckham	240	2,583	59	1999	NLW	Eutrophic

Lake Name	County	Surface Area (Acres)	Volume (Acre/Ft.)	TSI	Year Sampled	Threats or Impairments	Carlson's TSI
Ellsworth	Comanche	5,600	95,200	49	1999		Mesotrophic
Elmer Thomas	Comanche	334	12,000	41	2000		Mesotrophic
Etling, Carl	Cimarron	159	1,717	57	2001	Turbidity (PS)	Eutrophic
Eucha	Delaware	2,860	79,600	62	1999	D.O. (PS), NLW	Hypereutrophic
Eufaula	Haskell	105,500	2,314,600	51	2000	Color (PS)	Eutrophic
Fairfax	Osage	111	1,795	47	1999	Color (PS), D.O. (PS)	Mesotrophic
Fort Cobb	Caddo	4,100	80,010	64	1999	NLW	Hypereutrophic
Fort Gibson	Cherokee	14,900	355,200	64	2001	Turbidity (PS)	Hypereutrophic
Fort Supply	Woodward	1,820	13,900	57	1999	Turbidity (NS) & NLW	Eutrophic
Foss	Custer	8,800	256,220	47	2000		Mesotrophic
Frederick	Tillman	925	9,526	50	2001	Turbidity (NS)	Mesotrophic
Fuqua	Stephens	1,500	21,100	48	2001	Color (NS), Turbidity (PS)	Mesotrophic
Grand Lake	Mayes	46,500	1,672,000	59	2001	D.O. (PS), Turbidity (NS)	Eutrophic
Great Salt Plains	Alfalfa	8,690	31,240	67	1999	Turbidity (NS) & NLW	Hypereutrophic
Greenleaf	Muskogee	920	14,720	54	2001	D.O. (PS)	Eutrophic
Guthrie	Logan	274	3,875	60	1999		Eutrophic
Healdton	Carter	370	3,766	42	2001		Mesotrophic
Hefner	Oklahoma	2,500	75,000	55	1999		Eutrophic
Henryetta	Okmulgee	450	6600	36	2000	pH (NS - PL)	Oligotrophic
Heyburn	Creek	880	7,105	45	2000		Mesotrophic
Holdenville	Hughes	550	11,000	44	1997		Mesotrophic
Hominy	Osage	165	5,000	50	1999	D.O. (PS)	Mesotrophic
Hudson	Osage	250	4,000	51	1999	Color (PS), D.O. (PS)	Eutrophic
Hudson	Mayes	10,900	200,300	58	2000		Hypereutrophic
Hugo	Choctaw	13,250	157,600	58	2000	Color (NS) Turbidity (NS)	Eutrophic
Hulah	Osage	3,570	31,160	59	2000	NLW	Eutrophic
Humphreys	Stephens	882	14,041	53	2001		Eutrophic
Jean Neustadt	Carter	462	6,106	58	2001	D.O. (PS), pH (PS - PL)	Eutrophic
John Wells	Haskell	194	1,352	46	1999	D.O. (PS)	Mesotrophic
Kaw	Osage	17,040	428,600	54	2000	Turbidity (NS)	Eutrophic
Keystone	Tulsa	23,610	557,600	55	1999	Color (NS) Turbidity (NS)	Eutrophic
Konawa	Seminole	1,350	23,000	47	1997		Mesotrophic
Langston	Logan	304	5,792	42	1997		Mesotrophic
Lawtonka	Comanche	2,398	56,574	52	1999		Eutrophic
Liberty	Logan	167	2,740	58	1999	D.O. (PS)	Eutrophic
Lloyd Church	Latimer	160	3,060	49	2001	D.O. (PS), pH (NS - PL)	Mesotrophic

Lake Name	County	Surface Area (Acres)	Volume (Acre/Ft.)	TSI	Year Sampled	Threats or Impairments	Carlson's TSI
						Turbidity (PS)	
Lone Chimney	Pawnee	550	6,200	57	1997		Eutrophic
Longmire, R.C.	Garvin	918		55	2001	D.O. (PS)	Eutrophic
Lugert-Altus	Greer	6,260	132,830	57	2000		Eutrophic
Maysville/Wiley Post	McClain	302	2,082	45	1997		Mesotrophic
McAlester	Pittsburg	1,521	13,398	47	2001	pH (PS - PL)	Mesotrophic
McGee Creek	Atoka	3,810	113,930	45	1999	D.O. (NS)	Mesotrophic
McMurtry	Noble	1,155	19,733	45	1999		Mesotrophic
Meeker	Lincoln	250	1,818	45	1999	Turbidity (NS)	Mesotrophic
Murray	Love	5,728	153,250	42	2001	D.O. (PS)	Mesotrophic
Nanih Waiya	Pushmataha	131	1,064	52	2000		Eutrophic
Okemah	Okfuskee	761	13,100	44	1997		Mesotrophic
Okmulgee	Okmulgee	668	14,170	46	1999	D.O. (PS)	Mesotrophic
Oologah	Rogers	29,460	553,400	53	2000	Turbidity (NS)	Eutrophic
Overholser ●	Oklahoma	1,500	15,000	62	2000	Turbidity (NS)	Eutrophic
Ozzie Cobb	Pushmataha	116	833	62	2000	D.O. (PS), pH (NS - PL) NLW	Hypereutrophic
Pauls Valley	Garvin	750	8,730	50	2001		Mesotrophic
Pawhuska	Osage	96	3,600	42	2000	D.O. (PS)	Mesotrophic
Pawnee	Pawnee	257	3,855	53	1997		Eutrophic
Perry	Noble	614	6,892	47	2000		Mesotrophic
Pine Creek	McCurtain	3,750	53,750	59	1999	pH (NS - PL)	Eutrophic
Ponca	Kay	805	14,440	56	2000		Eutrophic
Prague	Lincoln	225	2,415	45	2000	D.O. (PS)	Mesotrophic
Purcell	McClain	150	2,600	57	1997		Eutrophic
Raymond Gary	Choctaw	263	1,681	53	2000	D.O. (PS), pH (PS - PL)	Eutrophic
Robert S. Kerr	Sequoyah	43,380	525,700	54	2000	Color (NS) Turbidity (NS)	Eutrophic
Rock Creek	Carter	248	3,588	55	2001	D.O. (PS), pH (PS - PL) Turbidity (NS)	Eutrophic
Rocky (Hobart) ‡	Washita	347	4,210	66	2001		Hypereutrophic
Sahoma	Creek	312	4,850	51	1997		Eutrophic
Sardis	Pushmataha	13,610	274,330	46	2000	Color (PS)	Mesotrophic
Shawnee Twin No. 1	Pottawatomie	1,336	22,600	42	1999	Color (PS)	Mesotrophic
Shawnee Twin No. 2	Pottawatomie	1,100	11,400	44	1999	D.O. (PS)	Mesotrophic
Shell Creek	Osage	573	9,500	57	1997		Eutrophic
Skiatook	Osage	10,190	322,700	49	2000	D.O. (PS)	Mesotrophic
Sooner	Pawnee	5,400	149,000	48	2000		Mesotrophic
Spavinaw ●	Mayes	1,584	38,000	58	1999	D.O. (PS), NLW	Eutrophic

Lake Name	County	Surface Area (Acres)	Volume (Acre/Ft.)	TSI	Year Sampled	Threats or Impairments	Carlson's TSI
Spiro, New	LeFlore	254	2,160	61	2001	D.O. (PS)	Hypereutrophic
Sportsman	Seminole	354	5,349	42	1999		Mesotrophic
Stanley Draper	Cleveland	2,900	100,000	41	1999	Turbidity (NS)	Mesotrophic
Stilwell	Adair	188	3,110	58	2001	D.O. (PS)	Eutrophic
Stroud	Creek	600	8,800	43	1997		Mesotrophic
Talawanda No. 1	Pittsburg	91	1,200	45	2001	D.O. (PS), pH (PS - PL)	Mesotrophic
Talawanda No. 2	Pittsburg	195	2,750	40	2001	D.O. (PS), pH (PS - PL)	Oligotrophic
Taylor (Marlow) ◘	Grady	227	1,877	65	2000		Hypereutrophic
Tecumseh	Pottawatomie	127	1,118	48	1999	Color (NS) Turbidity (NS)	Mesotrophic
Tenkiller	Sequoyah	12,900	654,100	58	2000		Eutrophic
Texoma	Bryan	88,000	2,643,300	57	2000	D.O. (PS)	Eutrophic
Thunderbird	Cleveland	6,070	119,600	56	2001	Color (NS), D.O. (PS) Turbidity (PS)	Eutrophic
Tom Steed	Kiowa	6,400	88,970	53	2000		Eutrophic
Vanderwork	Washita	135	1,578	62	1997	NLW	Hypereutrophic
Vincent, Loyd	Ellis	160	2,579	49	2000		Mesotrophic
W.R. Holway	Mayes	712	48,000	55	2000	D.O. (PS)	Eutrophic
Waurika	Jefferson	10,100	203,100	59	2000		Eutrophic
Waxhoma	Osage	197	2,100	46	1999	Color (NS)	Mesotrophic
Wayne Wallace	Latimer	94	1,746	58	2000	D.O. (PS)	Eutrophic
Webbers Falls	Muskogee	11,600	170,100	57	2001	Turbidity (PS)	Eutrophic
Wes Watkins	Pottawatomie	1,132		52	1999		Eutrophic
Wetumka	Hughes	169	1,839	52	2001	Turbidity (NS)	Eutrophic
Wewoka	Seminole	371	3,301	46	1997		Mesotrophic
Wister ✷	LeFlore	7,333	62,360	58	2000	D.O. (PS) NLW	Eutrophic
Yahola ●	Tulsa	431	6,445	60	1999		Eutrophic

† 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 major controlling factor in limiting biological productivity (Light-limited system)

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

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

IMPAIRMENT CODES		
D.O. = DISSOLVED OXYGEN	PS = PARTIALLY SUPPORTING	NS= NOT SUPPORTING
NLW = NUTRIENT LIMITED WATER	PL = PROVISIONALLY LISTED	

Results of Stream Sampling Efforts

Table 2 lists the BUMP permanent ambient trend stream monitoring sites and their associated beneficial uses. Beneficial uses that are not being met are shown in **RED**. Listed next to the support code indicating that the beneficial use was not being met is the variable code which indicates which water quality variable violated the OWQS criteria. It is apparent that an inordinate number of water bodies are deemed impaired due to their exceedance of the turbidity standard of 10 or 50 nephelometric turbidity units. The OWQS states that turbidity standards only apply during seasonal base flow conditions. In other words, the criteria should not be applied where normal in-stream conditions exceed the OWQS due to natural processes from a high-flow event. Several "quick" methods are available to assist in the determination of seasonal base flow including the existence of a periphyton line and visual estimation of the degree of flow. However, to reliably determine base flow, a measurement of stream discharge at the time of sampling is needed. This measurement when used in concert with the "quick" methods described above will give a reliable indication of whether the stream is at, below, or above seasonal base flow conditions. Because the BUMP network encompasses the state's large rivers and streams, discharge is often obtained by comparing stream stage to a continuously updated rating curve. Due to the intense nature of establishing a reliable rating curve, rated discharges are often provisional for a number of months. Therefore, the determination of the previous year's base flow and consequently eligible turbidity values are also **provisional** at the publication of this report. As of the beginning of 2002, the OWRB is now guaging all but 4 permanent station locations. Where permanent water-quality monitoring stations were located near a United States Geological Survey (USGS) stream-flow monitoring station, the information collected by USGS is used to determine if a high-flow event exceeding seasonal base flow had occurred at the time of sampling. All other stations are being rated through a cooperative effort between the OWRB Monitoring Section and the USGS.

A problem of a different nature was encountered when staff began to look at metals and beneficial use support. Metals fall under the general heading of **Toxicants** and to determine beneficial use support the concentration is "plugged" into an equation designed to address the issue of water hardness. This is performed because toxicity of some compounds is directly related to the hardness of the water. When staff performed the necessary calculations to come up with the appropriate criteria to utilize for determining use support, some very low concentrations were calculated which were far less than the contract laboratory practical quantitation level (PQL) or detection limit. Per USAP instructions for criteria less than the PQL, ½ of the PQL was used as the concentration detected in the water column. Even with that assumption, in certain instances ½ of the MQL was still orders of magnitude greater than the criteria calculated and adjusted for hardness. In 2001, this resulted in a large number of Fish & Wildlife Propagation beneficial use non-supporting listings due to toxicants when in fact it is uncertain if a beneficial use impairment was present or was an artifact of the USAP directions for dealing with PQL's. To address the problem, the OWRB has worked with the contract laboratory to lower the metals" PQL's to address the hardness-adjusted criteria. For stations with an average total hardness of less than 150 mg/L, a more precise method is being used to determine levels of cadmium, copper, lead, and silver. This method delivers PQL's that are generally below or no less than half the site-specific, hardness-dependent criterion. In reviewing sample results using this more precise method, stations that were previously listed with uncertainty have been removed if sample data is now below the criterion.

It is essential that Oklahoma quantify impacts in a comprehensive and scientific manner and look for trends in water quality to identify waters which are not meeting their assigned beneficial uses. As a state, we must manage our water resources effectively and direct money to areas in most need of protection or remediation to ensure that we continue to have good quality and sufficient quantity of water to meet our needs well into the 21st century.

As the reader has hopefully realized, comprehensive statewide data sets on rivers and streams for accurately assessing beneficial use impairments has not existed since 1993. With the implementation of monitoring on a large scale in October of 1998, this is no longer the case. With the availability of data, it is the desire of the Oklahoma Water Resources Board to provide the legislature and professional water managers with a comprehensive and up-to-date document for their review and approval. Administrative and Technical staff at the OWRB look forward to conducting the Beneficial Use Monitoring Program far into the future and providing the state of Oklahoma with the information it needs to make informed decisions related to the effective management of it's precious water resources.

Table 2. List of Permanent Ambient Trend Stream Sites and their Beneficial Use Attainment.

STATION NAME	FWP	PBCR	PPWS	AG	NUTRIENT
Arkansas River, US 64, Moffett	S	CBD	CBD	S	NT
Arkansas River, off US 77, Newkirk	**NS (5)**	**NS (6, 10,11)**	S	**NS (15)**	NT
Arkansas River, SH 104, Haskell	S	**NS (10,11)**	N/A	**PS (15)**	NT
Arkansas River, SH 18, Ralston	**PS (5)**	**NS (10,11)**	S	S	NT
Arkansas River, SH 97, Sand Springs	S	S	N/A	S	NT
Arkansas River, US 62, Muskogee	S	**NS (6)**	N/A	S	NT
Arkansas River, US 64, Bixby	**NS (3)**	S	N/A	S	NT
Barren Fork, SH 51, Eldon	S	**NS (10,11)**	S	S	NT
Beaver River, off US 64, Guymon	**PS (5)**	**NS (8, 9, 10,11)**	S	S	NT
Beaver River, US 83, Turpin	S	**NS (6, 7, 8, 9 10,11)**	S	**NS (15,** 16**)**	NT
Beaver River, SH 23, Beaver	**NS (3)**	**NS (6, 7, 8, 9 10,11)**	S	**NS (15,** 16**)**	NT
Beaver River, CR N1650, Gate	S	**NS (10,11)**	S	S	NT
Beaver River, US 183, Fort Supply	S	CBD	S	S	NT
Big Cabin Creek, off US 69, Big Cabin	S	S	S	S	NT
Bird Creek, SH 266, Port of Catoosa	**PS (1,3,5)**	**NS (6, 8, 9, 10,11)**	S	S	NT
Black Bear Creek, SH 18, Pawnee	**NS (3, 5)**	**NS (10,11)**	S	S	NT
Blue River, US 70, Durant	S	**NS (10,11)**	S	S	NT
Brushy Creek, off US 270, Haileyville	**NS (5)**	**NS (6, 10,11)**	S	S	NT
Canadian River, SH 2, Whitefield	S	S	S	S	NT
Canadian River, US 183, Taloga	**PS (5)**	**NS (10,11)**	N/A	**NS (15, 17)**	NT
Canadian River, US 270, Calvin	**NS (5)**	S	S	**PS (15, 17)**	NT
Canadian River, US 377, Konawa	**NS (5)**	**NS (10,11)**	S	**NS (15, 17)**	NT
Canadian River, US 66, Bridgeport	**PS (5)**	**NS (6, 10,11)**	N/A	**NS (15, 17)**	NT

STATION NAME	FWP	PBCR	PPWS	AG	NUTRIENT
Canadian River, US 77, Purcell	NS (4, 5)	N/A	N/A	NS (15)	NT
Caney Creek, off SH 100, Barber	PS (5)	NS (10,11)	S	S	NT
Caney River, off US 75, Ramona	NS (3, 5)	NS (6, 10,11)	S	S	NT
Chickaskia River, US 177, Blackwell	NS (3, 5)	NS (6, 10,11)	S	S	NT
Cimarron River, SH 34, Buffalo	S	NS (6, 8, 9, 10,11)	S	S	NT
Cimarron River, SH 99, Oilton	NS (5)	NS (6, 10,11)	N/A	S	NT
Cimarron River, US 77, Guthrie	PS (5)	NS (6, 10,11)	N/A	S	NT
Cimarron River, US 81, Dover	NS (3, 5)	NS (6, 8, 9, 10,11)	N/A	S	NT
Cimarron River, off US 64, Mocane	NS (3)	NS (6, 10,11)	S	NS (15, 16)	NT
Cimarron River, US 412, Orienta	NS (5)	NS (10,11)	N/A	S	NT
Cimarron River, SH 33, Ripley	NS (5)	NS (10,11)	N/A	S	NT
Clear Boggy Creek, off US 69, Caney	NS (3, 5)	NS (10, 11)	S	S	NT
Cow Creek, SH 5, Waurika	NS (5)	NS (10, 11)	S	PS (15)	NT
Deep Fork River, off SH 16, Beggs	NS (5)	NS (10,11)	S	S	NT
Deep Fork River, US 377, Stroud	NS (3, 5)	NS (10,11)	PS (14)	S	NT
East Cache Creek, SH 53, Walters	NS (5)	NS (6,10, 11)	S	S	NT
Elk Creek, off US 183, Hobart	S	NS (10,11)	S	S	NT
Elk River, SH 43, Tiff City (MO)	S	NS (10,11)	S	S	NT
Elm Fork River, SH 9, Mangum	NS (3)	NS (8, 9, 10,11)	NS (12)	S	NT
Flint Creek, US 412, Flint	S	NS (10,11)	S	S	NT
Fourche-Maline Creek, off US 270, Red Oak	NS (1, 3, 5)	NS (6, 8, 9, 10,11)	S	S	NT
Glover River, SH 3, Glover	NS (1, 3)	NS (10,11)	S	S	NT
Honey Creek, off SH 25, Grove	S	NS (10,11)	S	S	NT
Illinois River, US 59, Watts	NS (5)	NS (10,11)	S	S	NT
Illinois River, US 62, Tahlequah	S	NS (10,11)	S	S	NT
Kiamichi River, off US 271, Tuskahoma	NS (2, 3)	S	S	S	NT
Kiamichi River, SH 63, Big Cedar	NS (3, 4)	S	S	S	NT
Kiamichi River, US 271, Antlers	NS (3)	NS (10,11)	S	S	NT
Little River, off SH 3, Cloudy	NS (2, 3, 4, 5)	NS (10,11)	S	S	NT
Little River, SH 56, Sasakwa	NS (3, 5)	NS (6, 10,11)	S	S	NT
Little River, US 70, Idabel	NS (1, 3, 5)	S	S	S	NT
Mountain Fork, SH 4, Smithville	NS (3, 4, 5)	S	S	S	NT
Mountain Fork, US 70, Eagletown	NS (2, 3)	NS (10,11)	S	S	NT
Mud Creek, SH 32, Courtney	NS (1, 5)	NS (6, 10,11)	S	S	NT

STATION NAME	FWP	PBCR	PPWS	AG	NUTRIENT
Muddy Boggy Creek, US 70, Unger	NS (3, 5)	NS (6)	S	S	NT
Muddy Boggy Creek, US 69, Atoka	NS (1, 5)	CBD	S	S	NT
Neosho River, off US 66, Commerce	S	CBD	S	S	NT
Neosho River, off SH 137, Connor Bridge	PS (5)	S	S	S	NT
Neosho River, SH 82, Langley	PS (1)	S	S	S	NT
Neosho River, US 412, Chouteau	S	S	S	S	NT
North Canadian River, Ind. Nat. Tpk., Dustin	NS (3, 5)	NS (6, 10,11)	S	S	NT
North Canadian River, off I-40, Shawnee	NS (3, 5)	NS (10,11)	N/A	NS (15)	NT
North Canadian River, off US 62, Harrah	NS (4, 5)	NS (10,11)	N/A	S	NT
North Canadian River, US 281, Seiling	PS (5)	NS (10,11)	S	S	NT
North Canadian River, US 75, Wetumka	NS (3, 5)	NS (6, 10,11)	S	S	NT
North Canadian River, US 412, Woodward	S	CBD	S	S	NT
North Canadian River, US 81, El Reno	PS (5)	NS (10,11)	S	S	NT
North Fork of the Red River, US 62, Headrick	PS (3, 5)	NS (6, 10,11)	PS (12)	NS (15, 16)	NT
North Fork of the Red River, SH 34, Carter	S	NS (10,11)	S	S	NT
Poteau River, off SH 112, Pocola	NS (3, 5)	NS (10,11)	S	S	NT
Poteau River, US 59, Heavener	S	S	S	S	NT
Red River, SH 79, Waurika	NS (3, 5)	S	PS (12)	NS (15, 16, 17)	NT
Red River, US 183, Davidson	NS (3, 5)	NS (6, 8, 9, 10,11)	N/A	NS (15, 16, 17)	NT
Red River, US 259, Harris	PS (5)	S	S	NS (15)	NT
Red River, US 271, Hugo	S	NS (10,11)	S	NS (15, 16, 17)	NT
Red River, US 81, Terral	NS (5)	NS (10,11)	S	NS (16, 17)	NT
Sager Creek, off US 412, West Siloam Springs	S	NS (10,11)	PS (nitrates)	S	T (18, 19)
Salt Fork of the Arkansas, SH 58, Ingersoll	NS (3, 5)	NS (6, 7, 8, 9, 10,11)	S	S	NT
Salt Fork of the Arkansas, US 77, Tonkawa	PS (5)	NS (10,11)	S	S	NT
Salt Fork of the Red River, SH 34, Mangum	CBD	CBD	CBD	CBD	CBD
Salt Fork of the Red River, off US 283, Elmer	NS (2, 3, 5)	NS (6, 7, 8, 9, 10,11)	NS (12)	S	NT
Sandy Creek, SH 6, Eldorado	NS (2, 3, 5)	N/A	N/A	NS (15, 16)	NT
Skeleton Creek, SH 74, Lovell	NS (5)	NS (6, 8, 9, 10,11)	S	S	NT
Spring Creek, off US 412, Murphy	PS (1)	S	S	S	NT
Spring River, off SH 137, Quapaw	NS (2. 3, 5)	S	S	S	NT
Verdigris River, US 412, Inola	NS (3)	CBD	S	S	NT
Verdigris River, SH 10, Lenepah	PS (3, 5)	NS (10,11)	S	S	NT
Verdigris River, SH 20, Keetonville	NS (3)	NS (10,11)	S	S	NT

STATION NAME	FWP	PBCR	PPWS	AG	NUTRIENT
Verdigris River, SH 51, Wagoner	NS (3, 5)	NS (6)	S	S	NT
Washita River, SH 152, Cordell	NS (3, 5)	NS (6, 10,11)	S	S	NT
Washita River, SH 19, Pauls Valley	NS (5)	NS (6, 10,11)	S	NS (15)	NT
Washita River, SH 33, Hammon	NS (5)	NS (6, 8, 9, 10,11)	S	S	NT
Washita River, US 177, Durwood	NS (5)	NS (6, 10,11)	S	S	NT
Washita River, US 281, Anadarko	NS (5)	NS (10,11)	S	S	NT
West Cache Creek, SH 5B, Taylor	NS (3, 5)	NS (6, 8, 9, 10,11)	S	PS (15, 16)	NT
Wolf Creek, off US 270, Fort Supply	S	NS (10,11)	S	S	NT

ASSIGNED OWQS BENEFICIAL USES

FWP = FISH & WILDLIFE PROPOGATION
PBCR = PRIMARY BODY CONTACT RECREATION
PPWS = PUBLIC AND PRIVATE WATER SUPPLY
AG = AGRICULTURE
NUTRIENT = NUTIENTS

SUPPORT CODES

S—FULLY SUPPORTING
PS—PARTIALLY SUPPORTING
NS—NOT SUPPORTING
CBD-CAN NOT BE DETERMINED
NT-NOT THREATENED (NUTRIENTS)
T-THREATENED (NUTRIENTS)

WATER QUALITY VARIABLES

1—DISSOLVED OXYGEN	2—METALS (ACUTE)	3—METALS (CHRONIC)
4—pH	5—TURBIDITY	6—FECAL COLIFORM (SL)
7—FECAL COLIFORM (GM)	8—*Escherichia coli* (SL)	9—*Escherichia coli* (GM)
10—ENTEROCOCCI (SL)	11—ENTEROCOCCI (GM)	12—METALS (1)
13—METALS (6)	14—FECAL COLIFORM (PPWS)	15—TOTAL DISSOLVED SOLIDS
16—CHLORIDES	17—SULFATES	18—TOTAL PHOSPHORUS
19—NITRITE + NITRATE		

Ardmore City Lake

Ardmore City Lake was sampled for four quarters, from November 2000 through August of 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 average lake-wide turbidity was 12 NTU (Plate 1), true color was 27 units, and average secchi disk depth was 76 centimeters in sample year 2001. Water clarity was good at Ardmore City Lake based on the high secchi disk depth and low turbidity values and similar to results from the 1997 summer evaluation. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 49 (Plate 1), indicating the lake was mesotrophic in sample year 2001. The TSI values for all sites throughout the sample year were fairly consistent and generally ranged from upper mesotrophic to lower eutrophic (Figure 8). In the summer of 1997, the calculated TSI value was also mesotrophic (TSI=45) although fewer samples were used to calculate the trophic status. Seasonal turbidity values per site for sample year 2001 are displayed in Figure 9a. All turbidity values were well below the turbidity standard of 25 NTU. Seasonal true color values are also displayed in Figure 9b. All color values were well below the aesthetics OWQS for color (70 units).

In 2001, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity values for Ardmore City Lake ranged from 0.07 parts per thousand (ppt) to 0.18 ppt for this sample year. Specific conductivity ranged from 0.165 to 0.370mS/cm, which falls within the range of values commonly reported for Oklahoma reservoirs. These values indicate low levels of ions were present in the system. The pH values at Ardmore City Lake ranged from 6.7 units at the lake bottom in the summer to 8.86 in the winter quarter, representing a neutral to slightly basic system. Oxidation-reduction potentials ranged from 202mV in the hypolimnion in the summer to 462mV in the fall. Reducing conditions were not present at this reservoir in the 2001 sample year. During the fall and winter quarters no stratification was present, the lake was well mixed, and dissolved oxygen values were generally above 7 mg/L (see Figure 9a-9f). Thermal stratification was evident in the spring and

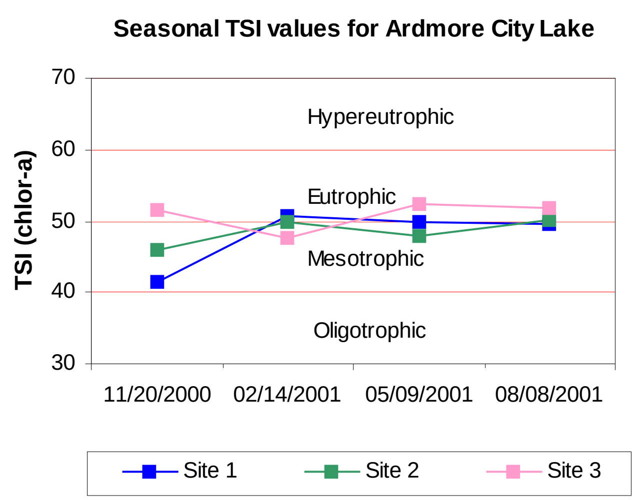


Figure 8. TSI values for Ardmore City Lake.

summer and anoxic conditions were present. Dissolved oxygen (mg/L) was less than 2 mg/L in the hypolimnion, below the thermocline in the spring. During the summer, the lake was stratified between 3 and 4 meters at which point dissolved oxygen dropped to <1mg/L for the rest of the water column at sites 1 and 2 (see Figure 9a-9f). If dissolved oxygen values are less than 2 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 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported, as in this case. At site 1, the dam, over 50% of the water column was anoxic with D.O. less than 1mg/L.

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 0.54 mg/L at the surface and 1.19 mg/L at the bottom. The TN at the surface ranged from 0.43 mg/L to 0.63 mg/L and from 0.62 mg/L to 2.83 mg/L at the lake bottom. Surface TN was highest in the fall quarter and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.036 mg/L at the surface and 0.092 mg/L at the lake bottom. The TP at the surface ranged from 0.021 mg/L to 0.075 mg/L at the surface and from 0.038 mg/L to 0.18 mg/L at the lake bottom. Similar to nitrogen, surface TP was highest in the fall quarter and lowest in the spring. The nitrogen to phosphorus ratio (TN:TP) was 15:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Ardmore City Lake was classified as mesotrophic with moderate productivity and nutrient levels, in both 2001 and 1997, indicating no significant increase or decrease in lake productivity or nutrient levels has occurred. Water clarity was good based on secchi disk depth and low turbidity and true color values. Because anoxic conditions were present in over 50% of the water column in the summer, Ardmore City Lake was only partially supporting the FWP beneficial use (USAP 785:46-15-5). Ardmore City Lake is a recreational reservoir managed by the City of Ardmore.

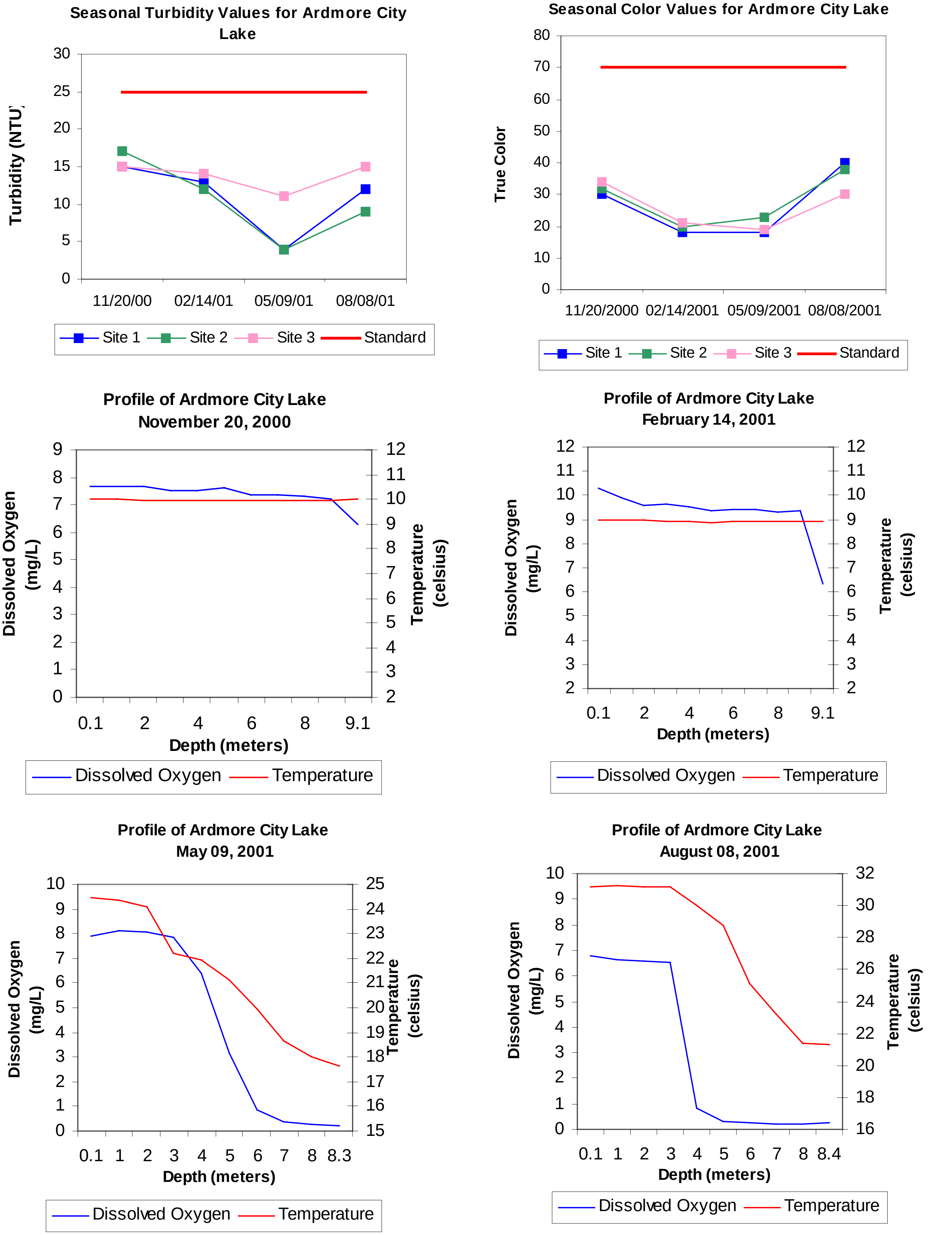


Figure 9a-9f. Graphical representation of data results for Ardmore City Lake.

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 1 - Lake Water Quality for

Ardmore City 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 (Plate 2), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=32). The TSI was 40 (Plate 2), indicating the lake was oligotrophic in sample year 2001. The TSI values for all sites throughout the sample year varied from oligotrophic to mesotrophic (Figure 10). 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. Turbidity values, per site, for sample year 2001 are displayed in Figure 11a. 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. Seasonal true color values are also displayed in Figure 11b. All true color values were well below the aesthetics OWQS of 70 units. It is interesting to note there was an ice storm in the winter that resulted in the contribution of trees and debris to the lakes in SE Oklahoma. Most likely this was the reason behind the results observed at the upper end of the lake (sites 7 and 8), where the turbidity was much higher and secchi disk depth much lower.

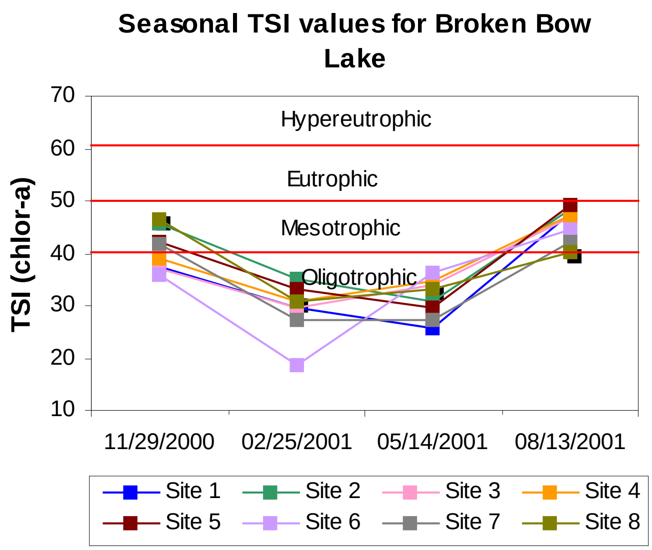


Figure 10. TSI values for Broken Bow Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity readings were consistently 0.0 parts per thousand (ppt) throughout sample year 2001 at all sites. Specific conductivity values were also very low, ranging from 0.001 in the spring to 0.045mS/cm at the lake bottom in the fall. These values are much lower than in most Oklahoma reservoirs, indicating there is virtually no salt content or extremely low levels of ions in

Broken Bow Lake. Values for pH ranged from 5.46 in the hypolimnion in the winter quarter to 8.13 units near the surface in the summer. Generally, most of the water column throughout the year was below 6.5 units (in fact, most values were between 5.5 and 6 mg/L) indicating the lake was slightly acidic and does not meet the fish and wildlife propagation OWQS for pH (OAC 785:45-5-12). 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 beneficial uses. Slightly acidic conditions seem to be common in this part of the state and may be due to natural conditions; therefore, Broken Bow Lake will only be listed as "provisionally not supporting"*****. Oxidation-reduction potentials (Redox) ranged from 395 mV to 581 mV, indicating the absence of reducing conditions. In the fall, a thermocline was present between 20 and 21 meters at the most of the lake sites, at which point the dissolved oxygen values dropped below 4mg/L to the lake bottom (see Figure 11c-11f). There was no thermocline in the winter quarter as the water was well mixed, and dissolved oxygen values were above 8 mg/L throughout the water column. In the spring, the first thermocline was between 5 and 6 meters; however, the D.O. concentration remained above 5.5 mg/L throughout the water column at sites 1-6. At sites 7and 8 in the upper end of the lake, D.O. values were less than 4 mg/L in the hypolimnion. A thermocline was present in the summer between 6 and 7 meters and at most sites the D.O. concentration dropped to less than 2 mg/L at some point in the water column; however, the FWP beneficial use was still supported (USAP 785:46-15-5).

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 was 0.35 mg/L at the surface and 0.56 mg/L for the lake bottom. The epilimnetic (surface) TN ranged from 0.18 mg/L to 0.60 mg/L and from 0.33 mg/L to 0.87 mg/L at the hypolimnion (bottom). TN was highest in the fall quarter and lowest in the summer and fall at the surface. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.02 mg/L for the surface and 0.016 mg/L at the lake bottom. The TP ranged from 0.007 mg/L to 0.059 mg/L at the surface and from 0.011 mg/L to 0.021 mg/L at the lake bottom. TP was highest and lowest in the spring at the surface. The nitrogen to phosphorus ratio (TN:TP) was 16:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Broken Bow Lake was oligotrophic, exhibiting low primary productivity and nutrient levels, consistent with results from the 1997 data collection. Broken Bow Lake, constructed by the USACOE, was constructed to serve as flood control, hydroelectric power, water supply, recreation and fish and wildlife purposes. Water clarity was excellent and the standards for true color and turbidity were fully supported based on current and previously collected data. Anoxic conditions were present although not at levels that present a concern in not supporting the OWQS fish and wildlife propagation beneficial use (USAP 785:46). Using USAP (OAC 785:46), Broken Bow Lake was not supporting the FWP beneficial use based on low pH values and should be "provisionally" listed and closely monitored in the future. According to ODEQ, Broken Bow Lake was sampled in 1998 and none of the fish tissue samples exceeded the screening level or low consumption advisory level for metals toxicity, although low levels of mercury were detected. In 1997, Broken Bow Lake exceeded the FDA Action Level for mercury residue (large mouth bass) and the ODEQ warning and concern levels. Consumption advisories are only released after contaminant levels are above ODEQ standards for two sample events.

***** 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.

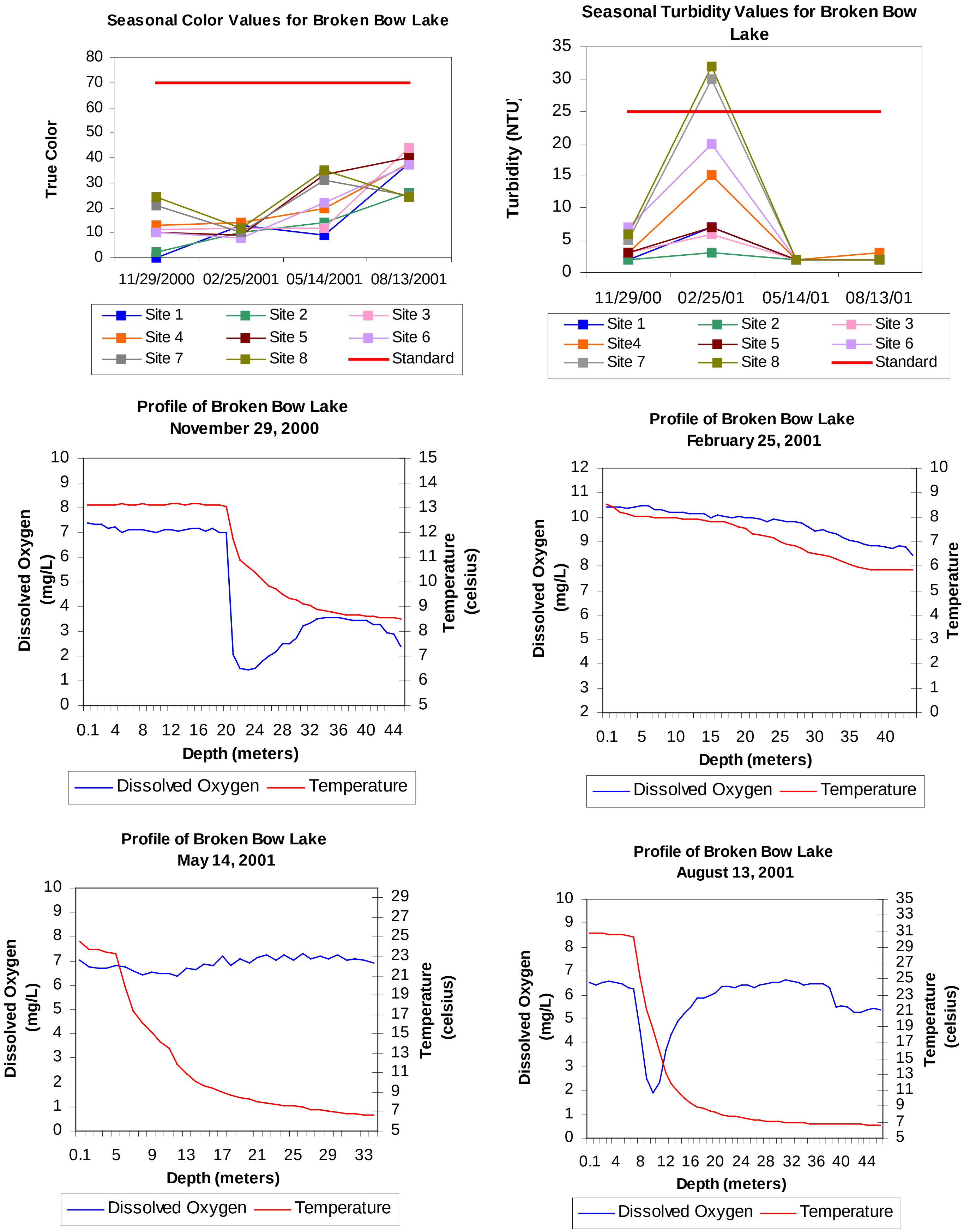
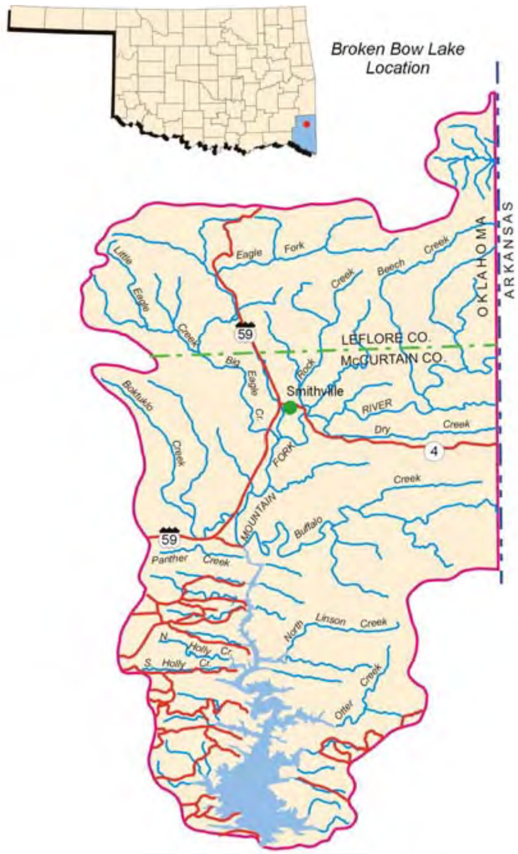


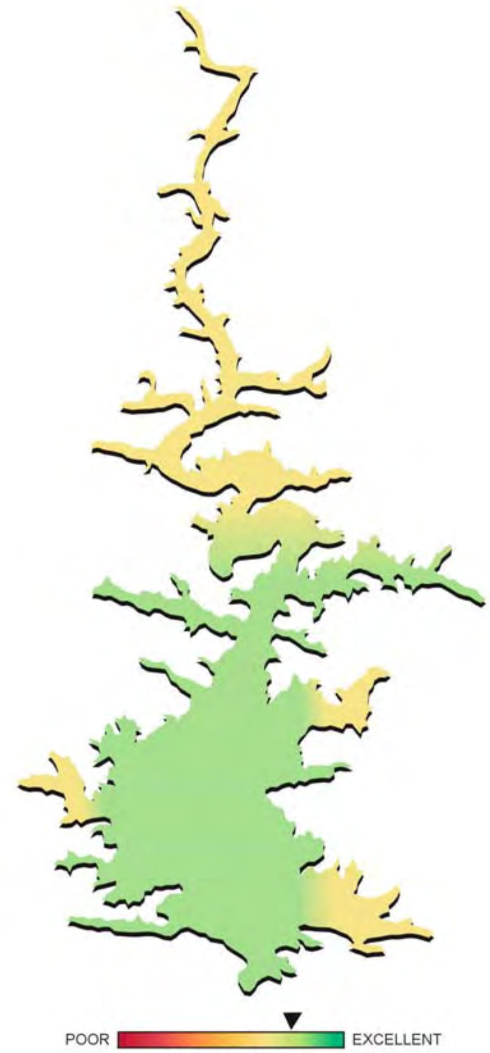
Figure 11a-11f. Graphical representation of data results for Broken Bow Lake.



Broken Bow Lake
and
Watershed

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

Turbidity
2001



Trophic State
2001

Plate 2 - Lake Water Quality for
Broken Bow Lake

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 (Plate 3), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 51 (Plate 3), 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 (see Figure 12). 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 OWQS of 25 NTU (see Figure 13a). The lake-wide annual turbidity of 4 NTU was representative of conditions at Brushy Creek Reservoir in 2001. Seasonal true color values are also displayed in Figure 13b. 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.

In 2001, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Brushy Creek salinity values ranged from 0.0 to 0.03 ppt, much lower than most of the salinity values recorded in Oklahoma lakes. Specific conductance values ranged from 0.025 to 0.089 mS/cm, which is lower than the typical range of values reported for Oklahoma reservoirs. The salt content and ion level in the system is negligible based on the low salinity and conductivity values. Values for pH were generally neutral, ranging from 6.08 in the spring to 8.07 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 range for 25% of the values and should be listed as not supporting beneficial

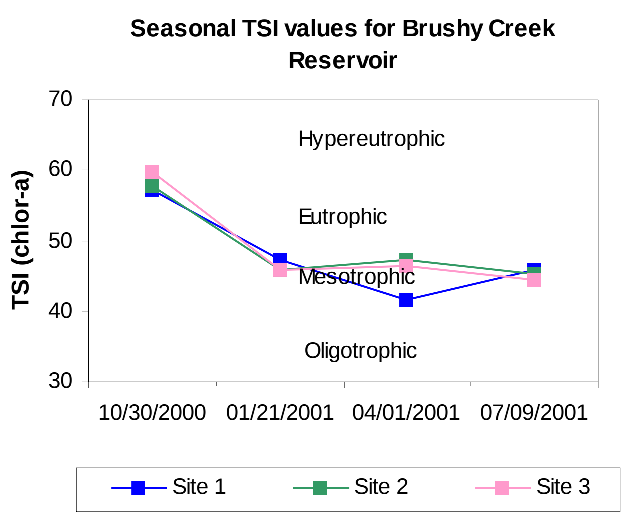


Figure 12. TSI values for Brushy Creek Reservoir.

uses. If 10 to 25% of the pH values fall outside the 6.5 to 9 range, the lake should be listed as partially supporting beneficial uses. The low pH values recorded primarily in the summer at Brushy Creek Reservoir 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 68mV at the lake bottom in the fall to 592mV in the spring. Other than two values at site 1 in the fall quarter, all other ORP values were above 100mV. In general, reducing conditions were not present in the reservoir. Brushy Creek was not thermally stratified in any of the first three seasons of sample year 2001 (see Figure 13c-13f). The lake was thermally stratified in the summer between several 1 meter intervals, the first being between 2 and 3 meters. Dissolved oxygen values ranged from 11 mg/L at the surface in the fall to 0.32 mg/L at the lake bottom. Roughly 44% of the water column was anoxic, which does not constitute a concern in meeting the FWP propagation beneficial use. If dissolved oxygen values are less than 2 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 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. The dissolved oxygen values in the winter and spring were above 4 mg/L and 5.8 mg/L, respectively (see Figure 13c-13f). During the summer, the D.O. values dropped at 4 meters from the surface to <1mg/L at all sites. About 60% of the water column at site 1, 50% at site 2, and 25% at site 3 were anoxic; therefore, the FWP beneficial use is considered partially supported.

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 was 0.97 mg/L at the surface and 1.31 mg/L for the lake bottom. The TN at the surface ranged from 0.34 mg/L to 2.03 mg/L and from 0.95 mg/L to 1.79 mg/L at the lake bottom. The highest surface TN was in the winter quarter and lowest in the spring. The lake-wide total phosphorus (TP) average was 0.07 mg/L at the surface and 0.06 at the lake bottom. The TP ranged from 0.009 mg/L to 0.04 mg/L at the surface and from 0.02 mg/L to 0.139 mg/L at the lake bottom. Surface TP was highest in the fall and lowest in the spring. The nitrogen to phosphorus ratio (TN:TP) was 13:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Brushy Creek Reservoir was classified as eutrophic in 2001, indicative of high primary productivity and nutrient rich conditions (Plate 3). Based on three summer values in 1997, the calculated TSI value was oligotrophic, much lower than the 2001 evaluation. This may be a result of changing conditions over time, or simply the result of more samples and a more accurate evaluation based on 2001 data. Water clarity was excellent and the standards for true color and turbidity were fully supported based on current and previously collected data. Anoxic conditions were present in the summer and constitutes listing as "partially supporting" the OWQS fish and wildlife propagation beneficial use based on D.O. values (USAP 785:46). According to USAP (OAC 785:46), Brushy Creek Reservoir was partially supporting the FWP beneficial use based on low pH values and should be "provisionally" listed and closely monitored in the future. Brushy Creek Reservoir is leased to the State of Oklahoma and was constructed in 1964 to serve as flood control and for recreational purposes. This area is considered part of Sallisaw State Park.

* 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.

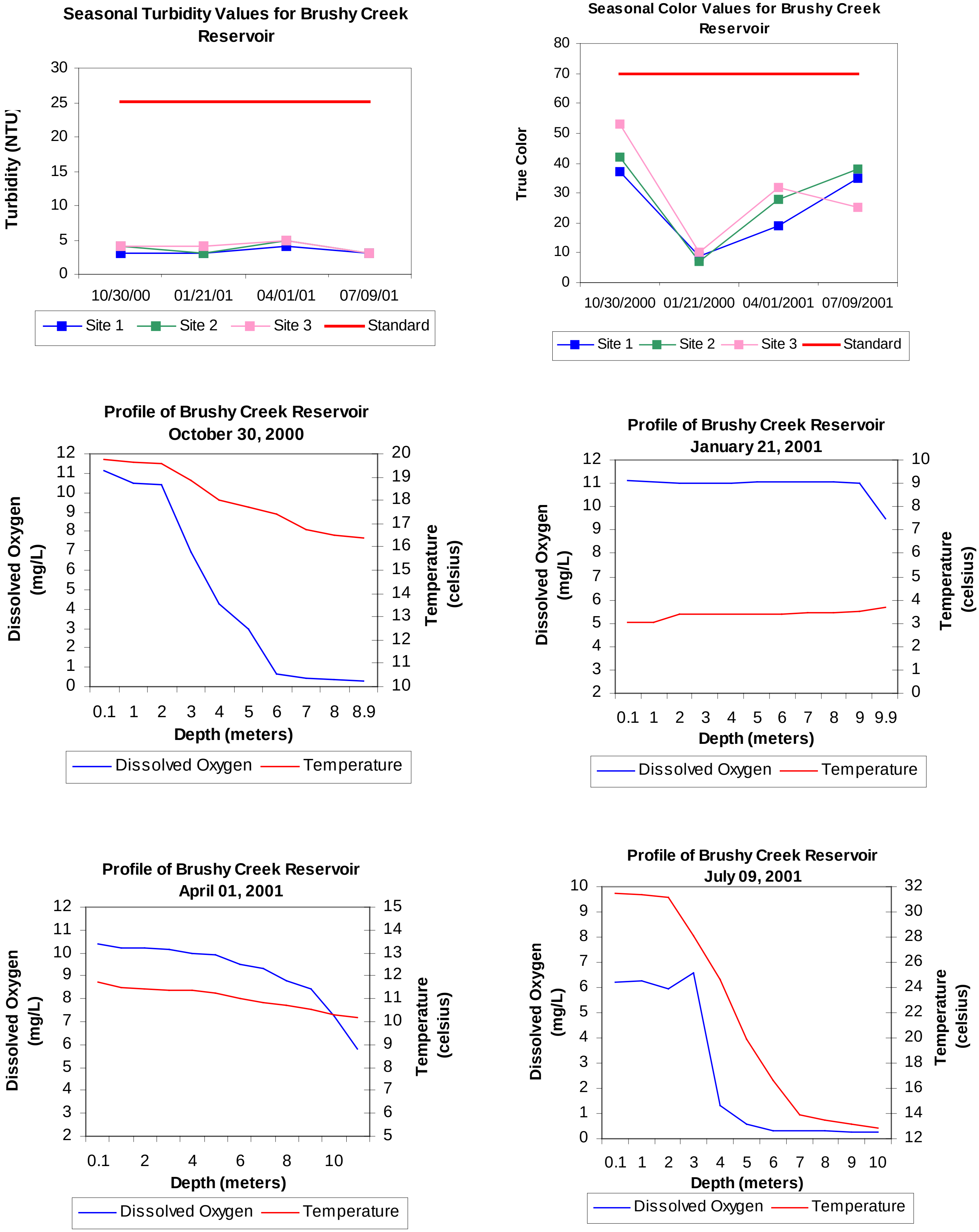
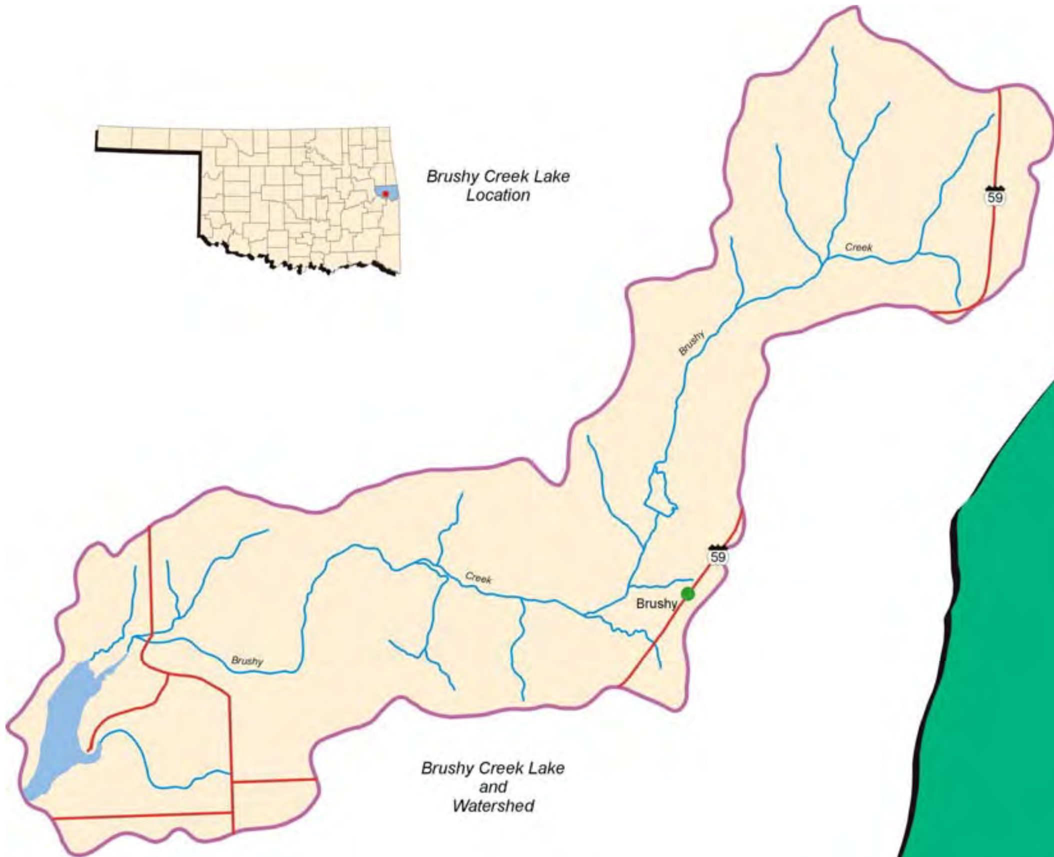
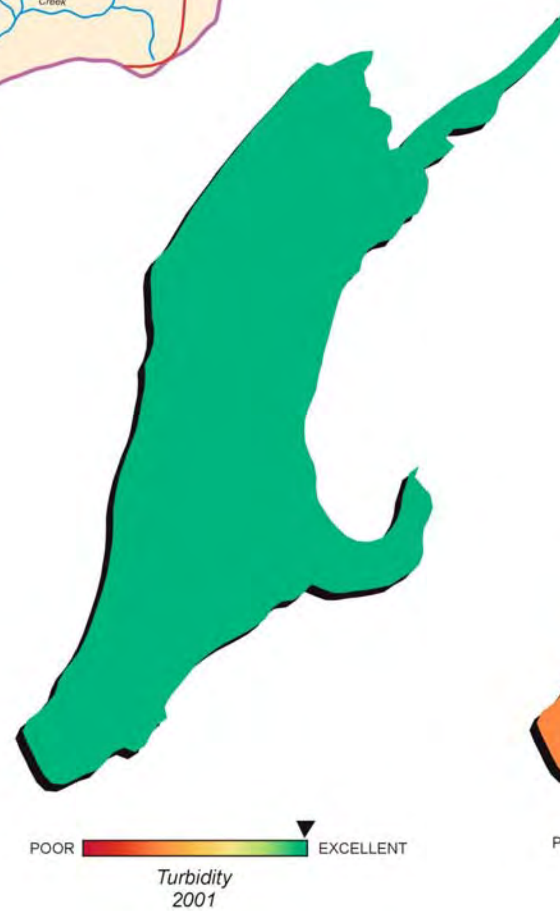


Figure 13a-13f. Graphical representation of data results for Brushy Creek Reservoir.



