TMDL Development For Cobb Creek Watershed

And Fort Cobb Lake

FY99 Section 319(h) Grant #C9996100-07

FINAL REPORT

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Executive Summary

Cobb Creek watershed includes two HUC 11 watersheds, 11130302120 & 11130302130 and crosses three counties in west-central of Oklahoma. Fort Cobb is located at the lower end of the watershed and there are four tributaries (Cobb Creek, Lake Creek, Willow Creek, and Fivemile Creek) contributing to the lake. The watershed is primarily rural. There is no point source discharge in the watershed.

Fort Cobb Lake and four tributaries were listed in the Oklahoma 1998 303(d) list for nutrients, suspended solids, siltation, and pesticides. Fort Cobb Lake, Lake Creek and Willow Creek are listed in the 2002 303(d) list. This TMDL report addresses both the 1998 and 2002 303(d) lists.

There are several federal and state agencies collecting water quality data in the watershed. Data used in this project are gathered from U.S. Geological Survey, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, Oklahoma Water Resources Board and Oklahoma Conservation Commission. The data were first used to check the status of impairments for all tributaries and Fort Cobb Lake. It was concluded that Cobb Creek, Lake Creek, Willow Creek and Fivemile Creek were not impaired with regard to nutrients and pesticides. It was also concluded that the Fort Cobb Lake was not impaired for pesticides.

The Fort Cobb Lake was used as the endpoint in the TMDL project. The TMDL targets were dissolved oxygen, anoxic volume and Trophic State Index (TSI) in the lake. Two water quality models were employed to link pollutant sources to water quality targets. A SWAT (Soil and Water Assessment Tool) model was calibrated to simulate nutrient loads to the lake. A three dimensional EFDC (Environmental Fluid Dynamic Code) model was calibrated and verified to model water quality in Fort Cobb Lake. The calibrated EFDC model was then used to predict how much reduction would be needed to restore the Fort Cobb Lake to meet all Oklahoma water quality standards. As a result, the model called for 78% reduction in nutrient load from the watershed. Due to the BMPs implemented in the recent years, it was estimated by the SWAT model that about 20% nutrient reduction had been achieved as of 2005. In order to achieve the recommended nutrient reduction, sediment load to streams and the lake will also be reduced. Therefore, the suspended solids and siltation impairments in Cobb Creek, Lake Creek, Willow Creek and Fivemile Creek are also addressed by this TMDL.

1. Introduction

1.1 Latest Revision

This TMDL report for Cobb Creek Watershed and Fort Cobb Lake was first drafted in 2004 and went through peer reviews among state agencies. Then, the report was sent to the EPA for technical review. After receiving the EPA's technical approval, the report was open for public review on November 24, 2004. A public meeting was held in the Town of Fort Cobb on January 13, 2005. The public review period ended on February 25, 2005. Five written comments were received during the public review period. Not all comments are addressed through the response to the comments process because the SWAT model for the watershed was recalibrated which leads to recalibration of the EFDC model for the lake. As a result, the following significant changes have been made to the TMDL reduction goal and this TMDL report:

1). Update on the SWAT Model

Since there were many questions on land use, tillage, fertilizer application rate, hydraulic calibration and so on, Oklahoma State University conducted a new survey in the Cobb Creek watershed to collect additional data. A detailed survey was given in 2005 to Oklahoma State University (OSU) Cooperative Extension Service Agents and Specialists to gain an understanding of agricultural practices and land cover that occurred from 1996 to 2001. This survey went into great detail about the different types of crops in the basin along with different tillage practices, common double crops, fertilization rates, cattle stocking rates, and harvest dates. With the newly collected data, OSU recalibrated the SWAT model. A pond option was also added to the SWAT model during the recalibration process. As a result, the SWAT model calibration was greatly improved. The newly calibrated model was used to generate nutrient inputs to the Fort Cobb Lake.

It should be emphasized that the SWAT model was calibrated to the conditions when water quality data were collected. Since then, the land cover in the watershed has been changed and certain BMPs have been implemented. In order to evaluate the improvement in nutrient reduction that has occurred in the past few years, OSU also updated the SWAT model with 2005 land cover. The updated SWAT model predicted that on average 20% phosphorus reduction has been achieved since 2001.

2). Update on the EFDC Model

Although there is little difference in the average annual total phosphorus loadings (1995-2000) between the current and previous SWAT model, the difference in loadings from year to year ranges from -37% to 43%, especially for the calibration and verification periods of the EFDC model (as shown in red in the following table). The difference is significant enough to require a new calibration of the EFDC model for the Fort Cobb Lake.