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



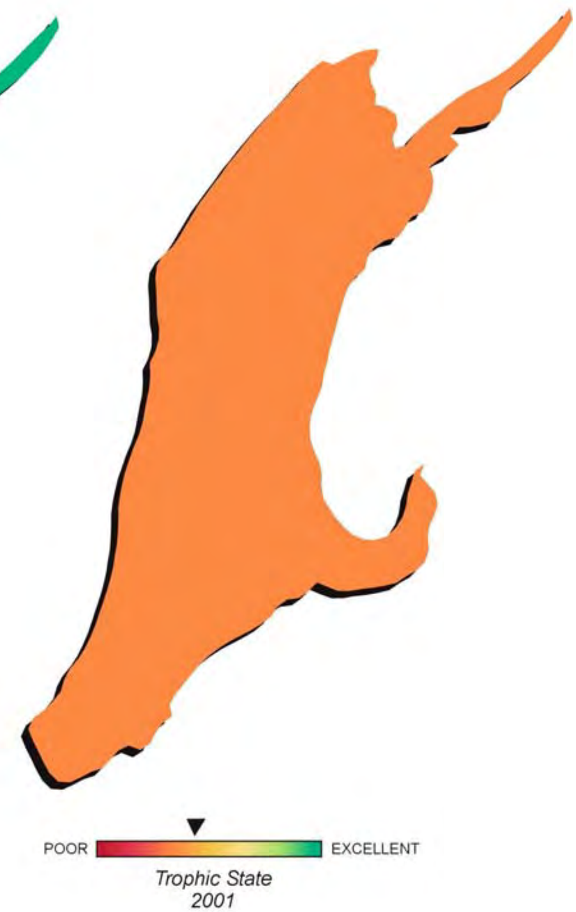


Plate 3 - Lake Water Quality for
Brushy Creek Reservoir

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 (Plate 4), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 41 (Plate 4), 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 (see Figure 14). 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 (see Figure 15a). All turbidity values for 2001 were below the OWQS of 25 NTU, although there was an evident increase in the spring quarter, when storm events resulting in runoff are more common (see Figure 15). The lake-wide annual turbidity of 12 NTU was representative of conditions at Carl Albert Lake in 2001. Seasonal true color values are also displayed in Figure 15b. All true color values were below the aesthetics OWQS of 70 units, although the summer values approached the standard.

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 0.0ppt to 0.02ppt. Readings for specific conductance were relatively consistent throughout the water column for each quarter, ranging from 0.006mS/cm (spring) to 0.064mS/cm (summer). Both salinity and conductivity values, less than typical values in Oklahoma reservoirs, indicated very low levels of current conducting compounds or salts were present. The pH values ranged from 5.81 in the spring to 7.77 in the winter. According to USAP (OAC 785:46-15-5), pH

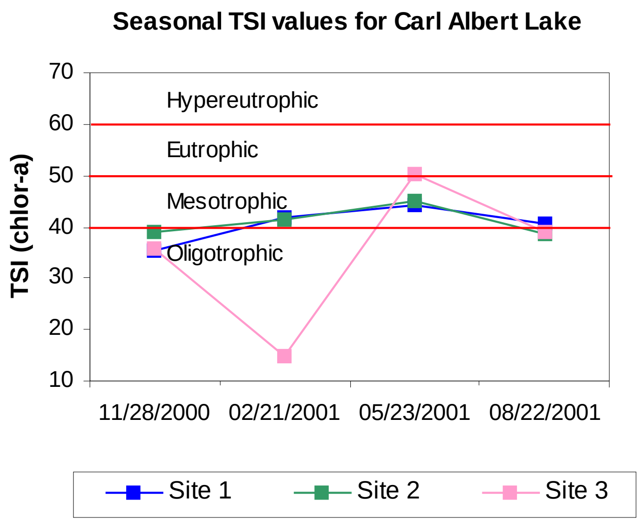


Figure 14. TSI values for Carl Albert Lake.

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 beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9 range, the lake should be listed as partially supporting beneficial uses. The low pH values recorded in the spring and summer at Carl Albert Lake may be due to natural conditions, and will be listed as "provisionally not supporting"* the FWP beneficial use. The oxidation-reduction potential (Redox) was fairly constant during each sampling interval, ranging from 348mV to 592mV, indicating an absence of reducing conditions. Carl Albert Lake was well mixed in the fall with no thermal stratification and dissolved oxygen concentrations above 9.3 mg/L throughout (see Figure 15c-15f). The lake was well mixed in the winter with D.O. levels above 8.2 mg/L although there was a thermocline present between 4 and 5 meters. The lake was thermally stratified in the spring and summer between several 1-meter intervals, the first being between 3 and 4 meters. D.O. levels were low in the spring, but did not constitute a concern in meeting the FWP propagation beneficial use. The lake was anoxic (<2 mg/L) for about 70% of the water column at site 1, the dam, and 55% at site 2 in the summer (see Figure 15c-15f). If dissolved oxygen values are less than 2 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 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 Carl Albert Lake.

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 was 0.32 mg/L at the surface and 0.48 mg/L for the lake bottom. The TN at the surface ranged from 0.16 mg/L to 0.42 mg/L and from 0.36 mg/L to 0.81 mg/L at the lake bottom. Surface TN was highest and lowest in the spring quarter. The lake-wide total phosphorus (TP) average was 0.03 mg/L at the surface and 0.06 at the lake bottom. The total phosphorus ranged from 0.015 mg/L to 0.051 mg/L at the surface and from 0.035 mg/L to 0.116 mg/L at the lake bottom. Surface TP was highest in the fall and lowest in the summer. The nitrogen to phosphorus ratio (TN:TP) was 10:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Carl Albert Lake was classified as mesotrophic, indicative of low to moderate primary productivity and nutrient levels (Plate 4). Based on three summer values in 1997, the calculated TSI value was also mesotrophic, although higher than the 2001 evaluation. The 2001 assessment is most likely a more accurate depiction of lake productivity as data was collected throughout the year. Water clarity was good and the standards for true color and turbidity were fully supported based on current and previously collected data. Anoxic conditions were present in the summer and constitutes listing as "partially supporting" the OWQS fish and wildlife propagation beneficial use (USAP 785:46). Greater than 25% of the pH values were less than the 6.5 to 9 criteria listed in USAP (785:46), indicating the FWP beneficial use was not supported and should be "provisionally" listed and closely monitored in the future. Carl Albert Lake is the municipal water supply reservoir for the City of Talihina and is also utilized for flood control and 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.

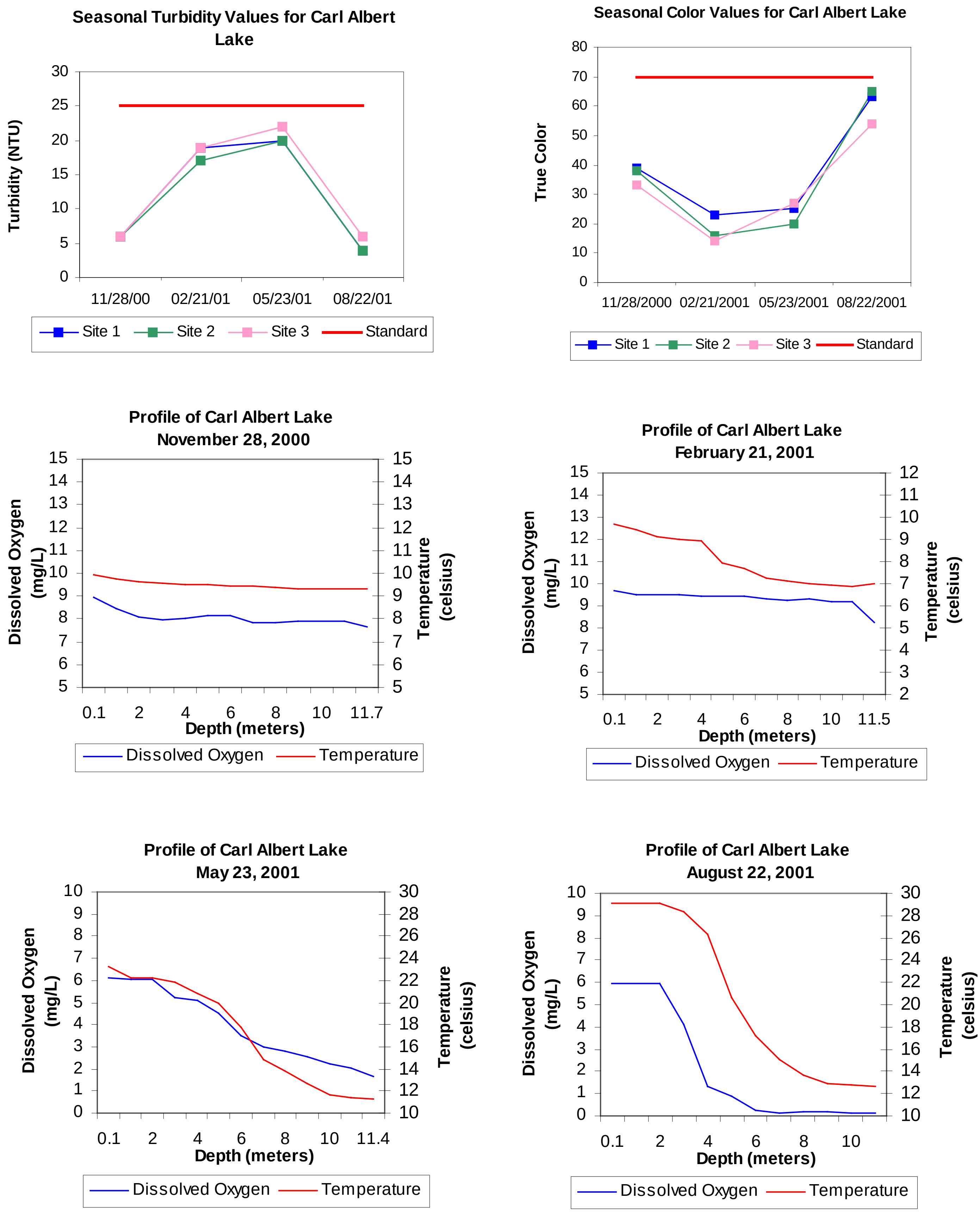
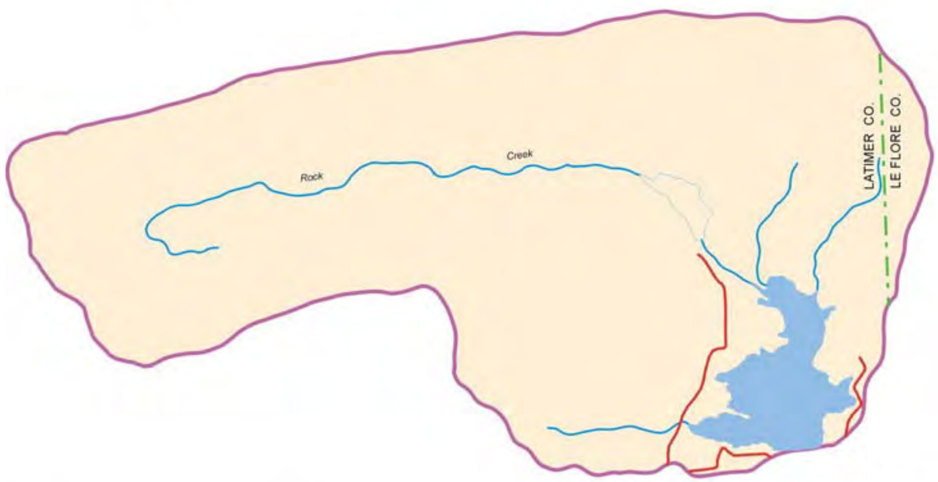


Figure 15a-15f. Graphical representation of data results for Carl Albert Lake.

Plate 4 - Lake Water Quality for
Carl Albert Lake

Carl Albert Lake
Location



Carl Albert Lake
and
Watershed

Lake Data

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

Turbidity
2001

Trophic State
2001

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 (Plate 5), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=10). The TSI was 44 (Plate 5), 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 (Figure 16). 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 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 OWQS of 25 NTU for all seasons (see Figure 17a). Seasonal true color values are also displayed in Figure 17b. All true color values were well below the aesthetics OWQS of 70 units.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Carter Lake salinity values ranged from 0.04ppt to 0.12ppt, 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 0.084mS/cm in the spring to 0.247mS/cm in the summer. Specific conductance values were also within the expected range for Oklahoma reservoirs, indicating low levels of electrical current conducting compounds like salts. Oxidation-reduction potentials (Redox) ranged from 263mV to 631mV, indicating that reducing conditions were

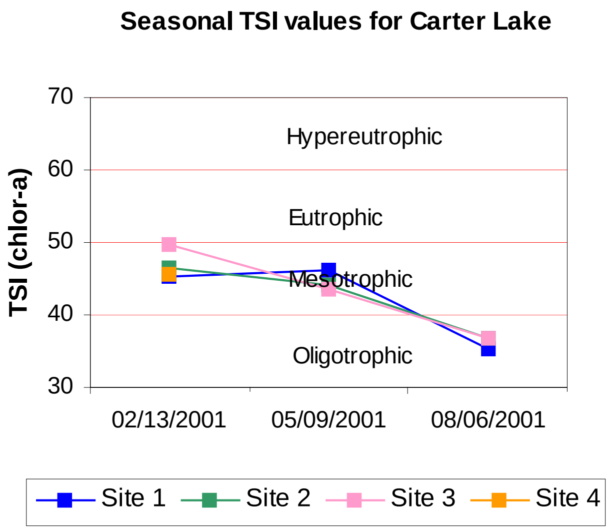


Figure 16. TSI values for Carter Lake.

not present in the water column during any time of the year. The pH values in Carter Lake were neutral, ranging from 6.77 in the summer to 8.79 units in the winter. The lake was well mixed and not thermally stratified during the winter quarter with dissolved oxygen values above 8 mg/L throughout (see Figure 17c-17e). In the spring, the lake was stratified between 3 and 4 meters, at which point the D.O. concentration dropped below 2 mg/L. Although close to 50% of the water column was anoxic, the fish and wildlife propagation beneficial use was still met. In the summer, the lake was stratified and a thermocline was present at several 1-meter intervals, the first being between 3 and 4 meters. Approximately 40% of the water column at the dam was anoxic, although the FWP beneficial use was still considered fully supported.

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 was 0.57 mg/L at the surface and 1.02 mg/L for the lake bottom. The epilimnetic TN ranged from 0.50 mg/L to 0.69 mg/L and from 0.65 mg/L to 1.52 mg/L in the lake hypolimnion. Surface TN was highest in the winter quarter and lowest in the summer. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.023 mg/L for the surface and 0.036 mg/L at the lake bottom. The TP ranged from 0.014 mg/L to 0.034 mg/L at the surface and from 0.029 mg/L to 0.042 mg/L at the lake bottom. Surface TP was also highest in the winter and lowest in the summer. The nitrogen to phosphorus ratio (TN:TP) was 24:1 for sample year 2001. This value is much greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Carter Lake was classified as mesotrophic, indicative of moderate productivity and nutrients (Plate 5). Water clarity was excellent and the standards for true color and turbidity were fully supported based on current and previously collected data. Anoxic conditions were present although not at levels that present a concern in not supporting the OWQS fish and wildlife propagation beneficial use (USAP 785:46). Carter Lake is the municipal water supply reservoir for the City of Madill and is also utilized for recreation purposes.

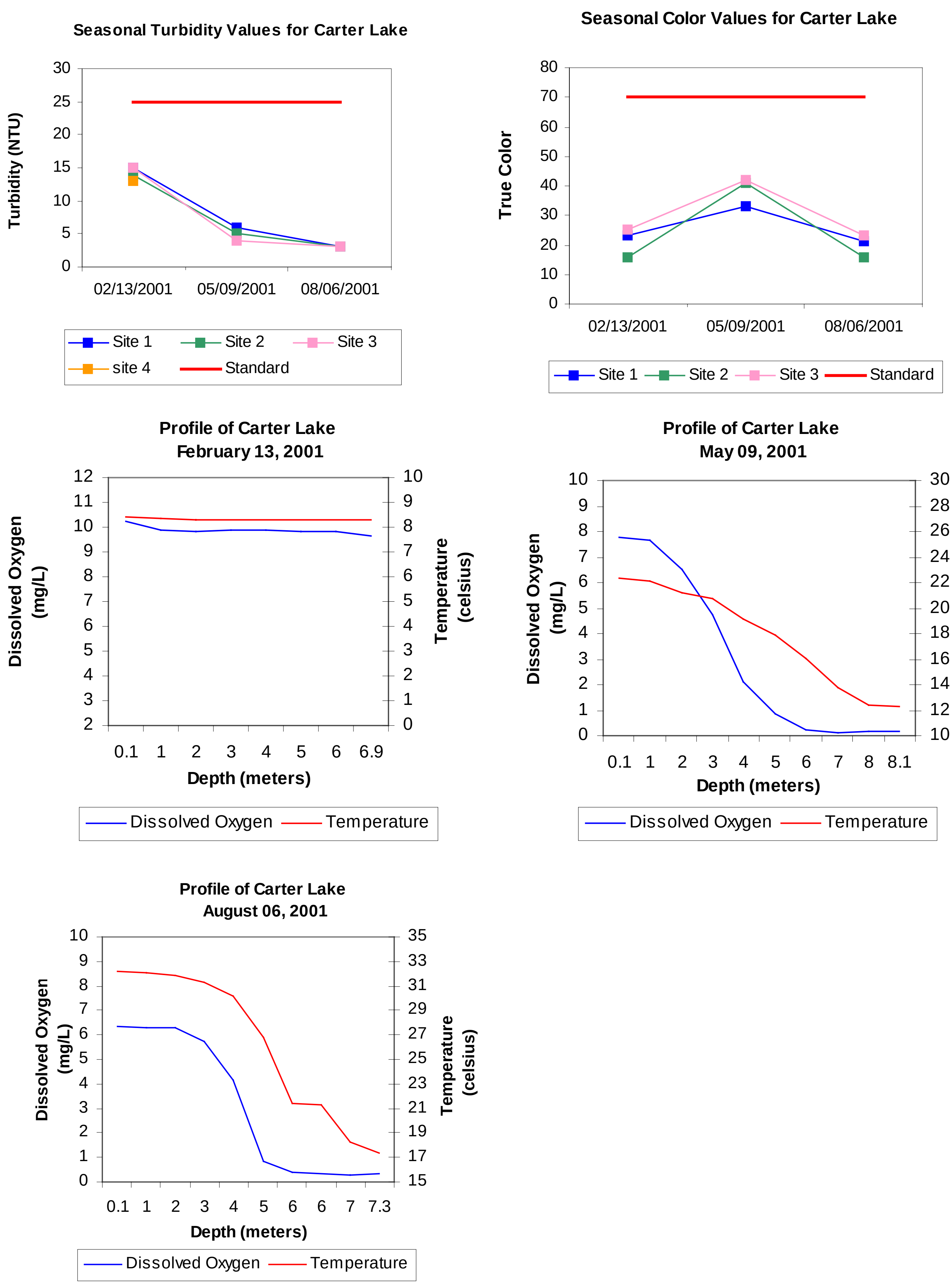
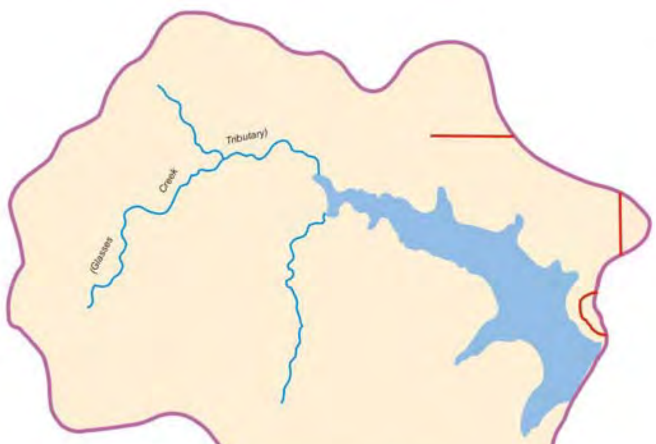
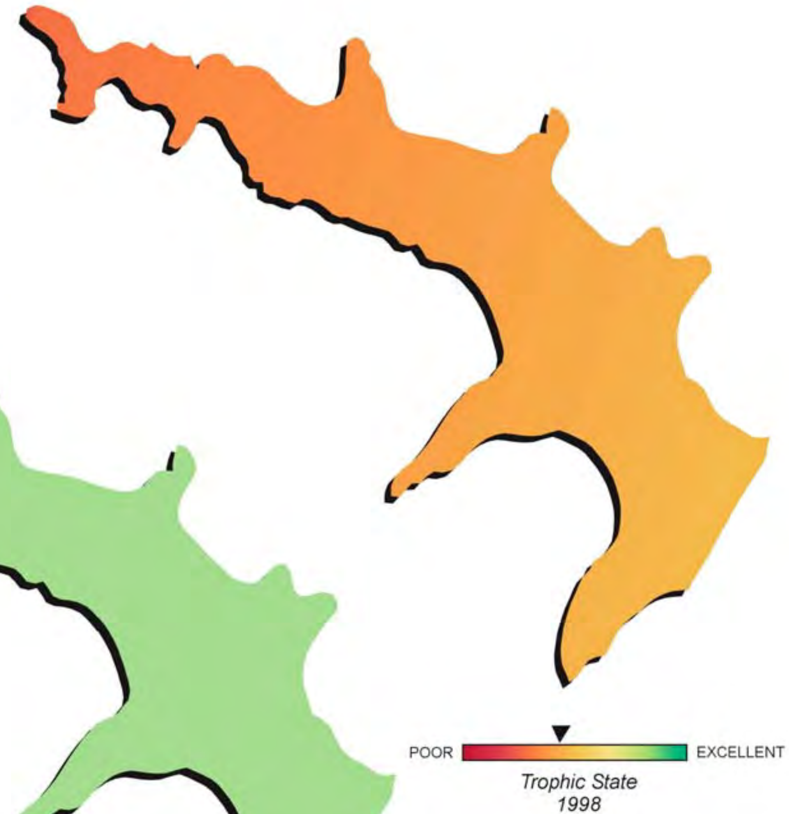


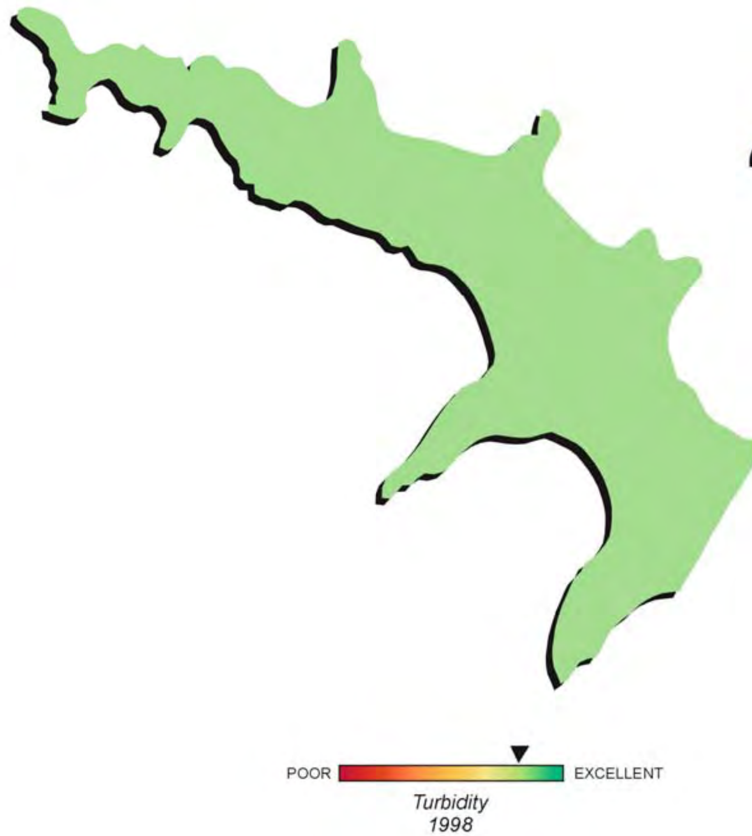
Figure 17a-17e. Graphical representation of data results for Carter Lake.

Carter Lake Location



Carter Lake and Watershed





Lake Data

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

Plate 5 - Lake Water Quality for

Carter Lake

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 (Plate 6), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 51 (Plate 6), 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 (Figure 18). 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 OWQS of 25 NTU for all seasons (see Figure 19a). The lake-wide annual turbidity of 8 NTU was representative of conditions at Cedar Lake in 2001. Seasonal true color values are also displayed in Figure 19b. 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.

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 0ppt at all sites in the fall, winter, and spring to 0.04ppt in the summer. Low to no salinity value in the water column indicates chlorides or salts were not present in the lake. Specific conductivity was slightly less than most values recorded in Oklahoma reservoirs, indicating minimal presence of electrical current conducting compounds like salts. Values ranged from 0.004mS/cm to 0.100mS/cm in the summer. Lake pH values were slightly acidic, ranging from 5.33 in the winter to 8.76 units in the

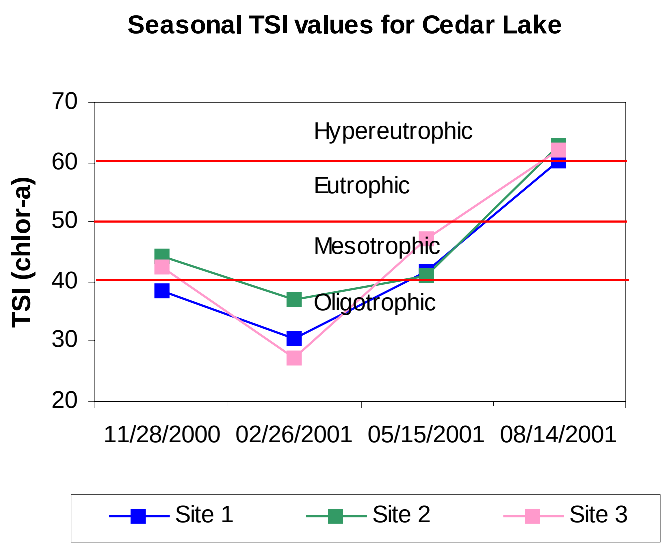


Figure 18. TSI values for Cedar Lake.

summer. 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 beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9 range, the lake should be listed as partially supporting beneficial uses. The low pH values recorded throughout the year at Cedar Lake may be due to natural conditions, and will be listed as "provisionally not supporting"* the FWP beneficial use. Low pH values are common in reservoirs in this part of the state. Oxidation-reduction potentials were greater than 416mV throughout the water column in the first three quarters, indicating reducing conditions were not present, but ranged from ranged from 118mV at the lake bottom to 474mV in summer. Low Redox values in the hypolimnion are not uncommon when the lake is stratified and anoxic conditions are present. The lake was not stratified in the fall or winter and the lake was well mixed with dissolved oxygen values above 6 mg/L (see Figure 19c-19f). The lake was thermally stratified in the spring and summer between several 1-meter intervals, the first being between 3 and 4 meters in the spring and 2 and 3 meters in the summer (see Figure 19c-19f). D.O. concentration was less than 2 mg/L below 4 meters from the surface to the lake bottom, 9 meters (about 50% of the water column), at the dam. In the summer, anoxic conditions were present for about 65% of the water column at the dam, 45% at sites 2 and 3, constituting a concern in meeting the FWP propagation beneficial use. If dissolved oxygen values are less than 2 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 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 Cedar Lake.

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 was 0.43 mg/L at the surface and 1.02 mg/L for the lake bottom. The TN at the surface ranged from 0.08 mg/L to 0.80 mg/L and from 0.08 mg/L to 2.62 mg/L at the lake bottom. Surface TN was highest in the summer quarter and lowest in the winter. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.025 mg/L at the surface and 0.143 mg/L at the bottom. The TP ranged from 0.01 mg/L to 0.05 mg/L at the surface and from 0.035 mg/L to 0.392 mg/L at the lake bottom. Surface TP was also highest in the summer and lowest in the winter. The nitrogen to phosphorus ratio (TN:TP) was 17:1 for 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Cedar Lake was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 6). According to USAP (OAC 785:46), Cedar Lake was not supporting the FWP beneficial use based on low pH values and should be "provisionally" listed and closely monitored in the future. Anoxic conditions were present in the spring and summer and constitutes listing as "partially supporting" the OWQS fish and wildlife propagation beneficial use based on D.O. values (USAP 785:46). The USDA constructed Cedar Lake, located in the Ouachita National Forest, in 1937 for recreational 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.

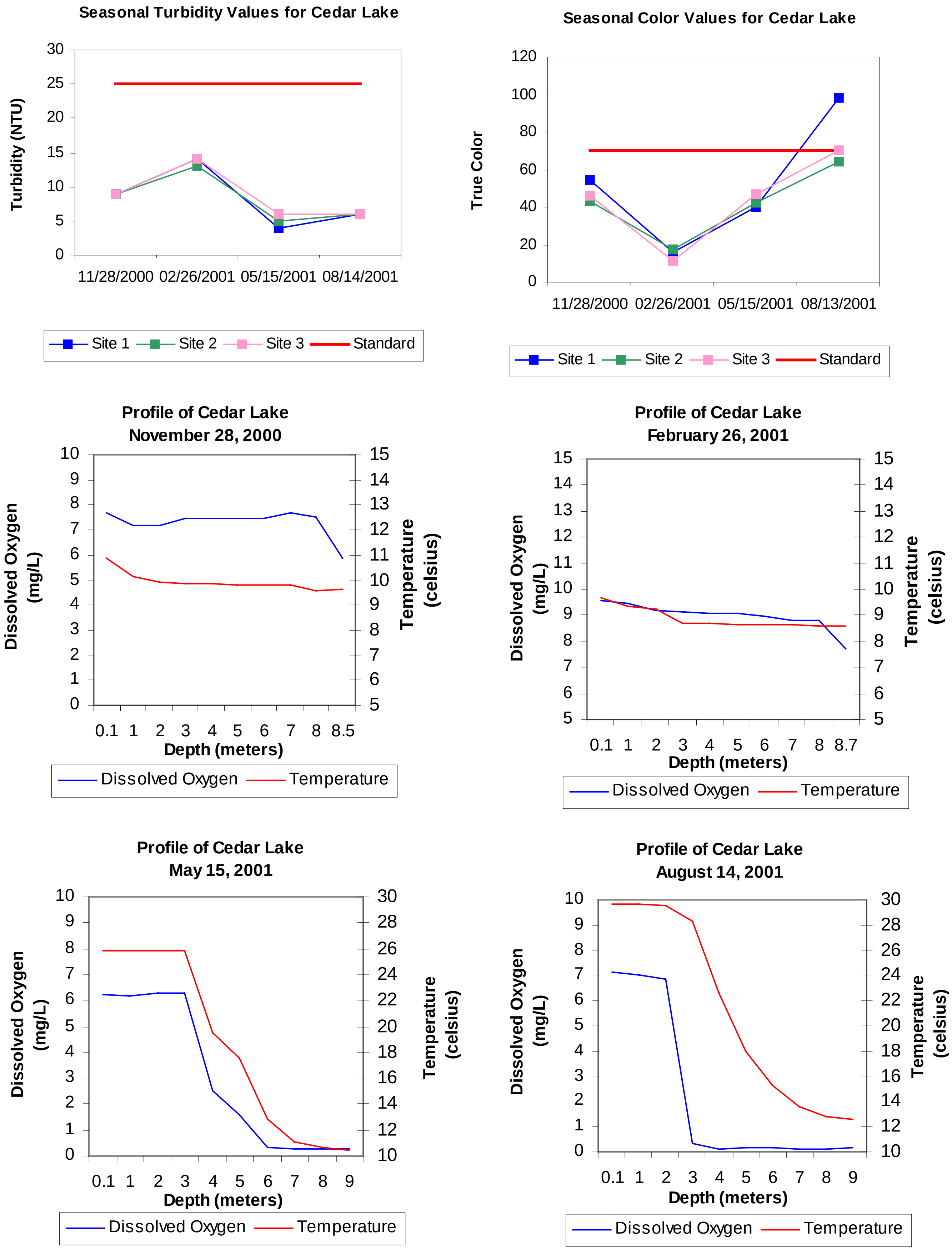


Figure 19a-19f. Graphical representation of data results for Cedar Lake.

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

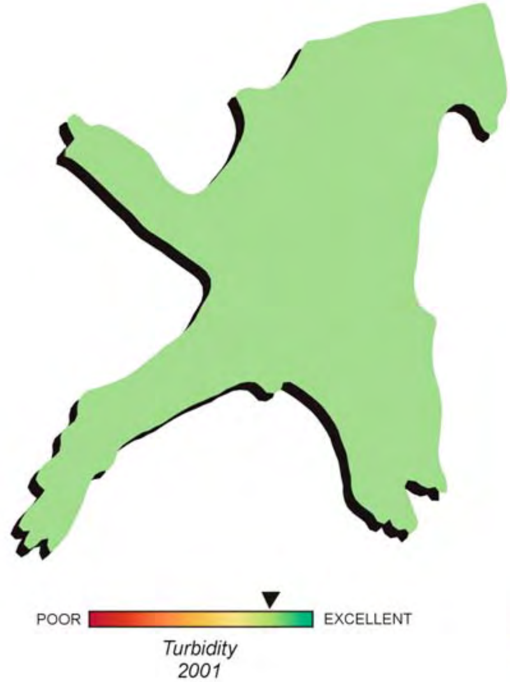


Plate 6 - Lake Water Quality for

Cedar Lake

Chandler Lake

Chandler Lake was sampled for four quarters, from October 2000 through July 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 annual turbidity value was 8 NTU (Plate 7), true color was 31 units, and secchi disk depth was 95 centimeters in 2001. Water clarity was good based on secchi disk depth, turbidity, and true color values. Compared to values recorded in the summer of 1998, turbidity and color were very similar, although secchi disk depth was much higher than previously reported. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 46 (Plate 7), indicating the lake was mesotrophic in sample year 2001. The TSI values throughout the sample year varied seasonally from oligotrophic in the winter to bordering eutrophic in the fall (Figure 20). Based on three summer values in 1998, the calculated TSI value was also mesotrophic (TSI=48). Turbidity values per site for sample year 2001 were below the OWQS of 25 NTU for all seasons (see Figure 21a). The lake-wide annual turbidity of 8 NTU was representative of conditions at Chandler Lake in 2001. Seasonal true color values are also displayed in Figure 21b. All true color values were below the aesthetics OWQS of 70 units, with the exception of site 1 in the summer. The lake-wide annual true color value of 46 units was representative of conditions at Chandler Lake in 2001.

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 0.09ppt in the spring to 0.14ppt in the winter and summer. Salinity concentrations were 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 within the expected range for Oklahoma reservoirs, indicating minimal presence of electrical current conducting compounds like salts. Values ranged from 0.194mS/cm in the spring to 0.299mS/cm in the winter. Lake pH values were neutral to slightly alkaline, ranging from 6.96 to 8.57 units. Oxidation-reduction potentials ranged from 251mV in the summer to 583mV in the winter, indicating reducing conditions were

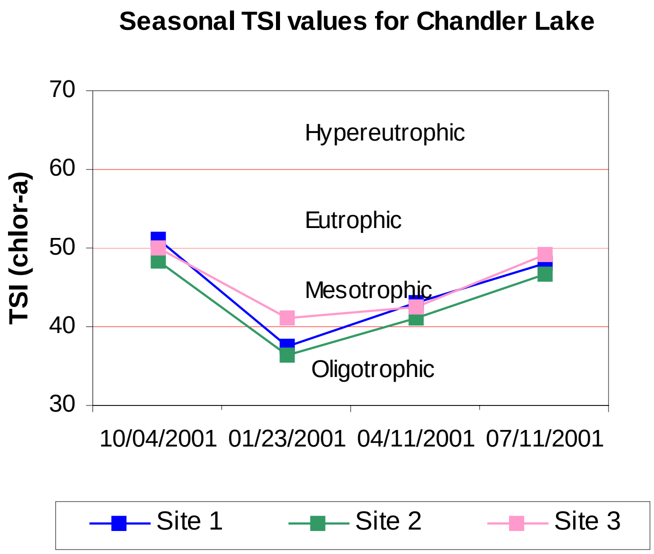


Figure 20. TSI values for Chandler Lake.

not present throughout the year. The lake was not stratified in the fall or winter, when the lake volume was well mixed, and D.O. concentration was above 6mg/L (65% saturation) throughout the water column (see Figure 21c-21f). The lake was thermally stratified in the spring between 4 and 5 meters, although the D.O. values remained above the 2mg/L criteria level (see Figure 21c-21f). In the summer, the lake was stratified between 3 and 4 meters at which point the D.O. concentration was less than 2 mg/L to the lake bottom. If dissolved oxygen values are less than 2 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 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 Chandler Lake.

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 was 0.52 mg/L at the surface and 0.94 mg/L for the lake bottom. The epilimnetic (surface) TN ranged from 0.24 mg/L to 0.68 mg/L and from 0.33 mg/L to 1.83 mg/L at the hypolimnion (bottom). TN was highest at site 3 in the winter and spring and lowest in the fall at site 2. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.03 mg/L for the surface and 0.22 mg/L at the lake bottom. The TP ranged from 0.021 mg/L to 0.041 mg/L at the surface and from 0.036 mg/L to 0.753 mg/L at the lake bottom. TP was highest in the spring and lowest in the winter at the surface. The nitrogen to phosphorus ratio (TN:TP) was 17:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Chandler Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 7). Based on three summer chlorophyll-a values in 1998, the calculated TSI value was also mesotrophic, indicating no significant change in trophic status over time. Water clarity was good and the criteria for true color and turbidity were fully supported based on current and previously collected data. Anoxic conditions were present in the summer and constitutes listing as “partially supporting” the OWQS fish and wildlife propagation beneficial use based on D.O. values (USAP 785:46). Chandler Lake is the municipal water supply reservoir for the City of Chandler and is also utilized for recreation purposes.

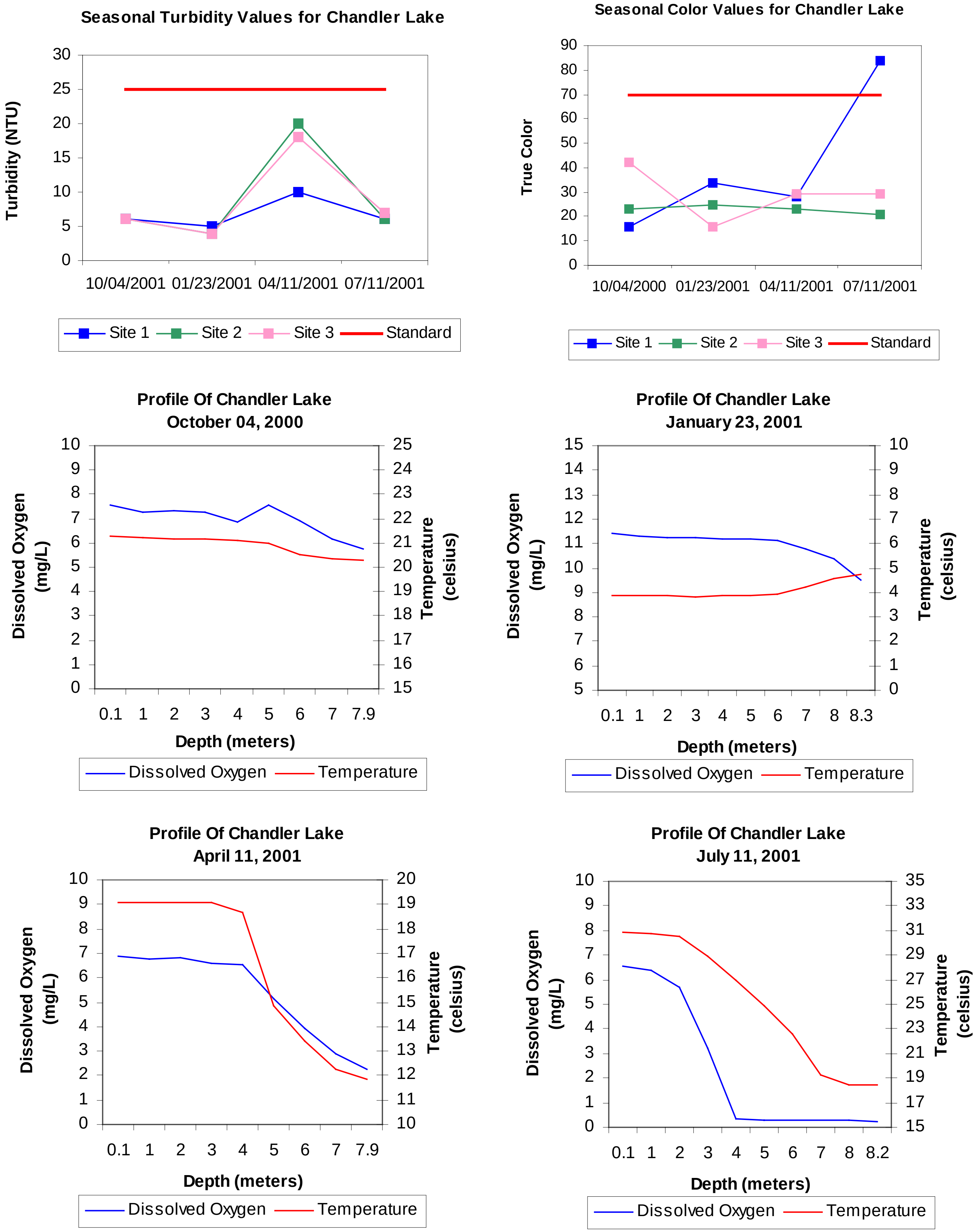
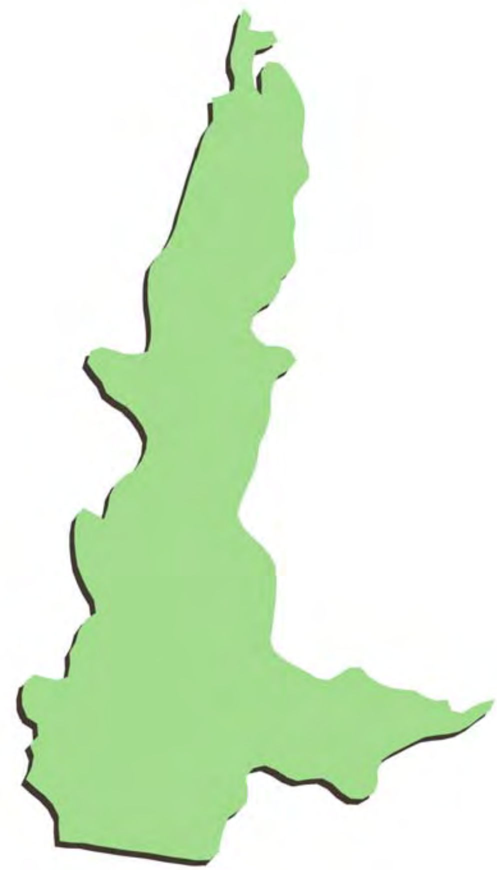


Figure 21a-21f. Graphical representation of data results for Chandler Lake.

Plate 7 - Lake Water Quality 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

Clear Creek Lake

Clear Creek Lake was sampled for four quarters, from November 2000 through July 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 annual turbidity value was 11 NTU (Plate 8), true color was 24 units, and secchi disk depth was 86 centimeters in 2001. Based on these three parameters, Clear Creek Lake had good water clarity. These values are very similar to those calculated in 1997, indicating no significant increase or decrease over time. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 53 (Plate 8), indicating the lake was eutrophic in sample year 2001. The TSI values throughout the sample year varied seasonally from oligotrophic/mesotrophic in the winter to bordering hypereutrophic in the fall (Figure 22). Based on three summer values in 1997, the calculated TSI value was mesotrophic (TSI=50), although bordering eutrophic, 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. All turbidity values were below the turbidity standard of 25 NTU (see Figure 23a). The lake-wide annual turbidity of 11 NTU was representative of conditions at Clear Creek Lake in 2001. Seasonal true color values are also displayed in Figure 23b. All true color values were below the aesthetics OWQS of 70 units.

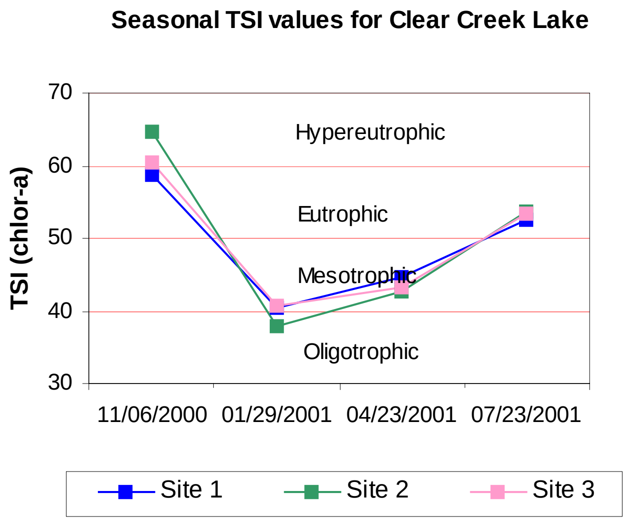


Figure 22. TSI values for Clear Creek Lake.

In 2001, 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. The salinity ranged from 0.23 to 0.32 parts per thousand (ppt), slightly higher than most Oklahoma reservoirs. Specific conductance ranged from 0.462 to 0.619mS/cm, higher than most Oklahoma lakes, which indicates moderate presence of current conducting ionic compounds (or other analogous materials) in the lake. The pH values at Clear Creek Lake were generally neutral ranging from 7.18 to 8.2 units. Oxidation-reduction potentials ranged from 123mV in the winter (only two values were less than 200 mV) to 466mV in the spring, which indicated an absence of reducing conditions. The lake was not thermally stratified in the fall, winter or spring and dissolved oxygen (D.O.) concentrations were above 6 mg/L throughout the water column during the first three seasons (see Figure 23c-23e). In the summer, the lake was stratified between 7 and 8 meters, although the D.O. concentration was less than 2 mg/L below 5 meters to the lake bottom. Anoxic conditions were not present at the other two sites in the summer, probably because they were both less than 5 meters in depth. If dissolved oxygen values are less than 2 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 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, there is not concern in meeting the FWP beneficial use at Clear Creek Lake.

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 was 0.70 mg/L at the surface and 0.78 mg/L for the lake bottom. The epilimnetic (surface) TN ranged from 0.59 mg/L to 0.80 mg/L and from 0.69 mg/L to 0.91 mg/L at the hypolimnion (bottom). TN was highest at site 1 in the spring and lowest in the fall at site 2. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.028 mg/L for the surface and 0.046 mg/L at the lake bottom. The TP ranged from 0.014 mg/L to 0.068 mg/L at the surface and from 0.022 mg/L to 0.089 mg/L at the lake bottom. TP was highest and lowest in the fall at the surface. The nitrogen to phosphorus ratio (TN:TP) was 25:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Clear Creek Lake was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 8). Water clarity was good and the OWQS criteria for true color and turbidity were fully supported based on current and previously collected data. Anoxic conditions were present in the summer although not at a level that would cause concern in meeting the OWQS fish and wildlife propagation beneficial use (USAP 785:46). Clear Creek Lake is one of the municipal water supply reservoirs for the City of Duncan and is utilized for recreation purposes.

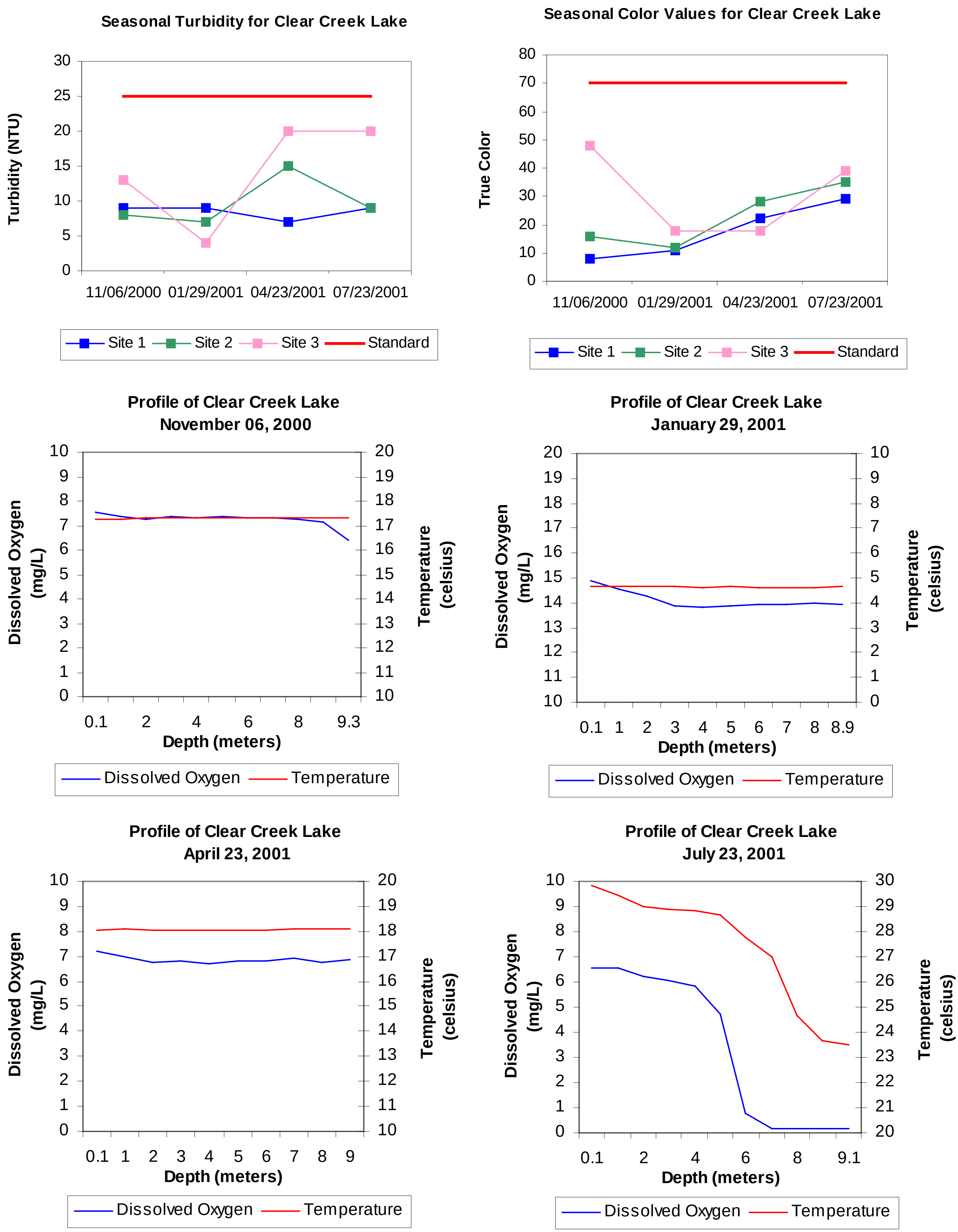
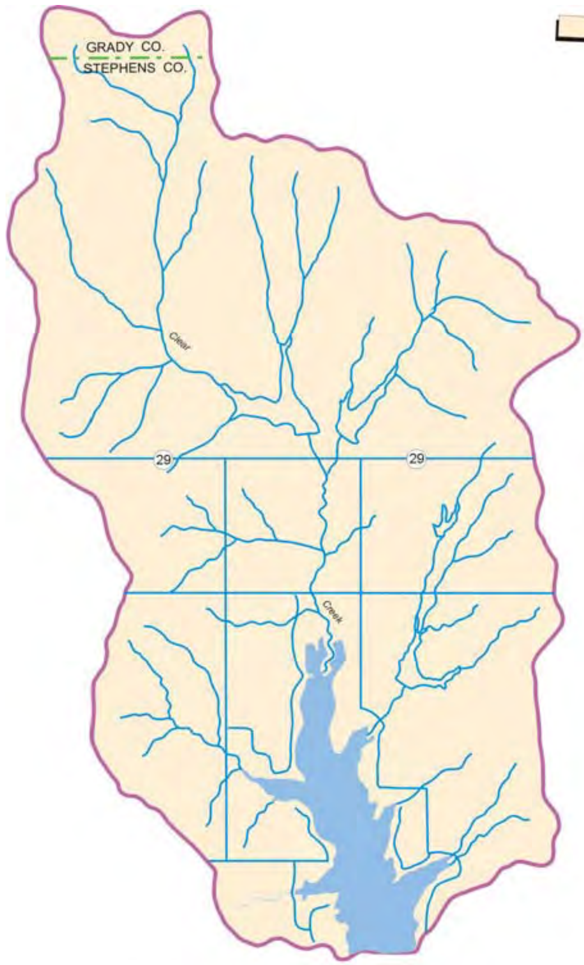


Figure 23a-23f. Graphical representation of data results for Clear Creek Lake.

Plate 8 - Lake Water Quality for
Clear Creek Lake



Clear Creek Lake and Watershed

Clear Creek Lake Location

Turbidity 2001

Trophic State 2001

Lake Data

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

Comanche Lake

Comanche Lake was sampled for four quarters from November 2000 through July 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 annual turbidity value was 20 NTU (Plate 9), true color was 58 units, and secchi disk depth was 53 centimeters in 2001. Based on these three parameters, Comanche Lake had average water clarity in comparison to other Oklahoma reservoirs. Water clarity was better in the summer of 1998, based on only three samples. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 50 (Plate 9), indicating the lake was mesotrophic in sample year 2001. The TSI values throughout the sample year varied seasonally from oligotrophic in the fall to eutrophic in the winter (Figure 24). Based on three summer values in 1998, the calculated TSI value was eutrophic (TSI=51), although bordering mesotrophic. All turbidity values in the fall quarter were above the turbidity standard of 25 NTU (see Figure 25a). In both the winter and summer, turbidity values were below the standard and values in the spring at two of the three sites were equal to the standard. The lake-wide annual turbidity was 20 NTU, although the lake was only partially supporting the Fish and 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 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 also displayed in Figure 25b. Of the 12 samples collected at Comanche Lake in 2001, 50% 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.

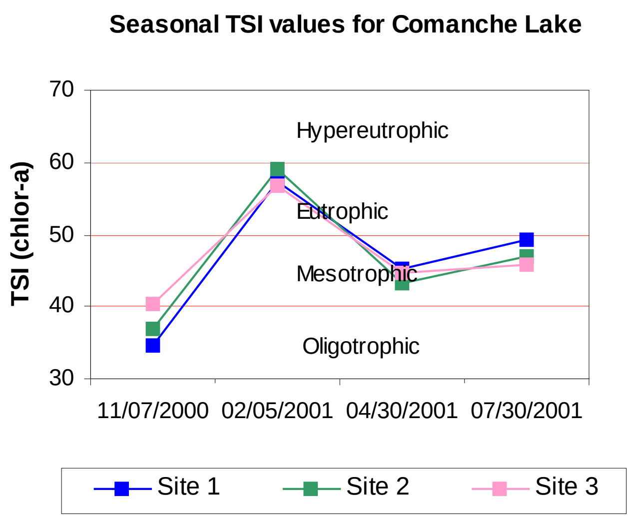


Figure 24. TSI values for Comanche Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. The salinity concentrations at Comanche Lake ranged from 0.09 to 0.14ppt, 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 within the expected range for Oklahoma reservoirs, indicating minimal presence of electrical current conducting compounds like salts. Values ranged from 0.194mS/cm in the winter to 0.299mS/cm in the summer. The pH values at Comanche Lake were neutral to alkaline ranging from 7.05 to 9.23 units. 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 beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9 range, the lake should be listed as partially supporting beneficial uses. The high pH values (consistently above 9 units) recorded throughout the water column in the winter are cause to list Comanche Lake as "provisionally partially supporting"* the FWP beneficial use. Oxidation-reduction potentials ranged from 120mV in the summer (only three values were less than 200 mV) to 501mV in the spring, which indicated an absence of reducing conditions. The lake was not thermally stratified in the fall or winter and dissolved oxygen (D.O.) concentrations were above 6 mg/L throughout the water column during the first two seasons (see Figure 25c-25d). In the spring, the lake was stratified between 2 and 3 meters and between 9 and 10 meters, although the D.O. concentration was not less than 2 mg/L until the second thermocline at the dam site (see Figure 25e). Anoxic conditions were not present at the other two sites in the spring, probably because they were both less than 8 meters in depth. In the summer the lake was stratified at several meter intervals, the first between 5 and 6 meters. From 6 meters below the surface to the lake bottom (11 meters) the D.O. values were less than 2 mg/L. If dissolved oxygen values are less than 2 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 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, Comanche Lake is meeting the FWP beneficial use based on D.O. concentration, although close to being considered a partially supporting reservoir.

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 was 0.56 mg/L at the surface and 0.94 mg/L on the lake bottom. The TN at the surface ranged from 0.45 mg/L to 0.70 mg/L and from 0.50 to 1.68 mg/L on the lake bottom. The highest surface TN value was reported in the spring and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.035 mg/L on the surface and 0.132 mg/L on the lake bottom. The TP ranged from 0.022 mg/L to 0.067 mg/L at the surface and from 0.033 to 0.291 mg/L on the lake bottom. The highest surface TP values were reported in the fall quarter and the lowest were in the summer. The nitrogen to phosphorus ratio (TN:TP) was 16:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Comanche Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels. High true color values in half of the samples collected in sample year 2001 constituted a threat in meeting the Aesthetics beneficial use and was listed as "not supporting". Some of the turbidity values were above the OWQS of 25 NTU, constituting a partially supported beneficial use for FWP (USAP 785:46). According to USAP (OAC 785:46), Comanche Lake was partially supporting the FWP beneficial use based on high pH values and should be "provisionally" listed and closely monitored in the future. Anoxic conditions were present in the summer although not at a level that would cause concern in meeting the OWQS fish and wildlife propagation beneficial use (USAP 785:46). Comanche Lake is the municipal water supply reservoir for the City of Comanche and is also utilized for 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.

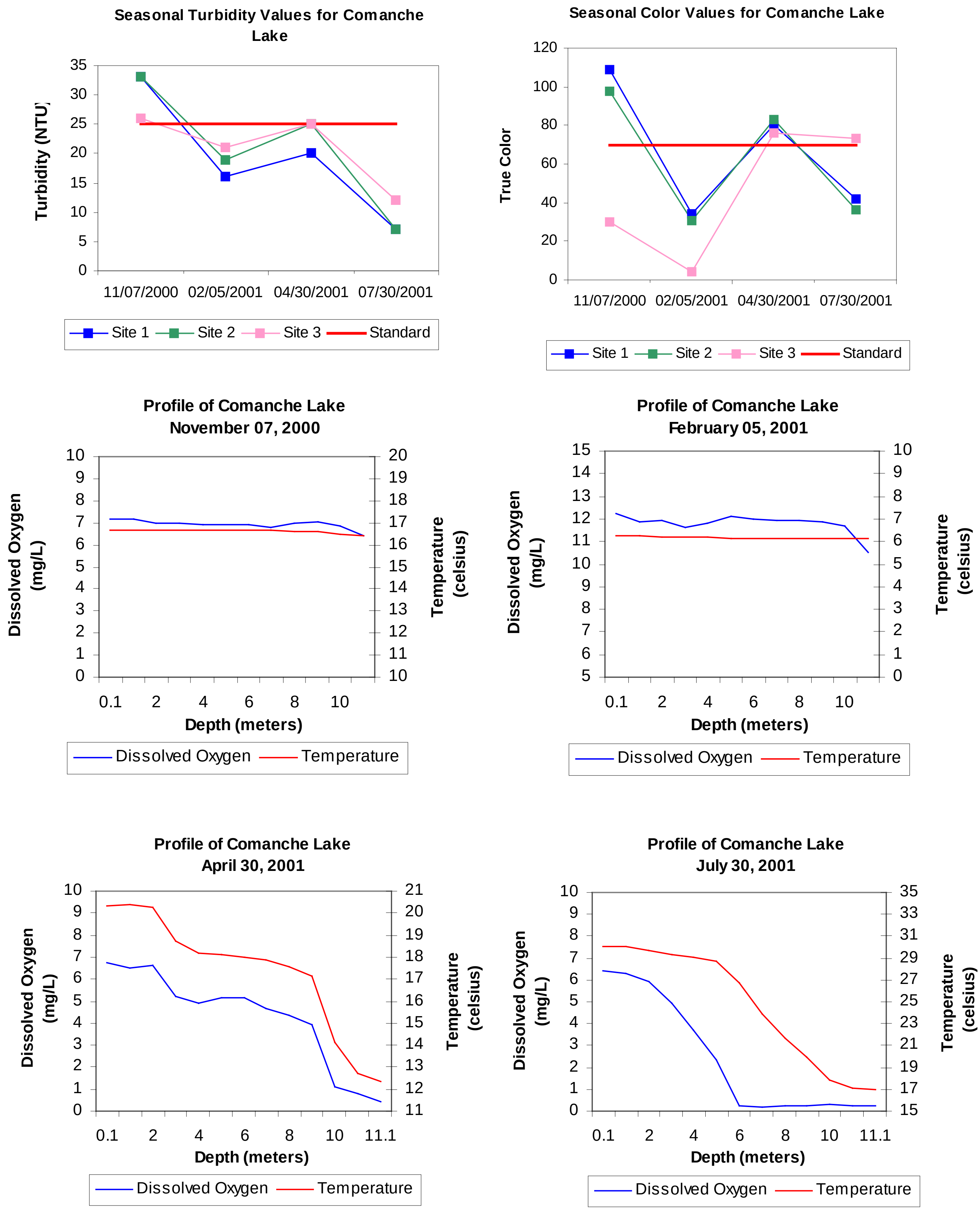


Figure 25a-25f. Graphical Representation of data results for Comanche Lake.

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 2001

Trophic State 2001

Plate 9 - Lake Water Quality for

Comanche 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 (Plate 10), 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, 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 10), 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 (Figure 26). In October 2000 (see picture), 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 FWP beneficial use (see Figure 27a). According to USAP (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 Dave Boyer Lake. Seasonal true color values are also displayed in Figure 27b. 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.

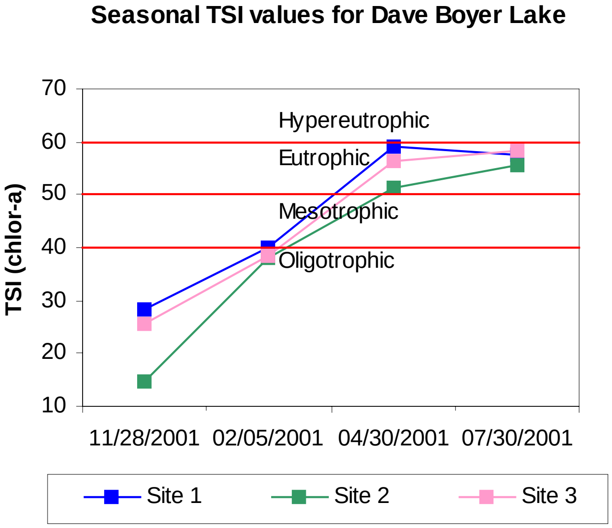
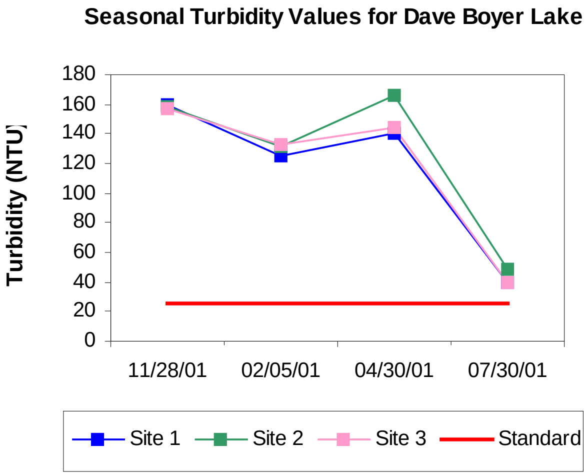


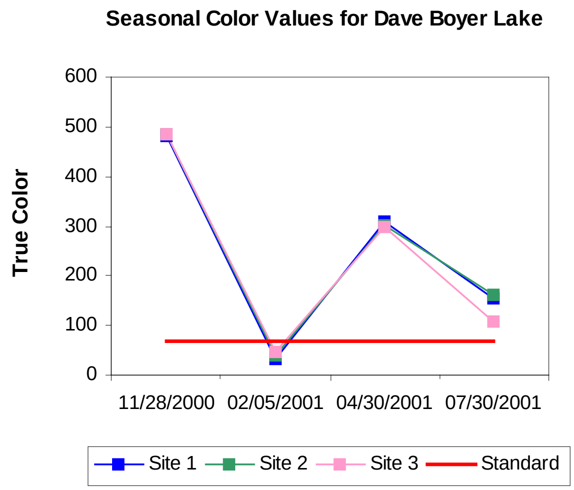
Figure 26. TSI values for Dave Boyer (Walters) Lake.

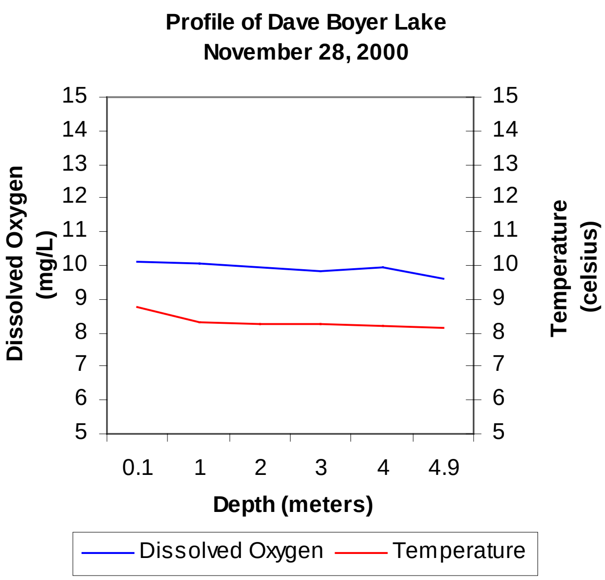
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Lake salinity values ranged from 0.05ppt to 0.14ppt, within the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Specific conductance values were also within the expected range for Oklahoma reservoirs, coinciding with the low salinity concentrations. Values ranged from 0.123mS/cm in the fall to 0.292mS/cm in the summer. Oxidation-reduction potentials ranged from 410mV to 473mV from the winter through summer season, indicating reducing conditions were not present. In the fall, however, the ORP values ranged from 142mV at the lake bottom at site 1 to 181mV at the surface, indicating reducing conditions were possibly present, although anoxic conditions were not. The pH was neutral to slightly alkaline with values ranging from 7.29 to 8.57 units. The lake was not thermally stratified and the water column appeared to be well mixed throughout the year at all sites (see Figure 27c-27f). Dissolved oxygen values remained above 5mg/L and the dissolved oxygen percent saturation was never less than 70% throughout the 2001 sample year (see Figure 27c-27f). The shallow depth of the lake, high color and turbidity, and prominent wind conditions in this lake most likely aided in keeping the water column mixed and oxygenated.

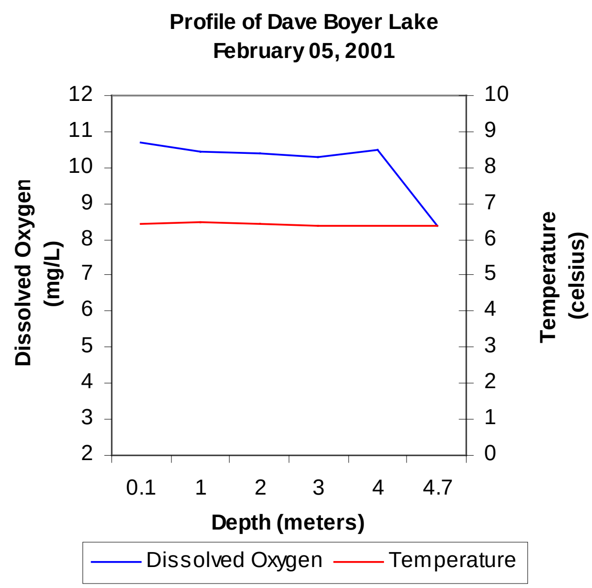
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001 was 0.95 mg/L at the surface and 0.94 mg/L on the lake bottom. The TN at the surface ranged from 0.53 mg/L to 1.16 mg/L and from 0.61 to 1.13 mg/L on the lake bottom. The highest surface TN value was reported in the spring and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.160 mg/L on the surface and 0.165 mg/L on the lake bottom. The TP ranged from 0.056 mg/L to 0.294 mg/L at the surface and from 0.073 to 0.216 mg/L on the lake bottom. Similar to the TN values, the highest surface TP values were reported in the fall quarter and the lowest were in the summer. The nitrogen to phosphorus ratio (TN:TP) was 6:1 for sample year 2001. This value is less than 7:1, characterizing the lake as nitrogen-limited (Wetzel, 1983).

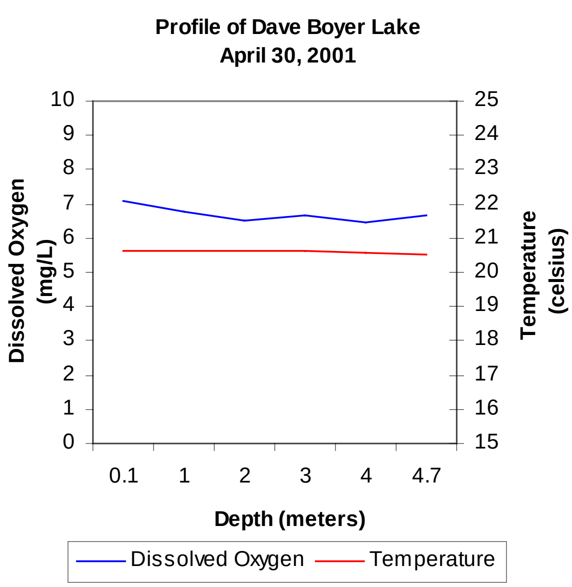
In summary, Dave Boyer Lake was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions. Water clarity is poor in this reservoir, but is expected based on the soil type of the area and the fact that it is located on a golf course with unpaved roads (sediment runoff from storm events is probably the major contributor). Out of the 35 lakes sampled 2001, this lake had the highest turbidity and color values and lowest secchi disk depths. Dave Boyer Lake was not supporting the FWP beneficial use based on the fact that all turbidity values were above the OWQS of 25 NTU (USAP 785:46). High true color values in 75% of the samples collected in sample year 2001 constituted a threat in meeting the Aesthetics beneficial use and was listed as “not supporting”. Dave Boyer Lake is the municipal water supply reservoir for the City of Walters and is also utilized for recreation purposes.











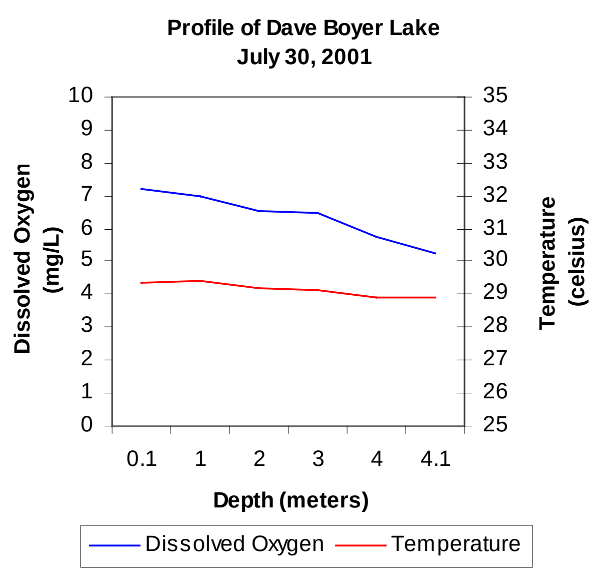
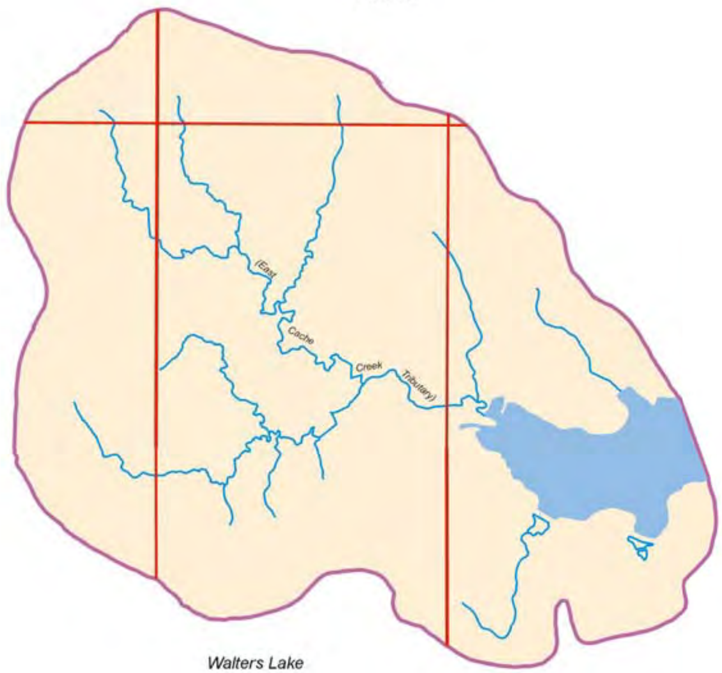


Figure 27a-27f. Graphical representation of data results for Dave Boyer (Walters) Lake.

Plate 10 - Lake Water Quality for
Dave Boyer (Walters) Lake

Walters Lake Location



Walters Lake and Watershed

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

Duncan Lake

Duncan 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 17 NTU (Plate 11), true color was 60 units, and secchi disk depth was 56 centimeters in 2001. Based on these three parameters, Duncan Lake had average water clarity in comparison to other Oklahoma reservoirs. Water clarity was slightly better in the summer of 1998, based on only three samples. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 49 (Plate 11), indicating the lake was mesotrophic, with moderate levels of productivity and nutrients. This value is slightly higher than the TSI in 1998 (TSI=46), based on three summer values, although in the same trophic category, indicating no significant increase or decrease over time. The TSI values were primarily mesotrophic in the first three seasons, but eutrophic at all three sites in the summer (see Figure 28). Turbidity values per site for sample year 2001 were below the OWQS of 25 NTU for all seasons except for the fall when all three values were above the standard (see Figure 29a). 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. The lake-wide annual turbidity of 17 NTU seems representative of conditions at Duncan Lake in 2001. Seasonal true color values are also displayed in Figure 29b. All true color values were below the aesthetics OWQS of 70 units, except for the fall when all three values were above the standard (see Figure 29b). Although 25% of the samples were above the standard, a beneficial use determination can not be made because the minimum data requirements were not met.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites during the study period. Lake salinity values ranged from 0.15ppt to 0.22ppt, within the expected range for most Oklahoma lakes and reflecting minimal presence of chlorides or other salts in the lake. Specific conductance values were slightly higher than most Oklahoma reservoirs, with values ranging from 0.312mS/cm in the winter to 0.412mS/cm in the summer, although does not indicate a high content of electrical current conducting

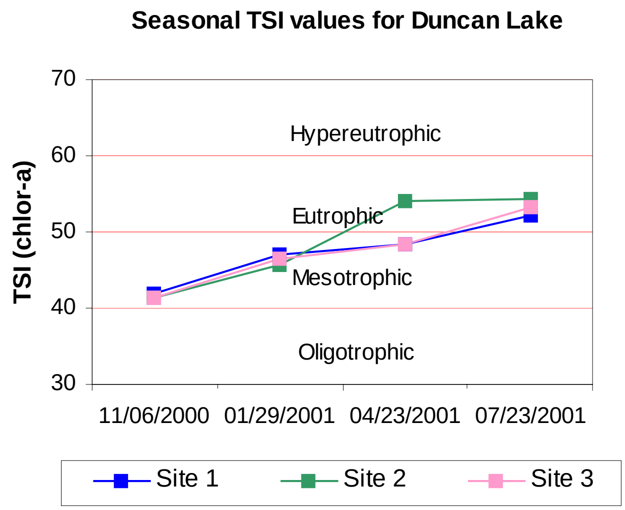


Figure 28. TSI values for Duncan Lake.

compounds or salts. Oxidation-reduction potentials ranged from 170mV to 459mV, indicating reducing conditions were not present. The pH was neutral to slightly alkaline with values ranging from 7.13 to 8.53 units. 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 29c-29f). Dissolved oxygen values remained above 6mg/L and the dissolved oxygen percent saturation was never less than 60% in the first three seasons (see Figure 29c-29e). In the summer, the lake was stratified between 6 and 7 meters and the D.O. concentration dropped from 5.6 mg/L to 0.39 mg/L. The readings at the lake bottom were anoxic at all three sites, but did not present a concern in meeting the FWP beneficial use according to USAP (OAC 785:46-15-5).

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 was 0.63 mg/L at the surface and 0.74 mg/L on the lake bottom. The TN at the surface ranged from 0.48 mg/L to 0.90 mg/L and from 0.52 to 0.99 mg/L on the lake bottom. 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 2001 was 0.038 mg/L on the surface and 0.067 mg/L on the lake bottom. The TP ranged from 0.024 mg/L to 0.067 mg/L at the surface and from 0.029 to 0.123 mg/L on the lake bottom. The highest surface TP values were reported in the fall quarter and the lowest were in the spring. The nitrogen to phosphorus ratio (TN:TP) was 16:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Duncan Lake was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 11). Anoxic conditions and pH values were not a cause for concern in meeting the OWQS for fish and wildlife propagation and although some of the true color and turbidity values were above the OWQS criteria, not enough data was available to make a beneficial use determination. Duncan Lake is one of the municipal water supply reservoirs for the City of Duncan and is utilized for recreation purposes.

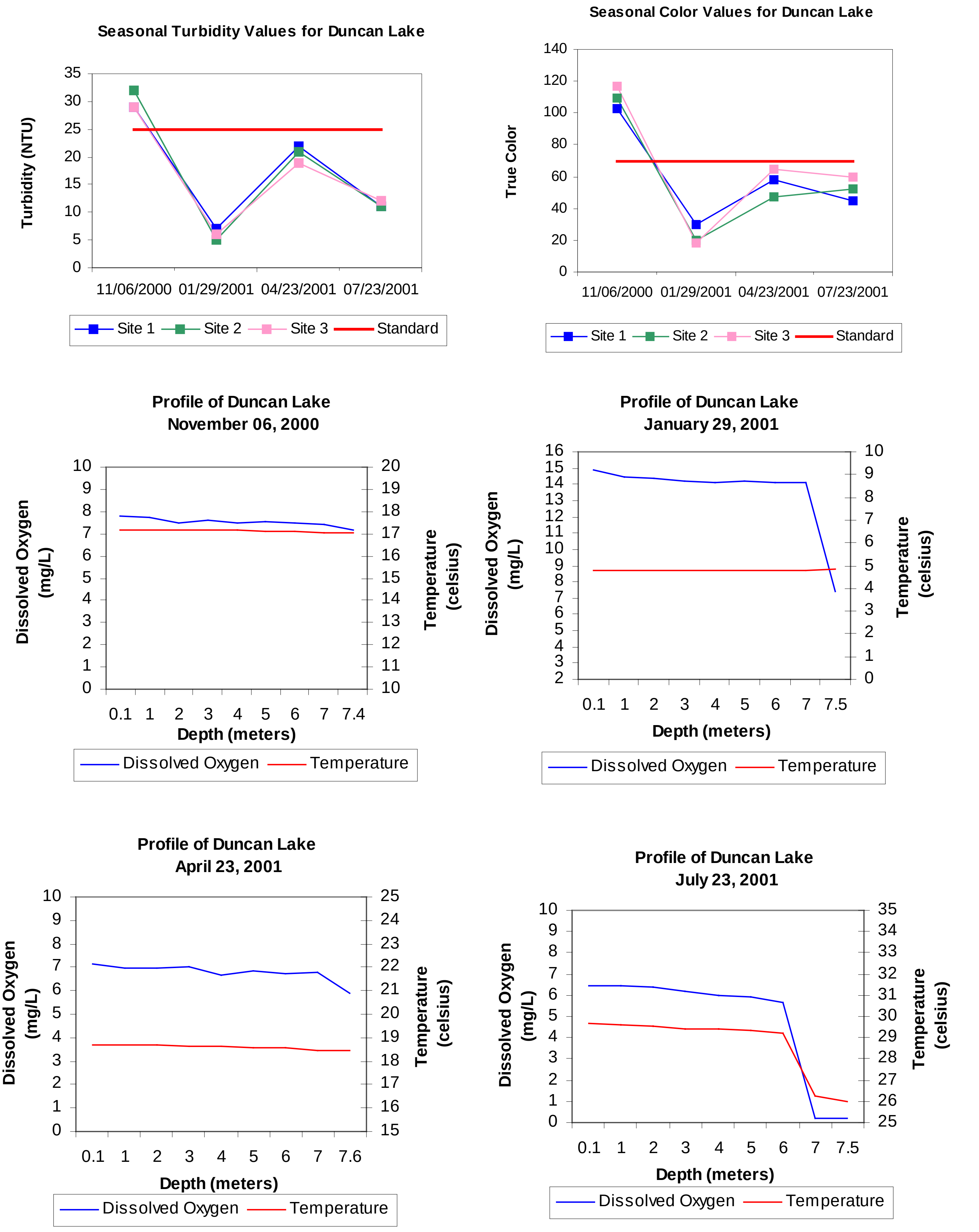
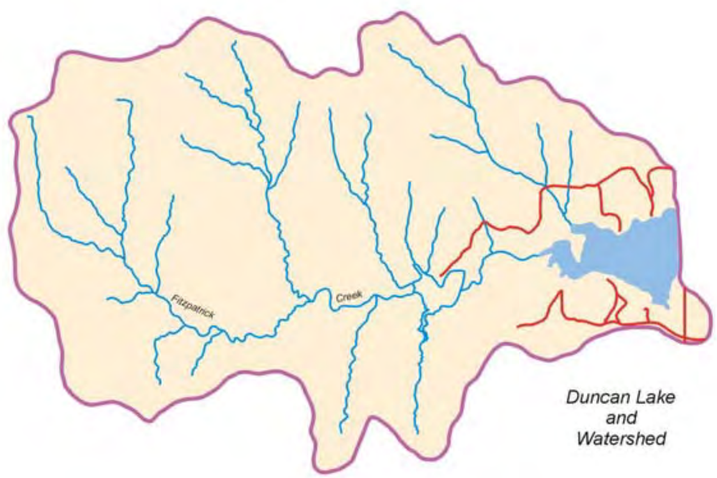


Figure 29a-29f. Graphical representation of data results for Duncan Lake.

Plate 11 - Lake Water Quality for
Duncan Lake

Duncan Lake Location



Duncan Lake and Watershed

Turbidity 2001

Trophic State 2001

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

Lake El Reno

Lake El Reno was sampled for four quarters, from October 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 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 12), true color was 38 units, and secchi disk depth was 45 centimeters in 2001. Based on these three parameters, Lake El Reno 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. The trophic state index, 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 12), indicating the lake was eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is slightly lower than the TSI in 1998 (TSI=59), based on three summer values, although in the same trophic category, indicating no significant increase or decrease over time. The TSI values were primarily eutrophic throughout the year, with hypereutrophic values in the fall and one unexplainable oligotrophic value in the spring (see Figure 30). Turbidity values for sites 1 and 2 for sample year 2001 were below the OWQS of 25 NTU; however, site 3 values were above the standard for three of the four quarters (see Figure 31a). According to USAP (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 partially supported at Lake El Reno. Seasonal true color values are also displayed in Figure 31b. All true color values were below the aesthetics OWQS of 70 units, although the values were very close to the standard in the fall (see Figure 31b). True color variation occurred from one season to the next, confirming the necessity for sampling throughout the year instead of just one or two seasons.

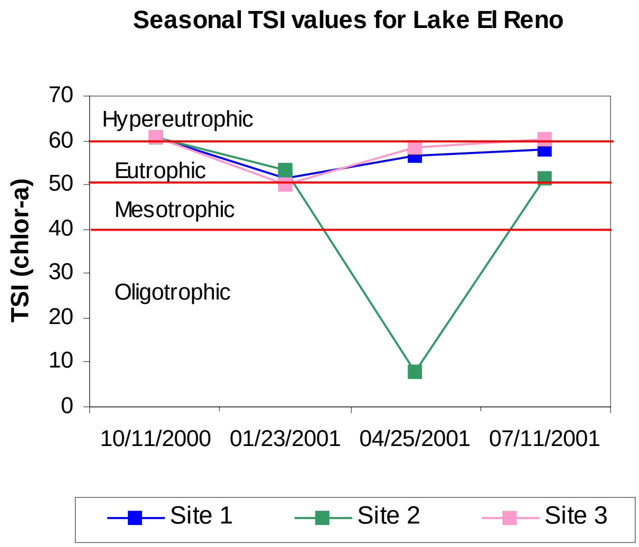


Figure 30. TSI values for Lake El Reno.

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. Lake salinity readings ranged from 0.4ppt to 0.54ppt, higher than most values recorded in

Oklahoma reservoirs. Readings for specific conductance were also higher than values recorded in most Oklahoma reservoirs. Conductivity ranged from 0.762mS/cm in the winter to 1.02mS/cm in the summer, indicating high concentrations of electrical current conducting compounds (salts) in the water column. Both the high salinity and conductivity values indicate Lake El Reno has a higher salt content than most Oklahoma lakes. Oxidation-reduction potentials ranged from 271mV to 625mV, indicating reducing conditions were not present during 2001. Lake pH values were neutral to slightly alkaline, ranging from 7.17 to 8.36 units. The lake was not thermally stratified during any of the four quarters (see Figure 31c-31f). The water column was evenly mixed and oxygenated in the fall, winter and spring quarters (see Figure 31c-31e). In the summer, anoxic conditions were present in the hypolimnion at site 1, although this does not constitute a concern in meeting the FWP beneficial use according to USAP (OAC 785:46-15-5).

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 was 0.78 mg/L at the surface and 0.99 mg/L on the lake bottom. The TN at the surface ranged from 0.25 mg/L to 1.06 mg/L and from 0.80 to 1.32 mg/L on the lake bottom. 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 was 0.182 mg/L on the surface and 0.232 mg/L on the lake bottom. The TP ranged from 0.106 mg/L to 0.261 mg/L at the surface and from 0.106 to 0.309 mg/L on the lake bottom. The highest surface TP values were reported in the fall quarter and the lowest were in the winter. The nitrogen to phosphorus ratio (TN:TP) was 4:1 for sample year 2001. This value is less than 7:1, characterizing the lake as nitrogen-limited (Wetzel, 1983).

In summary, Lake El Reno was as eutrophic, indicative of high primary productivity and nutrient rich conditions (Plate 12). Based on three summer chlorophyll-a values in 1998, the calculated TSI value was also eutrophic, indicating no significant change in trophic status over time. Some of the turbidity values were above the OWQS of 25 NTU, constituting a partially supported beneficial use for FWP (USAP 785:46). Lake El Reno is utilized by the City of El Reno for flood control and recreational purposes.

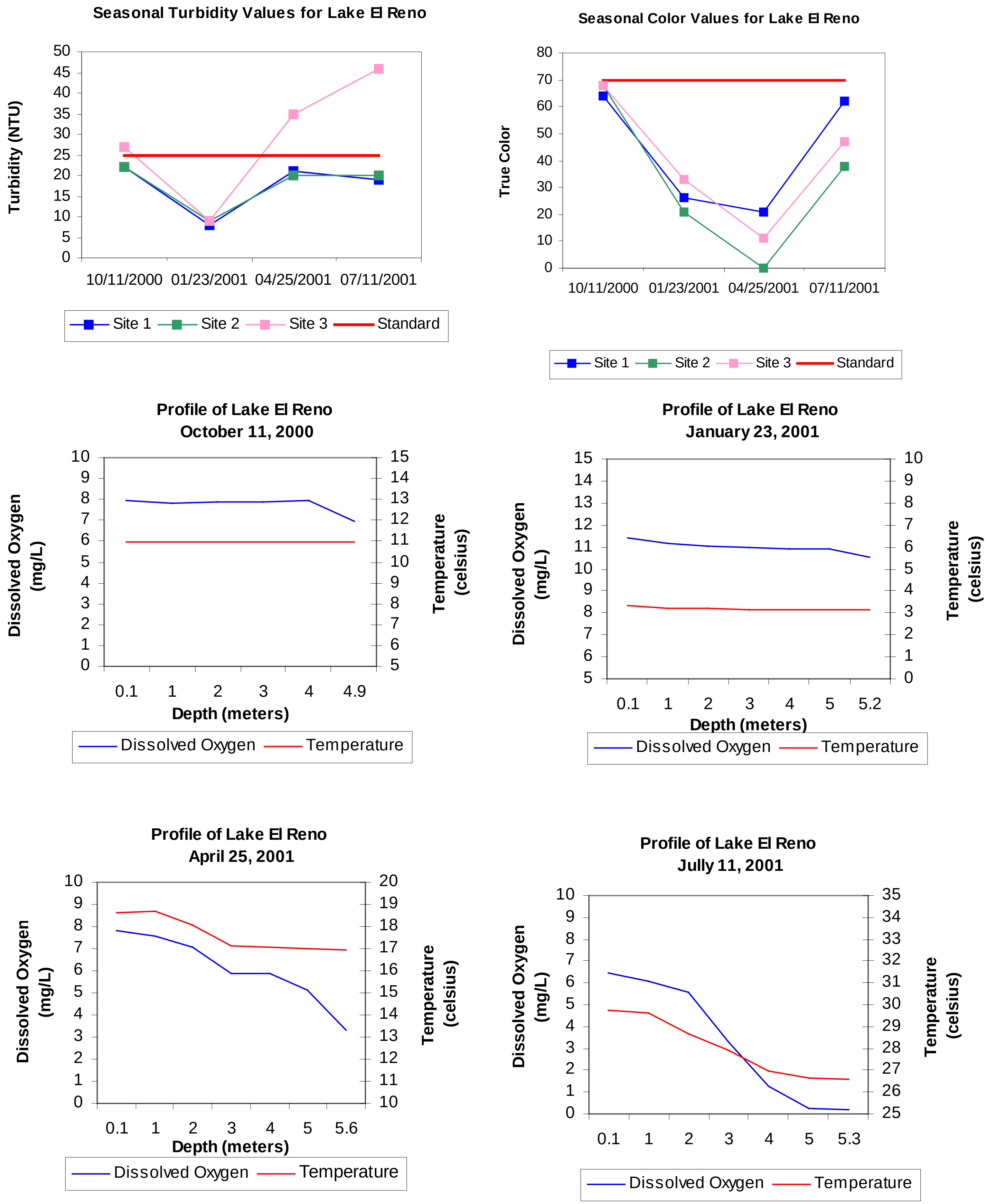
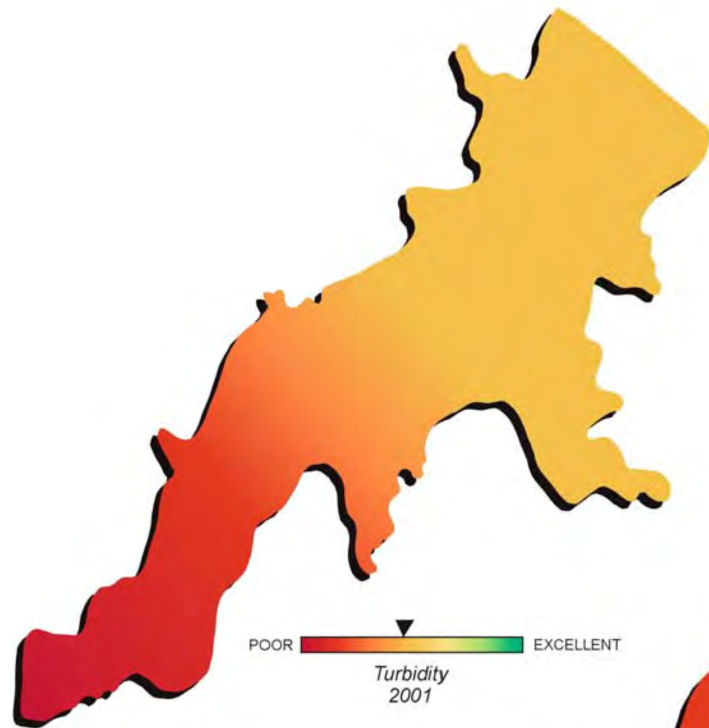
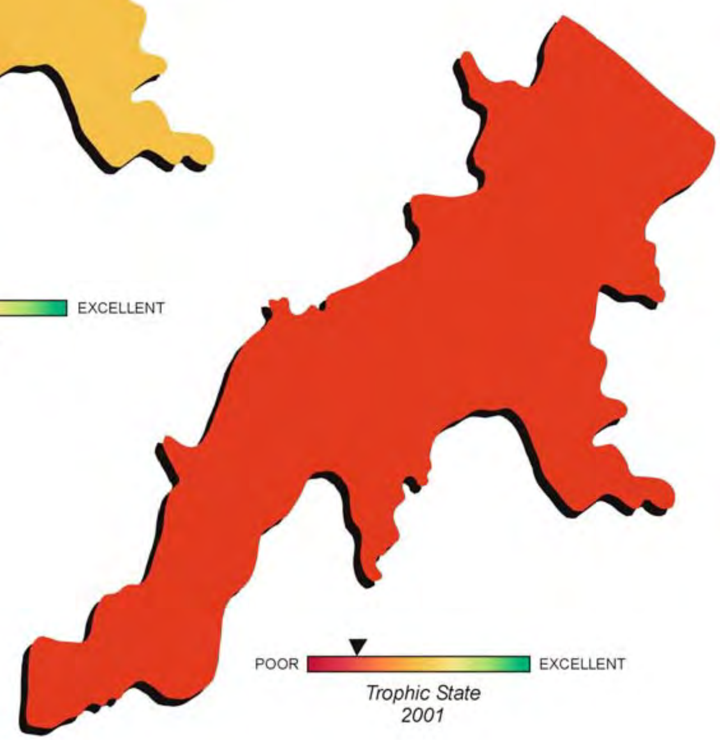


Figure 31a-31f. Graphical representation of data results for Lake El Reno.





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

Plate 12 - Lake Water Quality for

Lake El Reno

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 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 (Plate 13), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for three quarters (n=10). The average TSI was 57 (Plate 13), 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 (see Figure 32). Only two of the ten turbidity values exceeded the OWQS of 25 NTU; however, this constitutes a listing as partially supporting the FWP beneficial use (see Figure 33a). According to USAP (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 also displayed in Figure 33b. All true color values were below the aesthetics OWQS of 70 units for all three seasons at all sites.

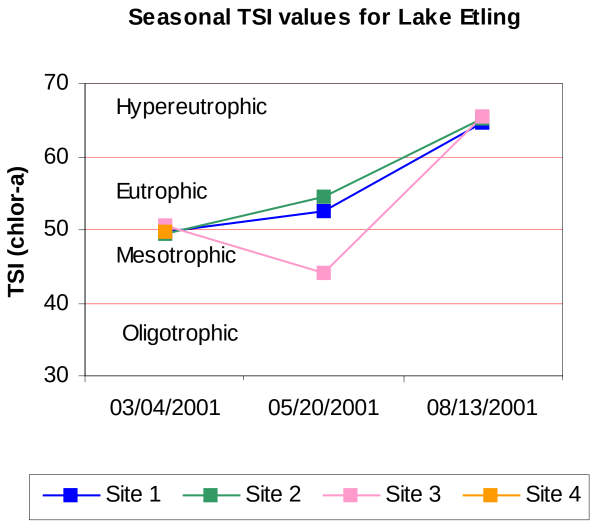


Figure 32. TSI values for Lake Etling.

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. Lake salinity values ranged from 0.41ppt to 0.52 ppt, higher than most values recorded in Oklahoma reservoirs. Readings for specific conductance were also higher than values recorded in most Oklahoma reservoirs. Conductivity ranged from 0.782mS/cm in the winter to 0.986mS/cm in the summer, indicating high concentrations of electrical current conducting compounds (salts) in the water column. Both the high salinity and conductivity values indicate Lake Etling has a higher salt content than most Oklahoma lakes. Oxidation-reduction potentials (redox) ranged from 217mV to 501mV, indicating reducing conditions were not present during 2001. Lake pH values were slightly alkaline with values ranging from 8.05 in the spring to 8.61 in the summer. The lake was not thermally stratified in the winter or spring and although vertical profiles were not recorded in the summer, it is doubtful that any thermal stratification was present. The lake was well mixed and oxygenated, with dissolved oxygen values above 4 mg/L in the winter, spring, and summer quarters (see Figure 33d-33f).

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 was 0.98 mg/L at the surface and 0.95 mg/L on the lake bottom (which only ranged from 1 to 3 meters). The TN at the surface ranged from 0.32 mg/L to 1.88 mg/L; however, the nutrients analyzed for the summer season were collected close to the shore because the sites had to be waded. 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 was 0.071 mg/L on the surface and 0.068 mg/L on the lake bottom. The TP ranged from 0.016 mg/L to 0.137 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 14:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Etling was classified as eutrophic indicative of high primary productivity and nutrient rich conditions (Plate 13). Based on three summer chlorophyll-a values in 1998, the calculated TSI value was also eutrophic, indicating no significant change in trophic status over time. Twenty percent of the turbidity values were above the OWQS of 25 NTU, constituting a partially supported beneficial use for FWP (USAP 785:46). Lake Etling is owned and operated by the State of Oklahoma for recreational purposes. It is located in close proximity to Black Mesa State Park, in the extreme NW corner of Oklahoma.

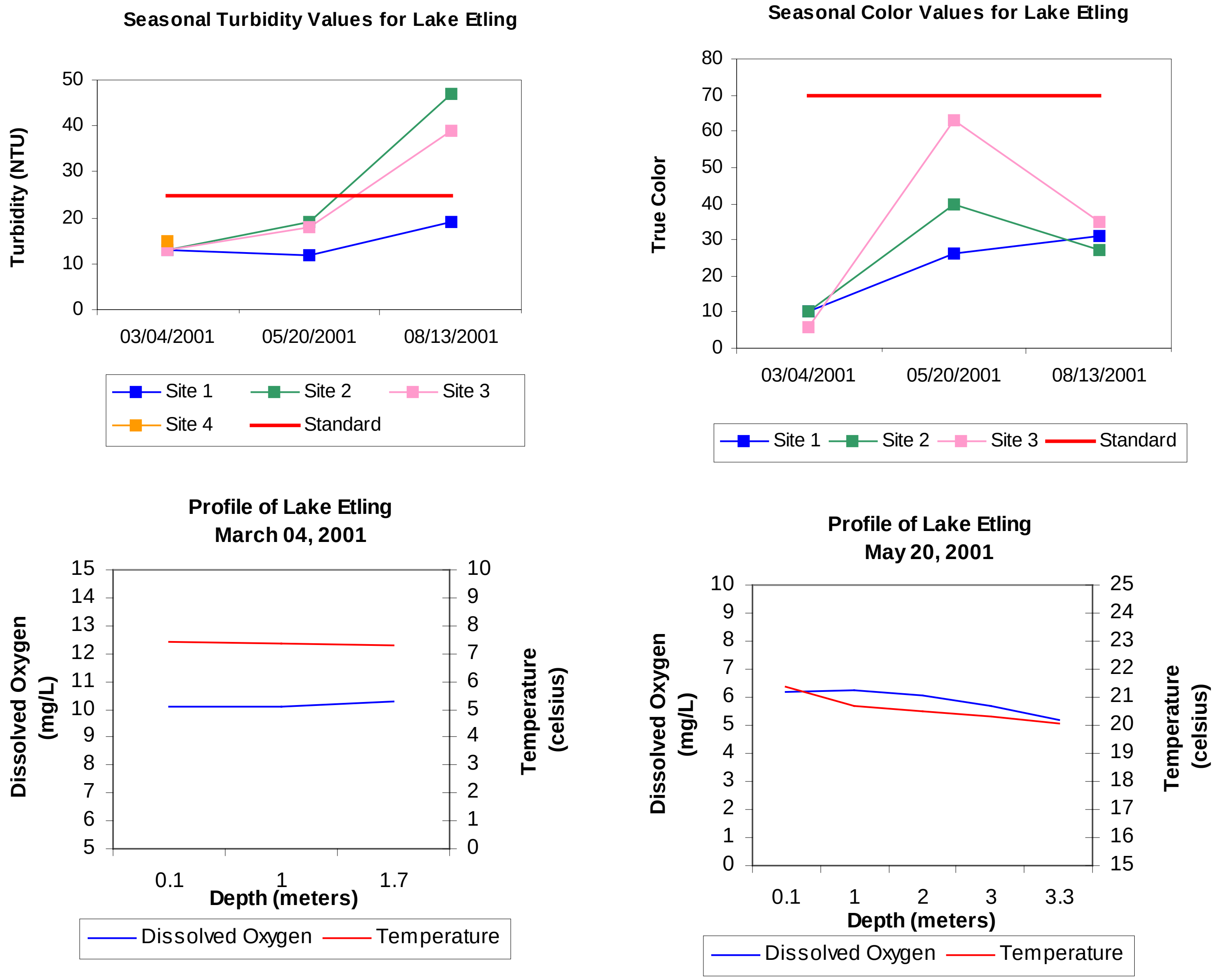


Figure 33a-33d. Graphical representation of data results for Lake Etling.

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

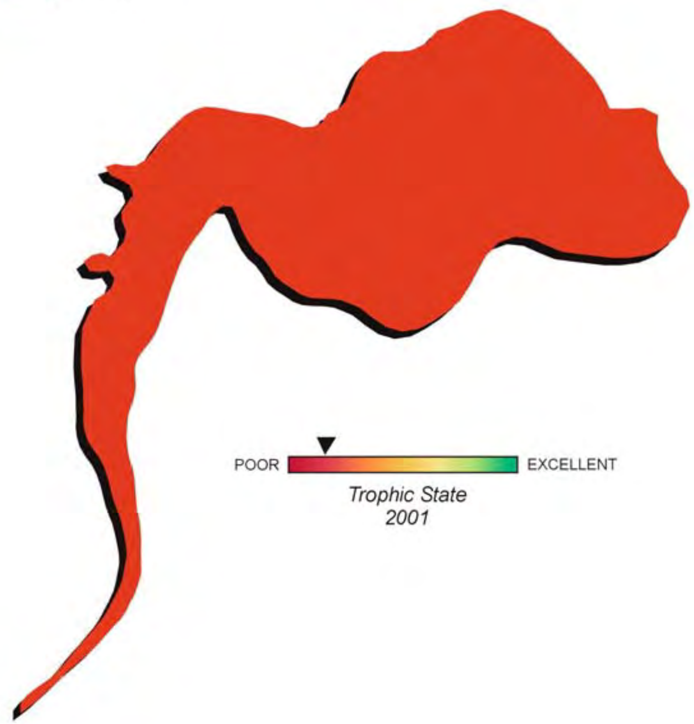


Plate 13 - Lake Water Quality for
Lake Etling

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 (Plate 14), true color was 46 units, and secchi disk depth was 82 centimeters in 2001. Based on these three parameters, Ft. 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=32). The average TSI was 64 (Plate 14), 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 (see Figure 34). Only five of the 31 turbidity values exceeded the OWQS of 25 NTU; however, this constitutes a listing as partially supporting the FWP beneficial use (see Figure 35a). According to USAP (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. Seasonal true color values are also displayed in Figure 35b. 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.

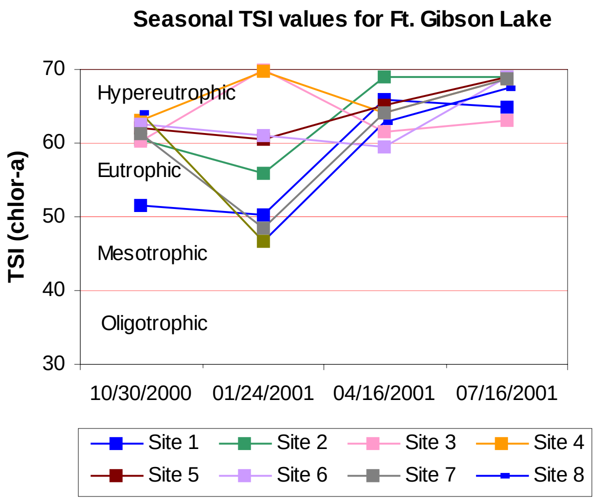


Figure 34. TSI values for Fort Gibson Lake.

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 ppt in the spring to 0.15 ppt at site 8 in the fall, 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 within the expected range for Oklahoma reservoirs, coinciding with the low salinity concentrations. Values ranged from 0.116mS/cm in the spring to 0.309mS/cm at site 8 in the fall. Oxidation-reduction potentials ranged from 252mV in the winter to 520mV in the spring, indicating reducing conditions were not present. The ORP values recorded in the fall quarter were consistently less than 100 throughout the water column although anoxic conditions were not present reducing conditions were. Lake pH values were slightly alkaline with values ranging from 6.91 in the summer to 9.09 in the winter. If 10 to 25% of the pH values fall outside the 6.5 to 9 range, the lake should be listed as partially supporting beneficial uses. The pH values that exceeded the criteria at Fort Gibson Lake were about 9% of the total value, just short of the "partially supporting" listing for FWP beneficial use. Thermal stratification was not evident in any of the first three seasons, although a slight decrease in temperature from the surface to bottom was visible (see Figure 35c-35e). Dissolved oxygen (D.O.) values were above 3.5mg/L throughout the water column at all sites in the fall, above 11 mg/L in the winter, and above 5 mg/L in the spring. Generally the water column was fairly oxygenated and well mixed (see Figure 35c-35f). In the summer, both stratification and anoxic conditions were present in Fort Gibson Lake. The lake was not stratified at sites 5, 6, 7, and 8 as this upper end of the lake is shallower than the rest of the reservoir. At site 1, the lake was not thermally stratified, but a gradual decrease in temperature from the surface to the bottom was evident (see Figure 35c-35f). Below 3 meters to the bottom (17.3 meters), D.O. concentration was less than 2 mg/L. At sites 2, 3 and 4 anoxic conditions, D.O. values less than 2 mg/L, were present below the thermocline although affecting less than 25% of the water column. If dissolved oxygen values are less than 2 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 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 Fort Gibson Lake; however, because greater than 50% of the water column was anoxic only at the dam site, more data is necessary to list the lake as partially supporting beneficial uses.

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 was 0.95 mg/L at the surface and 1.31 mg/L on the lake bottom. The TN at the surface ranged from 0.42 mg/L to 1.88 mg/L (fall through spring as summer values did not meet QA objectives) and from 0.72 to 1.75 mg/L on the lake bottom. 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 was 0.093 mg/L on the surface and 0.210 mg/L on the lake bottom. The TP ranged from 0.02 mg/L to 0.254 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 10:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Fort Gibson Lake was classified as hypereutrophic, indicative of excessive primary productivity and excessive nutrients, the extreme upper end of the eutrophication process. In the summer of 1998, the TSI was also hypereutrophic although based on only 8 values. Because the TSI in 2001 and 1998 was hypereutrophic, Fort Gibson Lake should be studied more intensively and listing this lake as a "nutrient-limited water" (NLW), TSI ≥ 62 with minimum number of samples (n=20) in lakes greater than 250 surface acres), should be investigated. Sixteen percent of the turbidity values were above the OWQS of 25 NTU, constituting a partially supported beneficial use for FWP (USAP 785:46). 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 Gibson Lake, constructed by the USACOE, was built for flood control and hydroelectric power purposes.

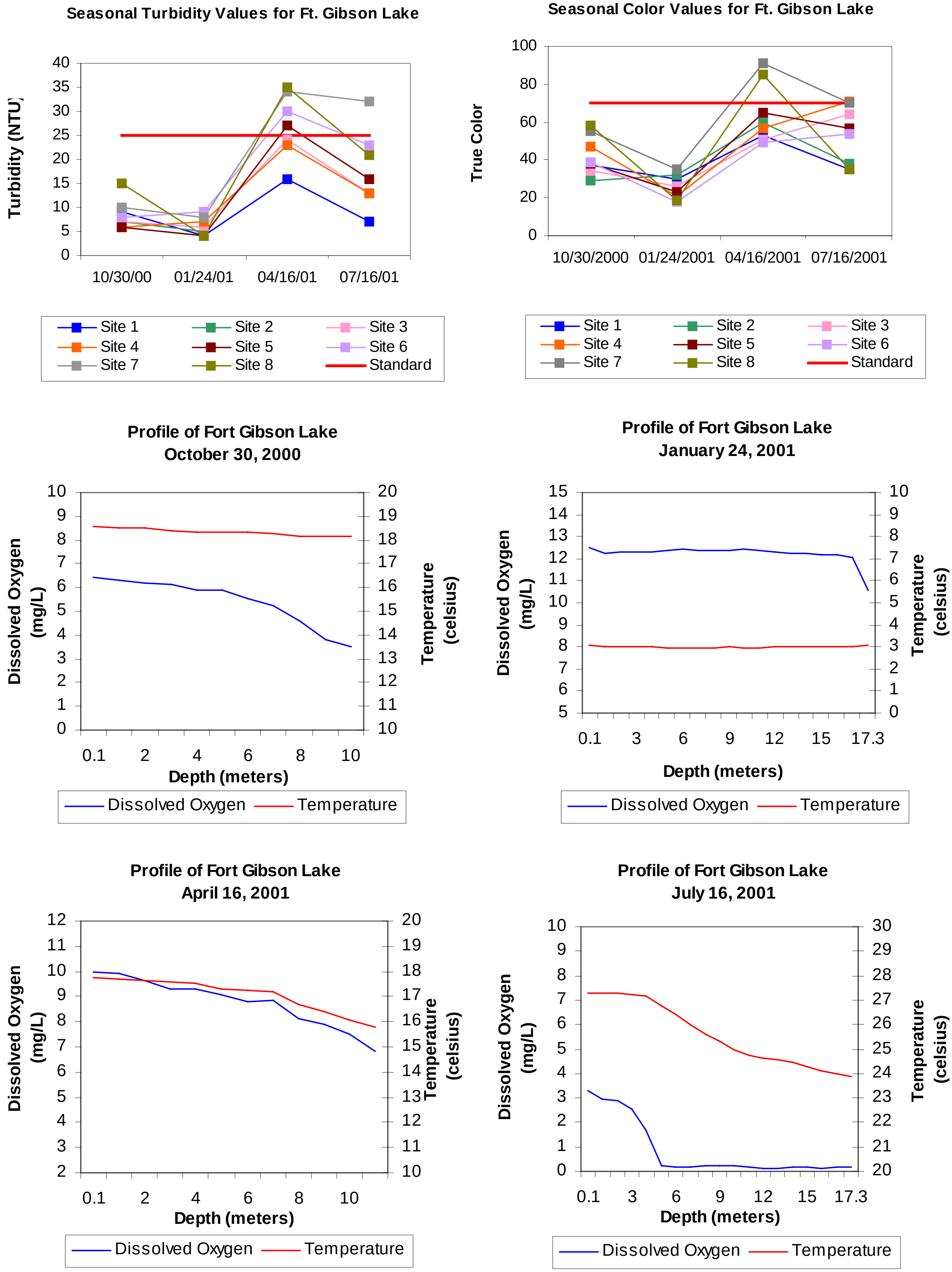


Figure 35a-35f. Graphical representation of data results for Fort GIbson Lake.

Fort Gibson Lake
Location

Fort Gibson Lake
and
Watershed

Lake Data

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

Turbidity
1998

Trophic State
2001

Plate 14 - Lake Water Quality for
Fort Gibson Lake

Lake Frederick

Frederick Lake was sampled for four quarters from October 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 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 98 NTU (Plate 15), true color was 107 units, and secchi disk depth was 16 centimeters in 2000. Based on these three parameters, Frederick Lake had poor water clarity in 2001, and in fact was second only to Dave Boyer Lake in highest turbidity and color values. Water clarity is the same compared to the summer of 2000 and 1997 and is likely always poor based on the soil composition and nature of this lake. The trophic state index, 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 15), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is equal to the TSI in 2000 (TSI=50), based on three summer values, indicating no significant increase or decrease in trophic status over time. The TSI values were either mesotrophic or eutrophic throughout the year at all sites and therefore the lake-wide TSI of 50 seems representative of conditions at Lake Frederick (see Figure 36). All 12 turbidity values (100%) in 2001 exceeded the OWQS of 25 NTU; however, 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres. Compiling historical data from the summers of 1994, 1997, and 2000 with the current data, 21 data points (100%) were assessed to determine that Lake Frederick is not supporting the FWP beneficial use based on high turbidity (see Figure 37a). Seasonal true color values are also displayed in Figure 37b. The true color values were variable throughout the sample year, ranging from all below the standard in the winter to all above in the summer. True color was not reported in the spring of 2001, therefore not enough data was available to make a beneficial use determination for the Aesthetics beneficial use. The annual lake-wide average of 107 units was well above the aesthetics OWQS of 70 units and indicates the Aesthetics beneficial use is not supported and will most likely be listed as such in the future.