Year	Total P (kg/yr)		Difference
	Previous Model	Current Model	
1995	257794	197000	30.9%
1996	34543	50000	-30.9%
1997	93353	104000	-10.2%
1998	**75933**	**53000**	**43.3%**
1999	47922	76000	-36.9%
2000	**53741**	**81000**	**-33.7%**
Average	**93881**	**93500**	**0.4%**

Trophic State Index (TSI) is the only TMDL target which is not met currently in the Fort Cobb Lake. Thus, TSI is the control factor in determining the reduction goal for this TMDL. A point-to-point comparison between predicted and observed TSI data and R^2 which measures the goodness-of-fit were added to the TMDL report in the model calibration. In addition, the same comparison was made for lake elevation and temperature calibration. Vertical temperature profiles were also added to the report to enhance the hydrodynamic calibration.

The recalibrated EFDC model was then used to predict the nutrient reduction rate needed to meet all TMDL targets. Due to the significant change in nutrient inputs to the lake, the TMDL reduction goal increased from 65% to 78%.

3). Nutrient Input from Migratory Birds

One comment suggested that direct defecation by migratory birds or waterfowl might be an important nutrient source. One section was added to this report to address the potential nutrient additions from waterfowl to Fort Cobb Lake.

Annual mid-winter waterfowl surveys were obtained from U.S. Fish and Wildlife Service for this assessment. Waterfowl in the lake are primarily ducks and small Canadian geese. The waterfowl phosphorus addition to the lake is estimated less than 2% of non-point source loading and primarily occurs in the winter. Therefore, we believe that waterfowl will have little impact on algae growth in the summer.

4). Other Revisions

In addition to the above major updates, many other changes were also made to this report. These changes include annual precipitation plot and EFDC control files etc. The annual rainfall data from 1975 to 2001 were plotted so that one would be able to see the representativeness and appropriateness of the calibration and verification period. The EFDC's master control files were attached at the end of this report so that those interested in the model parameters could check the final parameters used in the EFDC model.

1.2 Introduction

Under Section 303(d) of the Clean Water Act (CWA) as amended by the Water Quality Act of 1987 and the United States Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations [Title 40 of the Code of Federal Regulation (40 CFR), Part 130], states, territories, and authorized tribes are required to develop lists for those waters within their boundaries not meeting water quality standards applicable to their designated uses. States are also required to establish priority rankings for waters on the list and develop Total Maximum Daily Loads (TMDLs) for all pollutants violating or causing violation of applicable water quality standards for each identified waterbody in the list.

A TMDL specifies the maximum amount of a pollutant that a waterbody can receive while still meeting water quality standards, and allocates pollutant load among all point and nonpoint pollution sources. Such loads are established at levels necessary to meet the applicable water quality standards with consideration given to seasonal variations and margins of safety. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. States then establish water quality-based controls and programs to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources [2].

Oklahoma's 1998 303(d) list identified all major streams (Cobb Creek, Lake Creek, Willow Creek, Fivemile Creek) and Fort Cobb Lake in the Cobb Creek watershed as not supporting their designated beneficial uses due to nutrients, suspended solids, siltation, pesticides, exotic species, unknown toxicity, and/or other habitat alterations. By definition, TMDLs can only be developed for specific pollutants. Exotic species, unknown toxicity and other habitat alterations are not pollutants that cause impairments of water being studied and are not within the scope of this report. This report addresses the remaining pollutants in the Cobb Creek watershed.

Cobb Creek watershed includes two HUC 11 watersheds, 11130302120 & 11130302130, which include portions of Caddo, Washita, and Custer counties in Oklahoma (Figure 1-1). At the lower end of the Cobb Creek watershed is Fort Cobb Lake.

Land use in the Cobb Creek watershed consists of forest (6%), pasture (41.4%), agricultural land (50.4%), water (2.1%) and urban area (0.1) [17]. The watershed is in one of the most intensive agricultural farming areas of the state. Over half of the state's peanuts are grown in or near the watershed, along with wheat, alfalfa and many other row crops [6]. The soils are very coarse and fragile, allowing for high infiltration rates and excessive erosion.