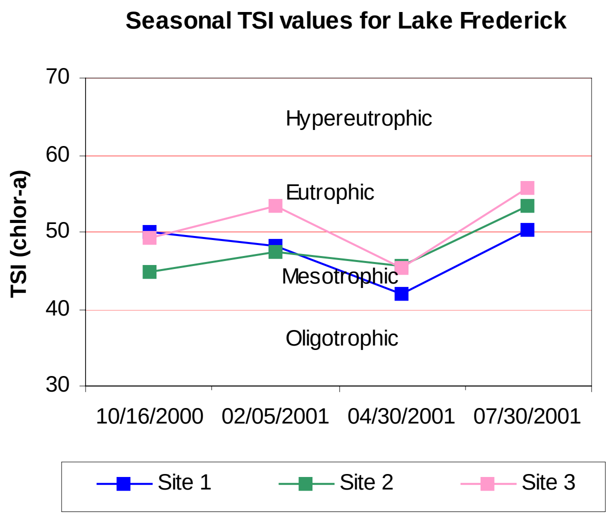


Figure 36. TSI values for Lake Frederick.

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. The salinity ranged from 0.13 to 0.21 parts per thousand (ppt), within the range of expected values for Oklahoma lakes, reflecting the minimal presence of chlorides or other salts in the lake. Specific conductance values ranged from 0.273 to 0.417mS/cm, indicating low to moderate levels of current conducting ionic compounds (or other analogous materials) were present. Oxidation-reduction potentials were fairly uniform and ranged from 367mV at the lake bottom to 476mV, indicating an absence of reducing conditions. In the fall, the ORP appeared erroneous and were not used in the assessment of Redox values. The pH values were neutral to slightly alkaline, ranging from 7.4 in the spring to 8.89 in the winter. Thermal stratification was not present in this reservoir in sample year 2001 (see Figure 37c-37f). The lake was well mixed and dissolved oxygen (D.O.) concentrations were above 5 mg/L in the fall, winter, and spring (see Figure 37c-37e). During the summer, hypolimnetic anoxia was present at the dam site, but not at the other two sites in the lake. If dissolved oxygen values are less than 2 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 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is fully supported at Lake Frederick.

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 was 0.78 mg/L at the surface and 0.91 mg/L on the lake bottom. The TN at the surface ranged from 0.06 mg/L to 1.34 mg/L and from 0.45 to 1.34 mg/L on the lake bottom. 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 was 0.079 mg/L on the surface and 0.115 mg/L on the lake bottom. The TP ranged from 0.047 mg/L to 0.135 mg/L and from 0.063 to 0.199 mg/L on the lake bottom. 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 10:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Frederick was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels. Water clarity is consistently poor at this lake, but is expected based on the soil type of the watershed. All turbidity values reported at Lake Frederick (including data from previous years) were above the OWQS of 25 NTU, indicating the lake was not supporting the FWP beneficial use (USAP 785:46). Lake Frederick is utilized by the City of Frederick for water supply, flood control and recreational purposes.

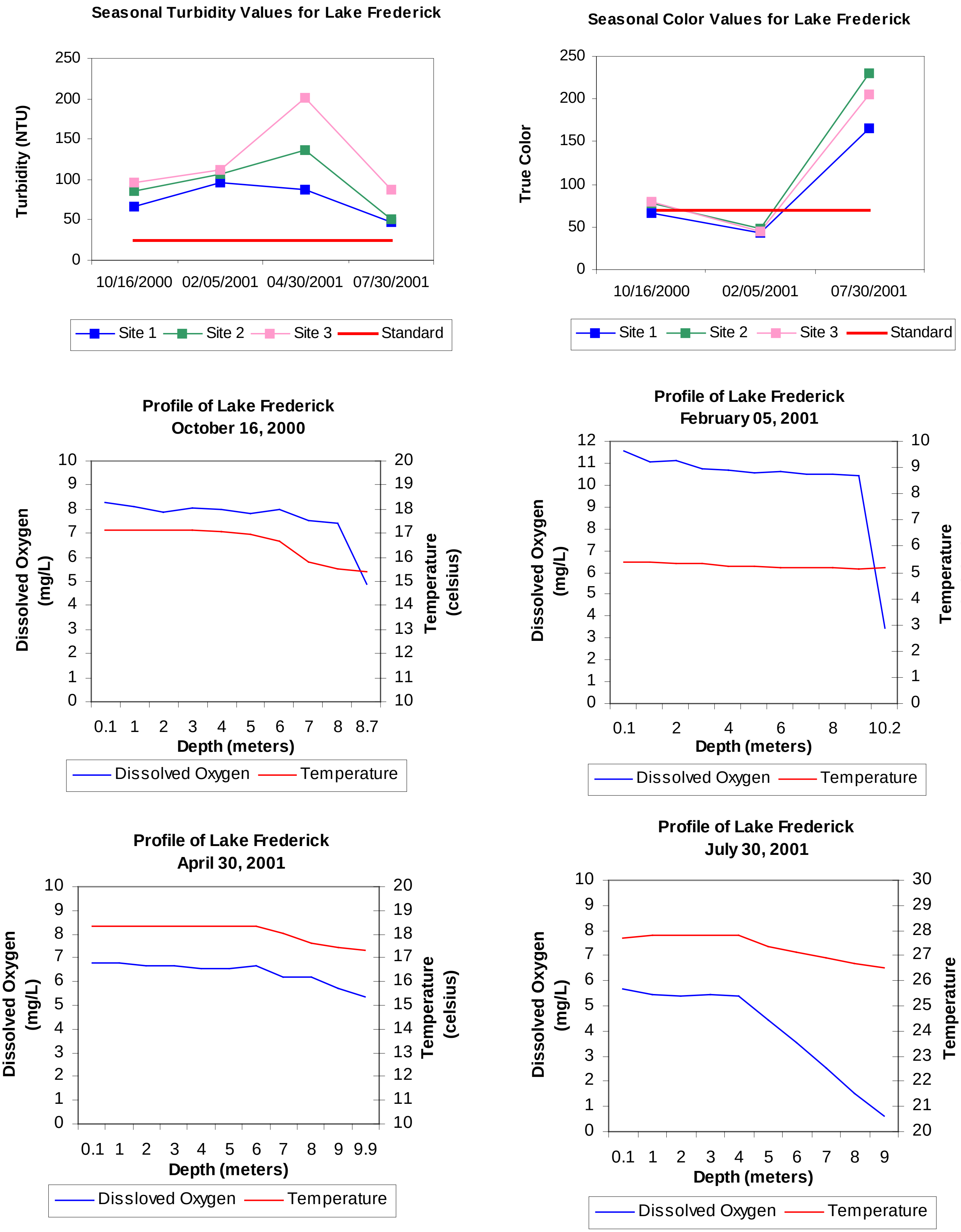


Figure 37a-37f. Graphical representation of data results for Lake Frederick.

Plate 15 - Lake Water Quality for
Lake Frederick

Frederick Lake
and
Watershed

Frederick Lake
Location

Lake Data

Owner	City of Frederick
County	Tillman
Constructed in	1974
Surface Area	925 acres
Volume	9,526 acre/feet
Shoreline Length	18 miles
Mean Depth	10.30 feet
Watershed Area	57 square miles

Fuqua Lake

Fuqua Lake was sampled for four quarters, from November 2000 through July 2001. Water quality samples were collected at 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 21 NTU (Plate 16), true color was 58 units, and secchi disk depth was 60 centimeters in 2001. Based on these three parameters, Fuqua Lake had average water clarity in 2001. Water clarity was much better in the summer of 1997 but was based on only five samples during one sampling event. The assessment of clarity for 2001 is a much more accurate depiction of the lake as this was based on four sampling events throughout the year (n=20). The 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 48 (Plate 16), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is higher than the one calculated in 1997 (TSI=42), although it is in the same category. The 2001 trophic assessment is a more accurate depiction of trophic status as chlorophyll-a values were variable at this reservoir throughout the year and only one sampling event would not be adequate or representative. The TSI values ranged from oligotrophic to eutrophic, although most values were in the mesotrophic category (see Figure 38). Five of the twenty turbidity values exceeded the OWQS of 25 NTU constituting a listing as "partially supporting" the FWP beneficial use (see Figure 39a). According to USAP (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 also displayed in Figure 39b. Six of the twenty true color values exceeded the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is considered not supported. In both the turbidity and true color graphics, it is obvious that the site 4 values were consistently above the OWQS.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all five sample sites during the study period. Salinity ranged from 0.21 to 0.28 parts per thousand (ppt), higher than most salinity values reported for Oklahoma lakes. Readings for specific conductance ranged from 0.427 to 0.554mS/cm, indicating moderate to high

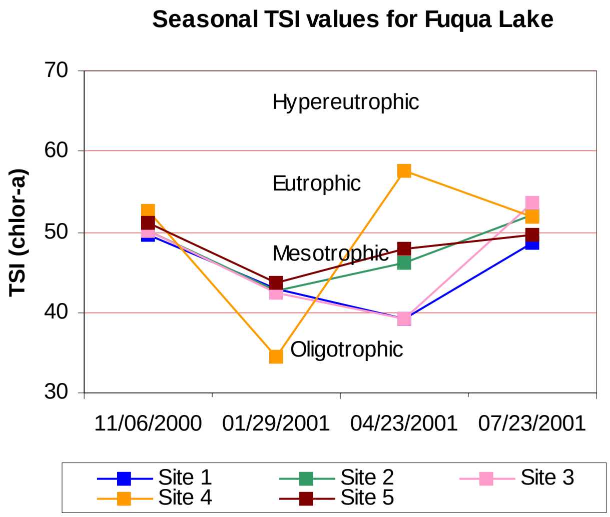


Figure 38. TSI values for Fuqua Lake.

concentrations of electrical current conducting compounds (salts) were present in the water column throughout the year. In general, pH values were neutral to alkaline, ranging from 7.18 in the summer to 8.47 units in the winter. Oxidation-reduction potentials ranged from 215mV at the sediment-water interface in the winter to 583mV in the summer, indicating that reducing conditions were not present in the water column. The lake was not thermally stratified in the fall, winter, or spring and dissolved oxygen concentrations were above 6 mg/L throughout the water column (see Figure 39c-39e). Anoxic conditions were present below the thermocline at site 1, constituting about 35% of the water (see Figure 39c-39f). The thermocline was between 5 and 6 meters at the dam site, and because all of the other sites were not greater than 5 meters in depth, stratification was not present. If dissolved oxygen values are less than 2 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 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 Fuqua Lake.

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 was 0.49 mg/L at the surface and 0.70 mg/L on the lake bottom. The TN at the surface ranged from 0.33 mg/L to 0.83 mg/L and from 0.42 to 1.49 mg/L on the lake bottom. 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 2001 was 0.038 mg/L on the surface and 0.074 mg/L on the lake bottom. The TP ranged from 0.015 mg/L to 0.113 mg/L and from 0.020 to 0.178 mg/L on the lake bottom. 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 13:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Fuqua Lake was classified as mesotrophic 2001, indicating moderate primary productivity and nutrient levels. The TSI in 1997 was also in the mesotrophic category. Some of the turbidity values were above the OWQS of 25 NTU, constituting a partially supported beneficial use for FWP (USAP 785:46). High true color values in 30% of the samples collected in sample year 2001 constituted a threat in meeting the Aesthetics beneficial use and was listed as “not supporting”. 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. Fuqua Lake is one of the municipal water supply reservoirs for the City of Duncan and is utilized for water supply, flood control, and recreational purposes.

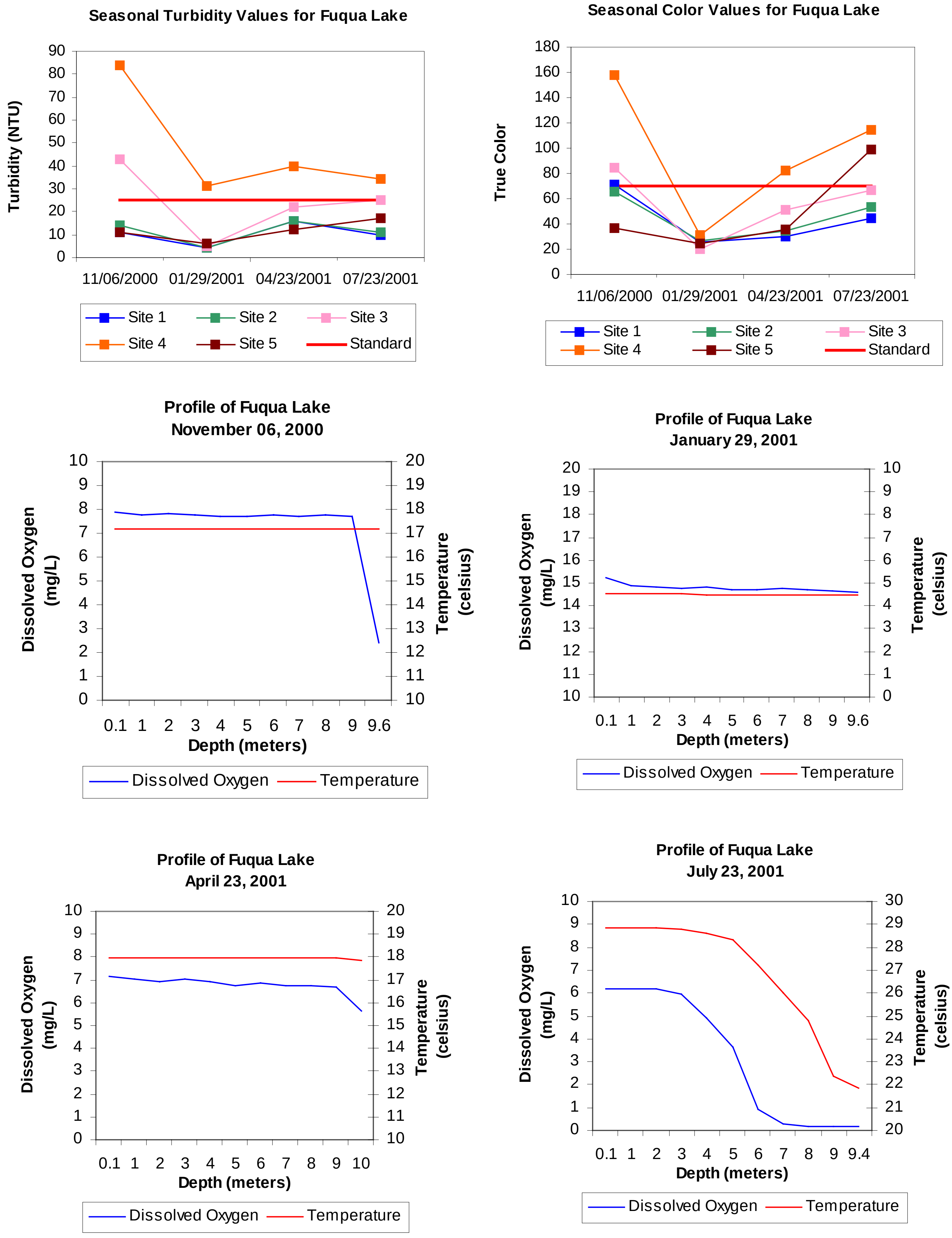


Figure 39a-39f. Graphical representation of data results for Fuqua Lake.

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
2001

Trophic State
2001

Plate 16 - 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 (Plate 17), 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, 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 (Plate 17), 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%) (see Figure 40). 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 OWQS of 25 NTU constituting a listing as "not supporting" the FWP beneficial use (see Figure 41a). According to USAP (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. Seasonal true color values are also displayed in Figure 41b.

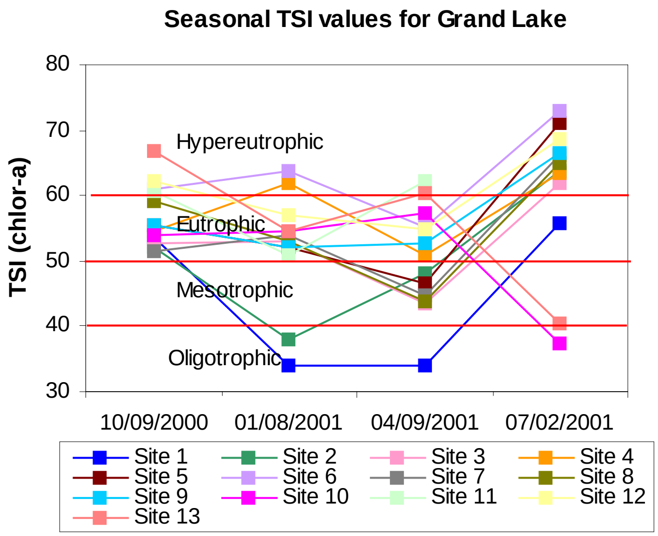


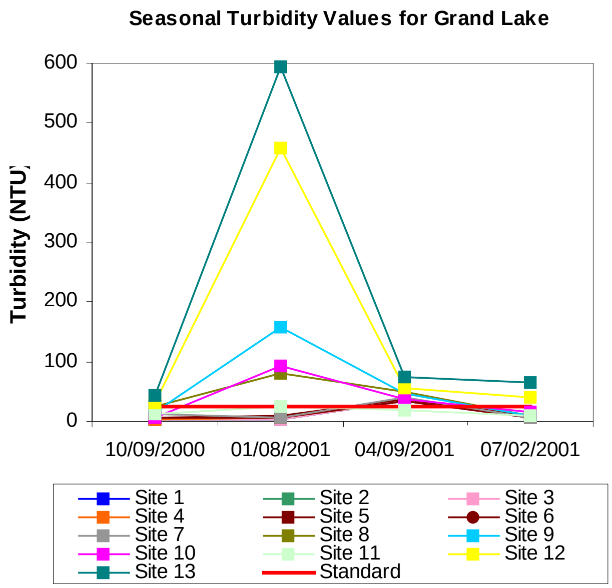
Figure 40. TSI values for Grand Lake.

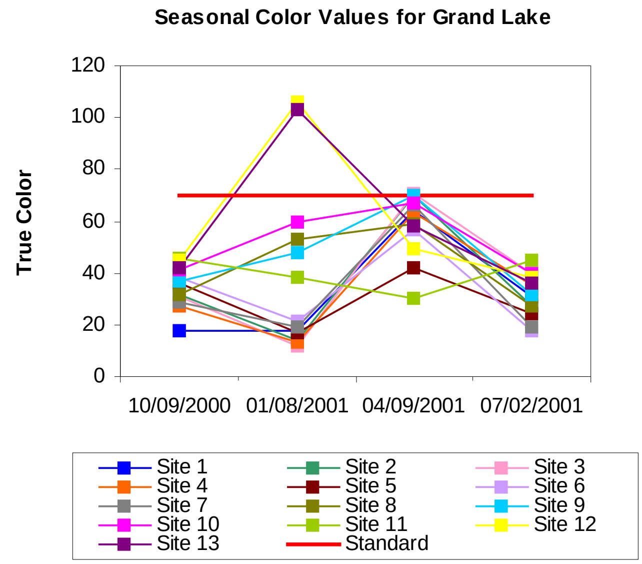
Only 3 of the 52 true color values exceeded the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is considered fully supported. For most sites, true color was highest in the spring and lowest in the winter, which is the common pattern for most lakes.

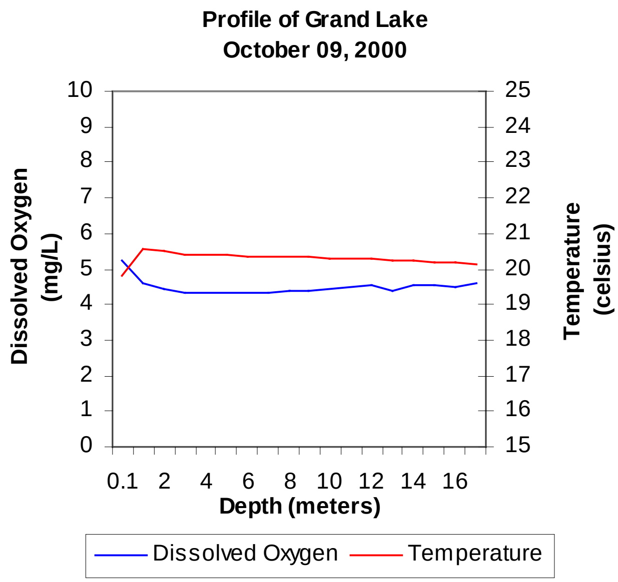
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all 13 sites during the study period. Winter profiles were recorded on two separate days during the sampling quarter as the upper end of the lake was frozen during the first sampling attempt. Salinity ranged from 0.06 at several sites in the summer to 0.2 parts per thousand (ppt) at site 13 in the spring, within the expected range of values reported for Oklahoma lakes. Specific conductivity ranged from 0.140mS/cm in the summer to 0.393mS/cm in the winter, indicating low concentrations of electrical conducting compounds (salts) were present in the water column, complimenting the low salinity values. In general, pH values were neutral to alkaline, ranging from 6.9 in the summer to 8.8 units in the winter. Oxidation-reduction potentials ranged from 153 mV near the sediment-water interface in the fall to 460mV in the spring, indicating that reducing conditions were not present in the water column during any season. In fact, most ORP values throughout the year were above 260 mV. The lake was not thermally stratified in the fall with D.O. concentrations above 4 mg/L throughout the water column except at site 3 at the lake bottom (see Figure 41c). Stratification was not present in the winter and D.O. values were above 8 mg/L throughout the water column, at all sites (see Figure 41d). In the spring, the lake was only stratified at sites 4 (between 10 and 11 meters), 5 (between 6 and 7 meters) and 6 (between 4 and 5 meters). Dissolved oxygen concentrations were above 5 mg/L throughout the lake except at site 12, where hypolimnetic anoxia was present. In the summer, the lake was not thermally stratified at most sites although a decreasing trend in temperature from the surface to the bottom was evident (see Figure 41f). Anoxic conditions were present at most sites ranging from 10% to over 60% of the water column. Anoxic conditions were not present at sites 8, 9, 12, and 13 as all of these sites are shallower than the others, all less than 10 meters deep. If dissolved oxygen values are less than 2 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 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 Grand Lake.

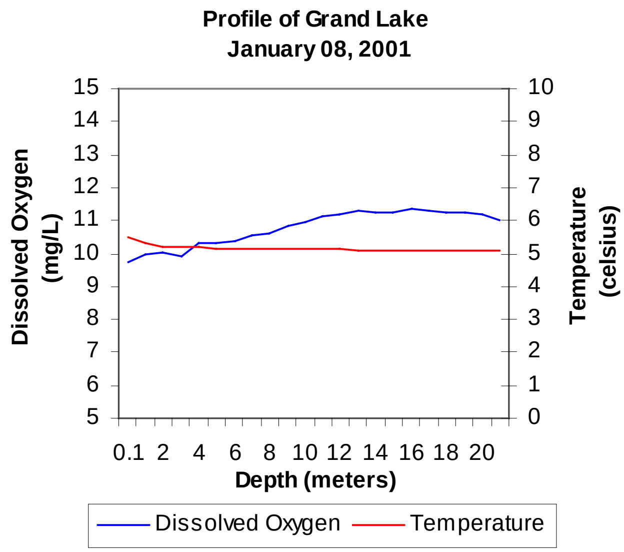
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001 was 1.46 mg/L at the surface and 1.48 mg/L on the lake bottom. The surface TN average at Grand Lake was the second highest for sample year 2001. The TN at the surface ranged from 0.30 mg/L to 3.81 mg/L and from 0.42 to 1.49 mg/L on the lake bottom. The highest surface TN value and the lowest were in the winter quarter. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.135 mg/L on the surface and 0.159 mg/L on the lake bottom. The TP ranged from 0.042 mg/L to 0.411 mg/L and from 0.066 to 0.259 mg/L on the lake bottom. The highest surface TP value was reported in the winter and the lowest was in the summer. The winter surface TP value was the highest value reported for this sample year. The nitrogen to phosphorus ratio (TN:TP) was 11:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

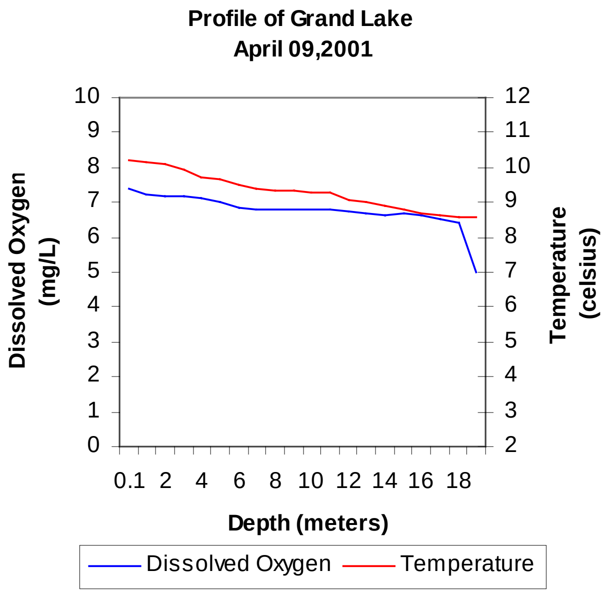
In summary, Grand Lake was classified as eutrophic in 2001, indicating high primary productivity and nutrient rich conditions. The annual surface TN average at Grand Lake was the highest for sample year 2001. The surface TP value (0.411 mg/L) reported in the winter was the highest TP reported in 2001. Because 44% of the turbidity values were above the OWQS of 25 NTU, Grand Lake is not supporting the FWP beneficial use (USAP 785:46). Based on anoxic conditions in the summer, the FWP beneficial use is only partially supported at Grand Lake. Grand Lake, the third largest Oklahoma reservoir based on surface area and volume, is quite variable from one end of the lake to the other and seasonally, based on the tributary influence for each part of the lake. It is truly difficult to quantify such a large lake without splitting up the lake based on tributaries, although defining this split would also be a difficult task. The information presented in this report should be seen as an overview and if more detailed information is needed, please contact the OWRB to obtain data records. Grand Lake was scheduled to be sampled by the ODEQ for metals and toxic compounds in 2001 although data is not available at this time. A confirmed fish kill at the stateline on Cave Springs Branch was reported in December 2000 possibly due to low D.O. values reported at the site. The Grand River Dam Authority (GRDA) constructed Grand Lake primarily for flood control and hydroelectric power purposes but is also utilized for recreational purposes. This reservoir is a popular recreational lake for Oklahomans as well as people from neighboring states. The Grand Lake Association is the largest citizen monitoring group affiliated with the Oklahoma Water Watch, the OWRB's citizen monitoring program.











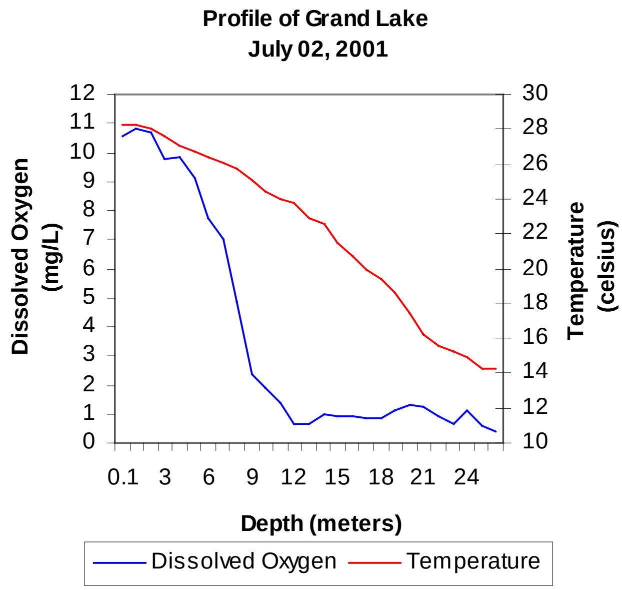


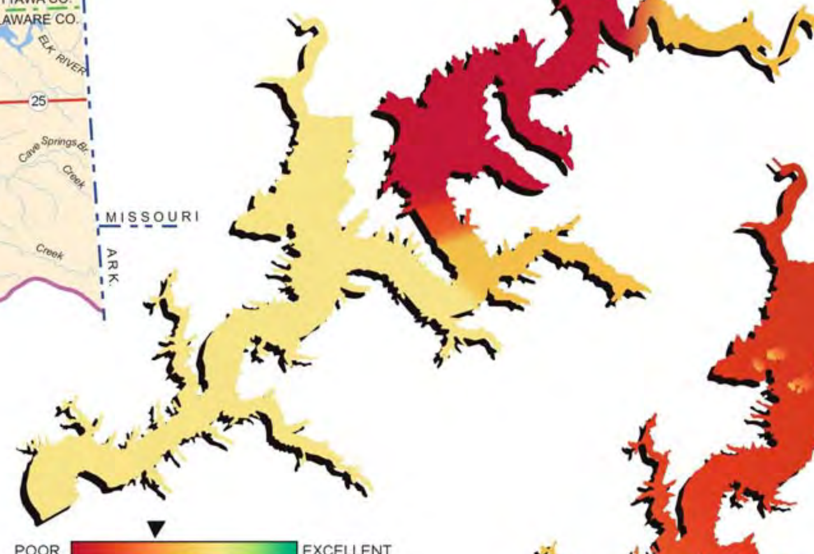
Figure 41a-41f. Graphical representation of data results for Grand Lake.

Plate 17 - Lake Water Quality for Grand Lake

Grand Lake and Watershed

Grand Lake Location

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



Turbidity 2001

Trophic State 2001

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 (Plate 18), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 54 (Plate 18), 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 (see Figure 42). The annual TSI of 54 seems representative of conditions at Greenleaf Lake throughout 2001. All turbidity values for in 2001 were below the OWQS of 25 NTU except in the winter at sites 2 and 3 (see Figure 43a). According to USAP (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. Seasonal true color values are also displayed in Figure 43b. All true color values were below the aesthetics OWQS of 70 units, therefore the Aesthetics beneficial use is considered fully supported at Greenleaf Lake (see Figure 43b).

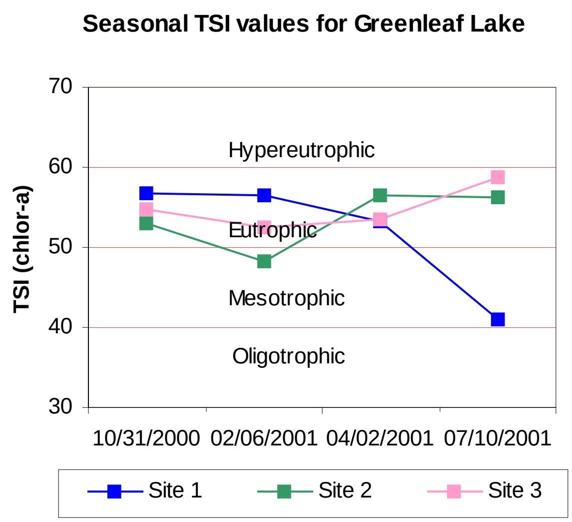


Figure 42. TSI values for Greenleaf Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites during the study period. Salinity ranged from 0.03 parts per thousand (ppt) to 0.04, 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 within the expected range for Oklahoma reservoirs, coinciding with the low salinity concentrations. Values ranged from 0.084mS/cm in the summer to 0.108mS/cm in the fall. Oxidation-reduction potentials ranged from 84mV at the lake bottom in the summer to 615mV in the winter. Reducing conditions were only present in the hypolimnion at the sediment water interface in the fall and summer, but reducing conditions were not present at all in the winter or spring. Lake pH values were neutral to slightly alkaline with values ranging from 6.45 to 8.45 in the summer. The surface pH readings in the summer were the highest throughout the year, but dropped below the chemocline to the lowest pH values in 2001. Thermal stratification was not evident in any of the first three seasons, although the D.O. concentration gradually decreased from the surface to the bottom in the fall (see Figure 43c). Dissolved oxygen (D.O.) values were consistent throughout the water column at each site in the winter and spring although the values varied between sites. In the summer, both stratification and anoxic conditions were present in Greenleaf Lake. The lake was stratified at several meter intervals, the first between 3 and 4 meters at the dam at which point anoxic conditions less than 2 mg/L were present to the lake bottom at all sites (see Figure 43f). If dissolved oxygen values are less than 2 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 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 Greenleaf Lake because approximately 50% of the water column was anoxic in the summer.

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 was 0.58 mg/L at the surface and 0.60 mg/L on the lake bottom. The TN at the surface ranged from 0.38 mg/L to 1.09 mg/L and from 0.34 to 1.01 mg/L on the lake bottom. 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 was 0.039 mg/L on the surface and 0.082 mg/L on the lake bottom. The TP ranged from 0.02 mg/L to 0.068 mg/L. The highest surface TP value was reported in the winter and the lowest was in the summer. The nitrogen to phosphorus ratio (TN:TP) was 15:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Greenleaf Lake is currently eutrophic, indicative of high primary productivity and nutrient rich conditions, similar to the TSI calculated in 1997. Both the turbidity and true color values meet the OWQS (OAC 785:45-5) listed for those parameters, although some of the turbidity values were above the 25 NTU standard. Anoxic conditions were present in the summer and constitutes listing as "partially supporting" the OWQS fish and wildlife propagation beneficial use based on D.O. values (USAP 785:46). According to ODEQ, the lake was sampled in 2000 and none of the fish tissue samples exceeded the screening level or low consumption advisory level for metals toxicity or organic residues. Greenleaf Lake is leased to the State of Oklahoma for recreational purposes and is located at Greenleaf State Park in the eastern part of the state.

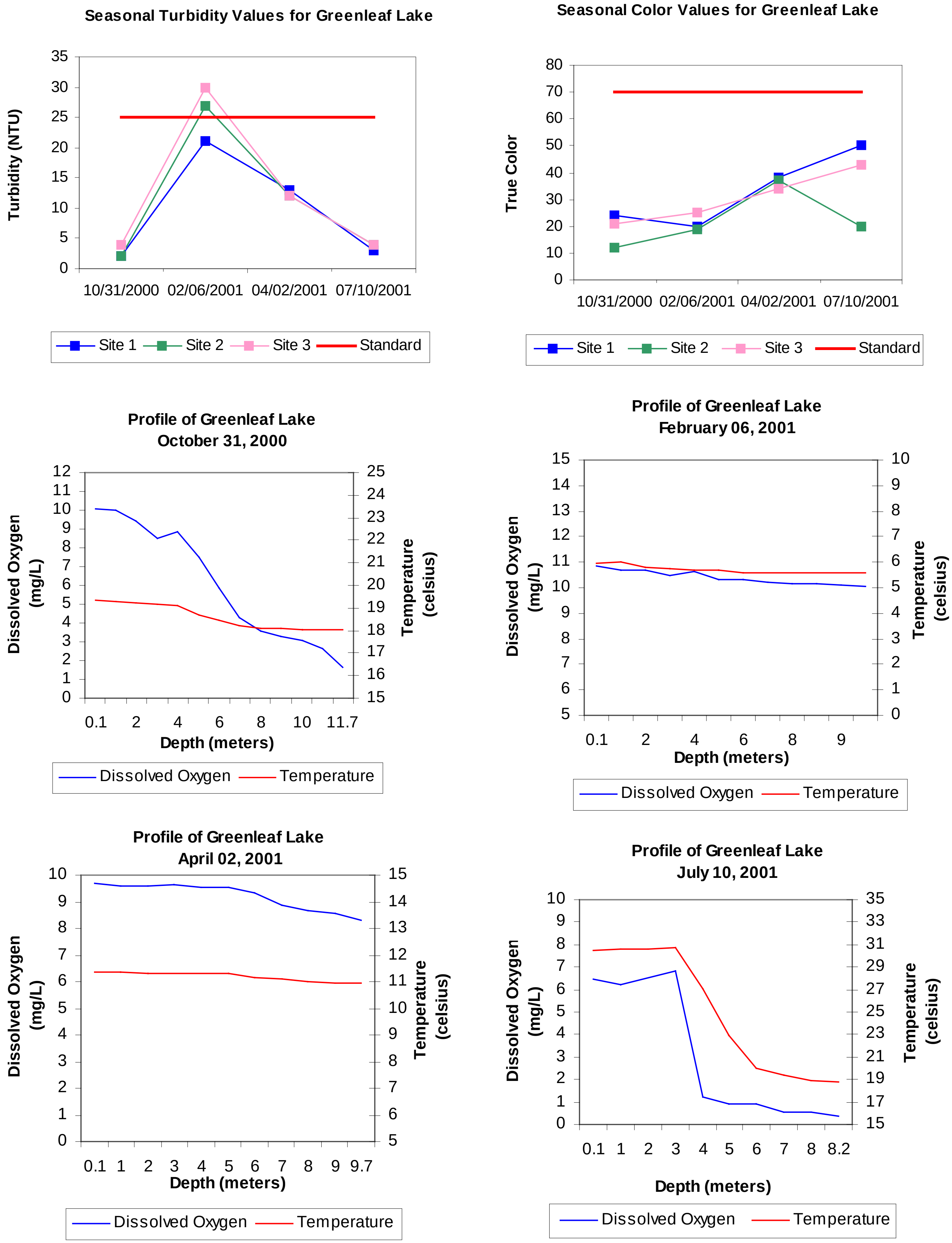


Figure 43a-43f. Graphical representation of data results for Greenleaf Lake.

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

Plate 18 - Lake Water Quality for
Greenleaf 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 (Plate 19), 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, 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 19), 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 (see Figure 44). 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 OWQS of 25 NTU except in the summer, when all three sites were below the standard (see Figure 45a). According to USAP (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. Seasonal true color values are also displayed in Figure 45b. 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 (see Figure 45b). 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.

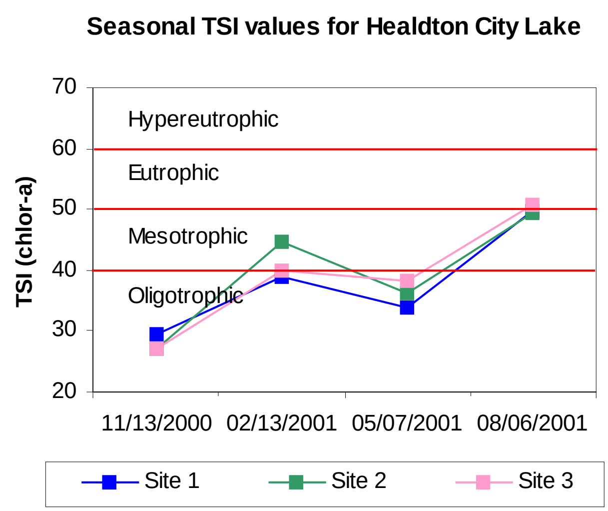


Figure 44. TSI values for Healdton Lake.

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 0.07 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 0.165 in the spring to 0.324mS/cm in the summer. These values indicated that low concentrations of electrical current conducting materials (salts) were present in the lake system, which is paralleled by low salinity values. In general, pH values were neutral to slightly alkaline, ranging from 7 to 8.79 units. Oxidation-reduction potentials (Redox) ranged from 232mV near the sediment-water interface to 468mV in the summer. Redox readings indicated that reducing conditions were not present in the reservoir, probably due in part to the wind conditions and high turbidity of the lake. The lake was not thermally stratified in the fall or winter quarters, and was well oxygenated with D.O. values above 5.9 mg/L throughout the water column (see Figure 45c-43d). In the spring the lake was stratified between 5 and 6 meters at the dam. Although hypolimnetic anoxia was present at site 1, this did not constitute a concern in meeting the FWP beneficial use. In the summer, a thermocline was present between 4 and 5 meters at the dam and half of the water column was less than 2 mg/L (see Figure 45f). If dissolved oxygen values are less than 2 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 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 Healdton Lake because approximately 50% of the water column was anoxic at site 1 in the summer; however the lake will not be listed based on this one vertical profile at the dam.

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 was 0.92 mg/L at the surface and 1.13 mg/L on the lake bottom. The TN at the surface ranged from 0.67 mg/L to 1.13 mg/L and from 0.93 to 1.31 mg/L on the lake bottom. 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 was 0.084 mg/L on the surface and 0.141 mg/L on the lake bottom. The surface TP ranged from 0.037 mg/L to 0.132 mg/L and from 0.081 to 0.209 mg/L on the lake bottom. 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 11:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Healdton City Lake was classified as mesotrophic in 2001, indicating moderate productivity and nutrient levels, although this value is based on only 12 samples. A minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres and this lake is 370 surface acres. Although most of the turbidity values were above the OWQS of 25 NTU, and about half of the true color values were above the OWQS of 70 units, only 12 samples were collected in 2001. The turbidity values at Healdton Lake were second only to Frederick, the lake with the highest turbidity in 2001. Water clarity was poor and turbidity extremely high, but this is probably the reason that productivity is kept to a minimum. Anoxic conditions in the summer are a cause for concern in meeting the fish and wildlife propagation beneficial use and should be examined more closely in the future. Healdton City Lake is the municipal water supply for the City of Healdton and is also utilized for flood control and recreation.

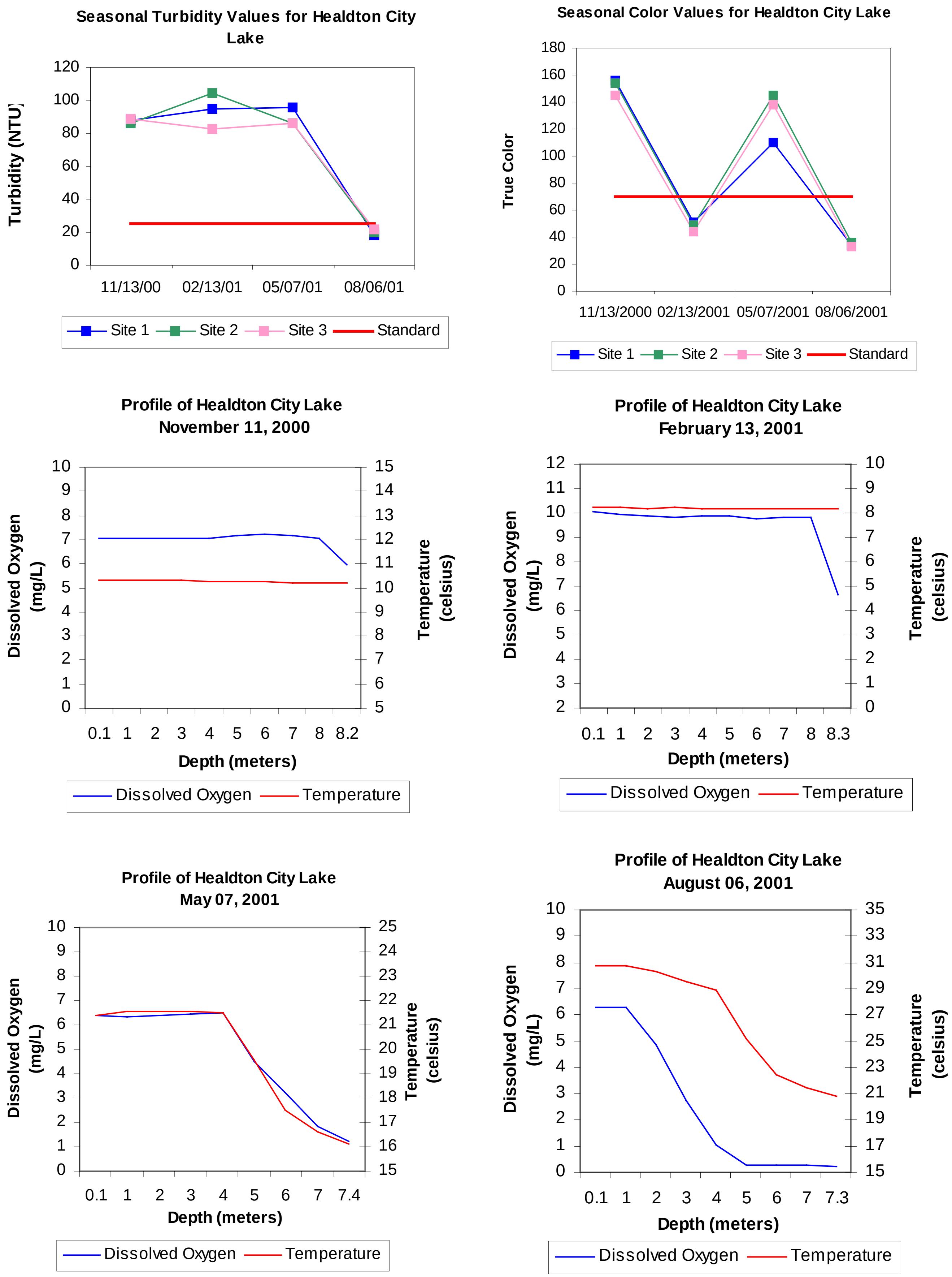


Figure 45a-45f. Graphical representation of data results for Headlton Lake.

Plate 19 - Lake Water Quality for
Healdton Lake

Healdton Lake and Watershed

Healdton Lake Location

Lake Data

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

POOR — EXCELLENT

Turbidity 2001

POOR — EXCELLENT

Trophic State 2001

Humphreys Lake

Humphreys Lake was sampled for four quarters, from November 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 (Plate 20), true color was 39 units, and secchi disk depth was 78 centimeters in 2001. Based on these three parameters, Humphreys Lake had good 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 53 (Plate 20), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is higher than the one calculated in 1997 (TSI=48) but is most likely a more accurate depiction of the trophic status at Humphreys Lake as the 2001 value is based on more samples collected year-round. The TSI values varied seasonally at Humphreys Lake throughout 2001 from mesotrophic (with one oligotrophic value) in the winter and summer to eutrophic in the spring and hypereutrophic in the summer (see Figure 46). All turbidity values in 2001 were below the OWQS of 25 NTU except site 3 in the fall (see Figure 47a). The annual turbidity value of 11 NTU seems to accurately reflect turbidity at Humphreys Lake. Seasonal true color values are also displayed in Figure 47b. True color values varied seasonally and were below the aesthetics OWQS of 70 units at all sites except site 3 in the fall, same as turbidity (see Figure 47b). The Aesthetics beneficial use is currently considered fully supported, although values in the fall (25%) are certainly close to the standard.

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 0.21 parts per thousand (ppt) to 0.3 ppt, higher than most salinity values reported for Oklahoma lakes. Readings for specific conductance ranged from 0.427 to 0.599mS/cm, indicating moderate to high 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 slightly alkaline, ranging from

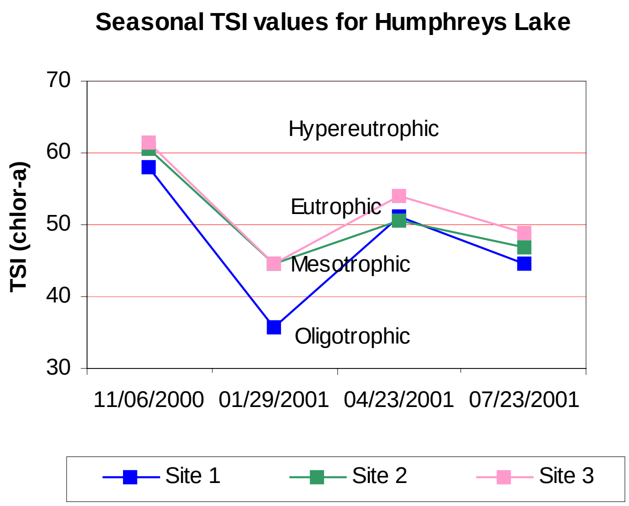


Figure 46. TSI values for Humphreys Lake.

7.02 to 8.31 units. Oxidation-reduction potentials (Redox) ranged from 150mV at the sediment-water interface in the summer to 475mV in the spring. Redox readings indicated that reducing conditions were not present in the reservoir, in fact, only 2 readings were less than 200mV in 2001. The lake was not thermally stratified in the fall, winter, or spring quarters (see Figure 47c-47e). D.O. values were above 4 mg/L in the fall throughout the water column and above 13 mg/L in the winter (see Figure 47c-47d). All D.O. values in the spring were above 4 mg/L, with the exception of the bottom reading at the dam site which was less than 2 mg/L (see Figure 47e). In the summer the lake was stratified between 6 and 7 meters at sites 1 and 2 although the D.O. concentration was less than 2 mg/L below 5 meters at both sites (see Figure 47f). If dissolved oxygen values are less than 2 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 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 Humphreys Lake because slightly less than 50% of the water column was anoxic at site 1 in the summer.

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 was 0.98 mg/L at the surface and 1.38 mg/L on the lake bottom. The TN at the surface ranged from 0.58 mg/L to 1.56 mg/L and from 0.93 to 1.31 mg/L on the lake bottom. The highest surface TN value was reported in the spring and the lowest was in the summer quarter. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.065 mg/L on the surface and 0.18 mg/L on the lake bottom. The surface TP ranged from 0.023 mg/L to 0.153 mg/L and from 0.055 to 0.499 mg/L on the lake bottom. 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 15:1 for sample year 2001. This value is greater 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 rich conditions. Although the lake was classified as mesotrophic in the summer of 1997, the 2001 evaluation is more accurate as it is based on more samples and year-round collections instead of summer only. The lake has good water clarity and both the turbidity or true color values indicate beneficial uses are fully supported. Anoxic conditions in the summer were present although not a level high enough to deem the lake as partially or not supporting beneficial uses. Humphreys Lake is one of the municipal water supply reservoirs for the City of Duncan and is utilized for water supply, flood control, and recreational purposes.

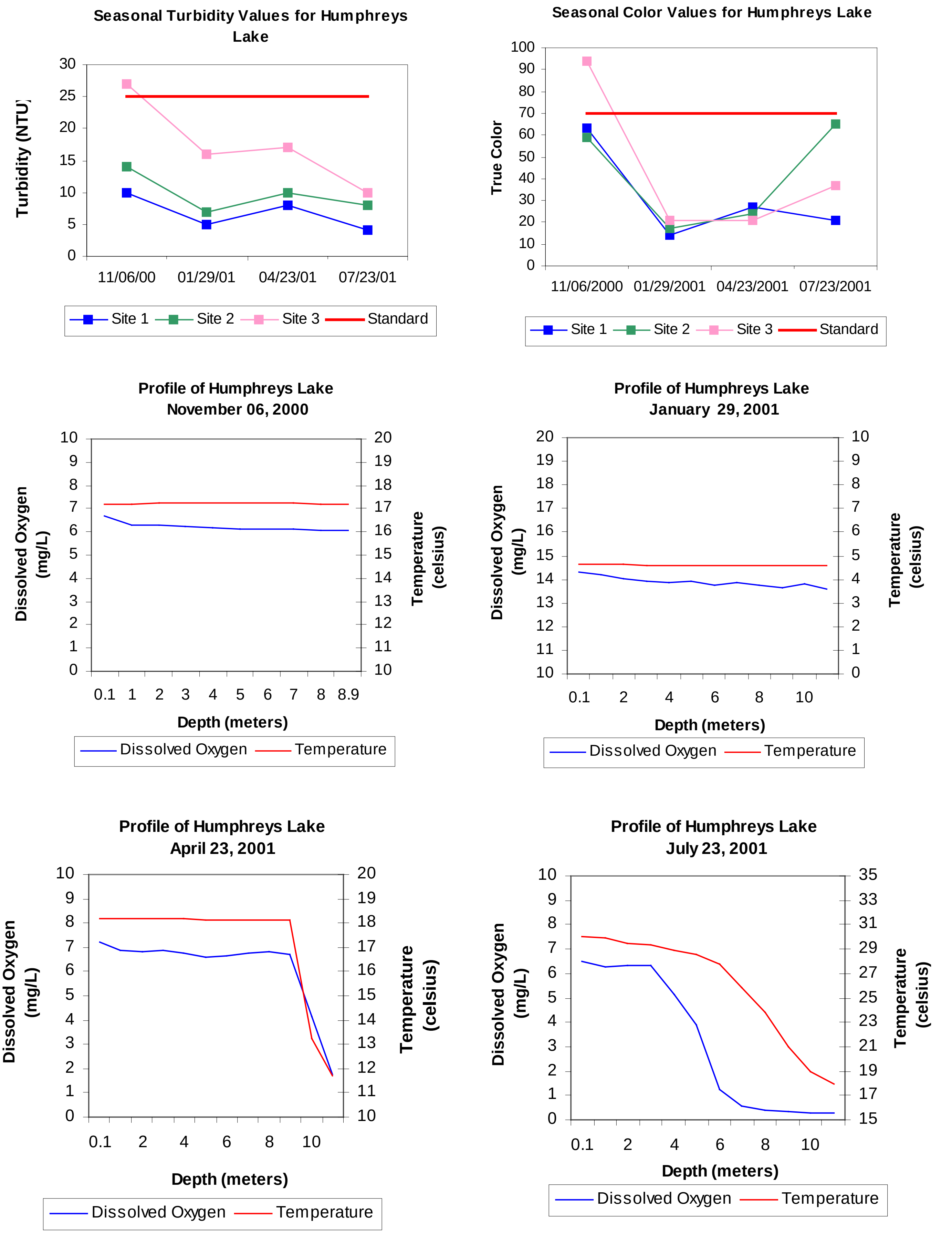


Figure 47a-47f. Graphical representation of data results for Humphreys Lake.

Plate 20 - Lake Water Quality for

Humphreys Lake

Humphreys Lake Location

Humphreys Lake and Watershed

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

Trophic State 2001

Turbidity 2001

Lake Jean Neustadt

Lake Jean Neustadt 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 17 NTU (Plate 21), true color was 52 units, and secchi disk depth was 70 centimeters in 2001. Based on these three parameters, Lake Jean Neustadt had fair to good water clarity in 2001. The turbidity values were higher and secchi disk depth lower 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 58 (Plate 21), classifying the lake as eutrophic, indicative of high levels of productivity and nutrient rich conditions. This value is higher than the one calculated in 1997 (TSI=52) but is most likely a more accurate depiction of the trophic status at Lake Jean Neustadt as the 2001 value is based on more samples collected year-round. The TSI values varied seasonally throughout 2001 although most values were eutrophic (see Figure 48). 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. All turbidity values in 2001 were below the OWQS of 25 NTU except site 3 in the winter (see Figure 49a). The annual turbidity value of 17 NTU accurately reflects turbidity at Lake Jean Neustadt. Seasonal true color values are also displayed in Figure 49b. True color values varied seasonally and were below the aesthetics OWQS of 70 units at all sites except in the spring, when the true color at all sites was above the standard (see Figure 49b). 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, therefore, 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. The salinity values ranged from 0.09 parts per thousand (ppt) to 0.18 ppt, within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance ranged from 0.191 to 0.362mS/cm, indicating low concentrations

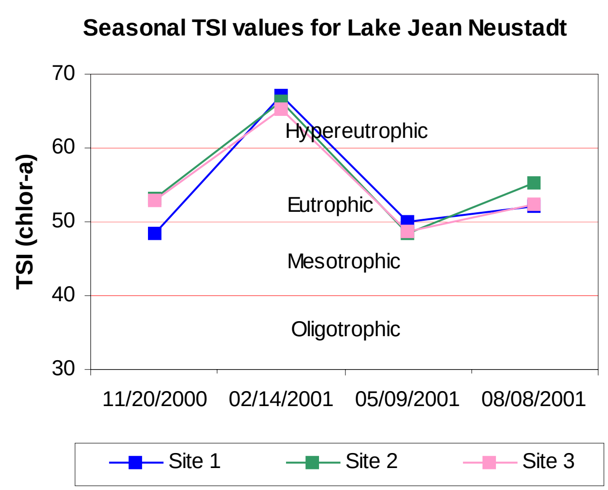


Figure 48. TSI values for Lake Jean Neustadt.

of electrical current conducting compounds (salts) were present in the water column throughout the year. These values were also corresponded with the low salinity values. In general, pH values were neutral to alkaline, ranging from 6.81 in the summer to 9.49 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 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 range, the lake should be listed as partially supporting beneficial uses. The high pH values (consistently above 9 units) recorded throughout the water column in the winter are cause to list Lake Jean Neustadt as "provisionally partially supporting"* the FWP beneficial use. Oxidation-reduction potentials (Redox) ranged from 92mV at the sediment-water interface in the summer to 471mV in the fall. Redox readings indicated that reducing conditions were not present in the reservoir in the first three sampling intervals, but were present in the hypolimnion in the summer at the dam site. The lake was not thermally stratified in the fall or winter and the D.O. values were above 8 mg/L throughout the water column at all sites (see Figure 49c-49d). In the spring the lake was stratified at several 1-meter intervals, the first one between 5 and 6 meters (see Figure 49e). Anoxic conditions were present below 6 meters to the lake bottom at site 1, the deepest site in the lake, constituting about 45% of the water column. In the summer, the lake was stratified between 4 and 5 meters and below 4 meters from the surface the D.O. values were less than 1 mg/L to the lake bottom (10.2 meters) (see Figure 49f). If dissolved oxygen values are less than 2 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 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 Jean Neustadt because greater than 50% of the water column was anoxic at site 1 in the summer.

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 was 0.58 mg/L at the surface and 0.86 mg/L on the lake bottom. The TN at the surface ranged from 0.38 mg/L to 0.83 mg/L and from 0.52 to 1.21 mg/L on the lake bottom. 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 was 0.046 mg/L on the surface and 0.067 mg/L on the lake bottom. The surface TP ranged from 0.023 mg/L to 0.069 mg/L and from 0.038 to 0.127 mg/L on the lake bottom. The highest surface TP value was reported in the winter and the lowest was in the summer. The nitrogen to phosphorus ratio (TN:TP) was 13:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Jean Neustadt was classified as eutrophic in 2001, indicative of high productivity and nutrient rich conditions. Both true color and turbidity values met standards in 2001. Water clarity was fair to good in 2001. According to USAP (OAC 785:46), Lake Jean Neustadt was partially supporting the FWP beneficial use based on high pH values and should be "provisionally" listed and closely monitored in the future. Anoxic conditions were present in the summer and constitutes listing as "partially supporting" the OWQS fish and wildlife propagation beneficial use based on D.O. values (USAP 785:46). Lake Jean Neustadt is owned by the City of Ardmore and is used primarily for recreational 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.

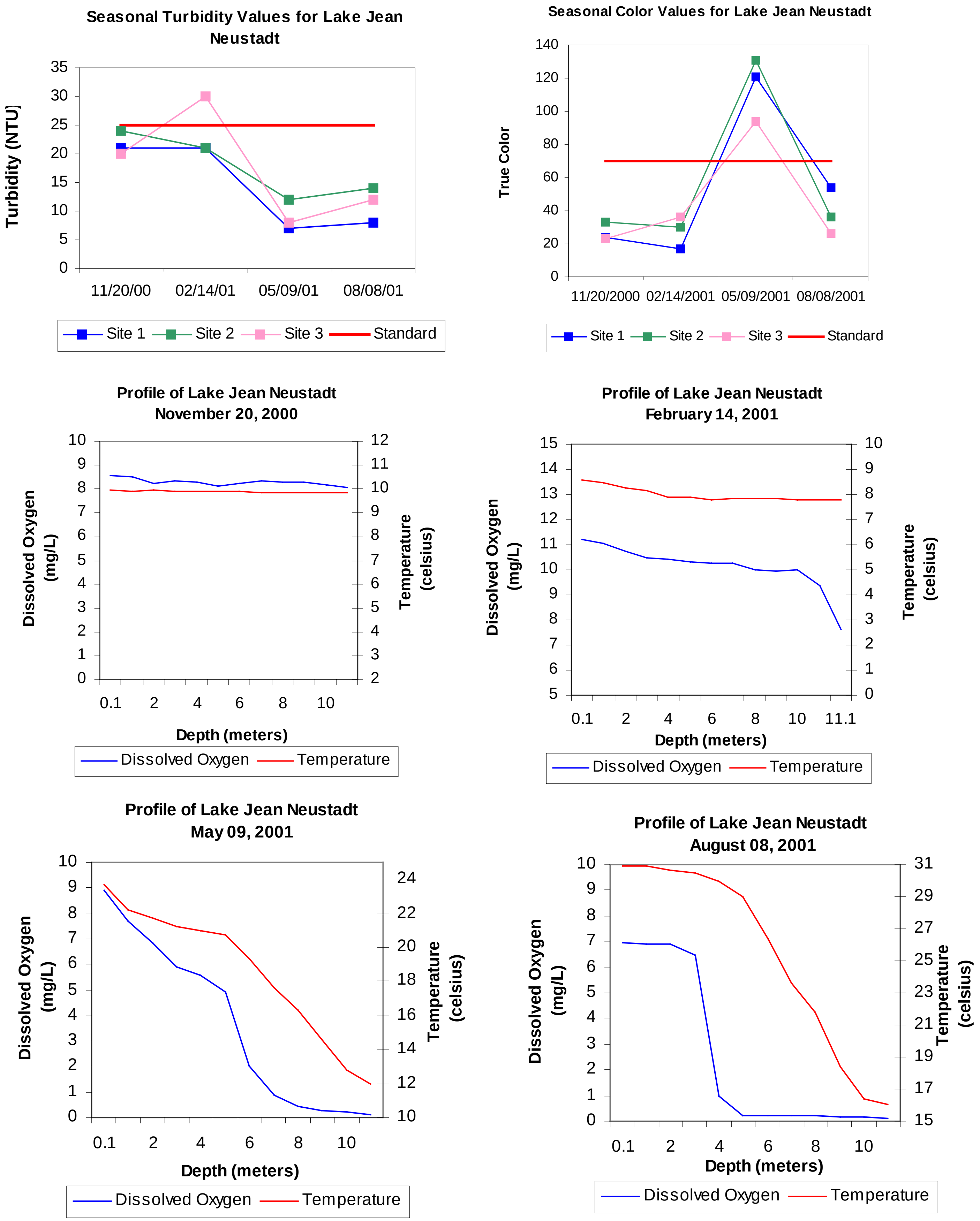


Figure 49a-49f. Graphical representation of data results for Lake Jean Neustadt.

Plate 21 - Lake Water Quality for
Lake Jean Neustadt

Trophic State
2001

Turbidity
2001

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

Lloyd Church (Wilberton) 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 USAP for lakes under 250 surface acres (785:46-15-3). 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 (Plate 22), 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, 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 (Plate 22), 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 (see Figure 50). The turbidity values in the winter quarter exceeded the OWQS of 25 NTU constituting a listing as "partially supporting" the FWP beneficial use (see Figure 51a). According to USAP (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 also displayed in Figure 51b. All of the true color values were below the numeric criteria of 70 units, therefore, the Aesthetics beneficial use is considered fully supported.

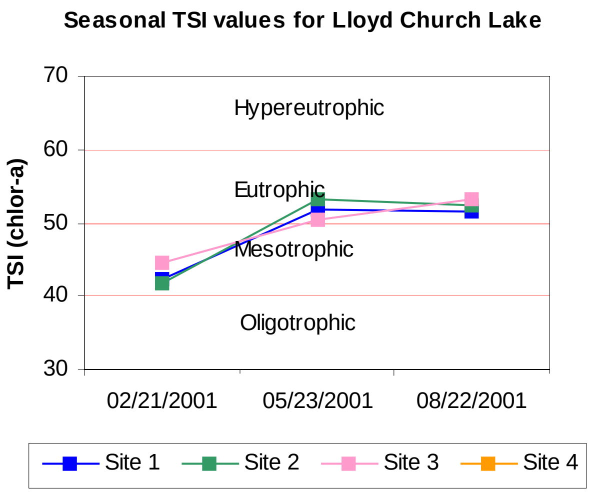


Figure 50. TSI values for Lloyd Church (Wilberton) Lake.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity values were 0 to 0.01 parts per thousand (ppt) indicating low salt content and within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were extremely low, ranging from

0.014 to 0.063mS/cm, indicating little to no presence of electrical current conducting compounds (salts) in the water column throughout the year. These values were also paralleled by the very low salinity values. In general, pH values were slightly acidic to neutral, ranging from 5.78 in the spring to 7.45 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 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 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 spring and summer are cause to list Lloyd Church Lake as "provisionally not supporting" * the FWP beneficial use. Oxidation-reduction potentials (Redox) ranged from 131mV at the sediment-water interface in the summer to 530mV in the spring. Redox readings indicated that reducing conditions were not present in the reservoir in the winter or spring sampling intervals, but were present in the hypolimnion in the summer at sites 1 and 2. The lake was not thermally stratified in the winter and the D.O. values were above 7.6 mg/L throughout the water column at all sites (see Figure 51c). In the spring, the lake was stratified at several 1-meter intervals, the first one between 4 and 5 meters, although D.O. concentration remained above 2 mg/L throughout the water column at all sites (see Figure 51d). In the summer, the lake was stratified between 4 and 5 meters and below 4 meters from the surface the D.O. values were less than 1 mg/L to the lake bottom at all sites (see Figure 51e). If dissolved oxygen values are less than 2 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 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Lloyd Church Lake because greater than 50% of the water column was anoxic at sites 1 and 2 in the summer.

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 was 0.39 mg/L at the surface and 0.62 mg/L on the lake bottom. The TN at the surface ranged from 0.22 mg/L in the winter to 0.50 mg/L in the summer. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.033 mg/L on the surface and 0.043 mg/L on the lake bottom. The surface TP ranged from 0.017 mg/L in the summer to 0.046 mg/L in the winter. The nitrogen to phosphorus ratio (TN:TP) was 12:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In 2001, Lloyd Church Lake was classified as mesotrophic, indicative of moderate productivity and nutrient levels. Some of the turbidity values were above the OWQS of 25 NTU, constituting a partially supported beneficial use for FWP (USAP 785:46). According to USAP (OAC 785:46), Lloyd Church Lake was not supporting the FWP beneficial use based on low pH values and should be "provisionally" listed and closely monitored in the future. Anoxic conditions were present in the summer and constitutes listing as "partially supporting" the OWQS fish and wildlife propagation beneficial use based on D.O. values (USAP 785:46). Lloyd Church Lake is the municipal water supply for the City of Wilburton and is also used for flood control and recreation. The extreme drought conditions in the summer of 2000 created cause for concern in meeting the water demands for the 1200 customers in Wilburton and 1400 customers in Latimer County Rural Water District No. 1, all dependent on Lloyd Church Lake for water supply.

* 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.

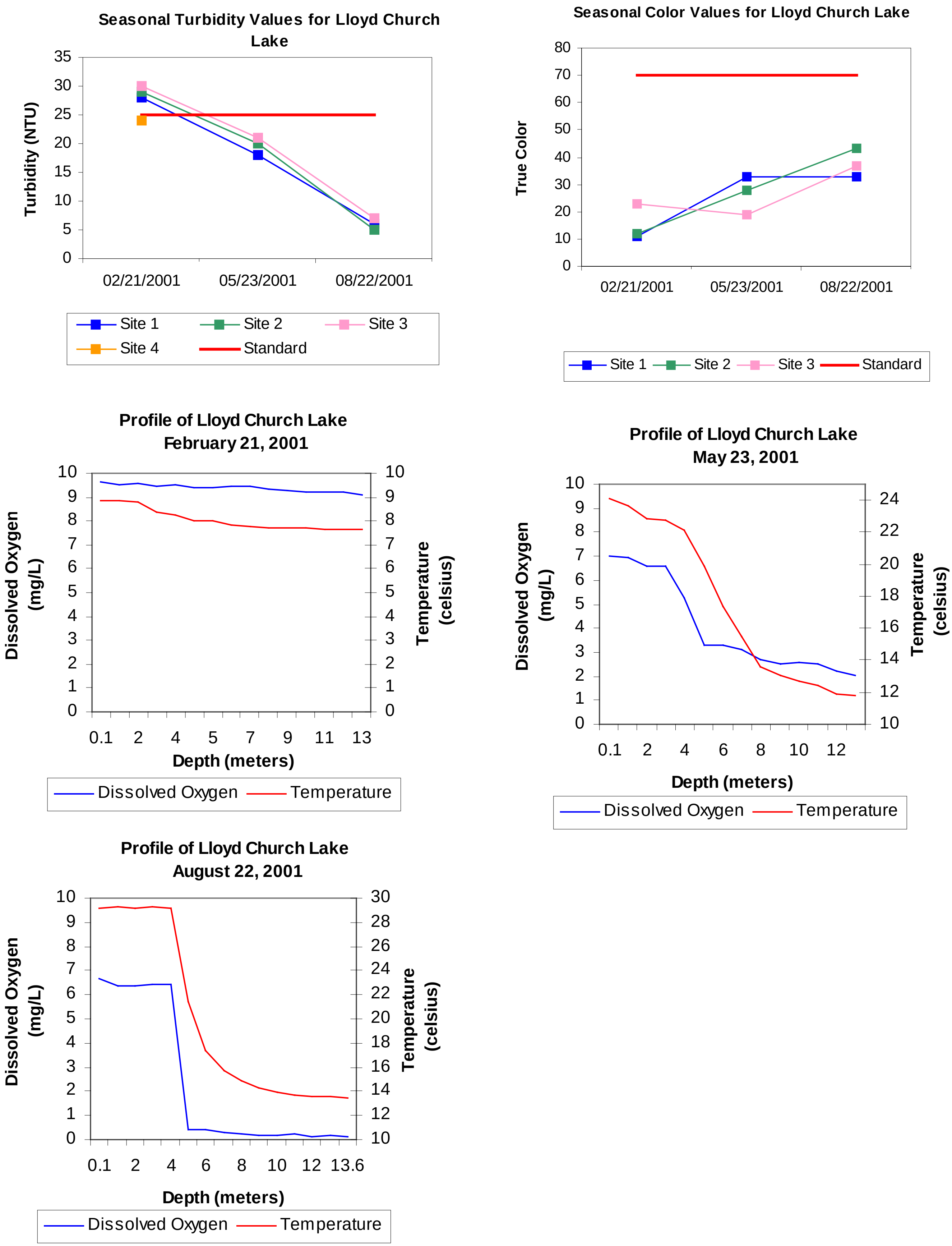
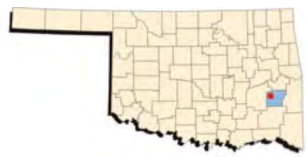
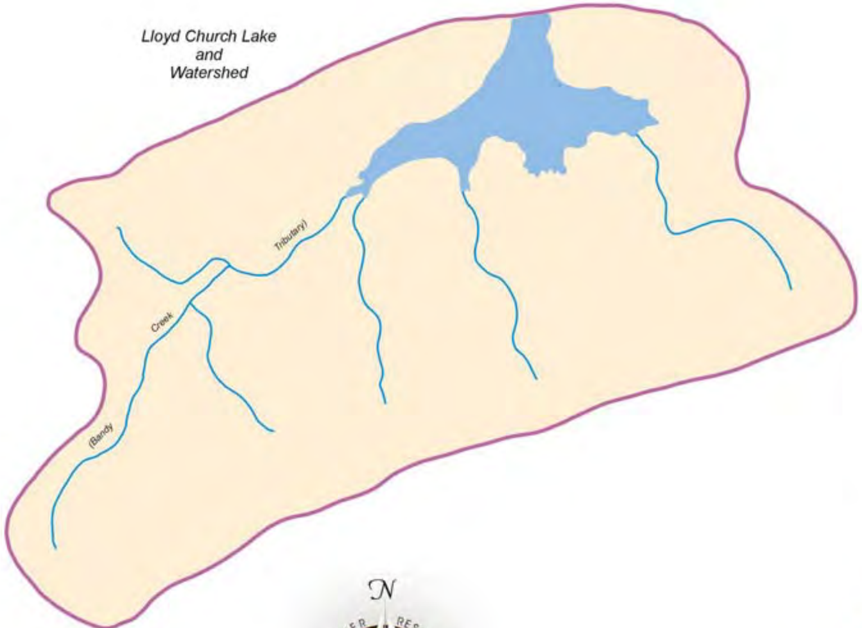


Figure 51a-51e. Graphical representation of data results for Lloyd Church Lake.

Plate 22 - Lake Water Quality for
Lake Lloyd Church

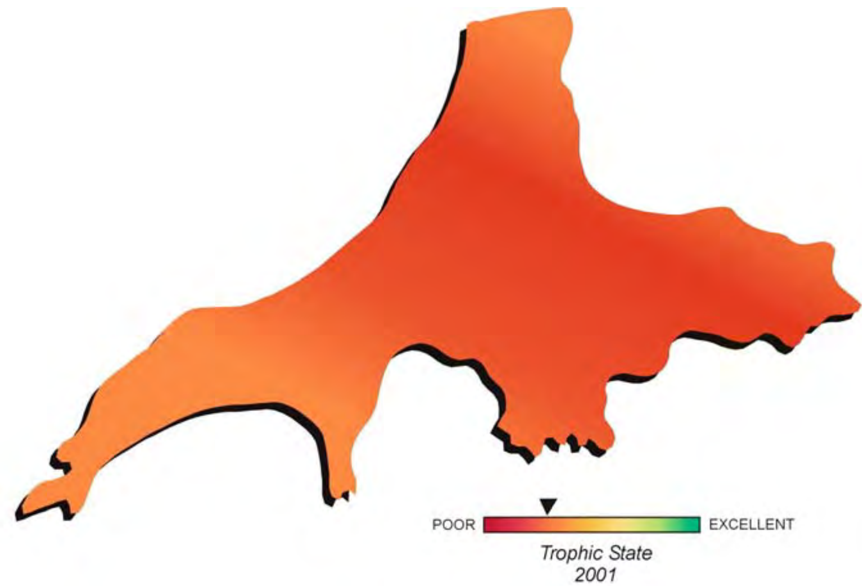


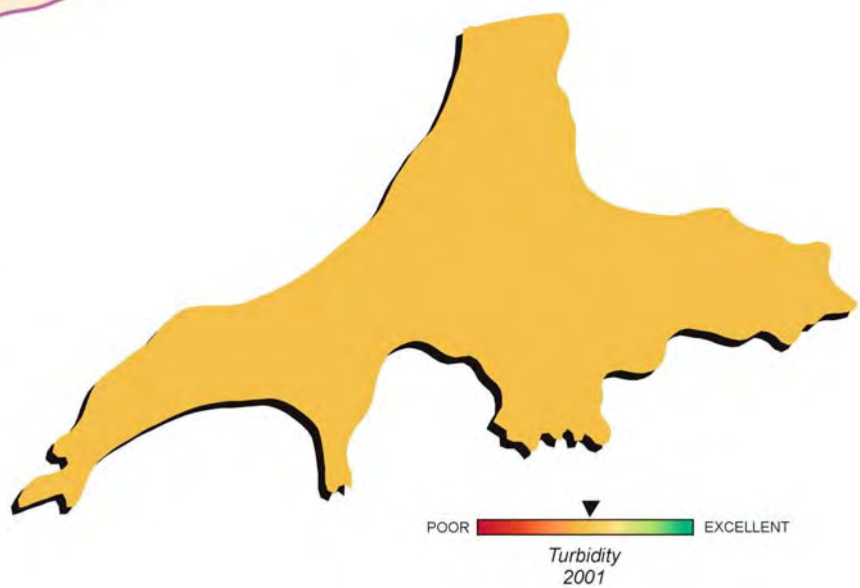
Lloyd Church Lake Location



Lloyd Church Lake and Watershed

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





Lake McAlester

Lake McAlester (1,521 surface acres) was sampled from October 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 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 60 NTU (Plate 23), true color was 107 units, and secchi disk depth was 25 centimeters in 2001. Based on these three parameters, Lake McAlester had poor water clarity. Water clarity was much worse in the summer of 1998, the last time this lake was sampled, as turbidity and true color were much higher and secchi disk depth values were much lower. The difference in the summer values compared to the year-round average illustrates the need to sample throughout the year to accurately reflect lake conditions. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 47 (Plate 23), classifying the lake as mesotrophic, indicative of moderate levels of productivity and nutrients. This value is slightly greater than the one calculated in the summer of 1998 (TSI=43), although in the same trophic category, but is a more accurate depiction of trophic status as more samples were collected throughout the year. The higher turbidity and true color in 1998 was probably the reason for the lower trophic evaluation as light was a limiting factor in lake productivity. The TSI values in 2001 were primarily mesotrophic although values at all three sites were considered eutrophic in the summer and two values in the winter were oligotrophic (see Figure 52). All turbidity values exceeded the OWQS of 25 NTU constituting a listing as “partially supporting” the FWP beneficial use (see Figure 53a). According to USAP (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 100% 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. Seasonal true color values are also displayed in Figure 53b. True color values varied seasonally and were below the aesthetics OWQS of 70 units at all sites in the winter and at two sites in the summer, but above at all sites in the fall and spring and one site in the summer (see Figure 53b). Although 60% of the samples collected in 2001 were above the standard, no listing can be made as a minimum of 20 samples are required, therefore, the Aesthetics beneficial use is considered fully supported.

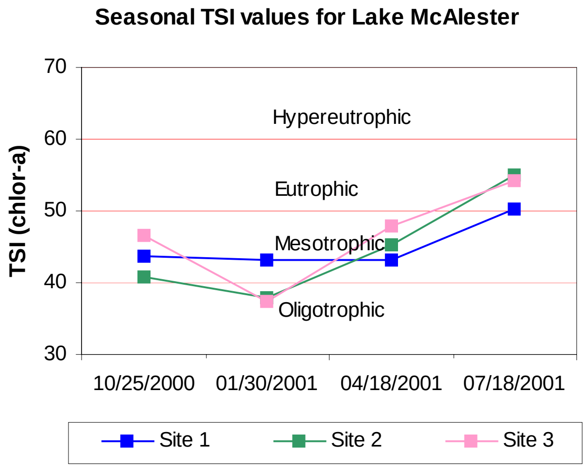


Figure 52. TSI values for Lake McAlester.

In 2001, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0ppt to 0.05ppt, indicating low salt content and within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were low, ranging from 0.028 to 0.118mS/cm, indicating minimal presence of electrical current conducting compounds (salts) in the water column throughout the year. These values were also paralleled by the low salinity values. In general, pH values were slightly acidic to neutral with values ranging from 6.27 in the summer to 7.58 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 beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9 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 summer are cause to list Lake McAlester as "provisionally partially supporting"* the FWP beneficial use. Oxidation-reduction potentials ranged from 243mV in the winter to 643mV in the summer, indicating an absence of reducing conditions. In the fall, the ORP values were unusually low (less than 50mV throughout the water column), indicating reducing conditions; however, anoxic conditions were not present at this time. Lake McAlester was not stratified in the fall, winter or spring and D.O. values were above 5 mg/L throughout the water column in all three seasons (see Figure 53c-53e). In the summer, the lake was thermally stratified between 4 and 5 meters at site 1 and below 5 meters from the surface the D.O. values were less than 2 mg/L to the lake bottom at sites 1 and 2 (see Figure 53f). If D.O. concentration is less than 2 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 McAlester because less than 50% of the water column was anoxic at sites 1 and 2 in the summer.

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 was 0.64 mg/L at the surface and 0.70 mg/L on the lake bottom. The TN at the surface ranged from 0.24 mg/L to 0.81 mg/L and from 0.50 to 0.85 mg/L on the lake bottom. 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 was 0.104 mg/L on the surface and 0.119 mg/L on the lake bottom. The surface TP ranged from 0.081 mg/L to 0.151 mg/L and from 0.081 to 0.148 mg/L on the lake bottom. The highest surface TP value was reported in the summer and the lowest was in the spring. The nitrogen to phosphorus ratio (TN:TP) was 6:1 for sample year 2001. This value is less than 7:1, characterizing the lake as nitrogen-limited (Wetzel, 1983).

In summary, Lake McAlester was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 23). The trophic status is the same as the status calculated in 1998. According to USAP (OAC 785:46), the lake was partially supporting the FWP beneficial use based on low pH values and should be "provisionally" listed and closely monitored in the future. Both turbidity and true color values exceeded the OWQS of 25 NTU and 70 units, respectively, however the minimum number of samples required to make beneficial use determinations was not met. Lake McAlester is the municipal water supply for the City of McAlester and is used for recreational 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.

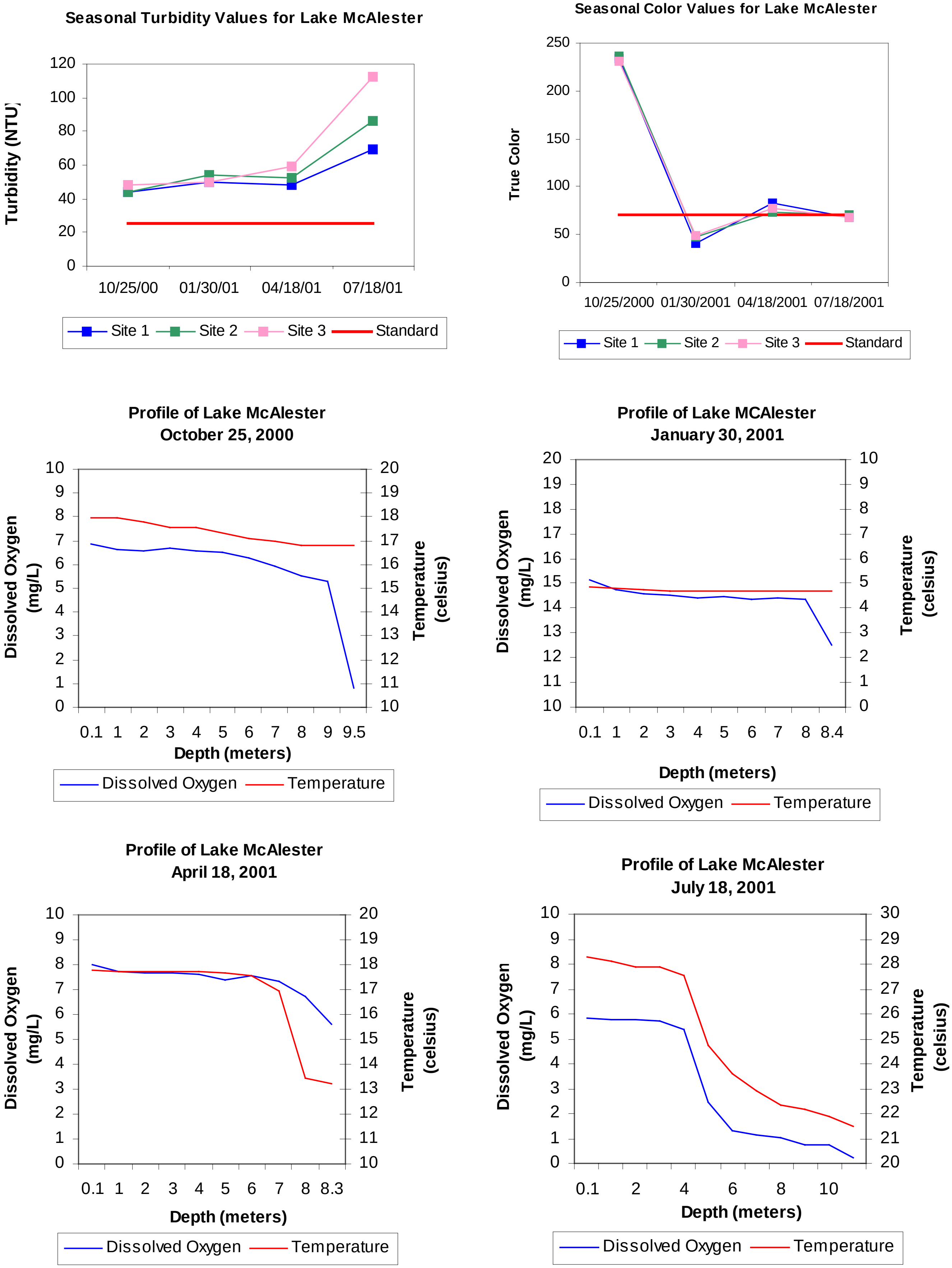
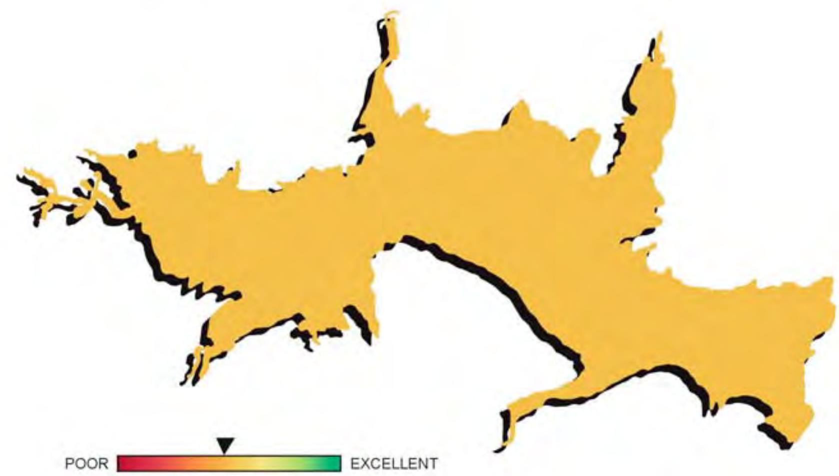


Figure 53a-53f. Graphical representation of data results for Lake McAlester.

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

Turbidity
2001



Trophic State
2001

Plate 23 - Lake Water Quality for
Lake McAlester

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 (Plate 24), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=20). The average TSI was 42 (Plate 24), 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 (see Figure 54). 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 OWQS of 25 NTU except site 5 in the winter (see Figure 55a). The annual turbidity value of 7 NTU accurately reflects turbidity at Lake Murray. Seasonal true color values are also displayed in Figure 55b. 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 (see Figure 55b).

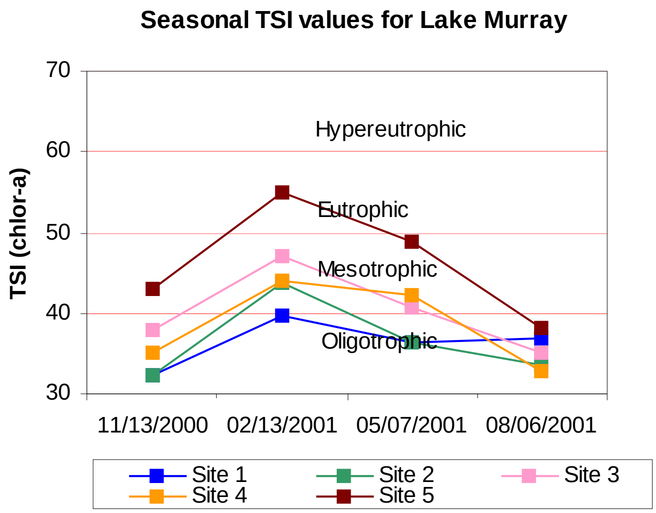


Figure 54. TSI values for Lake Murray.

In 2001, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.07ppt to 0.14ppt, indicating low 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 0.164 to 0.284mS/cm, indicating low presence of electrical current conducting compounds (salts) in the water column throughout the year. These values also corresponded with the low salinity values. In general, pH values were neutral with values ranging from 6.98 in the summer to 9.11 in the winter. Although several values were above the 9-unit threshold, the lake is fully supporting the FWP beneficial use based on pH values. Oxidation-reduction potentials ranged from 364mV in the spring to 494mV in the summer, indicating an absence of reducing conditions. Lake Murray was not stratified in the fall or winter and D.O. values were above 5 mg/L throughout the water column in both seasons (see Figure 55c-55d). In the spring, the lake was thermally stratified between 10 and 11 meters at site 1 and at different depths for sites 2, 3, and 4 (see Figure 55e). The water column at site 5 was not stratified because it was only 4 meters deep. The D.O. concentration was generally above 5 mg/L throughout the water column, except at the sediment-water interface at sites 1 and 2 (see Figure 55e). In the summer the lake was stratified between 7 and 8 meters, and below 8 meters D.O. values were less than 1 mg/L to the lake bottom at sites 1, 2, and 4 (see Figure 55f). The remaining sites, 3 and 5, were not 8 meters deep. If D.O. concentration is less than 2 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 Murray because 50% of the water column or greater was anoxic at sites 1, 2, and 4 in the summer.

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 was 0.39 mg/L at the surface and 0.58 mg/L on the lake bottom. The TN at the surface ranged from 0.19 mg/L to 0.73 mg/L and from 0.28 to 0.80 mg/L on the lake bottom. 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 was 0.018 mg/L on the surface and 0.053 mg/L on the lake bottom. The surface TP ranged from 0.006 mg/L to 0.049 mg/L and from 0.010 to 0.112 mg/L on the lake bottom. The highest surface TP value was reported in the spring and the lowest was in the fall. The nitrogen to phosphorus ratio (TN:TP) was 22:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Murray was classified as mesotrophic, indicative of moderate primary productivity and nutrient levels (Plate 24). The trophic status is the same as the status calculated in 1998 and water clarity remains excellent at this reservoir. Anoxic conditions were present in the summer and constitutes listing as “partially supporting” the OWQS fish and wildlife propagation beneficial use based on D.O. values (USAP 785:46). 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. Lake Murray, located in Love County, is owned by the State of Oklahoma and is utilized for recreational purposes. Lake Murray State Park truly is one of Oklahoma’s treasures.

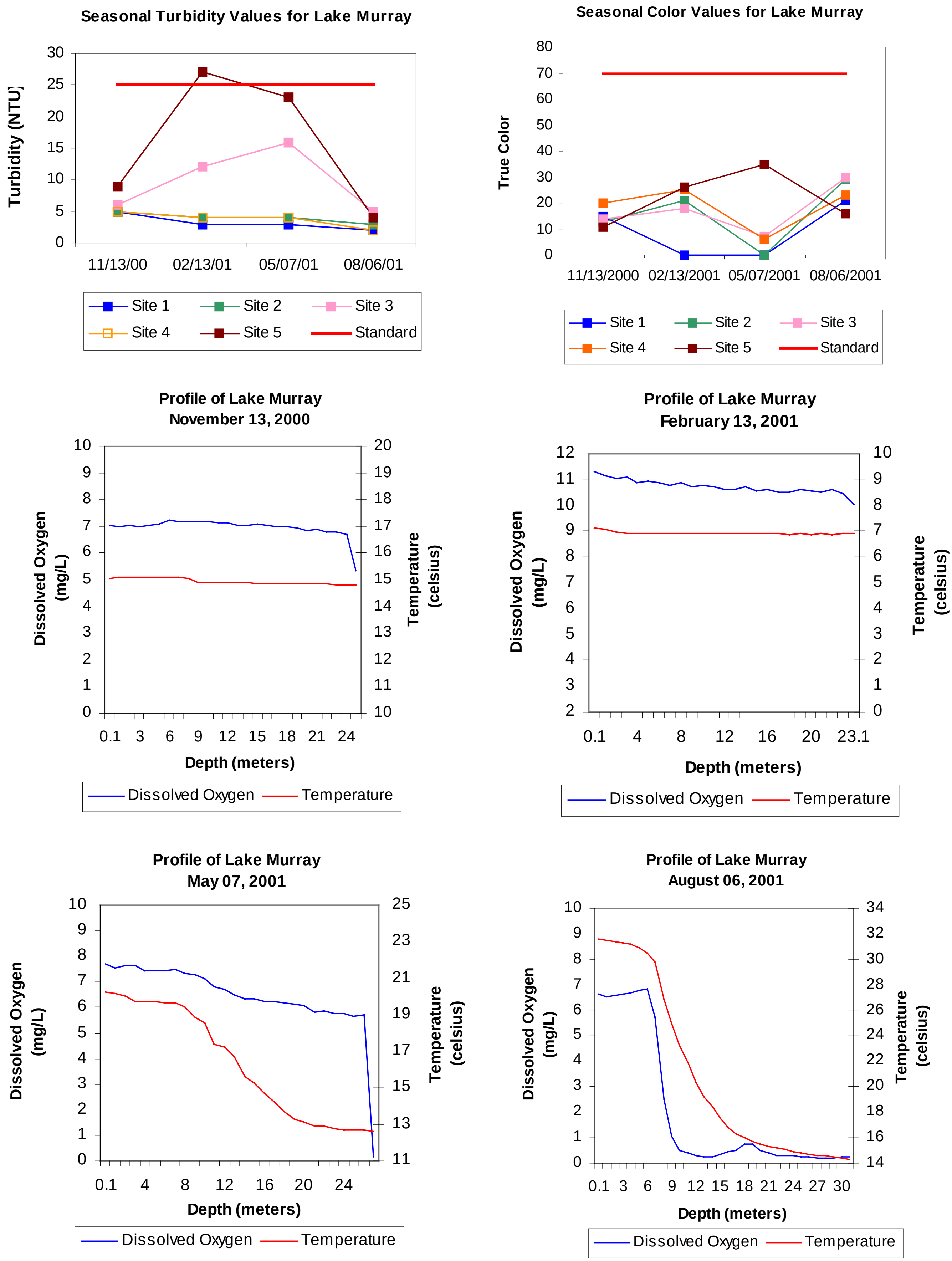


Figure 55a-55f. Graphical representation of data results for Lake Murray.

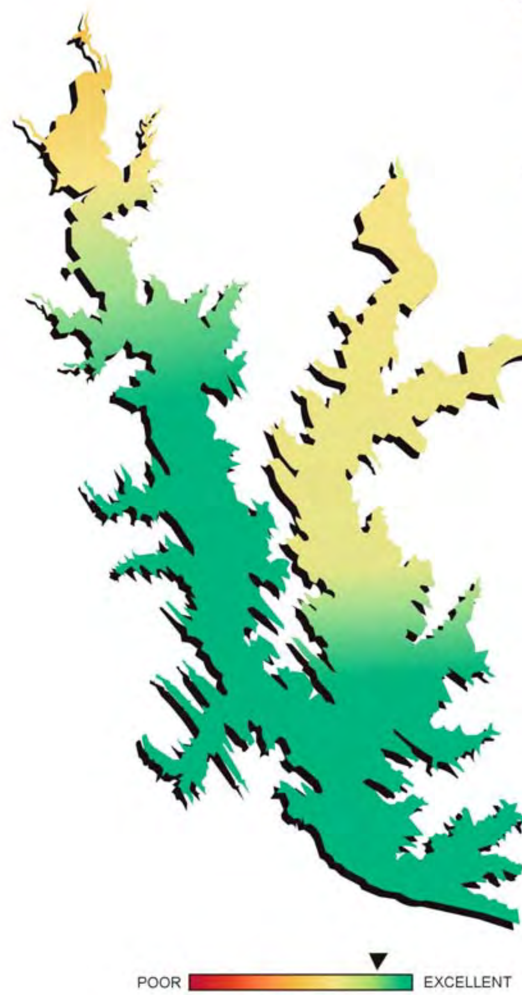
Plate 24 - Lake Water Quality for
Lake Murray

Lake Murray and Watershed

Lake Murray Location

Lake Data

Owner	State of Oklahoma
County	Love (Dam)
Constructed	1960
Surface Area	5,728 acres
Volume	153,250 acre/feet
Shoreline Length	67 miles
Mean Depth	26.75 feet
Watershed Area	55 square miles



Turbidity
2001

Trophic State
2001

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 (Plate 25), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 61 (Plate 25), 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 (see Figure 56). 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 (see Figure 57a). 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. Seasonal true color values are also displayed in Figure 57b. True color values varied seasonally and were below the aesthetics OWQS of 70 units at all sites in the winter and spring, but above at all sites in the summer (see Figure 57b). 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.

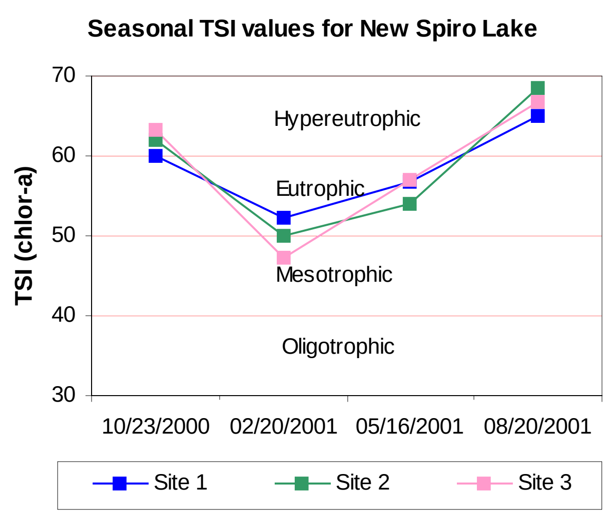


Figure 56. TSI values for New Spiro Lake.

In 2001, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.01ppt to 0.05ppt, indicating low salt content and within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were low, ranging from 0.056 to 0.159mS/cm, indicating minimal presence of electrical current conducting compounds (salts) in the water column throughout the year. These values also paralleled the low salinity values. In general, pH values were slightly acidic to slightly alkaline with values ranging from 6.22 in the spring to 8.4 in the summer. Although several values were below the 6.5-unit threshold, the lake is fully supporting the FWP beneficial use based on pH values. Oxidation-reduction potentials ranged from 286mV in the summer to 474mV in the spring, indicating an absence of reducing conditions. In the fall, the ORP values were unusually low (less than 85mV throughout the water column), indicating reducing conditions; however, anoxic conditions were not present at this time. New Spiro Lake was not stratified in the fall or winter and D.O. values were above 3 mg/L throughout the water column in both seasons (see Figure 57c-57d). In the spring and summer, the lake was thermally stratified between 2 and 3 meters and between 3 and 4 meters at site 1, respectively (see Figure 57e-57f). In the spring, below 2 meters the D.O. values were less than 2 mg/L to the lake bottom at site 1 (see Figure 57e). In the summer, anoxic conditions were present below 1 meter at site 1 and below 2 meters at site 2. Although this lake is fairly shallow (about 4 to 5 meters deep), about 50% of the water column was anoxic. If D.O. concentration is less than 2 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 New Spiro Lake.

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 was 1.37 mg/L at the surface and 1.54 mg/L on the lake bottom. The TN at the surface ranged from 0.06 mg/L to 2.51 mg/L and from 0.60 to 2.32 mg/L on the lake bottom. 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 was 0.15 mg/L on the surface and 0.169 mg/L on the lake bottom. The surface TP ranged from 0.067 mg/L to 0.372 mg/L and from 0.076 to 0.365 mg/L on the lake bottom. The highest surface TP value was reported in the winter and the lowest was in the spring. The nitrogen to phosphorus ratio (TN:TP) was 9:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, New Spiro Lake was classified as hypereutrophic, indicative of excessive primary productivity and nutrient levels although this value is based on only 12 samples (Plate 25). A minimum of 20 samples are required to make beneficial use determinations in lakes greater than 250 surface acres and this lake is 254 surface acres. Although about 1/4 of the turbidity values were above the OWQS of 25 NTU, and about 1/3 of the true color values were above the OWQS of 70 units, only 12 samples were collected in 2001. Anoxic conditions were present in the summer and constitutes listing as “partially supporting” the OWQS fish and wildlife propagation beneficial use based on D.O. values (USAP 785:46). New Spiro Lake, located in LeFlore County, is the municipal water supply for the City of Spiro and is utilized for recreational purposes.

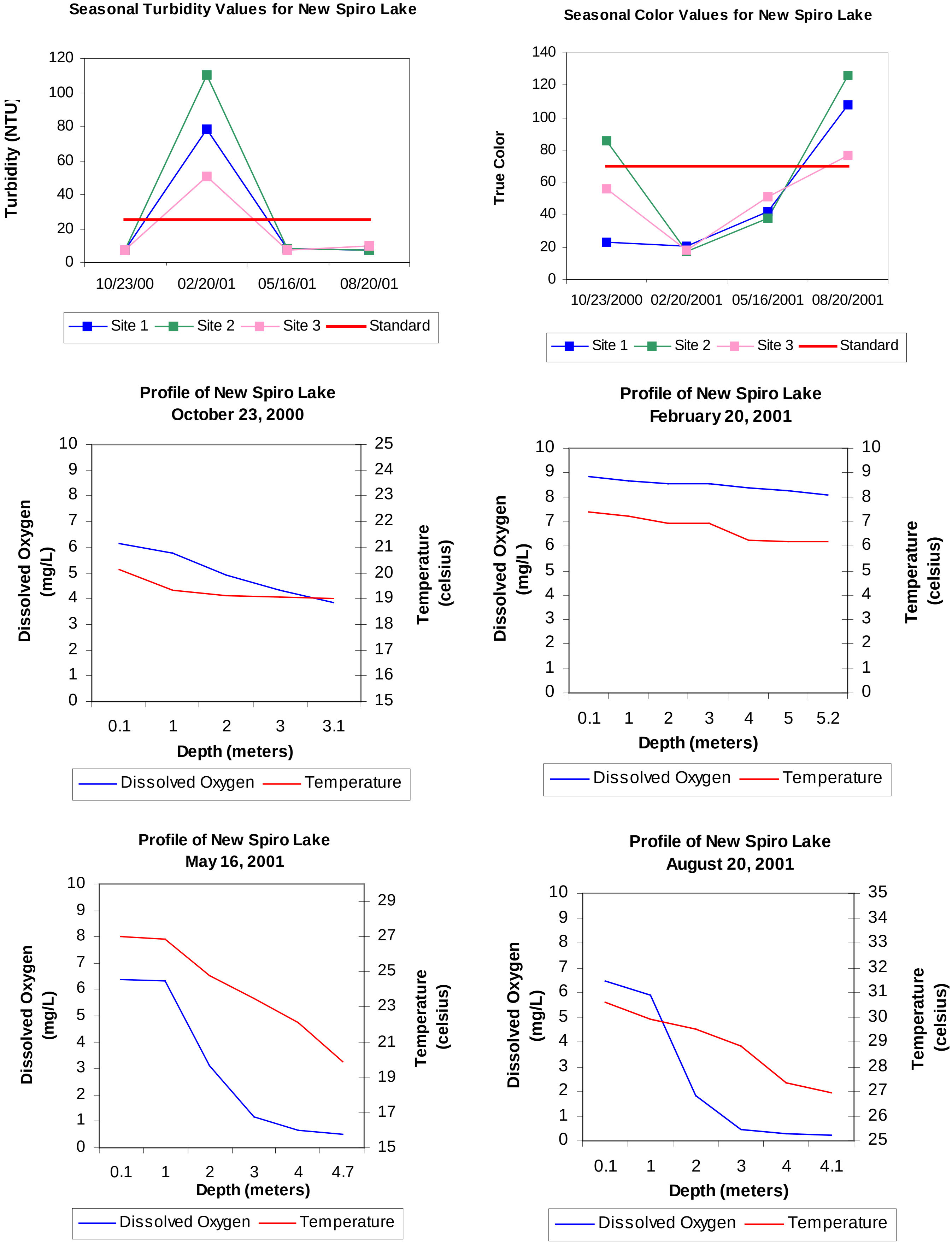
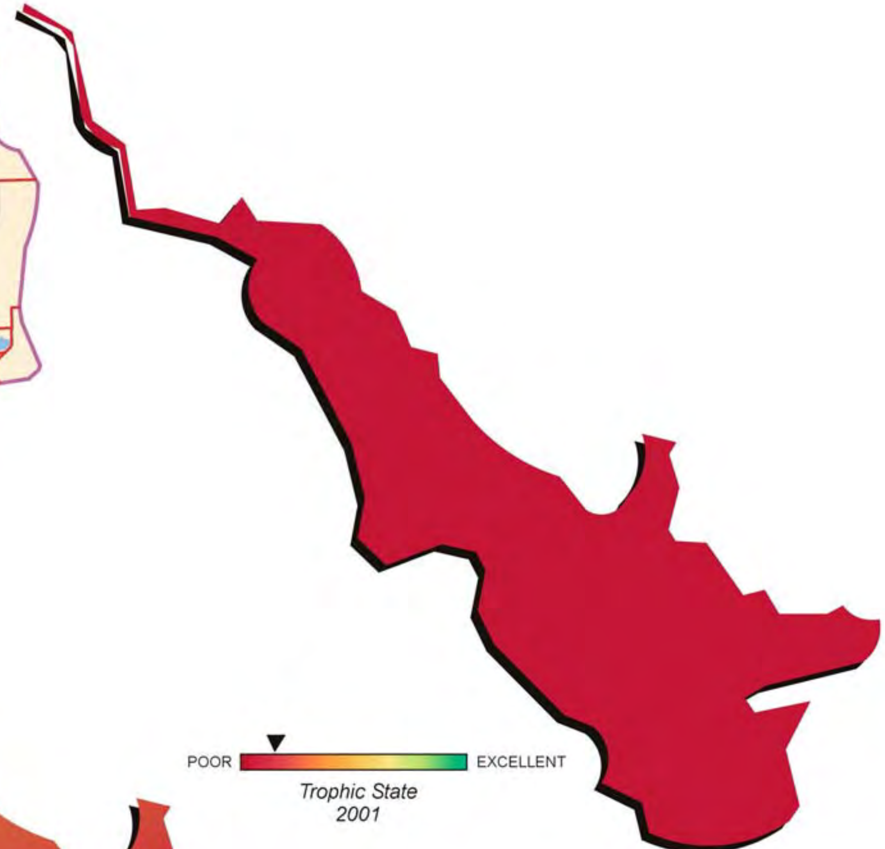
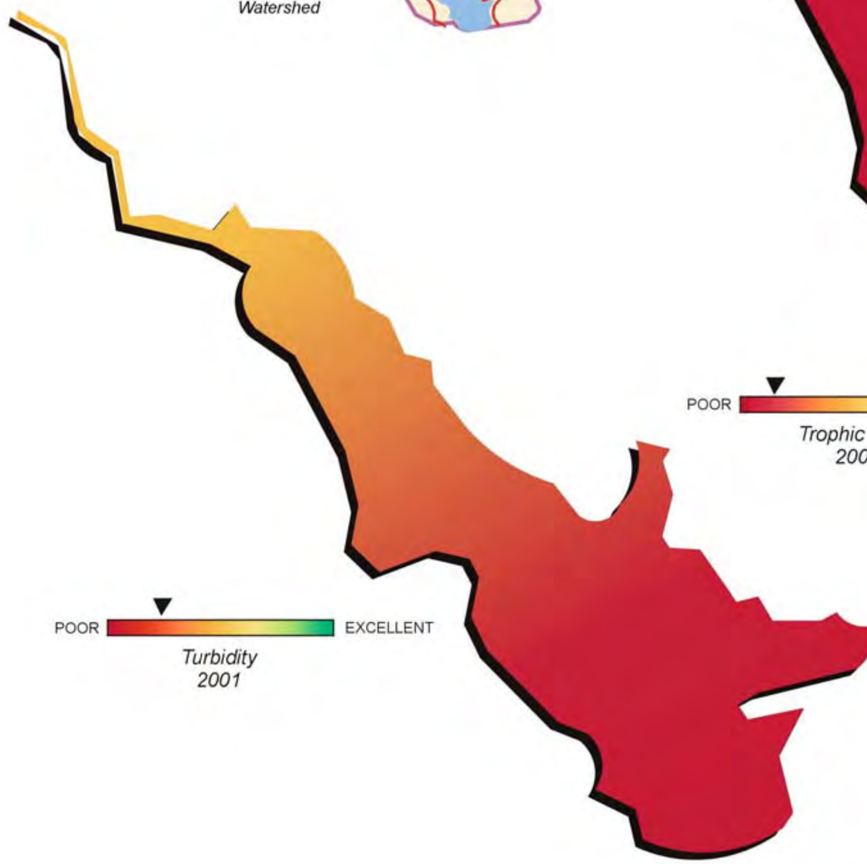


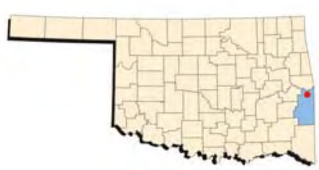
Figure 57a-57f. Graphical representation of data results for New Spiro Lake.

Plate 25 - Lake Water Quality for
Spiro (New) Lake

New Spiro Lake and Watershed







New Spiro Lake Location

Lake Data

Owner	City of Spiro
County	LeFlore
Constructed	1960
Surface Area	254 acres
Volume	2,160 acre/feet
Shoreline Length	5 miles
Mean Depth	8.50 feet
Watershed Area	14 square miles

Paul Valley City Lake

Pauls Valley City Lake was sampled for four quarters from November 2000 through August 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 site 1, the dam. The lake-wide annual turbidity value was 28 NTU (Plate 26), true color was 72 units, and secchi disk depth was 38 centimeters in 2001. Based on these three parameters, Pauls Valley Lake had fair to poor water clarity in comparison to other Oklahoma reservoirs. Water clarity was not as good in the summer of 1998, based on only three summer samples, indicating the importance of monitoring water quality throughout the year and not just one season. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The TSI was 50 (Plate 26), indicating the lake was mesotrophic/bordering eutrophic in sample year 2001. The TSI values throughout the sample year were either mesotrophic or eutrophic and therefore the TSI number seems appropriate (see Figure 58). Based on three summer values in 1998, the calculated TSI value was exactly the same (TSI=50), indicating no change in trophic status over time. Turbidity values in the fall, winter and summer seasons were below the turbidity standard of 25 NTU (see Figure 59a). There was an apparent spike in turbidity in the spring quarter, possibly due to the seasonal rain events, at which point the values were 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. Seasonal true color values are also displayed in Figure 59b. True color values varied from below the aesthetics OWQS of 70 units at all sites in the winter and summer, to above the standard at all sites in the fall and summer (seeFigure 59b). Although 42% of samples in 2001 were above 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.

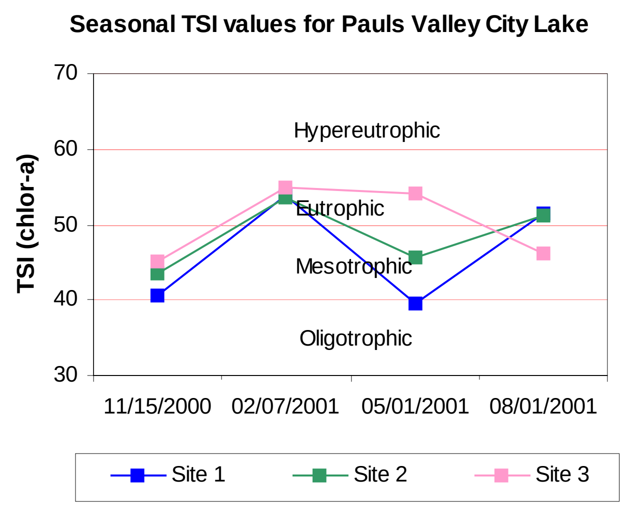


Figure 58. TSI values for Paul Valley City Lake.

In 2001, vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. Salinity values ranged from 0.09ppt to 0.14ppt, within the expected range of salinity values reported for most Oklahoma lakes. Readings for specific conductance were also within the expected range for most Oklahoma lakes, ranging from 0.204 to 0.299mS/cm, indicating little presence of electrical current conducting compounds (salts) in the water column throughout the year. These values were also corresponded with the low salinity values. In general, pH values were neutral to alkaline with values ranging from 7.08 in the summer to 8.9 in the winter. Oxidation-reduction potentials ranged from 183mV in the fall to 592mV in the winter, indicating an absence of reducing conditions. Pauls Valley City Lake was not stratified in the fall, winter, or spring and D.O. values were above 4 mg/L throughout the water column in all three seasons (see Figure 59c-57e). In the summer, the lake was thermally stratified between 4 and 5 meters and below the thermocline at site 1, dissolved oxygen levels were below 1mg/L for just less than 50% of the water column, although values at the other 2 sites were not anoxic (see Figure 59f). According to USAP, the FWP beneficial use is considered fully supported at Pauls Valley Lake because less than 50% of the water column was anoxic in the summer.

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 was 0.55 mg/L at the surface and 0.80 mg/L on the lake bottom. The TN at the surface ranged from 0.41 mg/L to 0.81 mg/L and from 0.57 to 0.96 mg/L on the lake bottom. The highest surface TN value was reported in the spring and the lowest was in the fall and summer. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.046 mg/L on the surface and 0.138 mg/L on the lake bottom. The surface TP ranged from 0.029 mg/L to 0.06 mg/L and from 0.073 to 0.172 mg/L on the lake bottom. The highest surface TP value was reported in the spring and the lowest was in the summer. The nitrogen to phosphorus ratio (TN:TP) was 6:1 for sample year 2001. This value is less than 7:1, characterizing the lake as nitrogen-limited (Wetzel, 1983).

In summary, Pauls Valley Lake was classified at the upper end of mesotrophic, indicating moderate primary productivity and nutrient levels although this value is based on only 12 samples (Plate 26). A minimum of 20 samples is required to make beneficial use determinations in lakes greater than 250 surface acres and this lake is 750 surface acres. Although about 1/4 of the turbidity values were above the OWQS of 25 NTU, and close to 1/2 of the true color values were above the OWQS of 70 units, only 12 samples were collected in 2001. Anoxic conditions were present in the summer although not greater than 50% of the water column, therefore the lake is still meeting the FWP beneficial use based on D.O. values (USAP 785:46). Pauls Valley City Lake, located in Garvin County, is the municipal water supply for the City of Pauls Valley and is utilized for recreational purposes.

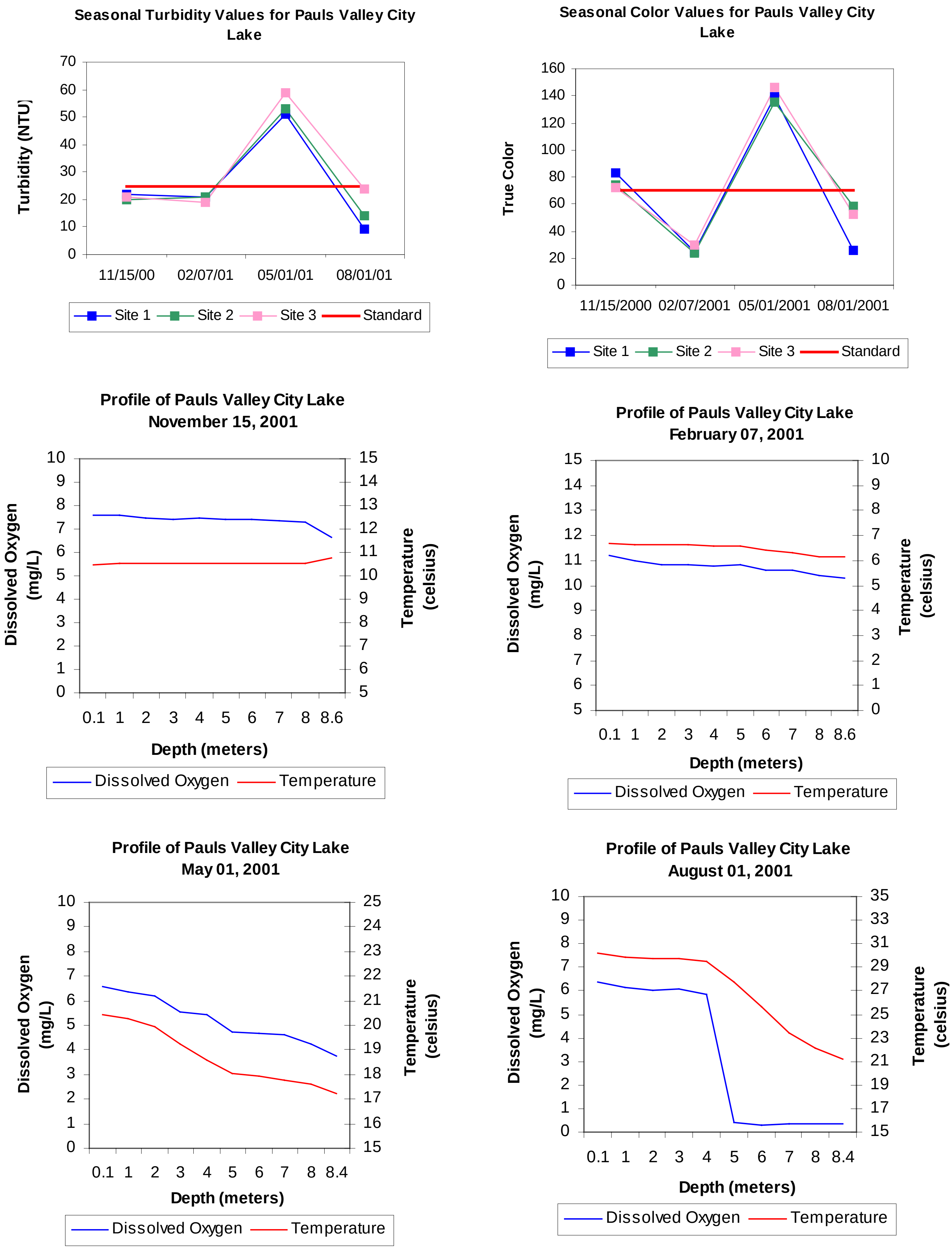
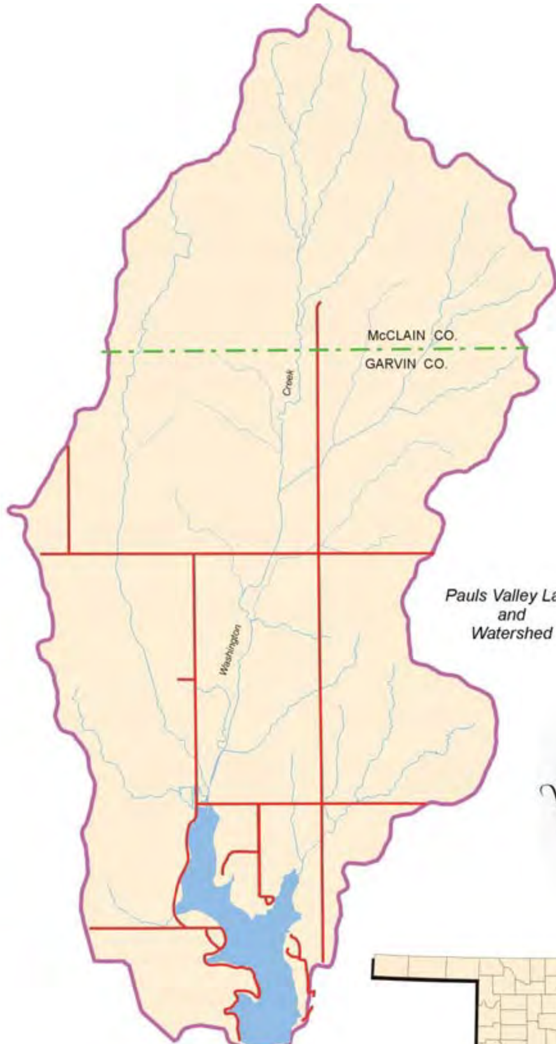


Figure 59a-59f. Graphical representation of data results for Pauls Valley City Lake.



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
2001

Trophic State
2001

Plate 26 - Lake Water Quality for
Pauls Valley Lake

R.C. Longmire Lake

RC Longmire 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 of the reservoir. Samples were collected from the lake surface at all sites and 0.5 meters from the lake bottom at site 1, the dam. The lake-wide annual turbidity value was 11 NTU (Plate 27), true color was 42 units, and secchi disk depth was 64 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 55 (Plate 27), indicating the lake was eutrophic, with high levels of productivity and nutrient rich conditions. This value is similar to the TSI in 1997 (TSI=58), based on three summer values, and in the same trophic category, indicating no significant increase or decrease over time. The TSI values were primarily eutrophic in 2001, except at all sites in the spring which were mesotrophic and the hypereutrophic value at site 3 in the summer (see Figure 60). The annual trophic assessment seems representative of conditions at RC Longmire Lake for 2001. Turbidity values per site were below the OWQS of 25 NTU for all seasons (see Figure 61a). The lake-wide annual turbidity of 11 NTU seems representative of conditions at RC Longmire Lake in 2001. Seasonal true color values are also displayed in Figure 61b. All true color values were below the aesthetics OWQS of 70 units, except for site 2 in the fall and site 1 in the spring which were above the standard (see Figure 61b). According to the default protocol in USAP (OAC 785:46-15-4), if 10 to 25% of the values exceed the numeric criteria, the lake should be listed as partially supporting beneficial uses. Although 17% of samples in 2001 were above 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.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites in 2001. Salinity ranged from 0.12 parts per thousand (ppt) in the fall to 0.18 ppt in the summer, indicating low salt content and within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 0.264mS/cm in the fall to 0.370mS/cm in the summer, indicating that low levels of electrical conducting compounds (salts) were present in the lake system, complimenting the fairly low salinity values. In general, pH values

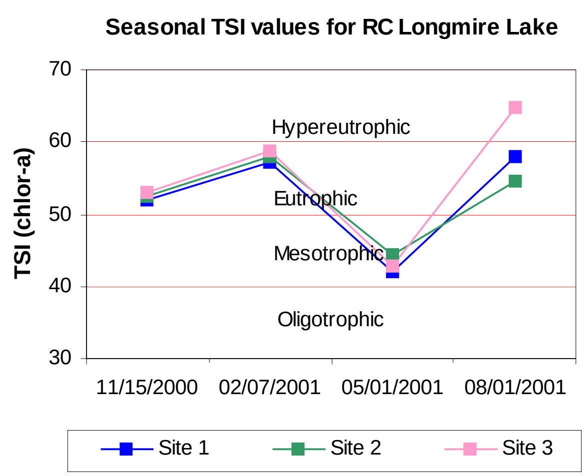


Figure 60. TSI values for R.C. Longmire Lake.

were neutral to alkaline, values ranging from 6.91 in the summer to 9.07 in the winter. Although several values in the winter were above the 9-unit threshold, the lake is fully supporting the FWP beneficial use based on pH values. Oxidation-reduction potentials ranged from 186mV to 593mV in the summer indicating reducing conditions were not present during the sampling intervals. The lake was not thermally stratified in the fall and winter and was well mixed with D.O. concentrations above 7 mg/L throughout the water column (see Figure 61c-61d). In the spring, a thermocline was present between 4and 5 meters at site 1, however, anoxic conditions were not present except at the sediment-water interface (see Figure 61e). In the summer the lake was stratified between 6 and 7 meters at the dam, but the other two sites were less than 5 meters deep. Below 5 meters at site 1 to the lake bottom (11.3 meters), D.O. values were less than 1 mg/L, constituting about 55% of the water column (see Figure 61f). If D.O. concentration is less than 2 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 RC Longmire Lake.

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 was 0.72 mg/L at the surface and 1.34 mg/L on the lake bottom. The TN at the surface ranged from 0.57 mg/L to 0.91 mg/L and from 0.73 to 2.43 mg/L on the lake bottom. The highest surface TN value was reported in the spring and the lowest was in the summer. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.041 mg/L on the surface and 0.168 mg/L on the lake bottom. The surface TP ranged from 0.023 mg/L to 0.063 mg/L and from 0.049 to 0.424 mg/L on the lake bottom. The highest surface TP value was reported in the winter and the lowest was in the spring. The nitrogen to phosphorus ratio (TN:TP) was 17:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, RC Longmire Lake was classified as eutrophic, indicating high primary productivity and nutrient rich conditions although this value is based on only 12 samples (Plate 27). A minimum of 20 samples is required to make beneficial use determinations in lakes greater than 250 surface acres and this lake is 918 surface acres. Previous trophic evaluations also placed this lake in the eutrophic category indicating no significant change in trophic status over time. Although about 17% of samples were above the 70 unit standard, only 12 samples were collected in 2001 and therefore the Aesthetics beneficial use is considered fully supported. Anoxic conditions were present in the summer for more than 50% of the water column at site 1, therefore the lake is considered partially supporting the FWP beneficial use based on D.O. values (USAP 785:46). RC Longmire Lake, located in Garvin County, is utilized for recreational purposes and considered a popular fishing reservoir.

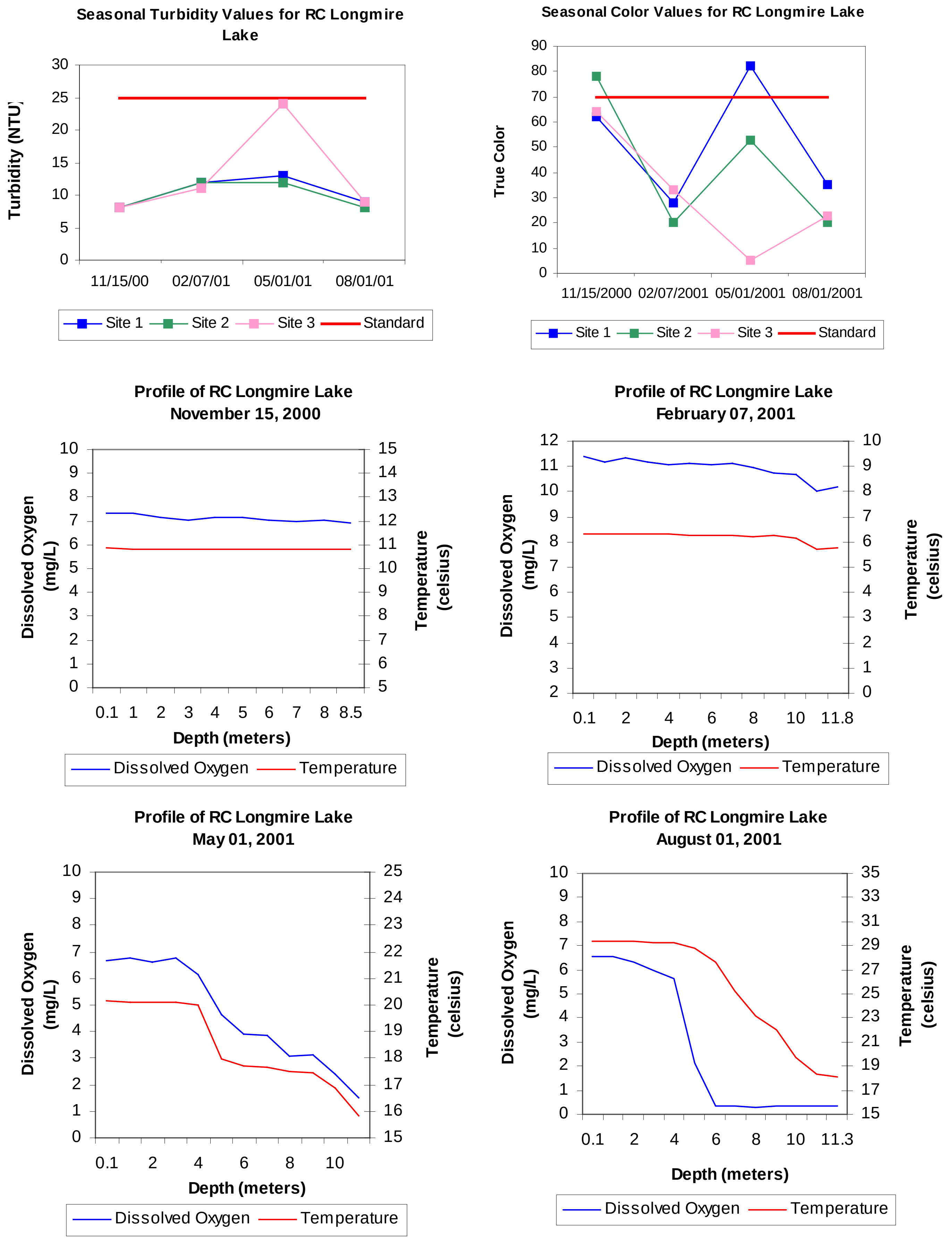
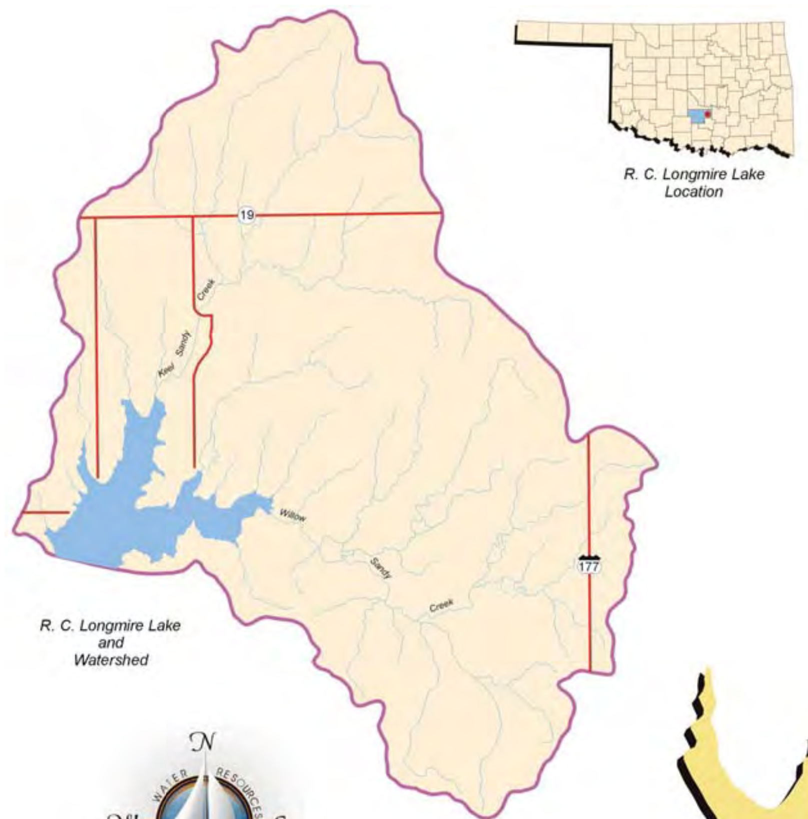
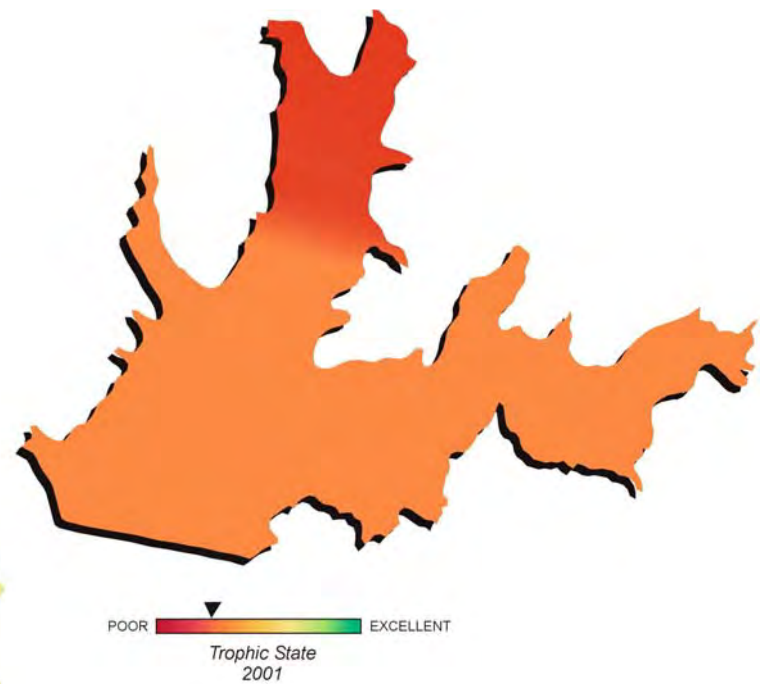


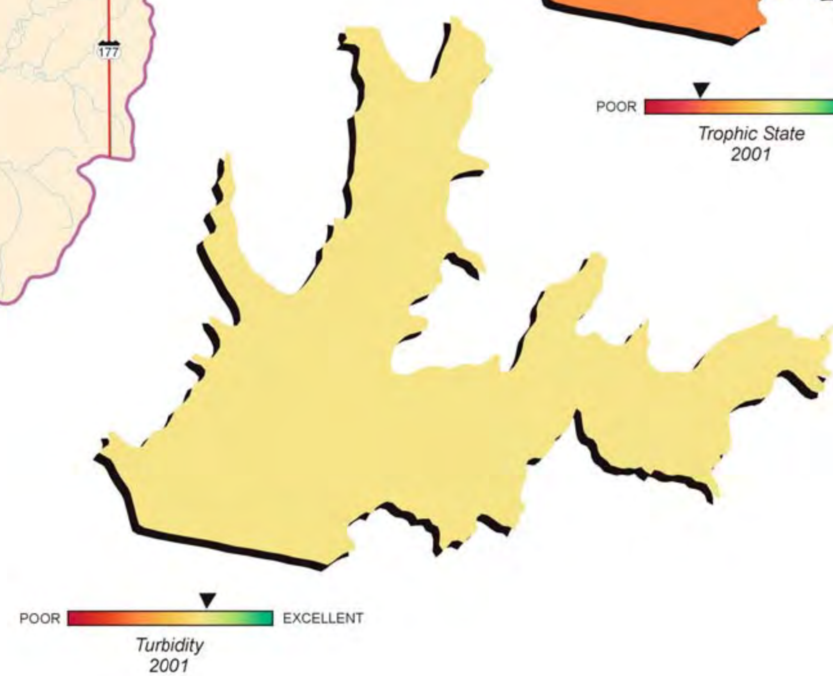
Figure 61a-61f. Graphical representation of data results for R.C. Longmire Lake.



R. C. Longmire Lake
and
Watershed

R. C. Longmire Lake
Location





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

Plate 27 - Lake Water Quality for
R. C. Longmire Lake

Rock Creek Reservoir

Rock Creek Reservoir was sampled for four quarters, from November 2000 through August 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. The lake-wide annual turbidity value was 29 NTU (Plate 28), true color was 48 units, and secchi disk depth was 48 centimeters in 2001. Based on these three parameters, Rock Creek Reservoir had fair water clarity. Water clarity was better in the summer of 1997, based on only three summer samples, but is most likely not as representative as the annual evaluation of turbidity, secchi disk depth, and true color. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=12). The average TSI was 55 (Plate 28), indicating the lake was eutrophic, with high levels of productivity and nutrient rich conditions. This value is similar to the TSI in 1997 (TSI=52), based on three summer values, and in the same trophic category, indicating no significant increase or decrease over time. The TSI values varied from mesotrophic in the fall to hypereutrophic in the winter, with most values in the eutrophic category the rest of the year (see Figure 62). 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. Turbidity values in 2001 varied from above the OWQS of 25 NTU in the fall and winter at all sites to below the standard at all sites in the summer (see Figure 63a). According to USAP (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. A minimum of 10 samples are required to make beneficial use determinations in lakes less than 250 surface acres and this reservoir is 248 surface acres. Because 58% of the samples collected in 2001 were above the standard, the lake is listed as not supporting the FWP beneficial use. Seasonal true color values are also displayed in Figure 63b. True color values were below the aesthetics OWQS of 70 units at all sites in the fall, winter, and summer, but above at two sites in the spring (see Figure 63b). Although 17% of the samples collected in 2001 were above the standard, no listing can be made as several true color samples did not meet QA objectives, therefore, the Aesthetics beneficial use is considered fully supported.

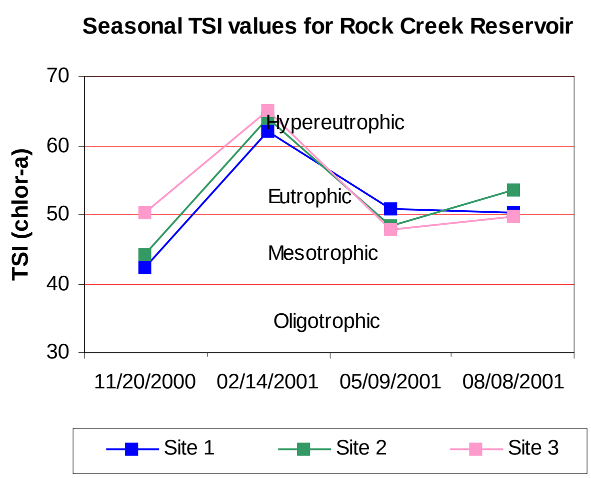


Figure 62. TSI values for Rock Creek Reservoir.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites in 2001. Salinity ranged from 0.06 parts per thousand (ppt) in the spring to 0.13 ppt in the summer, indicating low salt content and within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 0.139mS/cm in the spring to 0.270mS/cm in the summer, indicating that low levels of electrical conducting compounds (salts) were present in the lake system, complimenting the low salinity values. In general, pH values were neutral to alkaline, values ranging from 6.7 in the summer to 9.41 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 beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9 range, the lake should be listed as partially supporting beneficial uses. The high pH values (above 9 units) recorded throughout the water column in the winter are cause to list Rock Creek Reservoir as "provisionally partially supporting"* the FWP beneficial use. Oxidation-reduction potentials ranged from 240mV to 577mV in the summer indicating reducing conditions were not present during the sampling intervals. The lake was not thermally stratified in the fall and winter and was well mixed with D.O. concentrations above 8 mg/L throughout the water column (see Figure 63c-63d). In the spring, a thermocline was present between 6 and 7 meters at site 1 and between 5 and 6 at site 2 (see Figure 63e). Below the thermocline anoxic conditions were present to the lake bottom, although only constituting about 25% of the water column (see Figure 63e). In the summer the lake was stratified between 4 and 5 meters at the dam and between 5 and 6 meters at site 2. Below 4 meters at site 1 to the lake bottom (8.4 m) and below 3 meters at site 2 to the bottom (6 m), D.O. values were less than 1 mg/L, constituting about 50% of the water column (see Figure 63f). If D.O. concentration is less than 2 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 Rock Creek Reservoir.

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 was 0.70 mg/L at the surface and 0.94 mg/L on the lake bottom. The TN at the surface ranged from 0.51 mg/L to 0.93 mg/L and from 0.76 to 1.07 mg/L on the lake bottom. The highest surface TN value was reported in the spring and the lowest was in the summer. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.057 mg/L on the surface and 0.099 mg/L on the lake bottom. The surface TP ranged from 0.026 mg/L to 0.127 mg/L and from 0.073 to 0.22 mg/L on the lake bottom. 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 12:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Rock Creek Reservoir was classified as eutrophic, indicating high primary productivity and nutrient rich conditions in 2001 (Plate 28). Previous trophic evaluations also placed this lake in the eutrophic category. About 50% of the turbidity values reported were above the OWQS of 25 NTU, indicating the lake was not supporting the FWP beneficial use (USAP 785:46). According to USAP (OAC 785:46), the lake was partially supporting the FWP beneficial use based on high pH values and should be "provisionally" listed and closely monitored in the future. Anoxic conditions were present in the summer for about 50% of the water column at sites 1 and 2, therefore the lake is considered partially supporting the FWP beneficial use based on D.O. values (USAP 785:46). Rock Creek Reservoir is owned by the City of Ardmore and used 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.

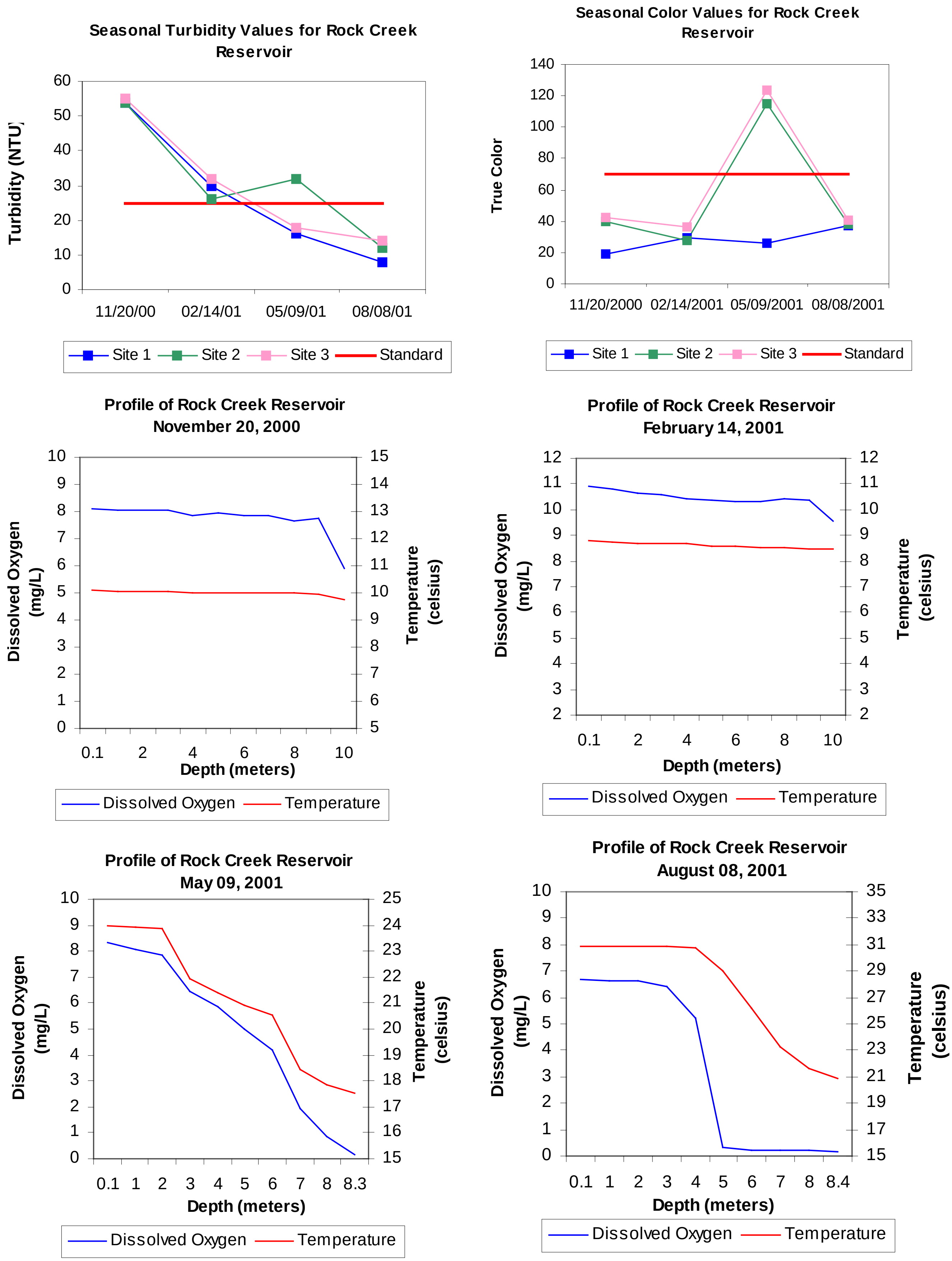
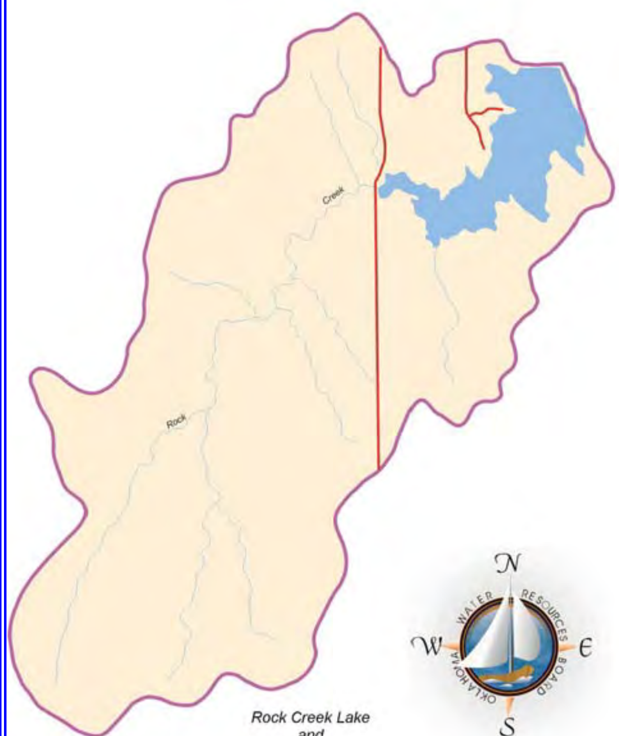


Figure 63a-63f. Graphical representation of data results for Rock Creek Reservoir.

Plate 28 - Lake Water Quality 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 20016

Trophic State 2001

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 (Plate 29), 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, 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 (Plate 29), 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 (see Figure 64). 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 (USAP 785:45-15-4). All turbidity values, except for two sites in the winter, were above the OWQS of 25 NTU (see Figure 65a). According to USAP (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. Seasonal true color values are also displayed in Figure 65b. 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.

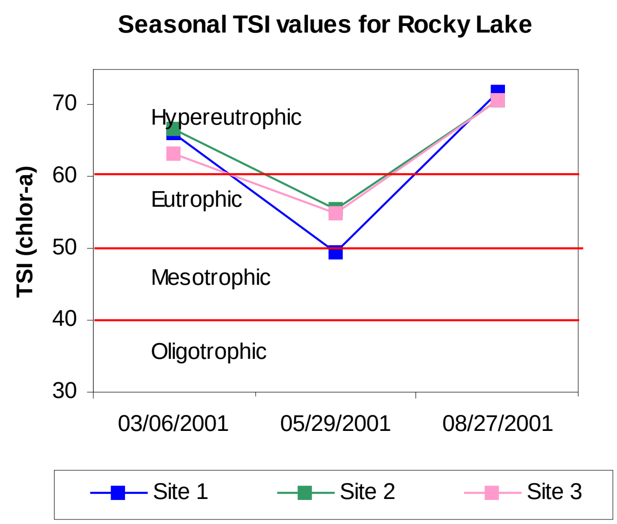
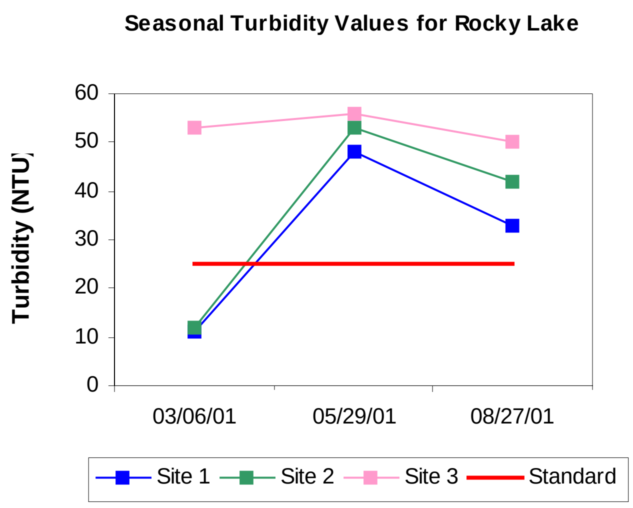


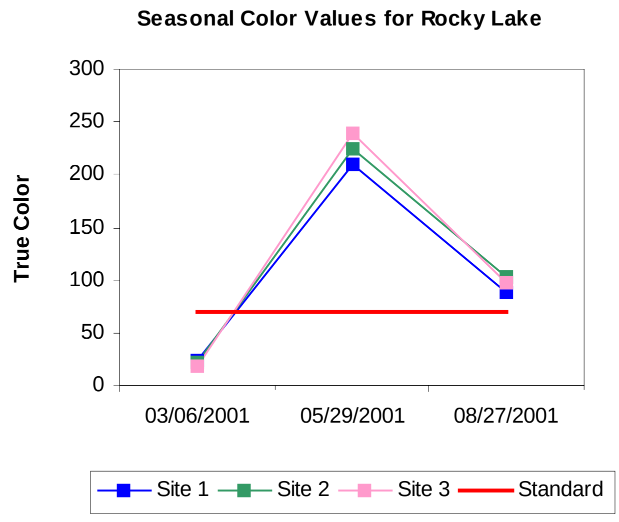
Figure 64. TSI values for Rocky (Hobart) Lake.

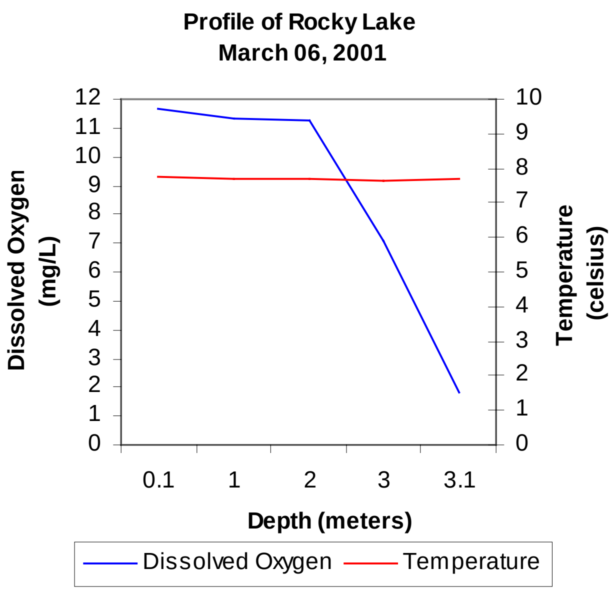
Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all three sample sites. The salinity values ranged from 0.16 parts per thousand (ppt) to 0.31 ppt, indicating low to moderate salt content and slightly above the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 0.365mS/cm in the spring to 0.612mS/cm in the winter, indicating that moderate levels of electrical conducting compounds (salts) were present in the lake system, complimenting the recorded salinity values. In general, pH values were neutral to slightly alkaline, ranging from 6.94 to 8.26 units. Oxidation-reduction potentials (Redox) ranged from 199mV at the sediment-water interface in the winter to 458mV in the spring. Redox readings indicated that reducing conditions were not present in the reservoir in any of the sampling intervals. The lake was not thermally stratified in the winter or spring and the D.O. values were above 2 mg/L throughout the water column (see Figure 65c-65d). In the summer, the lake was stratified between the surface and 1-meter although the D.O. values remained above 2 mg/L throughout the lake except at the sediment-water interface (see Figure 65e). The shallow depth of this lake and the consistent wind conditions seem to keep the water column well mixed and fairly well oxygenated throughout the year. According to USAP, the FWP beneficial use is considered fully supported at Rocky Lake.

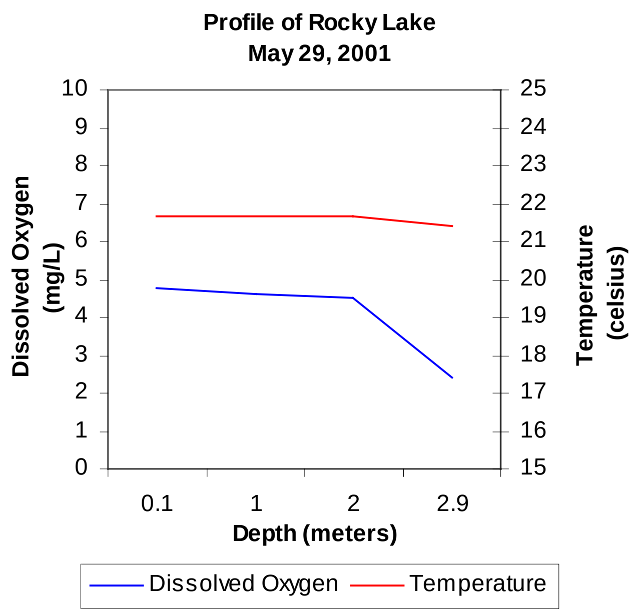
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001 was 1.78 mg/L at the surface and the only bottom sample collected was 1.94 mg/L. The TN at the surface ranged from 1.38 mg/L in the summer to 2.96 mg/L in the winter. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.189 mg/L on the surface and the only bottom sample collected was 0.318 mg/L. The surface TP ranged from 0.060 mg/L in the winter to 0.279 mg/L in the summer. Rocky Lake had the highest surface TN and TP averages in 2001. The nitrogen to phosphorus ratio (TN:TP) was 9:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Rocky Lake was classified as hypereutrophic, indicating excessive primary productivity and nutrients in 2001, although this assessment was only based on 10 samples and therefore can not be identified as a potential Nutrient Limited Watershed (TSI≥62) because 20 samples were not used in the assessment (Plate 29). Rocky Lake had the highest surface TN and TP averages in 2001. Although most of the turbidity and true color values exceeded the criteria listed in OWQS for each parameter, the beneficial uses remain fully supported as the minimum data requirements were not met in the 2001 assessment. Rocky Lake, located in Washita County, is the municipal water supply for the City of Hobart and is also used for recreation.









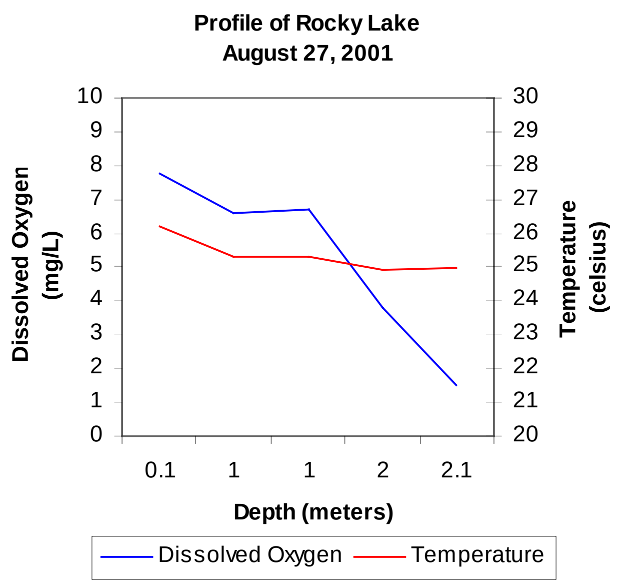


Figure 65a-65e. Graphical representation of data results for Rocky (Hobart) Lake.

Plate 29 - Lake Water Quality for
Rocky (Hobart) Lake

Lake Data

Owner	City of Hobart
County	Washita
Constructed in	1933
Surface Area	347 acres
Volume	4,210 acre/feet
Shoreline Length	8 miles
Mean Depth	11.64 feet
Watershed Area	58 square miles

Turbidity
2001

Trophic State
2001

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 (USAP 785:45-15-4). The lake-wide annual turbidity value was 4 NTU (Plate 30), true color was 26 units, and secchi disk depth was 168 centimeters in 2001. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=10). The average TSI was 58 (Plate 30), 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 (see Figure 66). 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 OWQS of 25 NTU (see Figure 67a). The lake-wide annual turbidity average of 4 NTU seems to accurately represent the conditions at this lake. Seasonal true color values are also displayed in Figure 67b. 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.

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 0.05 parts per thousand (ppt) to 0.1 ppt, indicating low salt content and within the expected range of salinity values reported for most Oklahoma lakes. Specific conductance ranged from 0.110mS/cm in the spring to 0.220mS/cm in the summer, indicating 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

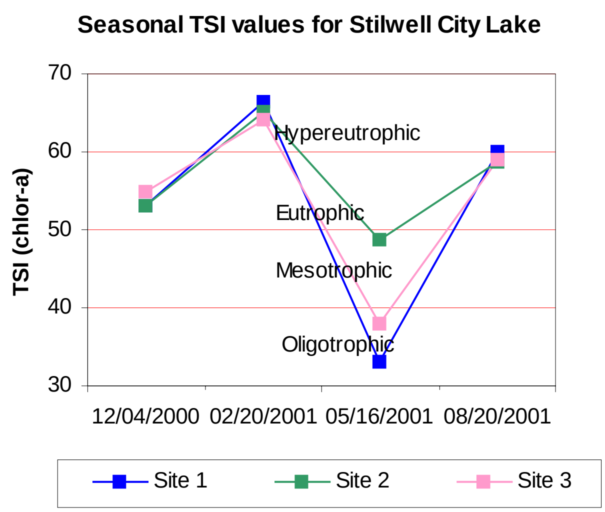


Figure 66. TSI values for Stillwell City Lake.

6.68 to 8.78 units. Oxidation-reduction potentials (Redox) ranged from 189mV at the sediment-water interface in the summer to 598mV in the fall. Redox readings indicated that reducing conditions were not present in the reservoir in any of the sampling intervals. The lake was not thermally stratified in the fall or winter and the D.O. values were above 6.4 mg/L throughout the water column (see Figure 67c-67d). In the spring, the lake was stratified at several 1-meter intervals, the first one between 3 and 4 meters at site 1 and 4 and 5 meters at site 2 (see Figure 67e). Below 5 meters at sites 1 and 2, the D.O. concentration was less than 1 mg/L to the lake bottom constituting greater than 50% of the water column (see graphics page). In the summer, the lake was stratified between 4 and 5 meters, at which point the D.O. values were less than 1 mg/L to the lake bottom (see Figure 67f). If D.O. concentration is less than 2 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered partially supported at Stilwell City Lake as greater than 50% of the water column was anoxic at sites 1 and 2 in both the spring and summer.

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 was 0.82 mg/L at the surface and 1.52 mg/L on the lake bottom. The TN at the surface ranged from 0.52 mg/L to 1.71 mg/L and from 0.70 to 2.74 mg/L on the lake bottom. 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 was 0.025 mg/L on the surface and 0.158 mg/L on the lake bottom. The surface TP ranged from 0.013 mg/L to 0.044 mg/L and from 0.023 to 0.363 mg/L on the lake bottom. The highest surface TP value was reported in the winter and the lowest was in the fall. The nitrogen to phosphorus ratio (TN:TP) was 33:1 for sample year 2001. This value is much greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Stilwell City Lake was eutrophic in 2001, indicative of high primary productivity and nutrient rich conditions. Water clarity is excellent at this lake and both the turbidity and true color values were well below the criteria listed in OWQS. Anoxic conditions were present in the summer for about 50% of the water column at sites 1 and 2, therefore the lake is considered partially supporting the FWP beneficial use based on low D.O. values (USAP 785:46). Stilwell City Lake, located in Adair County, is the municipal water supply for the City of Stilwell and is utilized for flood control and recreation.

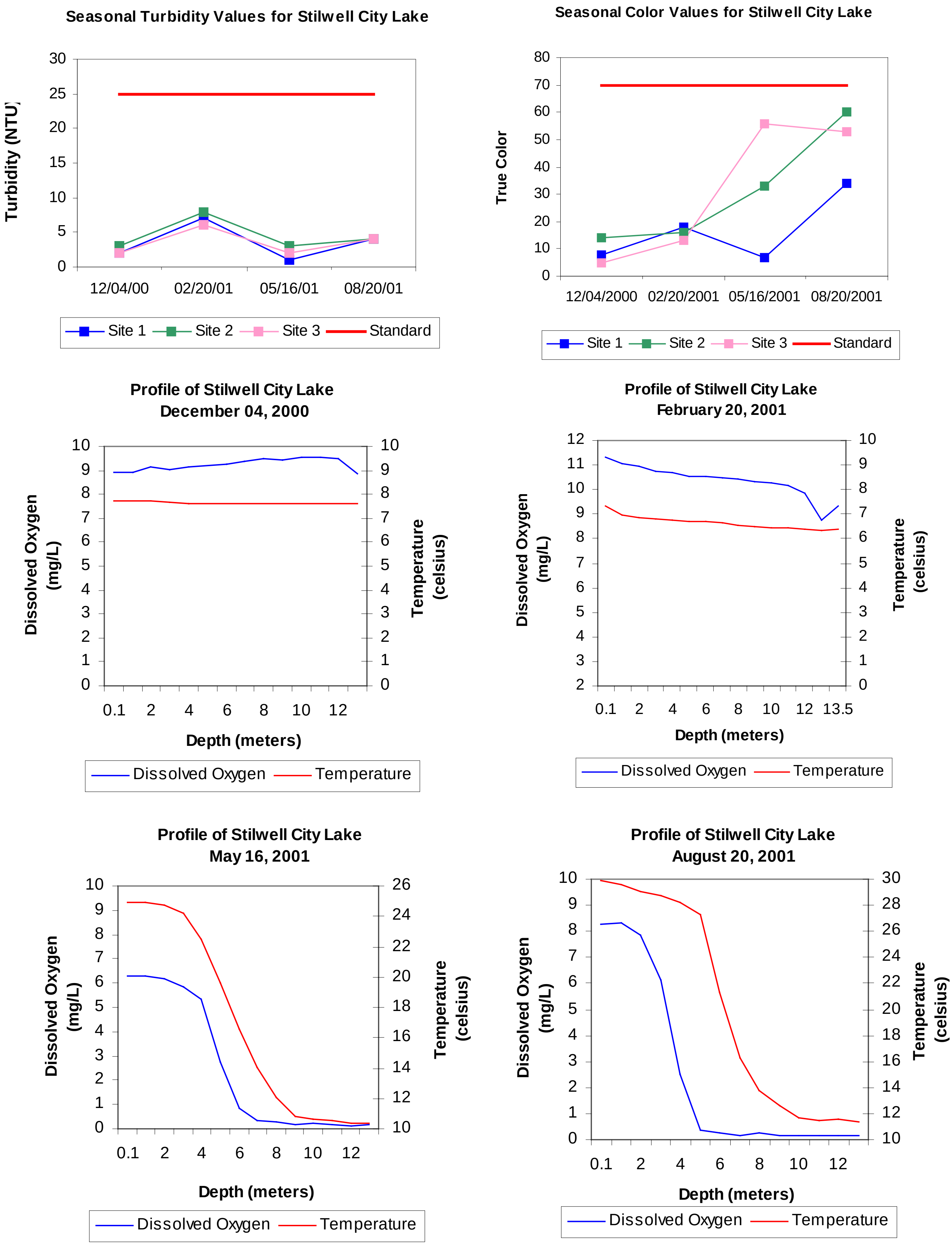


Figure 67a-67f. Graphical representation of data results for Stillwell City Lake.

Lake Data

Owner	City of Stilwell
County	Adair
Constructed	1965
Surface Area	188 acres
Volume	3,110 acre/feet
Shoreline Length	4 miles
Mean Depth	16.54 feet
Watershed Area	4,693 acres

Plate 30 - Lake Water Quality for
Stilwell Lake

Talawanda Lake No. 1

Talawanda Lake No. 1 (91 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 (USAP 785:45-15-4). The lake-wide annual turbidity value was 3 NTU (Plate 31), true color was 28 units, and secchi disk depth was 175 centimeters in 2001. Based on these three parameters, Talawanda Lake No. 1 had excellent water clarity, very similar to values in the summer of 1998. Secchi disk depth was second only to Broken Bow Lake this sample year, although Talawanda Lake No. 1 had the lowest annual turbidity value of all 35 lakes sampled this year. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=10). The average TSI was 45 (Plate 31), classifying the lake as mesotrophic, indicative of moderate levels of primary productivity and nutrients. This value is equal to the one calculated in 1998 (TSI=45) indicating no change in trophic status over time and that the summer conditions may reflect year-round trophic conditions at this lake. All TSI values were in the mesotrophic category in 2001, except for the eutrophic value at site 3 in the fall (see Figure 68). All turbidity values were well below the OWQS of 25 NTU (see Figure 69a). The lake-wide annual turbidity average of 3 NTU seems to accurately represent the conditions at this lake. Seasonal true color values are also displayed in Figure 69b. All of the true color values were well below the numeric criteria of 70 units in 2001, although some seasonal variability was evident. Currently, 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. The salinity values ranged from 0 parts per thousand (ppt) to 0.05 ppt, indicating low salt content compared to most Oklahoma lakes. Specific conductance ranged from 0.027mS/cm in the spring to 0.117mS/cm in the fall, indicating minimal levels of electrical conducting compounds (salts) were present in the lake system, corresponding with the recorded salinity values. In general, pH values were slightly acidic to neutral, ranging from 6.13 to 7.69 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9

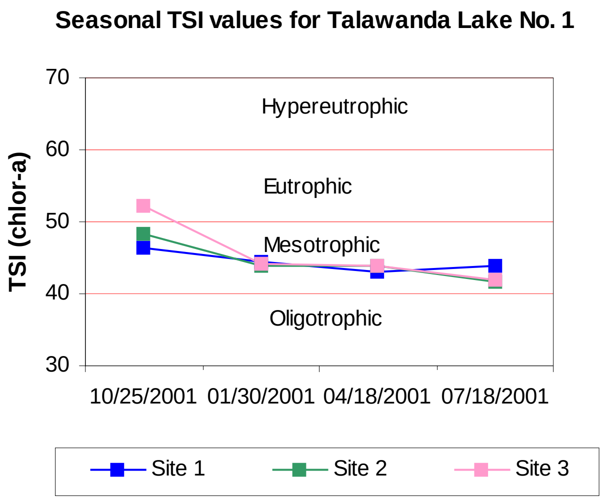


Figure 68. TSI values for Talawanda Lake No.1.

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 range, the lake should be listed as partially supporting beneficial uses. The low pH values (below 6.5 units) recorded throughout the water column primarily in the summer are cause to list Talawanda Lake No. 1 as "provisionally partially supporting"* the FWP beneficial use. Oxidation-reduction potentials (Redox) ranged from 260mV at the sediment-water interface in the winter to 571mV in the spring. Redox readings indicated that reducing conditions were not present in the reservoir from the winter through the summer. Reducing conditions were present in the fall sampling interval, ranging from –199 at the sediment water interface at site 1 to 50mV. The lake was thermally stratified in the fall between 4 and 5 meters and hypolimnetic anoxia was present at site 1 (see Figure 69c). The lake was not stratified in the winter and D.O. values were above 5 mg/L throughout the water column (see Figure 69d). In the spring, the lake was stratified between 4 and 5 meters at site 1 where temperature dropped drastically from 18 to 13°C, although D.O. concentration remained above 3.9 throughout the water column (see Figure 69e). In the summer, the lake was stratified at several 1-meter intervals, the first between 3 and 4 meters, at which point the D.O. values were less than 1 mg/L to the lake bottom at all three sites (see Figure 69f). If D.O. concentration is less than 2 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 Talawanda Lake No. 1 as greater than 50% of the water column was anoxic in the summer.

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 was 0.39 mg/L at the surface and 0.76 mg/L on the lake bottom. The TN at the surface ranged from 0.05 mg/L to 0.56 mg/L and from 0.52 to 1.24 mg/L on the lake bottom. The highest surface TN value was reported in the winter and the lowest was in the spring. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.018 mg/L on the surface and 0.039 mg/L on the lake bottom. The surface TP ranged from 0.006 mg/L to 0.03 mg/L and from 0.007 to 0.069 mg/L on the lake bottom. The highest surface TP value was reported in the summer and the lowest was in the fall. The nitrogen to phosphorus ratio (TN:TP) was 22:1 for sample year 2001. This value is much greater 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 levels. Water clarity is excellent at this lake and both the turbidity and true color values were well below the criteria listed in OWQS. According to USAP (OAC 785:46), the lake was partially supporting the FWP beneficial use based on low pH values and should be "provisionally" listed and closely monitored in the future. Anoxic conditions were present in the summer for about 50% of the water column, therefore the lake is considered partially supporting the FWP beneficial use based on low D.O. values (USAP 785:46). Talawanda Lake No. 1 is owned by the City of McAlester 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.

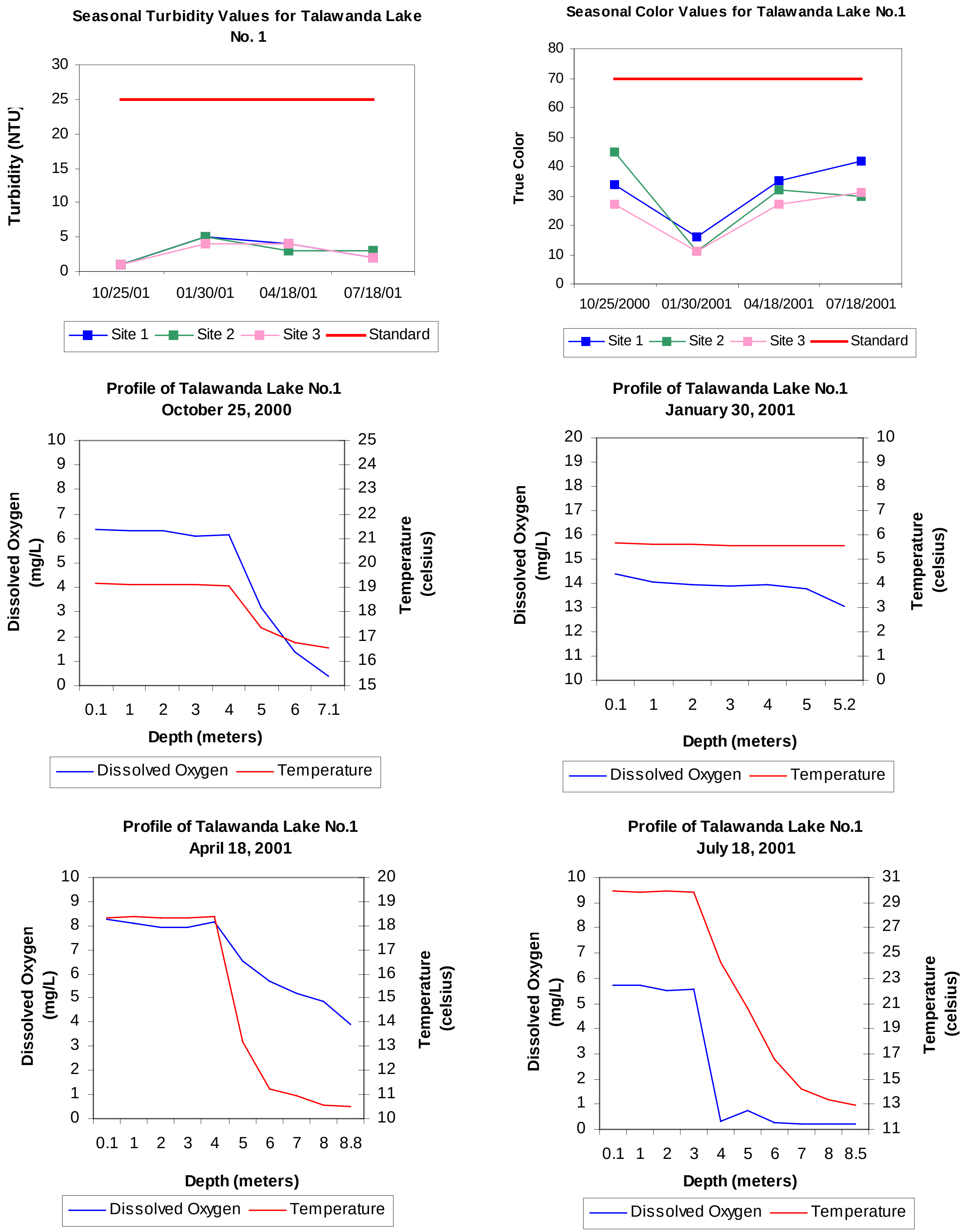
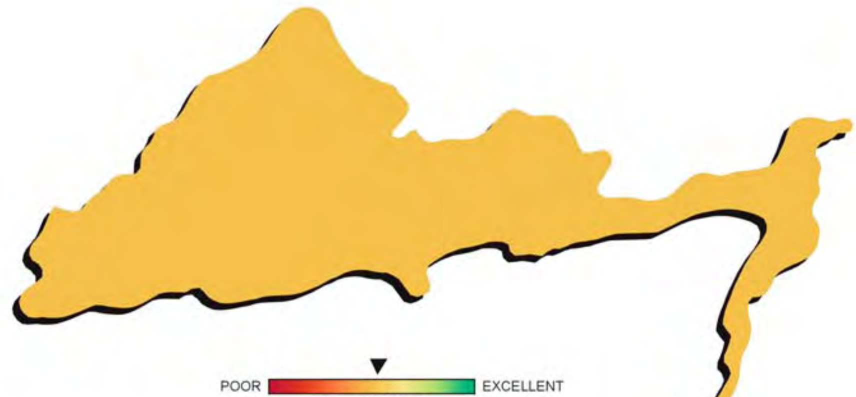


Figure 69a-69f. Graphical representation of data results for Talawanda Lake No. 1.

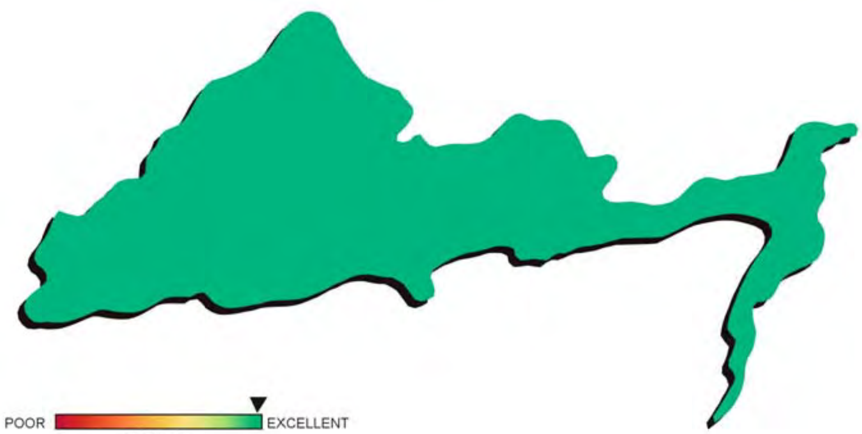
Talawanda Lake No.1
and
Watershed

Lake Data

Owner	City of McAlester
County	Pittsburg
Constructed	1902
Surface Area	91 acres
Volume	1,200 acre/feet
Shoreline Length	3 miles
Mean Depth	14.10 feet
Watershed Area	1,271 acres



Trophic State
2001



Turbidity
2001

Plate 31 - Lake Water Quality for

Talawanda Lake No. 1

Talawanda Lake No. 2

Talawanda Lake No. 2 (195 surface acres) was sampled for four quarters, from October 2000 through July 2001. Water quality samples were collected at 2 sites to represent the reservoir. Samples were collected at the lake surface at both 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 therefore data will be aggregated with the summer of 1998 data to make beneficial use determinations (USAP 785:45-15-4). The lake-wide annual turbidity value was 6 NTU (Plate 32), true color was 27 units, and secchi disk depth was 125 centimeters in 2001. Based on these three parameters, Talawanda Lake No. 2 had excellent water clarity, even better than the values reported in the summer of 1998. The trophic state index, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=8). The average TSI was 40 (Plate 32), classifying the lake as oligotrophic, indicative of low levels of primary productivity and nutrients. This value is similar to the one calculated in 1998 (TSI=41) although in a different trophic category. To obtain the required number of samples (n=10), data from the summer of 1998 was also included in the trophic assessment, resulting in the same TSI=40. TSI values ranged from oligotrophic to mesotrophic (see Figure 70). All turbidity values were well below the OWQS of 25 NTU (see Figure 71a). The lake-wide annual turbidity average of 6 NTU seems to accurately represent the conditions at this lake. Seasonal true color values are also displayed in Figure 71b. All of the true color values were well below the numeric criteria of 70 units in 2001, following the same pattern as Talawanda Lake No. 1. Currently, 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. The salinity values ranged from 0 parts per thousand (ppt) to 0.04 ppt, indicating low salt content compared to most Oklahoma lakes. Specific conductance ranged from 0.026mS/cm in the spring to 0.103mS/cm in the fall, indicating minimal levels of electrical conducting compounds (salts) were present in the lake system, corresponding with the recorded salinity values. In general, pH values were slightly acidic to neutral, ranging from 6.25 to 7.59 units. According to USAP (OAC 785:46-15-5), pH values are exceeding standards if they fall outside the 6.5 to 9 range for

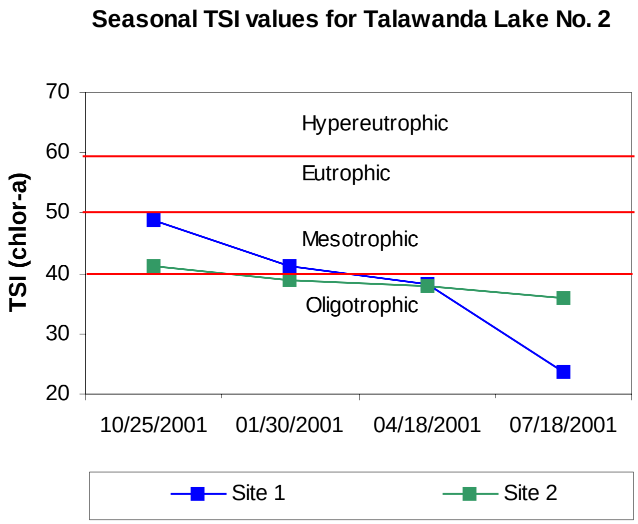


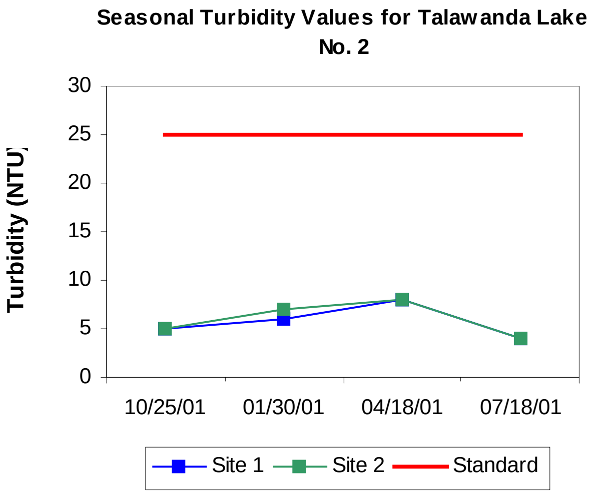
Figure 70. TSI values for Talawanda Lake No. 2.

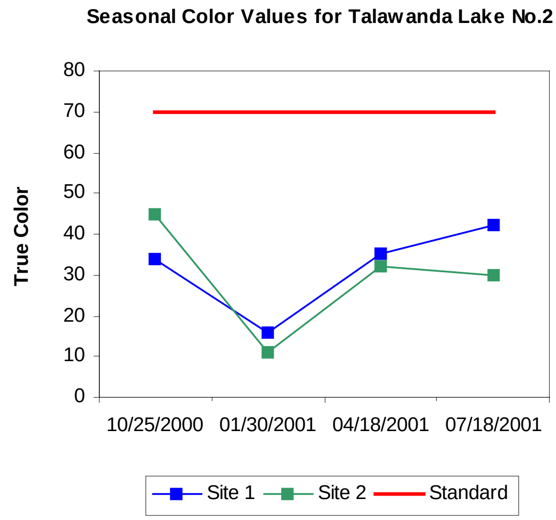
≥25% of the values and should be listed as not supporting beneficial uses. If 10 to 25% of the pH values fall outside the 6.5 to 9 range, the lake should be listed as partially supporting beneficial uses. The low pH values (below 6.5 units) recorded throughout the water column primarily in the summer are cause to list Talawanda Lake No. 2 as “provisionally partially supporting”* the FWP beneficial use. Oxidation-reduction potentials (Redox) ranged from 144mV at the sediment-water interface in the winter to 529mV in the spring. Redox readings indicated that reducing conditions were not present in the reservoir from the winter through the summer. Reducing conditions were present in the fall sampling interval, ranging from –101 at the sediment water interface at site 1 to 77mV. The lake was not thermally stratified in the fall although the D.O. concentration fell below 2 mg/L at the sediment-water interface at site 1 (see Figure 71c). The lake was not stratified in the winter and D.O. values were above 5 mg/L throughout the water column (see Figure 71d). In the spring, the lake was stratified between 7 and 8 meters at site 1 where temperature dropped drastically from 18 to 13°C, although D.O. concentration remained above 5.1 mg/L throughout the water column (see Figure 71e). In the summer, the lake was stratified at several 1-meter intervals, the first between 5 and 6 meters, at which point the D.O. values were less than 1 mg/L to the lake bottom at 14.4 meters (see Figure 71f). If D.O. concentration is less than 2 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 Talawanda Lake No. 2 as greater than 50% of the water column was anoxic in the summer.

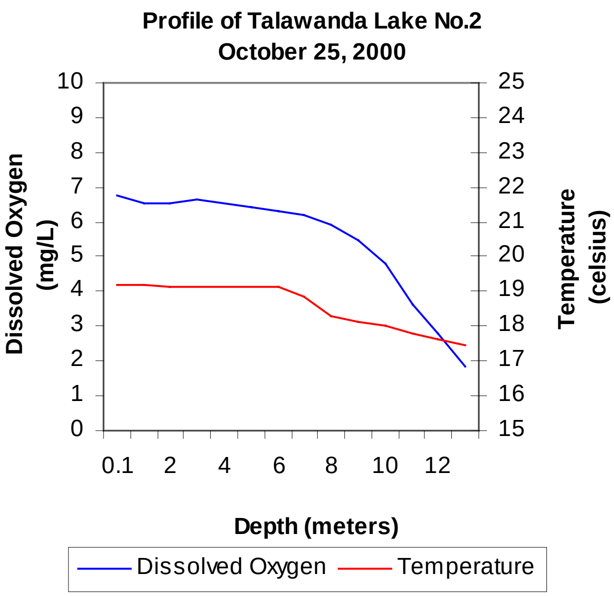
Collected water samples were analyzed for nutrients, including total nitrogen and total phosphorus, although there are currently no numerical OWQS for these parameters. The lake-wide total nitrogen (TN) average for sample year 2001 was 0.38 mg/L at the surface and 0.48 mg/L on the lake bottom. The TN at the surface ranged from 0.24 mg/L to 0.61 mg/L and from 0.33 to 0.59 mg/L on the lake bottom. The highest surface TN value was reported in the spring and the lowest was in the fall. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.016 mg/L on the surface and 0.027 mg/L on the lake bottom. The surface TP ranged from 0.010 mg/L to 0.021 mg/L and from 0.013 to 0.039 mg/L on the lake bottom. The highest surface TP value was reported in the summer and the lowest was in the fall. The nitrogen to phosphorus ratio (TN:TP) was 24:1 for sample year 2001. This value is much greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

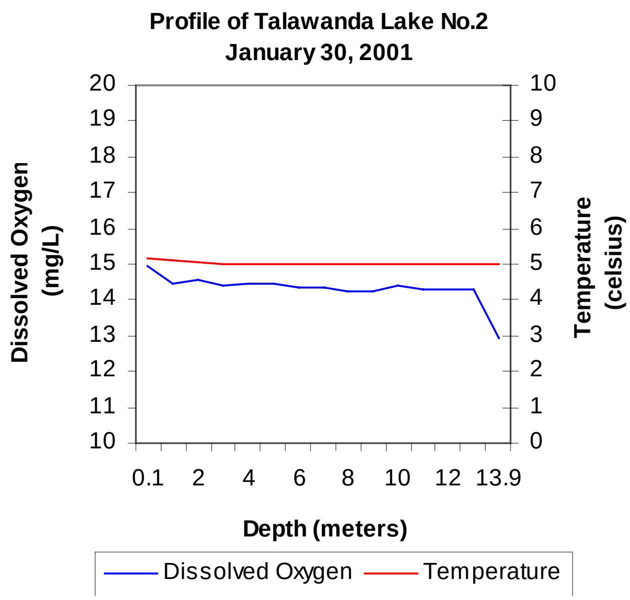
In summary, Talawanda Lake No. 2 was classified as oligotrophic, indicative of low primary productivity and nutrient levels, although bordering mesotrophic status. Water clarity is excellent at this lake and both the turbidity and true color values were well below the criteria listed in OWQS. According to USAP (OAC 785:46), the lake was partially supporting the FWP beneficial use based on low pH values and should be “provisionally” listed and closely monitored in the future. Anoxic conditions were present in the summer for about 50% of the water column, therefore the lake is considered partially supporting the FWP beneficial use based on low D.O. values (USAP 785:46). Talawanda Lake No. 2 is a municipal water supply for the City of McAlester and is also utilized for recreation. Although the Talawanda lakes are similar in most aspects and are only separated by an earthen dam, there are some differences in bathymetry and productivity of the lakes.

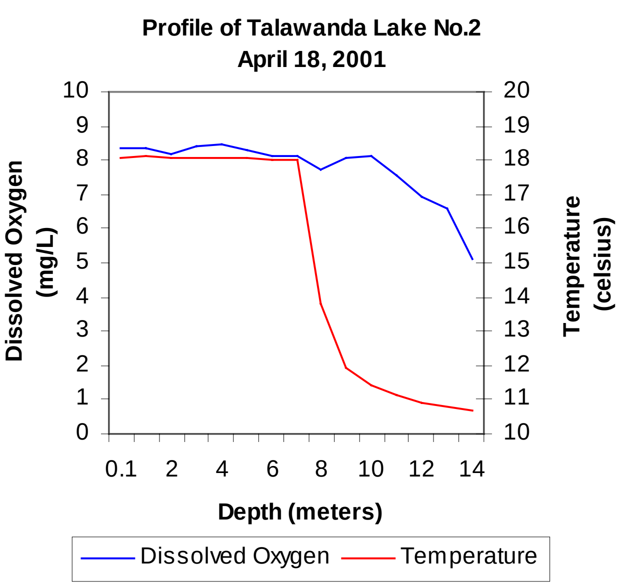
* Water bodies can only be **provisionally** listed as partially supporting or not supporting for pH due to the “other than by natural causes” clause listed in USAP OAC 785:46-15-5(d). Before waters are formally listed, the OWRB needs to further address this definition.











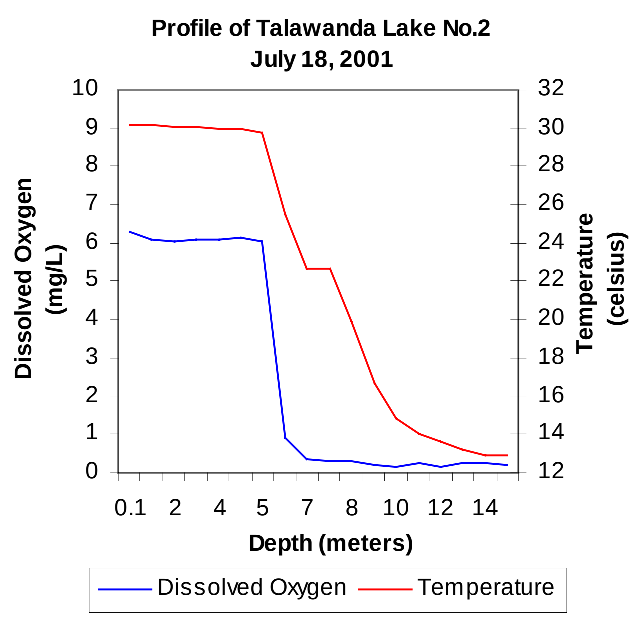


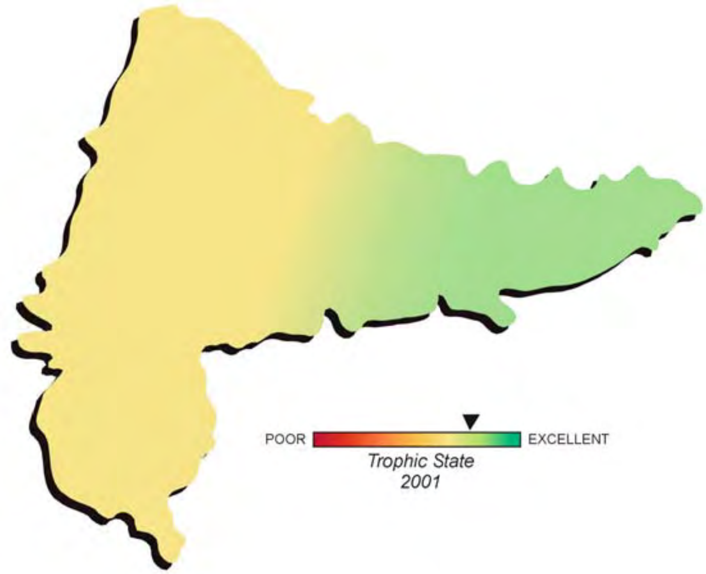
Figure 71a-71f. Graphical representation of data results for Talawanda Lake No. 2.

Talawanda Lake No. 2
Location

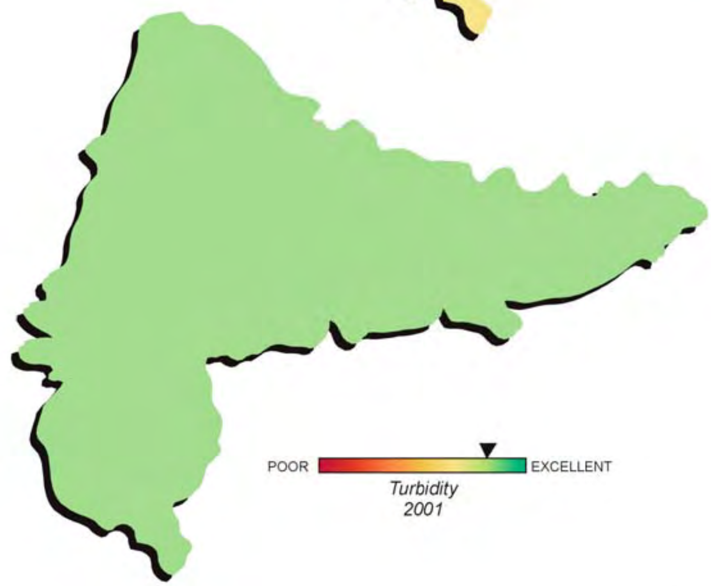
Talawanda Lake No. 2
and
Watershed

Lake Data

Owner	City of McAlester
County	Pittsburg
Constructed	1924
Surface Area	195 acres
Volume	2750 acre/feet
Shoreline Length	4 miles
Mean Depth	14.10 feet
Watershed Area	2,304 acres



Trophic State
2001



Turbidity
2001

Plate 32 - Lake Water Quality for
Talawanda Lake No. 2

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 (Plate 33), 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, 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 33), 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) (see Figure 72). 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 OWQS of 25 NTU; however, this constitutes a listing as partially supporting the FWP beneficial use as 14% of the samples were above the criteria (see Figure 73a). According to USAP (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 also displayed in Figure 73b. 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.

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 0.12 ppt in the fall to 0.2 ppt at site 1 in the summer, 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

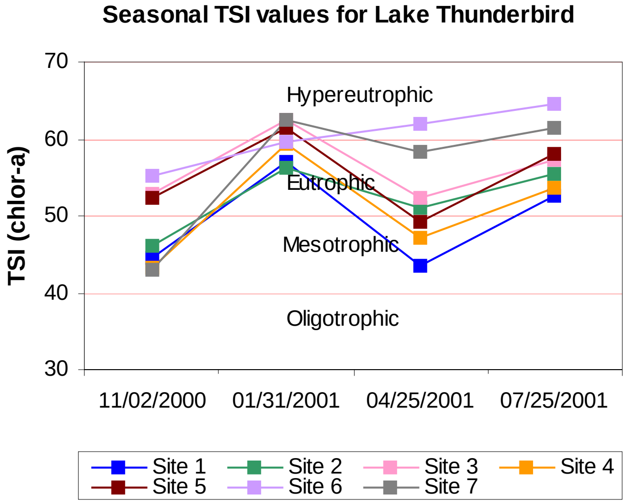


Figure 72. TSI values for Lake Thunderbird.

also within the expected range for Oklahoma reservoirs, coinciding with the low salinity concentrations. Values ranged from 0.241mS/cm in the fall to 0.409mS/cm at site 1 in the summer, indicating that low to moderate levels of electrical conducting compounds (salts) were present in the lake system. Oxidation-reduction potentials ranged from 191mV at the sediment-water interface in the winter to 498mV in the spring, indicating reducing conditions were not present. The ORP values recorded in the fall quarter are quite different, as they were consistently less than 50 throughout the water column although anoxic conditions were not present. The pH values were neutral to alkaline with values ranging from 7 at site 1 in the summer to 8.83 at site 5 in the winter. Thermal stratification was not evident in any of the first three seasons (see Figure 73c-73e). Generally the water column was fairly well oxygenated and mixed (see Figure 73c-73e). Dissolved oxygen (D.O.) values were above 3.7mg/L throughout the water column at all sites in the fall, above 9.6 mg/L in the winter and above 5.35 mg/L in the spring. In the summer, both stratification and anoxic conditions were present in Lake Thunderbird. The lake was not stratified at sites 6 and 7 as this upper end of the lake is shallower than the rest of the reservoir. At site 1, the lake was stratified at several 1-meter intervals, the first between 5 and 6 meters, at which point the D.O. values were less than 1 mg/L to the lake bottom at 13 meters (see Figure 73f). At sites 2 through 5 a thermocline was present between 4 and 5 meters with anoxic conditions present below this point to the lake bottom. If D.O. concentration is less than 2 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 Thunderbird as greater than 50% of the water column was anoxic in the summer.

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 was 0.81 mg/L at the surface and 1.03 mg/L on the lake bottom. The TN at the surface ranged from 0.54 mg/L to 1.41 mg/L and from 0.85 to 1.4 mg/L on the lake bottom. The highest surface TN value was reported in the winter at site 6 and the lowest was in the spring at site 6 and summer at site 3. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.058 mg/L on the surface and 0.110 mg/L on the lake bottom. The surface TP ranged from 0.022 mg/L to 0.271 mg/L and from 0.036 to 0.289 mg/L on the lake bottom. 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 14:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Lake Thunderbird was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions. In the summer of 1998, the TSI was also eutrophic although based on only 8 values. Fourteen percent of the turbidity values were above the OWQS of 25 NTU, constituting a partially supported beneficial use for FWP (USAP 785:46). The true color criteria was exceeded in 29% of samples in 2001, therefore, the Aesthetics beneficial use was not supported based on recent data. Anoxic conditions were also present in the summer throughout the lake for over 50% of the water column, therefore the lake is considered partially supporting the FWP beneficial use based on low D.O. values (USAP 785:46). According to ODEQ, the lake was sampled in 1999 and none of the fish tissue samples exceeded the screening level or low consumption advisory level for metals toxicity or organic residues. Lake Thunderbird, constructed by the Bureau of Reclamation, was built for flood control, municipal water supply, and recreation/fish and wildlife purposes.

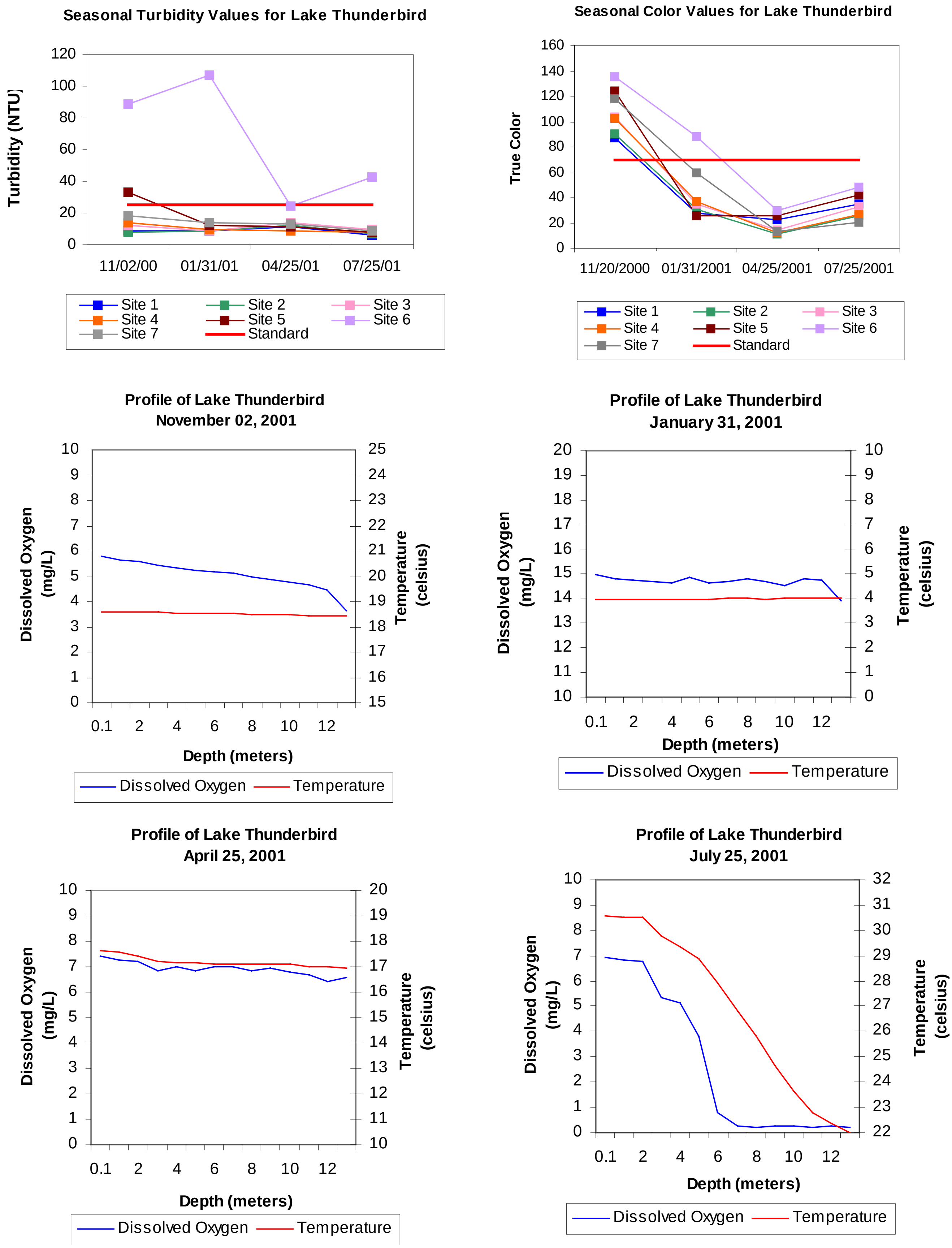
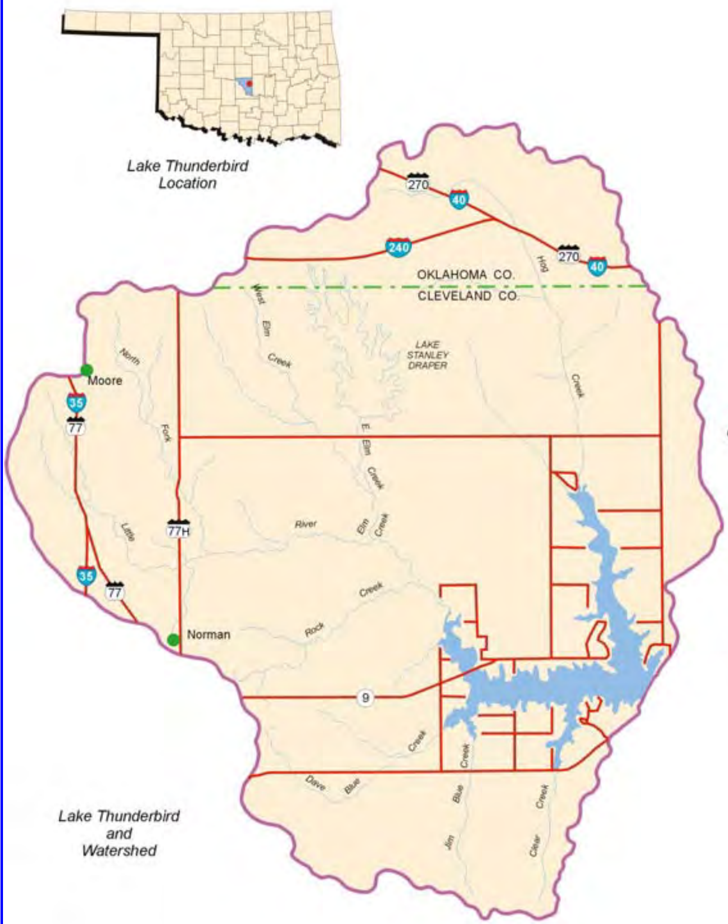


Figure 73a-73f. Graphical representation of data results for Lake Thunderbird.



Lake Data

Constructed by	Bureau of Reclamation
County	Cleveland
Constructed	1965
Surface Area	6,070 acres
Volume	119,600 acre/feet
Shoreline Length	86 miles
Mean Depth	19.70 feet
Watershed Area	256 square miles

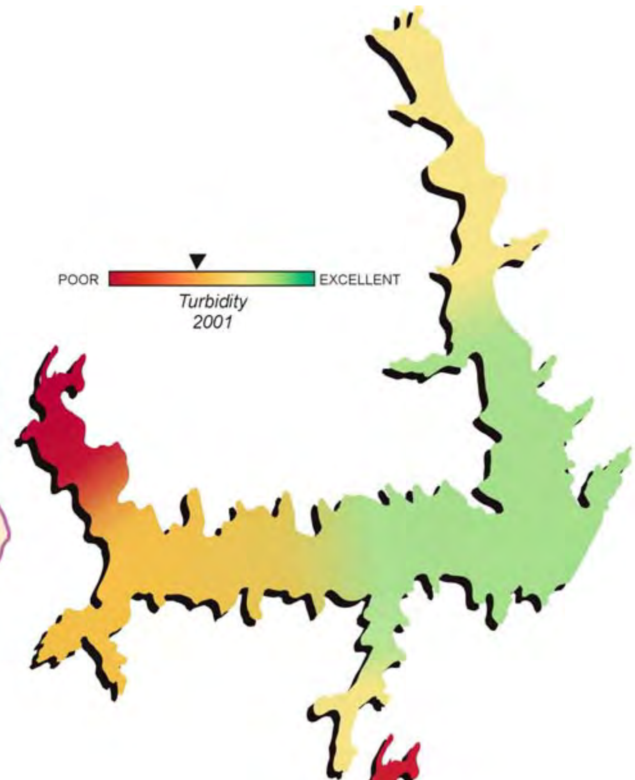


Plate 33 - Lake Water Quality for

Lake Thunderbird

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 (Plate 34), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=24). The average TSI was 57 (Plate 34), 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) (see Figure 74). 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 OWQS of 25 NTU; however, although 25% of the samples were above the standard, the lake was listed as partially supporting the FWP beneficial use (see Figure 75a). According to USAP (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. Seasonal true color values are also displayed in Figure 75b. 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.

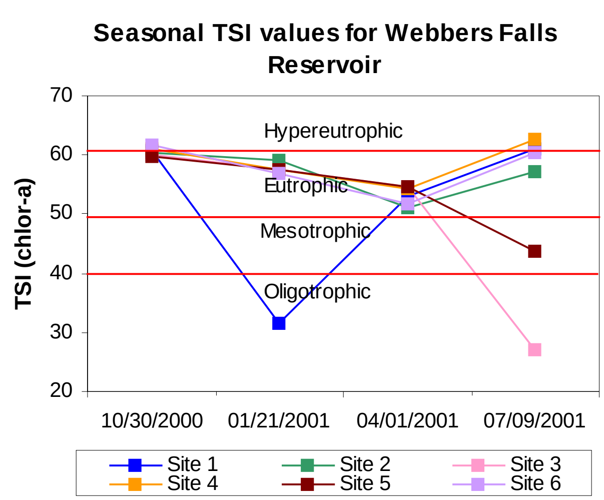


Figure 74. TSI values for Webbers Falls Reservoir.

Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential, and salinity were recorded at all sample sites. In the fall of 2000, a vertical profile was taken at the dam only as the Hydrolab battery failed at site 1. Lake salinity values ranged from 0.39 ppt in the summer to 0.79 ppt in the winter, much higher than the range of expected values for Oklahoma lakes, reflecting an abundance of chlorides or other salts in the lake. Specific conductance values were also higher than most values recorded in Oklahoma reservoirs, corresponding with the high salinity concentrations. Values ranged from 0.761mS/cm in the summer to 1.496mS/cm in the winter, indicating that high levels of electrical conducting compounds (salts) were present in the lake. Both the high salinity and conductivity values indicate Webbers Falls Reservoir has a higher salt content than most Oklahoma lakes. Oxidation-reduction potentials ranged from 185mV at the sediment-water interface in the fall to 516mV in the spring, indicating reducing conditions were not present. The pH values were slightly alkaline with values ranging from 7.46 at site 6 in the summer to 8.47 at site 5 in the winter. Thermal stratification was not evident in any of the sampling intervals (see Figure 75a-75f). Generally the water column was fairly well oxygenated and mixed (see Figure 75a-75f). Dissolved oxygen (D.O.) values were above 7 mg/L throughout the water column at all sites in the fall and above 3 mg/L in the winter, spring, and summer (see Figure 75d-75f). The only anoxic D.O. values recorded in sample year 2001 were at site 3 in the winter throughout the water column; however, these values are most likely erroneous as the other sites are not anoxic. According to USAP, the FWP beneficial use is fully supported at Webbers Falls Reservoir.

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 was 1.08 mg/L at the surface and 1.13 mg/L on the lake bottom. The TN at the surface ranged from 0.58 mg/L to 1.93 mg/L and from 0.67 to 1.78 mg/L on the lake bottom. The highest surface TN value was reported in the spring and the lowest was in the fall. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.132 mg/L on the surface and 0.140 mg/L on the lake bottom. The surface TP ranged from 0.086 mg/L to 0.206 mg/L and from 0.088 to 0.199 mg/L on the lake bottom. 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 8:1 for sample year 2001. This value is slightly higher than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Webbers Falls Reservoir was classified as eutrophic, indicative of high levels of primary productivity and nutrient rich conditions. The turbidity criteria was exceeded in 25% of samples in 2001, although possibly due to excessive inflow from storm events; therefore, the FWP beneficial use was partially supported based on recent data. Both the high salinity and conductivity values indicate this reservoir has a higher salt content than most Oklahoma lakes, which is expected as the lake is actually an extension of the Arkansas River. According to ODEQ, the lake was sampled in 2000 and none of the fish tissue samples exceeded the screening level or low consumption advisory level for metals toxicity or organic residues. Webbers Falls Reservoir, constructed by the US Army Corps of Engineers, was built primarily for navigation and hydroelectric power but is also utilized for recreational purposes.

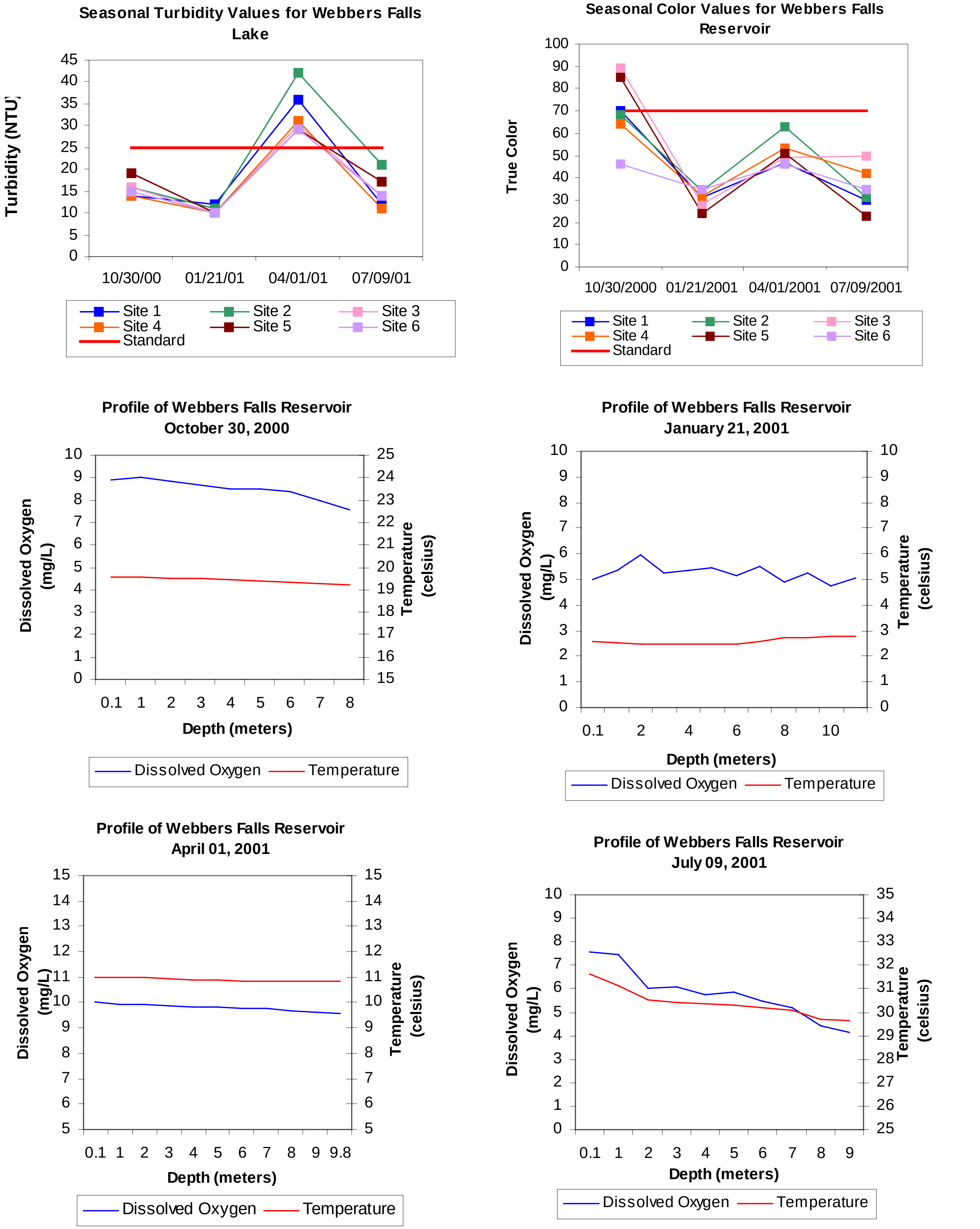


Figure 75a-75f. Graphical representation of data results for Webbers Falls Reservoir.

Plate 34 - Lake Water Quality for
Webbers Falls Reservoir

Webbers Falls Lake
Location

Webbers Falls Lake
and
Watershed

Lake Data

Constructed by	Corps of Engineers
County	Muskogee
Constructed in	1970
Surface Area	11,600 acres
Volume	170,100 acre/feet
Shoreline Length	175 miles
Mean Depth	15.2
Watershed Area	97,033 square miles

Turbidity
2001

Trophic State
2001

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 (USAP 785:45-15-4). The lake-wide annual turbidity value was 15 NTU (Plate 35), 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, using Carlson's TSI (chlorophyll-a), was calculated using values collected at all sites for four quarters (n=10). The average TSI was 52 (Plate 35), 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 (see Figure 76). 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 OWQS of 25 NTU in the fall, winter, and summer at all sites to above the standard at all sites in the spring (see Figure 77a). According to USAP (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 25% of the samples collected in 2001 were above the standard, the lake is listed as partially supporting the FWP beneficial use as the spike in turbidity in the spring was probably due to seasonal rain events. Seasonal true color values are also displayed in Figure 77b. True color values were below the aesthetics OWQS of 70 throughout the year, except at site 1 in the spring quarter (see Figure 77b). Currently, the Aesthetics beneficial use is considered fully supported.

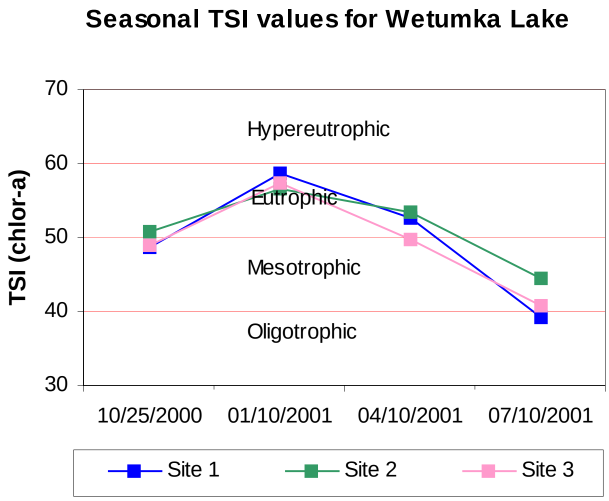


Figure 76. TSI values for Wetumka Lake.

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 0.01 parts per thousand (ppt) to 0.05 ppt, indicating low salt content compared to most Oklahoma lakes. Specific conductance ranged from 0.057mS/cm in the spring to 0.129mS/cm in the fall, indicating minimal levels of electrical conducting compounds (salts) were present in the lake system, corresponding with the recorded salinity values. In general, pH values neutral, ranging from 6.37 to 7.44 units. Oxidation-reduction potentials (Redox) ranged from 178mV at the sediment-water interface in the winter to 456mV in the spring. Redox readings indicated that reducing conditions were not present in the reservoir from the winter through the summer. Reducing conditions were present in the fall sampling interval, ranging from –83 at the sediment water interface at site 2 to 87mV. The lake was not thermally stratified in the fall or winter and D.O. values were above 4 mg/L throughout the water column (see Figure 77c-77d). In the winter, D.O. values were extremely variable from one site to the next probably due to the fact that the lake was partially frozen at the surface, possibly causing erroneous readings. In the spring, the lake was stratified between 3 and 4 meters, although anoxic conditions were not present below the thermocline (see Figure 77e). In the summer, the lake was stratified at several 1-meter intervals, the first between 2 and 3 meters, at which point the D.O. values were less than 2 mg/L to the lake bottom at sites 1 and 2 (see Figure 77f). If D.O. concentration is less than 2 mg/L for 50 to 70% of the water column, the FWP beneficial use is deemed partially supported. According to USAP, the FWP beneficial use is considered supported at Wetumka Lake although close to 50% of the water column was anoxic in the summer.

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 was 0.56 mg/L at the surface and 0.63 mg/L on the lake bottom. The TN at the surface ranged from 0.33 mg/L to 1.06 mg/L and from 0.42 to 0.80 mg/L on the lake bottom. The highest surface TN value was reported in the spring and the lowest was in the fall. The lake-wide total phosphorus (TP) average for sample year 2001 was 0.048 mg/L on the surface and 0.065 mg/L on the lake bottom. The surface TP ranged from 0.02 mg/L to 0.109 mg/L and from 0.039 to 0.094 mg/L on the lake bottom. The highest surface TP value was reported in the spring and the lowest was in the summer. The nitrogen to phosphorus ratio (TN:TP) was 12:1 for sample year 2001. This value is greater than 7:1, characterizing the lake as phosphorus-limited (Wetzel, 1983).

In summary, Wetumka Lake was classified as eutrophic, indicative of high primary productivity and nutrient rich conditions. Although the lake-wide annual turbidity average was below the OWQS of 25 NTU, 25% of the samples collected in 2001 were above the standard. The FWP beneficial use is considered partially supported based on high turbidity values. Anoxic conditions were present in the summer for close to 50% of the water column, therefore lake D.O. should be closely in the future (USAP 785:46). Wetumka Lake is the municipal water supply for the City of Wetumka and is utilized for recreation.

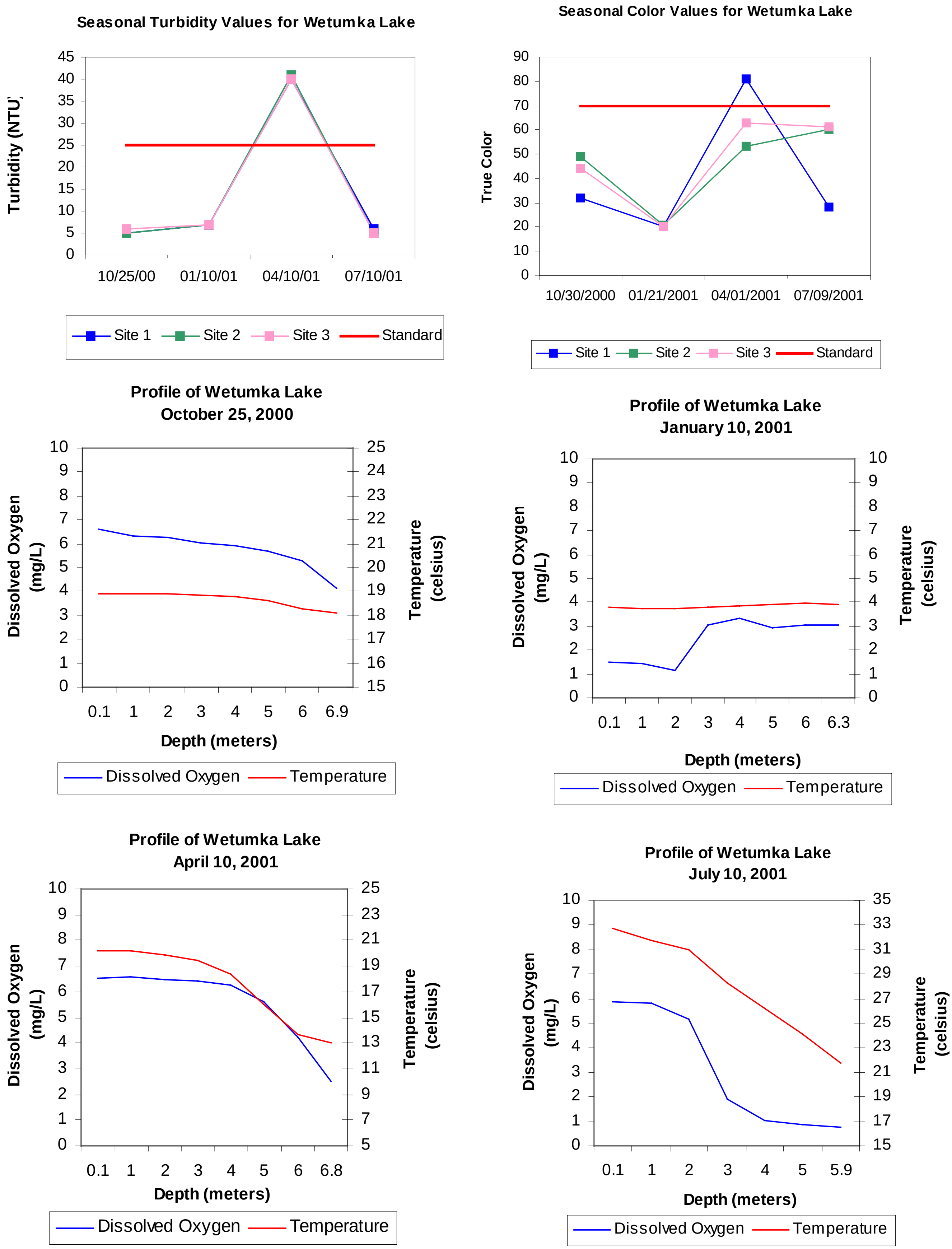


Figure 77a-77f. Graphical representation of data results for Wetumka Lake.

Wetumka Lake and Watershed

Wetumka Lake Location

Trophic State 2001

Turbidity 2001

Lake Data

Owner	City of Wetumka
County	Hughes
Constructed	1939
Surface Area	169 acres
Volume	1,839 acre/feet
Shoreline Length	6 miles
Mean Depth	10.88 feet
Watershed Area	2,689 acres

Plate 35 - Lake Water Quality for

Wetumka Lake

STREAM MONITORING PROGRAM

The Stream Beneficial Use Monitoring Program was initiated in November of 1998. Implementation of the program was delayed due to the relocation of the ODEQ State Environmental Laboratory to a new building and the fact that the OWRB required a few months to assemble the necessary infrastructure to implement stream sampling (purchase of equipment, database development, assignment of personnel, etc.). The BUMP streams staff has been collecting monthly information since November of 1998 and a summary of the data results from year 2001 sampling is presented in this section. Results are presented by 8-digit USGS HUC with streams discussed in alphabetical order for each HUC. Hopefully information is presented in a readily understandable manner for the reader. Each stream site is dealt with individually with a brief narrative outlining the site location and other pertinent information. Also included in the narrative is a brief synopsis of data results. Additional graphical representations of the data are included for each site to allow for a more thorough examination of the data and how conclusions of use support were made. All of the permanent monitoring sites are listed and discussed very briefly.

RIVER AND STREAM MONITORING OVERVIEW

Historically, data on rivers and streams across the state has been very sketchy. Over the years, various local, tribal, state, and federal agencies have managed a number of sampling programs. These programs have varied in nature ranging from short-term, site-specific sampling to the former Oklahoma State Department of Health (OSDH) statewide sampling program. However, a comprehensive, statewide ambient trend-monitoring program had not existed since 1989, the last year that the OSDH conducted monthly sampling. Furthermore, a program with the specific intent of documenting statewide beneficial use impairments on a long-term basis had never existed until the Beneficial Use Monitoring Program (BUMP) was started in September of 1998 with subsequent sampling begun in November of the same year. By establishing a monitoring network that evaluates general water quality through the use of an existing framework like the Oklahoma Water Quality Standards, the state of Oklahoma initiated a progressive phase in the long-term assessment of the overall health of our state's streams and rivers.

MATERIALS & METHODS

The Monitoring Network. The BUMP rivers and streams network consists of two major station classifications — permanent ambient trend sites and rotating sites. Permanent ambient trend monitoring sites are relatively static within the program. In general, they do not change from year to year and have been chosen to allow for long-term assessment of beneficial uses and water quality trends. Since program inception a small number of sites have been dropped from the program and new sites added to more effectively assess the water quality of our major stream basins. Rotating stations are only actively monitored for a predetermined period of time and for a specific purpose.

With the creation of the permanent monitoring network in September of 1998, OWRB staff established three overarching objectives for the program. First, the network must encompass the entire state. To accomplish this, a commitment was made to locate at least one site in each of the 8-digit USGS hydrologic units (HUC) (Table 8).

Table 8. Eight Digit United States Geological Survey HUC Watersheds.

8 Digit HUC Number	Description	8 Digit HUC Number	Description
11040001	Cimarron Headwaters	**11100301**	Middle North Canadian
11040002	Upper Cimarron	**11100302**	Lower North Canadian
11040006	Upper Cimarron – Liberal	**11100303**	Deep Fork
11040007	Crooked	**11110101**	Polecat – Snake
11040008	Upper Cimarron – Bluff	**11110102**	Dirty – Greenleaf
11050001	Lower Cimarron – Eagle Chief	**11110103**	Illinois
11050002	Lower Cimarron – Skeleton	**11110104**	Robert S. Kerr Reservoir
11050003	Lower Cimarron	**11110105**	Poteau
11060001	Kaw Lake	**11120105**	Lower Prairie Dog Town Fk., Red
11060002	Upper Salt Fork – Arkansas	**11120202**	Lower Salt Fork – Red
11060003	Medicine Lodge	**11120302**	Middle North Fork – Red
11060004	Lower Salt Fork – Arkansas	**11120303**	Lower North Fork – Red
11060005	Chickaskia	**11120304**	Elm Fork – Red
11060006	Black Bear – Red Rock	**11130101**	Groesbeck – Sandy
11070103	Middle Verdigris	**11130102**	Blue – China
11070105	Lower Verdigris	**11130201**	Farmers – Mud
11070106	Caney	**11130202**	Cache
11070107	Bird	**11130203**	West Cache
11070205	Middle Neosho	**11130208**	Northern Beaver
11070206	Grand Lake	**11130210**	Lake Texoma
11070207	Spring	**11130301**	Washita Headwaters
11070208	Elk	**11130302**	Upper Washita
11070209	Lower Neosho	**11130303**	Middle Washita
11090103	Rita Blanca	**11130304**	Lower Washita
11090201	Lower Canadian – Deer	**11140101**	Bois D'Arc – Island
11090202	Lower Canadian – Walnut	**11140102**	Blue
11090203	Little	**11140103**	Muddy Boggy
11090204	Lower Canadian	**11140104**	Clear Boggy
11100101	Upper Beaver	**11140105**	Kiamichi
11100102	Middle Beaver	**11140106**	Pecan – Waterhole
11100103	Coldwater	**11140107**	Upper Little
11100104	Palo Duro	**11140108**	Mountain Fork
11100201	Lower Beaver	**11140109**	Lower Little
11100203	Lower Wolf		

Currently, all but four of these 8-digit HUCs has at least one sampling station. A map of the 8-digit USGS HUCs is included as Figure 78. The second objective was that the foundation of the monitoring network should be principally the state's largest rivers, the Arkansas River and the Red River, and their major tributaries, such as the Canadian River and the Washita River. Currently, fifty-seven of the ninety-nine stations currently being monitored (57%) are active at the time of this report meet this criteria. These sites are dispersed over 20 different rivers and streams with the majority located on the Arkansas River and several tributaries including the Cimarron River, the Canadian River, the Verdigris River, and Neosho River as well as the Red River and several tributaries including the Washita River, the Kiamichi River, and the Little River. Secondary consideration was given to the major tributaries of rivers such as Canadian River and the Little River. Currently, thirty-six of the ninety-nine sites (36%) active at the time of this report meet this criteria. Further consideration was given to areas of the state (e.g., the Panhandle) that were underrepresented as well as rivers and streams (e.g., The Deep Fork River) that were conspicuously missing from the network. Currently, seven of the one hundred stations (7%) active at the time of this report met one of these criteria. The third and last objective was that OWRB staff deemed it essential to seek the advice and input of other state environmental agencies and professionals before making a final determination of permanent monitoring station locations. In particular, the ODEQ and OCC continue to be very helpful in assisting with locating permanent stations.

Operating within these overarching objectives, the staff of the OWRB has selected and performed monitoring on one-hundred thirteen (113) permanent ambient trend-monitoring sites since September of 1998 and is currently monitoring ninety-nine (99) permanent stations (Table 9). The placement of a site location necessitates several considerations. Above all, a site must be accessible by vehicle and be safe for sampling personnel and other motorists. It is also essential that a site be located in an area where representative data can be acquired. The OWQS Use Support Assessment Protocols (USAP) set spatial limitations on the data that is collected. In summary, a site can only represent twenty-five stream miles for non-wadable streams and ten stream miles for wadable streams (with some exceptions). Furthermore, a site can only be representative of the waterbody identification number (12 digit HUC number) in which it is located and the site cannot be located within a regulatory mixing zone. This requires that monitoring sites be selected so that they represent as long a stream reach as possible while maintaining the spatial integrity outlined in USAP. Thirdly, it is important that historical data be considered. Many of the current BUMP permanent monitoring sites were selected from a set of historical monitoring stations which were a part of the OSDH (the environmental Division that conducted the Ambient Program later became part of the ODEQ) Ambient Trend Monitoring Program. Before initial sampling began in 1998, OWRB staff worked closely with the ODEQ to integrate many of the historical sites into the BUMP. Although the historical data from these sites can not be used to assess beneficial uses (USAP sets a temporal limitation of five years), the historical data set benefits the state in assessing long-term water quality trends. Lastly, it is imperative that rivers and streams which have been designated in the OWQS as Outstanding Resource Waters (ORW), High Quality Waters (HQW), or Sensitive Water Supplies (SWS) be given unique consideration even if they do not meet the objectives as outlined. For example, Sager Creek is not a tributary of a major tributary of a major river. However, it is listed as an ORW and therefore is sampled as part of the BUMP. During a network re-evaluation in August of 2000, ten (10) stations were added to the network and another 10 stations were inactivated or dropped from the network. In all instances, new monitoring sites/stations were established that met the overarching goals of the monitoring program. A map of permanent ambient trend-monitoring stations is included as Figure 79.

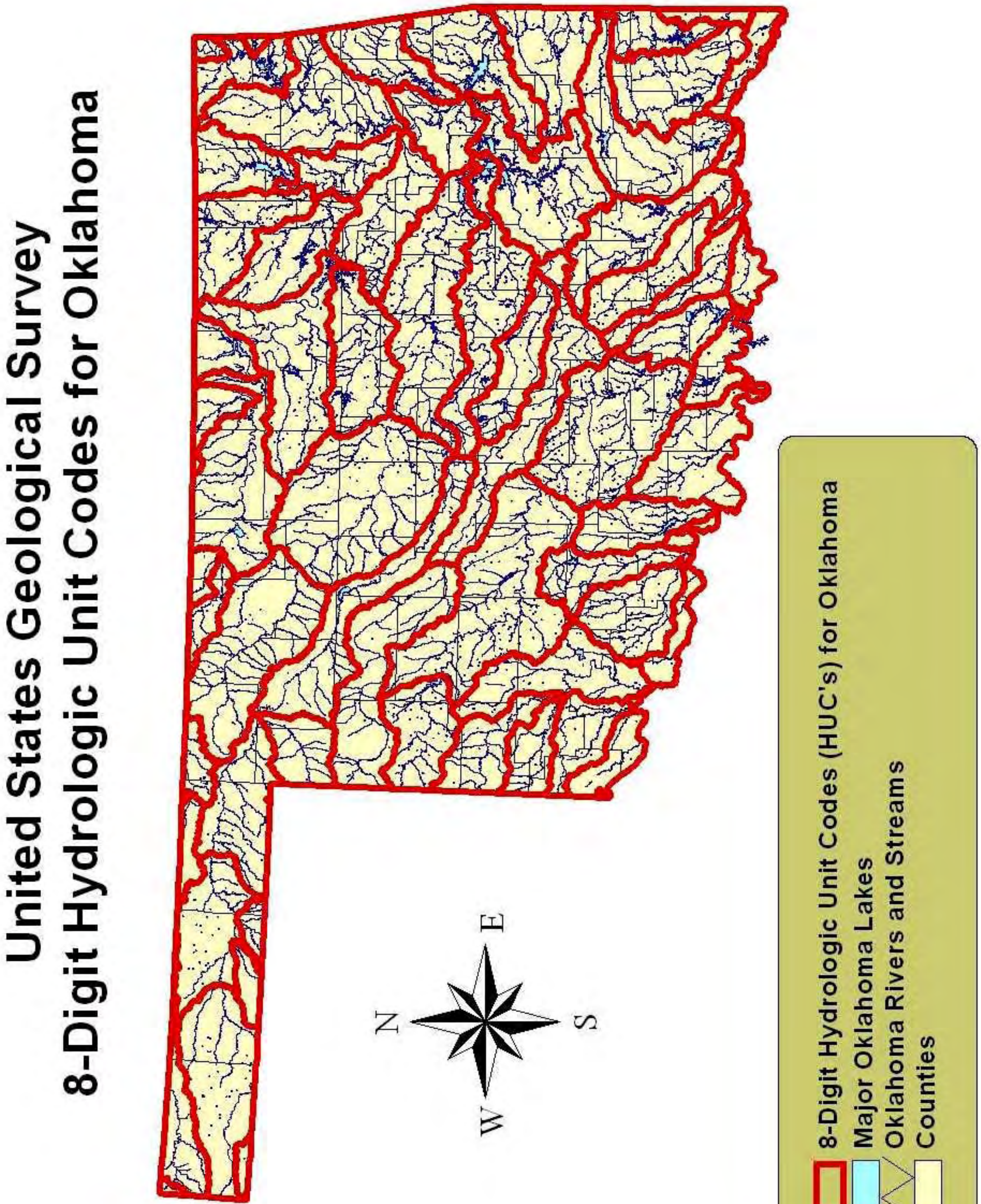


Figure 78. USGS 8-digit Hydrologic Unit Codes for Oklahoma.

Table 9. Permanent Ambient Trend Monitoring Stations.

	4-DIGIT USGS #	WBID #	STATION NAME	COUNTY	STATUS
1	1111	220200010010	Arkansas River, US 64, Moffett	Sequoyah	Active 11/98-P
2	1106	621210000030	Arkansas River, off US 77, Newkirk	Kay	Active 9/99-P
3	1111	120410010080	Arkansas River, SH 104, Haskell	Muskogee	Active 11/98-P
4	1106	621200010200	Arkansas River, SH 18, Ralston	Osage	Active 11/98-P
5	1111	120420010130	Arkansas River, SH 97, Sand Springs	Tulsa	Active 9/99-P
6	1111	121400010260	Arkansas River, US 62, Muskogee	Muskogee	Active 9/99-P
7	1111	120420010010	Arkansas River, US 64, Bixby	Tulsa	Active 11/98-P
8	1111	120400010260	Arkansas River, US 69, Muskogee	Muskogee	Inactive 11/98-12/99
9	1111	121700050010	Baron Fork, SH 51, Eldon	Cherokee	Active 11/98-P
10	1110	720500020010	Beaver River, US 183, Fort Supply	Harper	Active 10/00-P
11	1110	720500020140	Beaver River, CR N1650, Gate	Beaver	Active 10/00-P
12	1110	720510000150	Beaver River, off US 64, Guymon	Texas	Active 11/98-P
13	1110	720500020290	Beaver River, SH 23, Beaver	Beaver	Active 11/98-P
14	1110	720500020010	Beaver River, US 283, Laverne	Harper	Active 11/98-9/00
15	1110	720500020450	Beaver River, US 83, Turpin	Texas	Active 10/00-P
16	1107	121600060060	Big Cabin Creek, off US 69, Big Cabin	Craig	Active 9/99-P
17	1107	121600060010	Big Cabin Creek, SH 28, Pensacola	Mayes	Inactive 11/98-8/99
18	1107	121300010010	Bird Creek, SH 266, Port of Catoosa	Tulsa	Active 11/98-P
19	1106	621200030010	Black Bear Creek, SH 18, Pawnee	Pawnee	Active 11/98-P
20	1114	410600010010	Blue River, US 70, Durant	Bryan	Active 11/98-P
21	1109	220600030020	Brushy Creek, off US 270, Haileyville	Pittsburg	Active 11/98-P
22	1109	220600010120	Canadian River, Ind. Nat. Tpk., Hanna	McIntosh	Active 11/98-9/99
23	1109	220300000010	Canadian River, SH 2, Whitefield	Haskell	Active 9/99-P
24	1109	520620020120	Canadian River, US 183, Taloga	Dewey	Active 11/98-P
25	1109	220600010119	Canadian River, US 270, Calvin	Hughes	Active 11/98-P
26	1109	520600010010	Canadian River, US 377, Konawa	Seminole	Active 11/98-P
27	1109	520620010050	Canadian River, US 66, Bridgeport	Blain	Active 11/98-P
28	1109	520610010010	Canadian River, US 77, Purcell	McClain	Active 11/98-P
29	1111	121700040010	Caney Creek, off SH 100, Barber	Cherokee	Active 9/99-P
30	1107	121400010010	Caney River, off US 75, Ramona	Washington	Active 11/98-P
31	1106	621100000010	Chickaskia River, US 177, Blackwell	Kay	Active 11/98-P
32	1104	620930000010	Cimarron River, off US 64, Mocane	Beaver	Active 10/99-P
33	1105	620910020010	Cimarron River, SH 34, Buffalo	Woods	Active 11/98-P
34	1105	620900010170	Cimarron River, SH 99, Oilton	Creek	Active 11/98-P
35	1105	620920010010	Cimarron River, US 412, Orienta	Major	Active 11/98-P
36	1105	620910030010	Cimarron River, US 77, Guthrie	Logan	Active 11/98-P
37	1105	620910010010	Cimarron River, US 81, Dover	Kingfisher	Active 11/98-P

	4-DIGIT USGS #	WBID #	STATION NAME	COUNTY	STATUS
38	1105	620900030010	Cimarron River, SH 33, Ripley	Payne	Active 10/00-P
39	1114	410400030020	Clear Boggy Creek, off US 69, Caney	Atoka	Active 11/98-P
40	1110	720500020070	Clear Creek, US 283, May	Ellis	Active 11/98-9/00
41	1113	311200000030	Cow Creek, SH 5, Waurika	Jefferson	Active 11/98-P
42	1110	520700020010	Deep Fork River, off SH 16, Beggs	Okmulgee	Active 11/98-P
43	1110	520700040180	Deep Fork River, US 377, Stroud	Lincoln	Active 11/98-P
44	1113	311300010020	East Cache Creek, SH 53, Walters	Cotton	Active 11/98-P
45	1112	311500030010	Elk Creek, off US 183, Hobart	Kiowa	Active 11/98-P
46	1107	121600030440	Elk River, SH 43, Tiff City (MO)	McDonald	Active 5/99-P
47	1112	311800000010	Elm Fork River, SH 9, Mangum	Greer	Active 11/98-P
48	1111	121700060010	Flint Creek, US 412, Kansas	Delaware	Active 11/98-P
49	1111	220100040020	Fourche-Maline Creek, off US 270, Red Oak	Latimer	Active 11/98-P
50	1114	410210080010	Glover River, SH 3, Glover	McCurtain	Active 11/98-P
51	1113	311100020010	Hickory Creek, off SH 32, Marietta	Love	Active 11/98-9/00
52	1107	121600030440	Honey Creek, off SH 25, Grove	Delaware	Active 11/98-P
53	1111	121700030350	Illinois River, US 59, Watts	Adair	Active 11/98-P
54	1111	121700030010	Illinois River, US 62, Tahlequah	Cherokee	Active 11/98-P
55	1114	410310010010	Kiamichi River, off US 271, Tuskahoma	Pushmataha	Active 11/98-P
56	1114	410310020010	Kiamichi River, SH 63, Big Cedar	LeFlore	Active 11/98-P
57	1114	410300030010	Kiamichi River, US 271, Antlers	Pushmataha	Active 11/98-P
58	1110	720500020130	Kiowa Creek, off US 283, Laverne	Harper	Active 11/98-9/00
59	1114	410210020140	Little River, off SH 3, Cloudy	Pushmataha	Active 11/98-P
60	1109	520800010010	Little River, SH 56, Sasakwa	Seminole	Active 11/98-P
61	1114	410200010200	Little River, US 70, Idabel	McCurtain	Active 11/98-P
62	1114	410210060020	Mountain Fork, SH 4, Smithville	McCurtain	Active 11/98-P
63	1114	410210040010	Mountain Fork, US 70, Eagletown	McCurtain	Active 11/98-P
64	1113	311100040010	Mud Creek, SH 32, Courtney	Love	Active 11/98-P
65	1114	410400050270	Muddy Boggy Creek, SH 3, Farris	Atoka	Active 11/98-6/99
66	1114	410400050270	Muddy Boggy Creek, US 69, Atoka	Atoka	Active 9/99-P
67	1114	410400010070	Muddy Boggy Creek, US 70, Unger	Choctaw	Active 7/99-P
68	1107	121600040220	Neosho River, off US 66 , Commerce	Ottawa	Active 10/00-P
69	1107	121600040010	Neosho River, off SH 137, Connor Bridge	Ottawa	Active 11/98-P
70	1107	121600020170	Neosho River, SH 82, Langley	Mayes	Active 11/98-P
71	1107	121600010280	Neosho River, US 412, Chouteau	Mayes	Active 11/98-P
72	1110	520510000110	North Canadian River, US 377, Centerview	Pottawatomie	Active 10/00-P
73	1110	520500010110	North Canadian River, Ind. Nat. Tpk., Dustin	McIntosh	Active 11/98-P
74	1110	520510000110	North Canadian River, off US 62, Harrah	Oklahoma	Active 11/98-P
75	1110	720500010010	North Canadian River, US 281, Seiling	Dewey	Active 11/98-P

	4-DIGIT USGS #	WBID #	STATION NAME	COUNTY	STATUS
76	1110	520510000010	North Canadian River, US 75, Wetumka	Hughes	Active 9/99-P
77	1110	520530000010	North Canadian River, US 81, El Reno	Canadian	Active 11/98-P
78	1110	720500010140	North Canadian River, US 412, Woodward	Woodward	Active 10/00-P
79	1112	311510010010	North Fork of the Red River, SH 34, Carter	Beckham	Active 11/98-P
80	1112	311500010020	North Fork of the Red River, US 62, Headrick	Tillman	Active 11/98-P
81	1110	720500020500	Palo Duro Creek, SH 3, Bryan's Corner	Texas	Active 11/98-9/00
82	1111	220100010010	Poteau River, off SH 112, Pocola	LeFlore	Active 11/98-P
83	1111	220100020010	Poteau River, US 59, Heavener	LeFlore	Active 11/98-P
84	1107	121610000010	Pryor Creek, US 69A, Sportsman Acres	Mayes	Active 9/99-9/00
85	1113	311100010190	Red River, I-35, Gainsville	Love	Inactive 11/98-8/99
86	1113	311200000010	Red River, SH 79, Waurika	Jefferson	Active 11/98-P
87	1113	311310010010	Red River, US 183, Davidson	Tillman	Active 11/98-P
88	1114	410100010010	Red River, US 259, Harris	McCurtain	Active 11/98-P
89	1114	410400010010	Red River, US 271, Hugo	Choctaw	Active 11/98-P
90	1113	311100010190	Red River, US 81, Terral	Jefferson	Active 11/98-P
91	1111	121700060080	Sager Creek, off US 412, West Siloam Springs	Delaware	Active 11/98-P
92	1106	621010010160	Salt Fork of the Arkansas, SH 58, Ingersoll	Alfalfa	Active 11/98-P
93	1106	621000010010	Salt Fork of the Arkansas, US 77, Tonkawa	Kay	Active 10/00-P
94	1106	621000010010	Salt Fork of the Arkansas, US 177, White Eagle	Noble	Active 11/98-9/00
95	1112	311600020010	Salt Fork of the Red River, off US 283, Elmer	Jackson	Active 11/98-P
96	1112	311600020010	Salt Fork of the Red River, off SH 34, Mangum	Greer	Active 10/00-P
97	1113	311600010040	Sandy Creek, SH 6, Eldorado	Jackson	Active 11/98-P
98	1105	620910030010	Skeleton Creek, SH 74, Lovell	Logan	Active 11/98-P
99	1107	121600010290	Spring Creek, off US 412, Murphy	Mayes	Active 11/98-P
100	1107	121600070010	Spring River, off SH 137, Quapaw	Ottawa	Active 11/98-P
101	1107	121500020260	Verdigris River, US 412, Inola	Rogers	Active 10/00-P
102	1107	121510010010	Verdigris River, US 60, Nowata	Nowata	Active 2/99-9/99
103	1107	121510020010	Verdigris River, SH 10, Lenepah	Nowata	Active 11/98-P
104	1107	121500030010	Verdigris River, SH 20, Keetonville	Rogers	Active 11/98-P
105	1107	121500010200	Verdigris River, SH 51, Wagoner	Wagoner	Active 9/99-P
106	1113	311100030010	Walnut Bayou, SH 32, Burneyville	Love	Active 9/99-9/00
107	1113	310830030060	Washita River, SH 152, Cordell	Washita	Active 11/98-P
108	1113	310810010010	Washita River, SH 19, Pauls Valley	Garvin	Active 11/98-P
109	1113	310840010010	Washita River, SH 33, Hammon	Custer	Active 11/98-P
110	1113	310800020010	Washita River, US 177, Durwood	Carter	Active 11/98-P
111	1113	310830010010	Washita River, US 281, Anadarko	Caddo	Active 11/98-P
112	1113	311310020010	West Cache Creek, SH 5B, Taylor	Cotton	Active 11/98-P
113	1110	720500030040	Wolf Creek, off US 270, Fort Supply	Woodward	Active 11/98-P

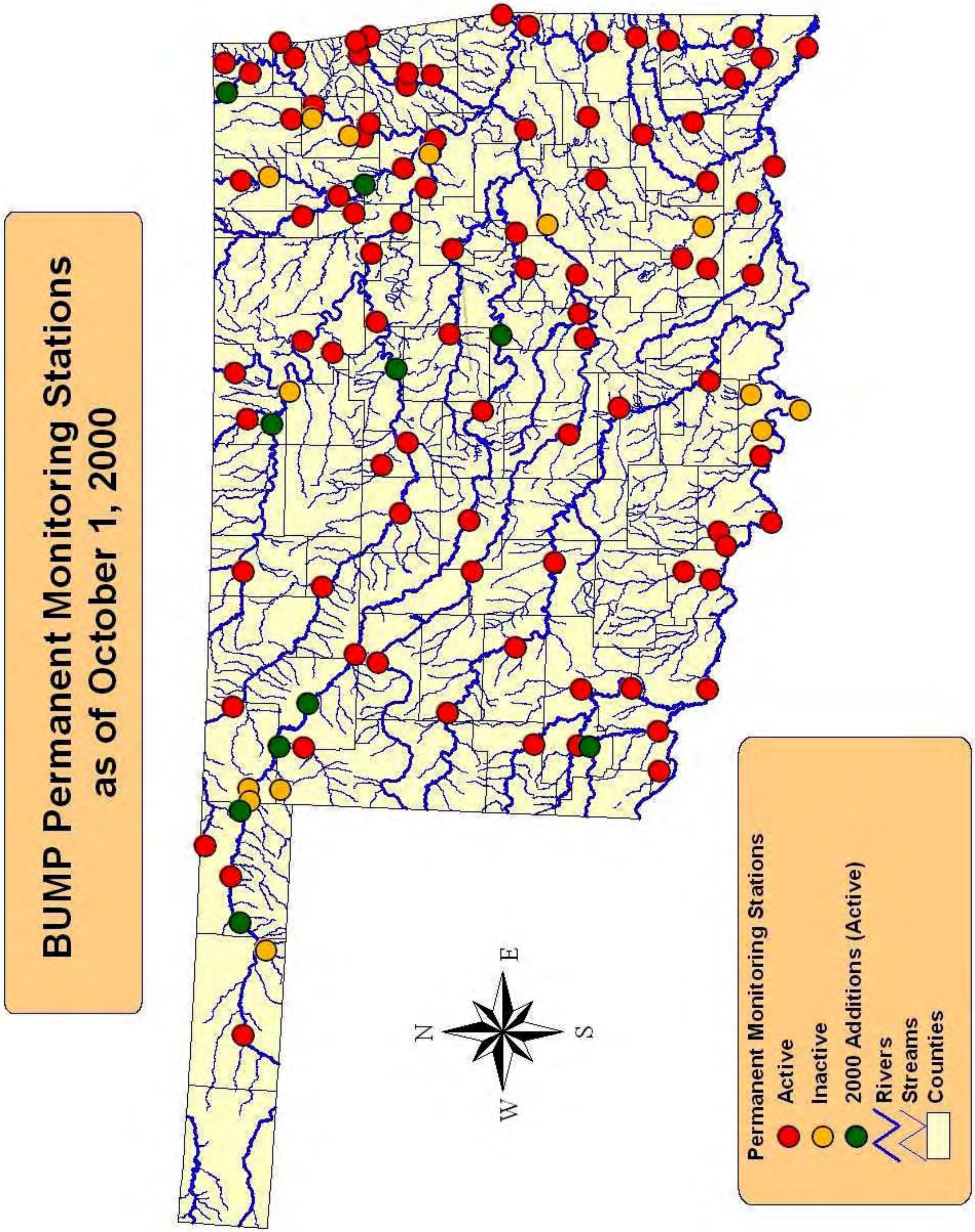


Figure 79. Beneficial Use Monitoring Program permanent ambient trend monitoring sites.

The water quality status of each site is discussed in more detail in the individual HUC narrative sections that follow this section of the report.

Rotating site selection is not as simple a process as permanent site selection. The goal of the rotating portion of the program is to provide short-term assessments on priority waters as identified by a state agency or other party. Two over-arching objectives were identified to aid in the determination of what would qualify as a rotating site. First of all, it was determined that data collection at a particular site should be short-term in nature and not extend past one sampling year. Data collected within that year should allow water quality managers to make the appropriate decisions regarding the segment being monitored. For instance, if a stream reach is listed as impaired due to pH on the 303(d) list, measuring pH throughout one year should allow the requesting agency or entity to either de-list the segment or determine what other monitoring efforts are necessary. Secondly, the monitoring should fall within the framework of the USAP. Since the inception of the program, the staff of the OWRB has met individually with representatives of other state agencies to identify their priority short-term monitoring needs. Once the OWRB receives a list of waters for monitoring from the interested agencies, staff evaluates the nominations and notifies the nominating agency of which waters would be monitored (all of the waters requested for monitoring have been accommodated since program inception). In all, one hundred ninety (190) monitoring stations have been or are currently being monitored. In most instances, the segments were listed for one or more variables in the state's 303d list. For a comprehensive list of historic and/or current rotational monitoring stations, **please contact the Oklahoma Water Resources Board/Water Quality Programs Division at (405) 530-8800.**

Stream Monitoring Variables. The variables that are monitored were chosen to reflect both objectives of the programs — assessment of beneficial uses within the framework of USAP as well as the assessment of general water quality. Even though a variable may not be listed in the OWQS with a specific criterion (e.g., hardness), the variable is an important constituent in analyzing and understanding the general water quality of a particular segment. See Table 10 for a list of monitoring variables.

Table 10. Variables Monitored by the BUMP Stream Sampling Program.

SAMPLE VARIABLES		
General Water Quality Variables – Sampled Monthly		
Dissolved Oxygen	pH	Specific Conductance
Temperature	Oxidation/Reduction Potential	% D.O. Saturation
Salinity	Total Alkalinity	Total Hardness
Chloride	Nephelometric Turbidity	Sulfate
Total Dissolved Solids		
Nutrients – Sampled Monthly		
*Kjeldahl Nitrogen	Ortho-Phosphorus	Total Phosphorus
*Nitrate Nitrogen	*Nitrite Nitrogen	Ammonia Nitrogen
Metals – Sampled Once Annually at a Minimum		
Arsenic	Cadmium	Chromium (Total)
Copper	Lead	Mercury

SAMPLE VARIABLES		
Nickel	Selenium	Silver
Zinc	Thallium	
Organics		
Analysis of Pesticides, Herbicides, Fungicides, and other organics		
Bacteriological Communities – Sampled 5 Times Annually at a Minimum		
Fecal Coliform	*Escherichia coli*	Enterococci

*Total nitrogen is calculated by OWRB staff, based upon concentrations for these compounds.

Data for water quality variables is collected in one of two ways. Some variables are monitored in-situ utilizing a Hydrolab® Minisonde or YSI multi-probe instrument. The measurement is taken at the deepest point of the channel at a depth of at least 0.1 meters and no greater than one-half of the total depth. The data are uploaded from the instrument to a data recorder, transferred manually to a field log sheet, and downloaded to the OWRB network. These variables include dissolved oxygen, %D.O. saturation, water temperature, pH, salinity, oxidation-reduction potential, total dissolved solids, and specific conductance. Data for all other variables are gathered from water quality samples collected at the station. Samples are collected either by suspending a modified DH-81 handline depth-integrating sampler (polyethylene collection bottle) from a bridge or by wading the stream with a DH-81 wadable depth-integrating sampler (polyethylene collection bottle). If sampling occurs from a bridge, the sampling is done on the down-stream side of the bridge spanning the stream of interest. Samples are collected using a combination of the depth-integration method and the equal-width increment method. The depth-integration method involves collection of samples from the surface of the water to the midpoint of the water column with water collected at a consistent rate on both the descent and the ascent. The equal-width-increments-method allows for collection of a composite sample by sampling with depth-integration at 5 to 10 equal widths across the stream. As each increment is sampled, the water is added to a polyethylene churn splitter. From this composite water sample, water quality variables are monitored in several ways. For laboratory analysis of general water quality variables and nutrients, water is aliquotted from the churn splitter to two (2) 1-liter bottles (one for sulfuric acid/ice preservation and one for ice preservation). If a sample is needed for metals analysis, water is aliquotted into another 1-liter acid washed bottle, preserved with nitric acid, and placed on ice. Sample water for the determination of nephelometric turbidity and total alkalinity is also aliquotted from the splitter churn. Nephelometric turbidity is determined through use of a HACH Portable turbidimeter. Total alkalinity is determined using a HACH alkalinity test kit. All instruments and test kits are calibrated and used according to manufacturer's instructions. Samples for organics analysis are collected separately using Teflon and glass containers as opposed to polypropylene. Because organics have an increased affinity for polypropylene, allowing a sample to contact polypropylene sample bottles or churn splitters may cause concentrations to be significantly underestimated. Therefore, a composite sample for organics analysis is collected by using a 1-liter Teflon collection bottle. At each increment, water is added to a 3-gallon glass bottle. The laboratory sample is aliquotted by inverting the glass bottle 10 times and dispensing to two (2) one-quart glass mason jars. The samples are placed on ice for preservation. For a more detailed discussion of sampling procedures, please contact the OWRB Water Quality Programs Division at (405) 530-8800 for a copy of the BUMP Standard Operating Procedures (SOP) or access the web address http://www.state.ok.us/~owrb/reports/publications.html to download a copy of the SOP document.

OWRB stream sampling personnel collect water quality data for all variables on permanent ambient trend monitoring stations (Table 9). In all cases, the rotating stations have been derived from stream segments listed on Oklahoma's 303(d) list and on streams submitted for monitoring by other state agencies. Therefore, the water quality variables analyzed are determined from the 303(d) listed cause code or by the requesting agency, with concurrence by OWRB staff. The 111 stations monitored for the OCC are located on stream segments designated for salinity on the 303(d) list. Each station is screened monthly before a sample is collected. A multi-probe instrument is used to collect data for total dissolved solids (TDS) and pH. When TDS is over 700 mg/L, a composite sample is collected and delivered to the laboratory for analysis of cations and anions. Methods used at rotating sites are identical to methods described for the permanent sites. On segments monitored for oil-field contamination, each station is screened monthly before a sample is collected.

Quality Assurance/Quality Control (QA/QC). QA/QC will not be discussed in detail in this report. However, for a comprehensive description of field QA/QC methods, please contact the Oklahoma Water Resources Board/Water Quality Programs Division at (405) 530-8800. For laboratory QA/QC methods please contact the Oklahoma Department of Environmental Quality/Customer Services Division at (405) 702-6100. Comprehensive QA/QC has been performed on all data collected and utilized for this report.

STREAM DATA ANALYSIS PROTOCOLS

BUMP data collection on streams began in November of 1998. In order to provide a structural framework for data analysis and interpretation within the confines of the OWQS, the program uses the Use Support Assessment Protocols (USAP) promulgated into rule in Oklahoma Administrative Code (OAC) 785:46-15. A detailed explanation of the relationship between the USAP and the data collected on streams and rivers as part of the BUMP is presented below. This explanation is broken down into seven (7) subsections: Data Requirements, Default Protocols, Assessment of Fish and Wildlife Propagation Support, Assessment of Primary Body Contact Recreation Support, Assessment of Public and Private Water Supply Support, Assessment of Agriculture Support, Nutrients and Metals. The latest USAP is included with this document as Appendix A and should provide greater insight into exactly how use support determinations were made for this report. In addition, OAC 785:45 (Oklahoma Water Quality Standards) and the justification document for the USAP can be obtained by contacting the OWRB/Water Quality Programs Division at (405) 530-8800 or through accessing the documents on the OWRB webpage at: http://www.state.ok.us/~owrb/rules/Rules.html.

Data Requirements. USAP divides the number of stream miles that can be represented by a single site/station (or spatial coverage) into two categories—non-wadable and wadable streams. Sites/stations can be representative of no more than 25 stream miles on non-wadable streams and 10 stream miles on wadable streams. These limitations can be adjusted based upon existing data, distance between monitoring sites, sources of pollution, and the influence of major hydrological features, such as major tributaries and dams (delineated by 12-digit waterbody identification segments). A definition of what constitutes a wadable and non-wadable is not outlined in the USAP, so federal guidance and best professional judgement was used by OWRB field staff. 305 (b) guidelines say that no monitoring site/station can be representative of more than 25 stream miles on large streams and rivers. Furthermore, in areas where topography and land use are relatively homogeneous and there are no other significant influences, a single monitoring station can be representative up to 50 to 75 stream miles. Therefore, only two firm guidelines are currently available for determining the spatial coverage of a monitoring site/station:

1) The spatial coverage can not extend outside the 12-digit segment in which the monitoring site/station is located except in those instances where it is determined that it is reasonable to do so (e.g., the segment break is not caused by a major hydrological influence).
2) No monitoring site/station can be representative of more than 25 stream miles (in some instances, monitoring sites/stations may be representative of up to 50 stream miles with a scientifically defensible justification).

Accordingly, spatial coverage for the 2001 BUMP report on streams will be limited to these two guidelines. The spatial coverage is subject to change dependent upon the language of the adopted version of USAP.

USAP sets two limitations on temporal coverage. First, data used in assessments must be collected such that assessments are not biased towards either critical-flow, base-flow, or high-flow conditions. This report uses data collected from December through October to assess support for 2001. Secondly, stream data more than five years old cannot be used to assess support unless no other data exists or a scientifically defensible reason can be brought forth justifying the use of older data. In general, the BUMP only uses data collected within the sampling year to determine use support for that reporting year.

USAP also sets data requirements on the number of samples needed and the magnitude of criteria exceedance for toxicants and dissolved oxygen before a use support determination can be made. The minimum number of samples required to assess use support for all general water quality variables is ten (10). This minimum number of samples is not applicable if data from samples already collected ensures that the use will not be supported. In other words, if a 25% percent exceedance is required to designate a use as not supporting and three (3) of the first five (5) samples collected were in exceedance of the criteria, then sampling can discontinue because you are assured of having >25% of minimum number of samples exceeding the criteria. The BUMP program collects at least ten samples per year on all general water quality parameters with the exception of bacteria, organics and metals. Toxicants (metals and organics) require a minimum of five (5) samples to determine that a use is supported, however, 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”.

Finally, USAP gives guidance on the treatment of practical quantitation level (PQL), or detection limits. An PQL is the minimum value that a particular test or instrument can “read-to” with an acceptable level of confidence. If a value is determined to be less than the PQL, then it is generally reported as a less than value (e.g., variable data point “x” = <2.0 g/L). In other words, the test or the instrument can not deliver a value less than the PQL without introducing significant statistical uncertainty to the resulting value. Moreover, when analyzing the data, this data point “x” can not be assigned a value of 2.0 g/L or 0.0 g/L. Consequently, the USAP states that it is to be assigned a value that is fifty percent of the PQL (“x” would equal 1.0 g/L).

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 ten percent (10%),
    - **ii)** partially supporting — greater than 10% but less than twenty-five percent (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
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 can not be considered partially supporting. In most instances, at least ten samples are required to calculate a geometric mean.

A short discussion of how use support is determined for the various beneficial uses assigned in the OWQS to our rivers and streams will begin below so that the reader will fully understand how use support was determined.

Assessment of Fish and Wildlife Propogation (FWP) 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), biological criteria, 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 program has not yet collected organics or fish flesh and biological criteria are in the process of being promulgated into rule for two ecoregions. Once biological criteria have been developed, the BUMP will begin collecting biological data. Only one variable needs to exceed the assessment protocol for the beneficial use to be partially supported or not supported.

The OWQS 785:45-5-12(g)(1) in a table entitled “Dissolved Oxygen Criteria” prescribes three screening levels for D.O. in streams. Streams are categorized in appendix C of the OWQS as habitat limited aquatic communities (HLAC), warm water aquatic communities (WWAC), and cool water aquatic communities (CWAC) and trout fisheries (TF). The prescribed screening level for each of the categories is: HLAC—4.0mg/l (April 1—June 15) and 3.0 mg/L (June 16—May 31); WWAC—4.0mg/l (June 16—October 15) and 5.0 mg/L (October 16—June 15); and CWAC and TF—5.0mg/l (June 1—October 15) and 6.0 mg/L (October 16—May 31). The protocol for short-term average numerical parameters is used to assess the level of support.

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 criterion need not be exceeded for the variable to be partially supported or not supported.

A numerical range for pH of 6.5 to 9.0 units is prescribed in 785:45-5-12(g)(3). The protocol for short-term average numerical parameters is used to assess the level of support.

Screening limits are established for turbidity in OWQS 785:45-5-12(g)(7)(A)(i) and (iii). CWAC are assigned a criterion of 10 Nephelometric Turbidity Units (NTU), and all other communities are assigned a criterion of 50 NTU. The protocol for short-term average numerical parameters is used to assess the level of support. In OWQS 785:45-5-12(g)(7)(C), it is stated that numerical criteria for turbidity “apply only to seasonal base flow conditions”. Therefore, those measurements that are taken above seasonal base flow are not included in determining support. To determine seasonal base flow, the average discharge for the sampling day is compared to the median flow of the three months surrounding the sampling day. If the station is not part of the USGS stream-flow monitoring program but has an upstream or downstream stream-flow station in close proximity, that station is used to determine whether the station in question is at seasonal base flow. If no proximal stream-flow station exists, stream-flow monitoring stations on other waterbodies that are in close geographical proximity were used to determine whether the station in question is at seasonal base flow. Because discharge data is not yet available from October of 2000 through September of 2001, turbidity data after September of 1999 is provisional and assessments related to turbidity may be subject to change. Therefore, all turbidity assessments are provisional. Changes will be reported in an addendum to this report. Furthermore, to assist staff in the determination of seasonal base flow at stations that do not have continuous discharge measurements, the OWRB is now collecting discharge measurements at all but four of the permanent monitoring stations.

Assessment of Primary Body Contact Recreation (PBCR) Support. Assessment of Primary Body Contact Recreation (PBCR) Support. The PBCR beneficial utilizes 2 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 both *E. coli* and Enterococci, 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. For the current reporting year, only the screening level for fecal coliform can be assessed. Insufficient data is available to calculate the geometric mean for data from any of the three classes.

Assessment of Public and Private Water Supply (PPWS) Support. Assessment of Public and Private Water Supply (PPWS) Support. The PPWS beneficial use utilizes two variables to assess use support: Toxicants and fecal coliform bacteria (FC). For purposes of this report, only metals are considered in the toxicant category. Only one variable needs to violate the assessment protocol for the beneficial use to be partially supported or not supported.

Numerical criteria for metals is established in OWQS 785:45-5-10(1) and (6) and in tables entitled “Raw Water Numerical Criteria” and “Water Column Criteria to Protect for the Consumption of Fish Flesh and Water”, respectively. The short term numerical average protocol is used to determine use support for both sets of criterion. If a substance has different numerical criteria listed in both tables, the most stringent criterion takes precedence. Furthermore, criteria in both tables need not be exceeded for the use to be partially supported or not supported.

A numerical screening level for FC of 5000 cfu/mL is set in OWQS 785:45-5-10(3)(A). The short term numerical average protocol is used to determine use support. Because this is a short-term parameter, 10 samples are required. Consequently, this parameter will rarely be assessed in this report.

Assessment of Agriculture (AG) 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 compared to the 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 OQC 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 Nutrient Support. The assessment of nutrients is unique from other variables monitored as part of the BUMP for several reasons. The OWQS do not promulgate numerical criteria for nutrients in surface waters. However, narrative criteria in OAC 785:45-3-2(c) requires that nutrient related water quality degradation cannot interfere with the maintenance of any beneficial use protected under OAC 785:46-13-3(a)(1). Secondly, because no numerical nutrient criteria exist, assessments of nutrients do not determine beneficial use support but determines whether a particular stretch of stream is nutrient-threatened. Therefore, the assessment of nutrients does not utilize any of the default protocols, but revolves around the use of a dichotomous key. The use of the key is a rather involved process and will not be verbally outlined in this report (see APPENDIX A).

The impact of nutrients on streams is related to the growth of phytoplankton. Phytoplankton are autotrophic which means that when light and consumables such as nutrients are available they can convert energy and grow. The available nutrients are total phosphorus and nitrite and nitrate (utilized as a combined nitrogen concentration). Several factors determine if the level of these compounds pose a threat to the health of the stream. Foremost, the size of the stream must be considered. Smaller streams (3^{rd} order or less) tend to be more susceptible to nutrient impacts and, therefore, smaller concentrations have similar effects as larger concentrations in larger streams (greater than 3^{rd} order). Depending on stream order, USAP has establihed preset threshold values for phophorus and nitrate/nitrite. The median of the sample values exceeds these threshold the following confounding factors are considered to determine if the excessive nutrients are threatening the health of the stream. Secondly, the amount of time the nutrient is resident in the stream is proportional to the impact. Therefore, the slope of the topography around the station must be considered. Thirdly, phytoplankton is light dependent for growth. Consequently, light must be able to able to penetrate the surface of the water. For that reason, water clarity must be measured by either using a nephelometric turbidity meter or a Secchi disk. Only turbidity readings taken at seasonal base flow are included when calculating the geometric mean. Logic states that low clarity will limit the impact of phytoplankton on the stream and that high clarity will increase the impact of phytoplankton. On smaller streams, available light is also measured by percent canopy shading. Lastly, the substrate composition of the streambed limits the impact of nutrients. Because phytoplankton need to attach to a firm substrate to maintain residence in a stream, muddy or soft bottom streams do not facilitate phytoplankton growth.

Assessment of Human Health Support. A new beneficial use was created in 1999 dealing with fish consumption. The fish consumption use is housed under the Human Health criteria. The new use deals with fish consumption bans and states that waters that the DEQ has issued a fish consumption ban on will be considered as not supporting it's fish consumption use. Currently the BUMP is not sampling any waters that have a fish consumption ban associated with them.

PERMANENT STREAM MONITORING STATION RESULTS & DISCUSSION

The results for the permanent monitoring stations are grouped alphabetically within the 4-digit USGS sub-basin in which they reside (Table 9). A map of the state with all of the 4-digit HUC basins is included as to aid the reader in finding a particular water body (Figure 80). Each of these sections has a similar arrangement. Immediately following the tab for a particular sub-basin, there will a 1 or 2-page synopsis of the physical, geographical, and hydrological attributes of the HUC. Included in this description will be a tabular listing of the stations located within the sub-basin.

Following the HUC description will be a detailed 1-3-page analysis of each site. The analysis includes a physical, geographical, and hydrological description of the site. Directly following the descriptive information, a short narrative is included that verifies that monitoring at the site complied with the data requirements outlined in USAP or, in some instances, an explanation is offered as to why certain data requirements were not followed. Next, a comprehensive assessment of each of the prescribed beneficial uses will be done both in a narrative format and graphically. An all-inclusive assessment of the stations can be found in Table 11. Under certain circumstances, a beneficial use was not assessed due to insufficient data. The non-assessment of use support occurred for a variety of reasons. The station may be new or inactivated before adequate data was collected for assessment, data may not be available due to laboratory, field, or equipment error, or sometimes data was not collected due to monetary or personnel constraints.

Table 11 lists the BUMP permanent ambient trend stream monitoring sites and their associated beneficial uses. Beneficial uses that are not being met are shown in **RED**. Listed next to the support code indicating that the beneficial use was not being met is the variable code which indicates which water quality variable violated the OWQS criteria. It is apparent that an inordinate number of water bodies are deemed impaired due to their exceedance of the turbidity standard of 10 or 50 nephelometric turbidity units. The OWQS states that turbidity standards only apply during seasonal base flow conditions. In other words, the criteria should not be applied where normal in-stream conditions exceed the OWQS due to natural processes from a high-flow event. Several "quick" methods are available to assist in the determination of seasonal base flow including the existence of a periphyton line and visual estimation of the degree of flow. However, to reliably determine base flow, a measurement of stream discharge at the time of sampling is needed. This measurement when used in concert with the "quick" methods described above will give a reliable indication of whether the stream is at, below, or above seasonal base flow conditions. Because the BUMP network encompasses the state's large rivers and streams, discharge is often obtained by comparing stream stage to a continuously updated rating curve. Due to the intense nature of establishing a reliable rating curve, rated discharges are often provisional for a number of months. Therefore, the determination of the previous year's base flow and consequently eligible turbidity values are also **provisional** at the publication of this report. As of the beginning of 2002, the OWRB is now guaging all but 4 permanent station locations. Where permanent water-quality monitoring stations were located near a United States Geological Survey (USGS) stream-flow monitoring station, the information collected by USGS is used to determine if a high-flow event exceeding seasonal base flow had occurred at the time of sampling. All other stations are being rated through a cooperative effort between the OWRB Monitoring Section and the USGS.

A problem of a different nature was encountered when staff began to look at metals and beneficial use support. Metals fall under the general heading of **Toxicants** and to determine beneficial use support the concentration is "plugged" into an equation designed to address the issue of water hardness. This is performed because toxicity of some compounds is directly related to the hardness of the water. When staff performed the necessary calculations to come up with the appropriate criteria to utilize for determining use support, some very low concentrations were calculated which were far less than the contract laboratory practical quantitation level (PQL) or detection limit. Per USAP instructions for criteria less than the PQL, ½ of the PQL was used as the concentration detected in the water column. Even with that assumption, in certain instances ½ of the MQL was still orders of magnitude greater than the criteria calculated and adjusted for hardness. In 2001, this resulted in a large number of Fish & Wildlife Propagation beneficial use non-supporting listings due to toxicants when in fact it is uncertain if a beneficial use impairment was present or was an artifact of the USAP directions for dealing with PQL's. To address the problem, the OWRB has worked with the contract laboratory to lower the metals PQL to address the hardness-adjusted criteria. For stations with an average total hardness of less than 150 mg/L, a more precise method is being used to determine levels of cadmium, copper, lead, and silver. This method delivers PQL's that are generally below or no less than half the site-specific, hardness-dependent criterion. In reviewing sample results using this more precise method, stations that were previously listed with uncertainty have been removed if sample data is now below the criterion.

It is essential that Oklahoma quantify impacts in a comprehensive and scientific manner and look for trends in water quality to identify waters which are not meeting their assigned beneficial uses. As a state, we must manage our water resources effectively and direct money to areas in most need of protection or remediation to ensure that we continue to have good quality and sufficient quantity of water to meet our needs well into the 21st century.

As the reader has hopefully realized, comprehensive statewide data sets on rivers and streams for accurately assessing beneficial use impairments has not existed since 1993. With the implementation of monitoring on a large scale in October of 1998, this is no longer the case. With the availability of data, it is the desire of the Oklahoma Water Resources Board to provide the legislature and professional water managers with a comprehensive and up-to-date document for their review and approval. Administrative and Technical staff at the OWRB look forward to conducting the Beneficial Use Monitoring Program far into the future and providing the state of Oklahoma with the information it needs to make informed decisions related to the effective management of it's precious water resources.

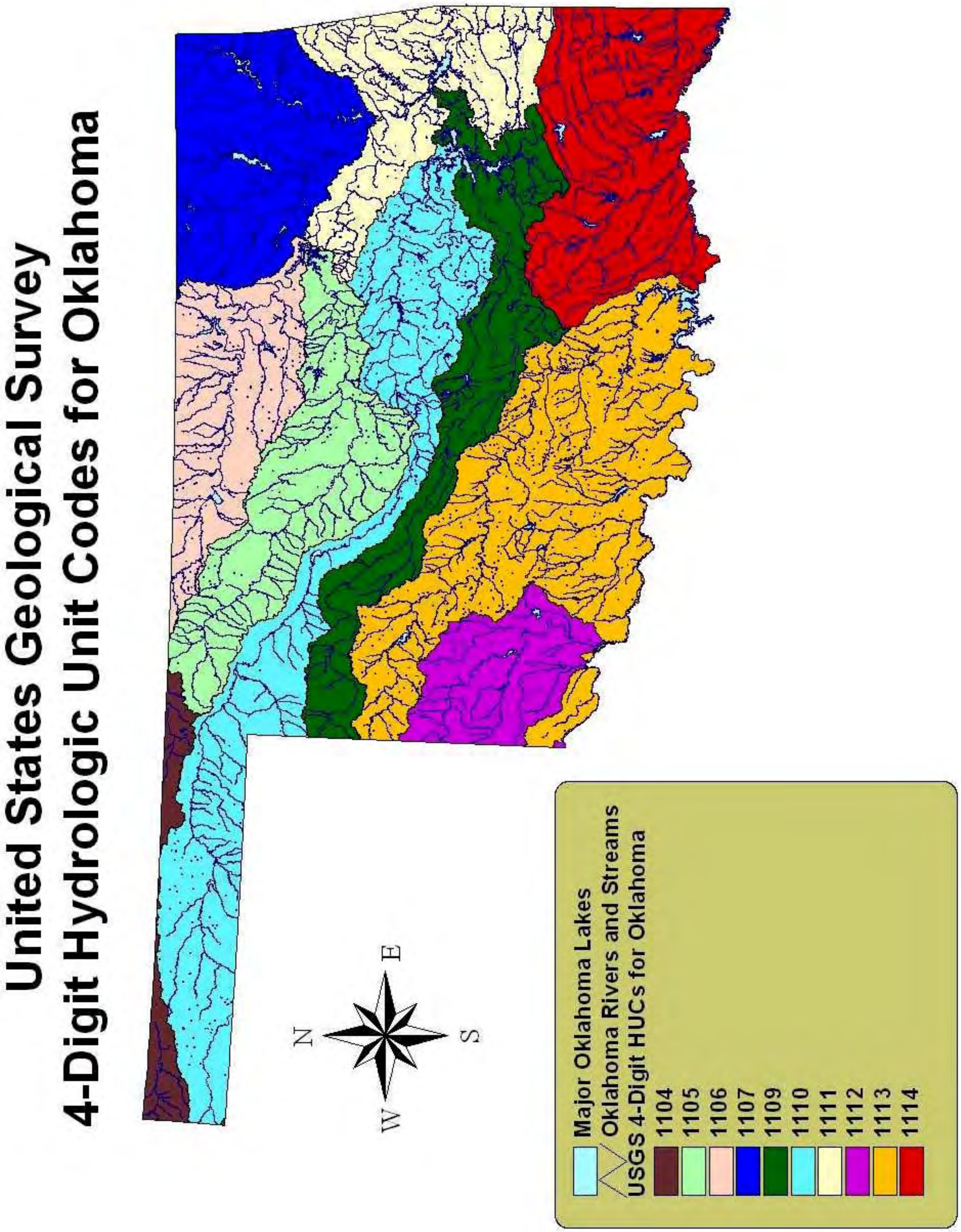


Figure 80. USGS 4-digit HUC basins.

Table 11. Permanent Ambient Trend Monitoring Stations and their Beneficial Use Support Status.

	STATION NAME	FWP	PBCR	PPWS	AG	NUTRIENT
1	Arkansas River, US 64, Moffett	S	CBD	CBD	S	NT
2	Arkansas River, off US 77, Newkirk	NS (5)	NS (6, 10,11)	S	NS (15)	NT
3	Arkansas River, SH 104, Haskell	S	NS (10,11)	N/A	PS (15)	NT
4	Arkansas River, SH 18, Ralston	PS (5)	NS (10,11)	S	S	NT
5	Arkansas River, SH 97, Sand Springs	S	S	N/A	S	NT
6	Arkansas River, US 62, Muskogee	S	NS (6)	N/A	S	NT
7	Arkansas River, US 64, Bixby	NS (3)	S	N/A	S	NT
8	Barren Fork, SH 51, Eldon	S	NS (10,11)	S	S	NT
9	Beaver River, off US 64, Guymon	PS (5)	NS (8, 9, 10,11)	S	S	NT
10	Beaver River, US 83, Turpin	S	NS (6, 7, 8, 9 10,11)	S	NS (15, 16)	NT
11	Beaver River, SH 23, Beaver	NS (3)	NS (6, 7, 8, 9 10,11)	S	NS (15, 16)	NT
12	Beaver River, CR N1650, Gate	S	NS (10,11)	S	S	NT
13	Beaver River, US 183, Fort Supply	S	CBD	S	S	NT
14	Big Cabin Creek, off US 69, Big Cabin	S	S	S	S	NT
15	Bird Creek, SH 266, Port of Catoosa	PS (1,3,5)	NS (6, 8, 9, 10,11)	S	S	NT
16	Black Bear Creek, SH 18, Pawnee	NS (3, 5)	NS (10,11)	S	S	NT
17	Blue River, US 70, Durant	S	NS (10,11)	S	S	NT
18	Brushy Creek, off US 270, Haileyville	NS (5)	NS (6, 10,11)	S	S	NT
19	Canadian River, SH 2, Whitefield	S	S	S	S	NT
20	Canadian River, US 183, Taloga	PS (5)	NS (10,11)	N/A	NS (15, 17)	NT
21	Canadian River, US 270, Calvin	NS (5)	S	S	PS (15, 17)	NT
22	Canadian River, US 377, Konawa	NS (5)	NS (10,11)	S	NS (15, 17)	NT
23	Canadian River, US 66, Bridgeport	PS (5)	NS (6, 10,11)	N/A	NS (15, 17)	NT
24	Canadian River, US 77, Purcell	NS (4, 5)	N/A	N/A	NS (15)	NT
25	Caney Creek, off SH 100, Barber	PS (5)	NS (10,11)	S	S	NT
26	Caney River, off US 75, Ramona	NS (3, 5)	NS (6, 10,11)	S	S	NT
27	Chickaskia River, US 177, Blackwell	NS (3, 5)	NS (6, 10,11)	S	S	NT
28	Cimarron River, SH 34, Buffalo	S	NS (6, 8, 9, 10,11)	S	S	NT
29	Cimarron River, SH 99, Oilton	NS (5)	NS (6, 10,11)	N/A	S	NT

	STATION NAME	FWP	PBCR	PPWS	AG	NUTRIENT
30	Cimarron River, US 77, Guthrie	PS (5)	NS (6, 10,11)	N/A	S	NT
31	Cimarron River, US 81, Dover	NS (3, 5)	NS (6, 8, 9, 10,11)	N/A	S	NT
32	Cimarron River, off US 64, Mocane	NS (3)	NS (6, 10,11)	S	NS (15, 16)	NT
33	Cimarron River, US 412, Orienta	NS (5)	NS (10,11)	N/A	S	NT
34	Cimarron River, SH 33, Ripley	NS (5)	NS (10,11)	N/A	S	NT
35	Clear Boggy Creek, off US 69, Caney	NS (3, 5)	NS (10, 11)	S	S	NT
36	Cow Creek, SH 5, Waurika	NS (5)	NS (10, 11)	S	PS (15)	NT
37	Deep Fork River, off SH 16, Beggs	NS (5)	NS (10,11)	S	S	NT
38	Deep Fork River, US 377, Stroud	NS (3, 5)	NS (10,11)	PS (14)	S	NT
39	East Cache Creek, SH 53, Walters	NS (5)	NS (6,10, 11)	S	S	NT
40	Elk Creek, off US 183, Hobart	S	NS (10,11)	S	S	NT
41	Elk River, SH 43, Tiff City (MO)	S	NS (10,11)	S	S	NT
42	Elm Fork River, SH 9, Mangum	NS (3)	NS (8, 9, 10,11)	NS (12)	S	NT
43	Flint Creek, US 412, Flint	S	NS (10,11)	S	S	NT
44	Fourche-Maline Creek, off US 270, Red Oak	NS (1, 3, 5)	NS (6, 8, 9, 10,11)	S	S	NT
45	Glover River, SH 3, Glover	NS (1, 3)	NS (10,11)	S	S	NT
46	Honey Creek, off SH 25, Grove	S	NS (10,11)	S	S	NT
47	Illinois River, US 59, Watts	NS (5)	NS (10,11)	S	S	NT
48	Illinois River, US 62, Tahlequah	S	NS (10,11)	S	S	NT
49	Kiamichi River, off US 271, Tuskahoma	NS (2, 3)	S	S	S	NT
50	Kiamichi River, SH 63, Big Cedar	NS (3, 4)	S	S	S	NT
51	Kiamichi River, US 271, Antlers	NS (3)	NS (10,11)	S	S	NT
52	Little River, off SH 3, Cloudy	NS (2, 3, 4, 5)	NS (10,11)	S	S	NT
53	Little River, SH 56, Sasakwa	NS (3, 5)	NS (6, 10,11)	S	S	NT
54	Little River, US 70, Idabel	NS (1, 3, 5)	S	S	S	NT
55	Mountain Fork, SH 4, Smithville	NS (3, 4, 5)	S	S	S	NT
56	Mountain Fork, US 70, Eagletown	NS (2, 3)	NS (10,11)	S	S	NT
57	Mud Creek, SH 32, Courtney	NS (1, 5)	NS (6, 10,11)	S	S	NT
58	Muddy Boggy Creek, US 70, Unger	NS (3, 5)	NS (6)	S	S	NT
59	Muddy Boggy Creek, US 69, Atoka	NS (1, 5)	CBD	S	S	NT

	STATION NAME	FWP	PBCR	PPWS	AG	NUTRIENT
60	Neosho River, off US 66, Commerce	S	CBD	S	S	NT
61	Neosho River, off SH 137, Connor Bridge	**PS (5)**	S	S	S	NT
62	Neosho River, SH 82, Langley	**PS (1)**	S	S	S	NT
63	Neosho River, US 412, Chouteau	S	S	S	S	NT
64	North Canadian River, Ind. Nat. Tpk., Dustin	**NS (3, 5)**	**NS (6, 10,11)**	S	S	NT
65	North Canadian River, off I-40, Shawnee	**NS (3, 5)**	**NS (10,11)**	N/A	**NS (15)**	NT
66	North Canadian River, off US 62, Harrah	**NS (4, 5)**	**NS (10,11)**	N/A	S	NT
67	North Canadian River, US 281, Seiling	**PS (5)**	**NS (10,11)**	S	S	NT
68	North Canadian River, US 75, Wetumka	**NS (3, 5)**	**NS (6, 10,11)**	S	S	NT
69	North Canadian River, US 412, Woodward	S	CBD	S	S	NT
70	North Canadian River, US 81, El Reno	**PS (5)**	**NS (10,11)**	S	S	NT
71	North Fork of the Red River, US 62, Headrick	**PS (3, 5)**	**NS (6, 10,11)**	**PS (12)**	**NS (15, 16)**	NT
72	North Fork of the Red River, SH 34, Carter	S	**NS (10,11)**	S	S	NT
73	Poteau River, off SH 112, Pocola	**NS (3, 5)**	**NS (10,11)**	S	S	NT
74	Poteau River, US 59, Heavener	S	S	S	S	NT
75	Red River, SH 79, Waurika	**NS (3, 5)**	S	**PS (12)**	**NS (15**, 16, 17**)**	NT
76	Red River, US 183, Davidson	**NS (3, 5)**	**NS (6, 8, 9, 10,11)**	N/A	**NS (15**, 16, 17**)**	NT
77	Red River, US 259, Harris	**PS (5)**	S	S	**NS (15)**	NT
78	Red River, US 271, Hugo	S	**NS (10,11)**	S	**NS (15**, 16, 17**)**	NT
79	Red River, US 81, Terral	**NS (5)**	**NS (10,11)**	S	**NS (16, 17)**	NT
80	Sager Creek, off US 412, West Siloam Springs	S	**NS (10,11)**	**PS (nitrates)**	S	**T (18, 19)**
81	Salt Fork of the Arkansas, SH 58, Ingersoll	**NS (3, 5)**	**NS (6, 7, 8, 9, 10,11)**	S	S	NT
82	Salt Fork of the Arkansas, US 77, Tonkawa	**PS (5)**	**NS (10,11)**	S	S	NT
83	Salt Fork of the Red River, SH 34, Mangum	CBD	CBD	CBD	CBD	CBD
84	Salt Fork of the Red River, off US 283, Elmer	**NS (2, 3, 5)**	**NS (6, 7, 8, 9, 10,11)**	**NS (12)**	S	NT
85	Sandy Creek, SH 6, Eldorado	**NS (2, 3, 5)**	N/A	N/A	**NS (15, 16)**	NT
86	Skeleton Creek, SH 74, Lovell	**NS (5)**	**NS (6, 8, 9, 10,11)**	S	S	NT
87	Spring Creek, off US 412, Murphy	**PS (1)**	S	S	S	NT
88	Spring River, off SH 137, Quapaw	**NS (2. 3, 5)**	S	S	S	NT

	STATION NAME	FWP	PBCR	PPWS	AG	NUTRIENT
89	Verdigris River, US 412, Inola	NS (3)	CBD	S	S	NT
90	Verdigris River, SH 10, Lenepah	PS (3, 5)	NS (10,11)	S	S	NT
91	Verdigris River, SH 20, Keetonville	NS (3)	NS (10,11)	S	S	NT
92	Verdigris River, SH 51, Wagoner	NS (3, 5)	NS (6)	S	S	NT
93	Washita River, SH 152, Cordell	NS (3, 5)	NS (6, 10,11)	S	S	NT
94	Washita River, SH 19, Pauls Valley	NS (5)	NS (6, 10,11)	S	NS (15)	NT
95	Washita River, SH 33, Hammon	NS (5)	NS (6, 8, 9, 10,11)	S	S	NT
96	Washita River, US 177, Durwood	NS (5)	NS (6, 10,11)	S	S	NT
97	Washita River, US 281, Anadarko	NS (5)	NS (10,11)	S	S	NT
98	West Cache Creek, SH 5B, Taylor	NS (3, 5)	NS (6, 8, 9, 10,11)	S	PS (15, 16)	NT
99	Wolf Creek, off US 270, Fort Supply	S	NS (10,11)	S	S	NT

ASSIGNED OWQS BENEFICIAL USES

FWP = FISH & WILDLIFE PROPOGATION | **PBCR = PRIMARY BODY CONTACT RECREATION**
PPWS = PUBLIC AND PRIVATE WATER SUPPLY | **AG = AGRICULTURE**
NUTRIENT = NUTRIENTS

SUPPORT CODES

FS = FULLY SUPPORTING
CBD = CANNOT BE DETERMINED
FS = PROVISIONALLY FULLY SUPPORTING
NS = NOT SUPPORTING
PS = PARTIALLY SUPPORTING
NS = PROVISIONALLY NOT SUPPORTING
T = THREATENED (NUTRIENTS)

WATER QUALITY VARIABLES

1—DISSOLVED OXYGEN	2— TOXICANTS (ACUTE)	3— TOXICANTS (CHRONIC)
4—pH	5—TURBIDITY	6—FECAL COLIFORM (SL)
7—FECAL COLIFORM (GM)	8—*Escherichia coli*	9— ENTEROCOCCI
10— TOXICANTS (1)	11— TOXICANTS (6)	12— FECAL COLIFORM (PPWS)
13— TOTAL DISSOLVED SOLIDS	14— CHLORIDES	15— SULFATES
16— TOTAL PHOSPHORUS	17— NITRITE + NITRATE	