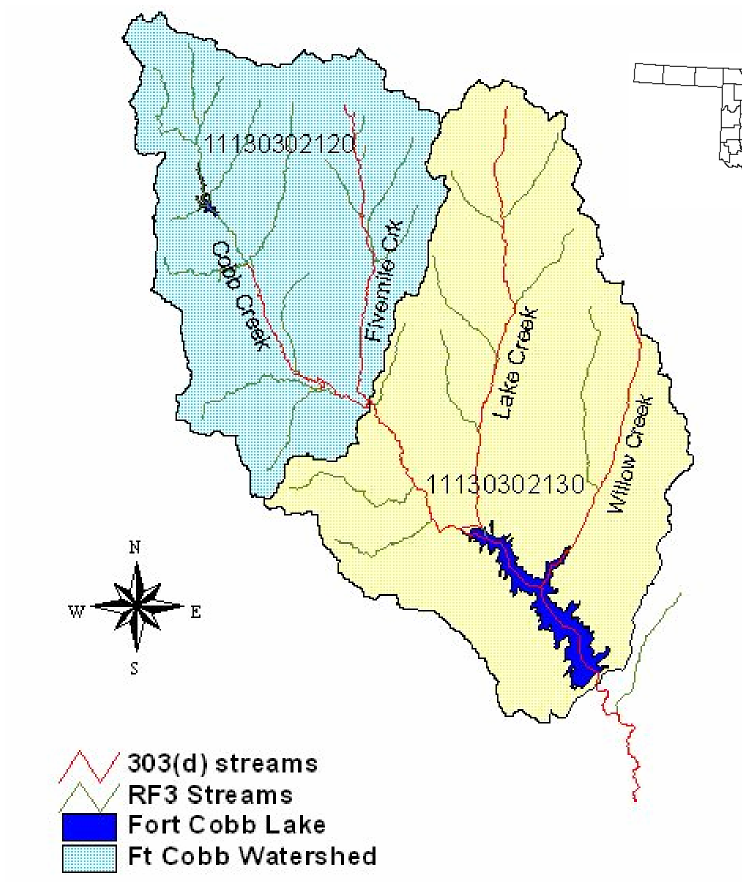


FIGURE 1-1. COBB CREEK WATERSHED STUDY AREA

This study consists of two modeling efforts: a watershed model to estimate non-point source loadings to the Fort Cobb Lake and a lake model to simulate hydrodynamics and water quality conditions in the lake and make comparisons to the applicable water quality criteria.

2. Problem Definition

Fort Cobb Lake and four streams were included in the Oklahoma 1998 303(d) list due to nutrients, suspended solids, siltation, pesticides, exotic species, unknown toxicity, and/or other habitat alternations. Since exotic species, unknown toxicity and other habitat alterations are not pollutants, they will not be included in this TMDL study and are not included in the following table.

TABLE 2-1: 1998 303(d) LIST FOR THE COBB CREEK WATERSHED

Waterbody ID	Name	Area (acres)/ Length (miles)	Nutrients	Siltation	Suspended Solids	Pesticide
OK310830060020	Fort Cobb Lake	3806			X	X
OK310830060010	Cobb Creek	17.3	X	X	X	X
OK310830060080	Fivemile Creek	12.2	X	X	X	
OK310830060040	Lake Creek	16.3	X	X	X	X
OK310830060030	Willow Creek	11.0	X	X	X	

All stream segments in Table 2-1 were assigned priority 3 in the 1998 Oklahoma 303(d) list. Since there are no permitted point source discharges in the entire watershed, the potential impairments are caused by the non-point sources in the watershed such as agricultural activities, cattle and limited small concentrated animal feeding operations (CAFO) in the watershed. There are two CAFOs in the watershed that are considered to be insignificant in the Soil and Water Assessment Tool (SWAT) model conducted by Oklahoma State University.

Because of the way the 303 (d) list was compiled and new information obtained through continuing data collection efforts, the 1998 303(d) list was revisited and reevaluated to determine whether the beneficial uses of waterbodies were still impaired by the listed pollutants. The Oklahoma 2002 Water Quality Assessment Integrated Report indicated that siltation impairments for Cobb Creek, Lake Creek, Willow Creek and Fivemile Creek and suspended solids impairments for Fort Cobb Lake, Cobb Creek, Lake Creek Willow Creek and Fivemile Creek were listed in error based on samples collected under high flow conditions. The siltation and suspended solids impairments for Lake Creek were corrected to turbidity impairment in the Oklahoma's 2002 303(d) list.

The Oklahoma 2002 303(d) list (Table 2-2) shows the latest status of impairments and impairment source codes for streams and lakes in the watershed. The source code of 9000 in Table 2-2 stands for unknown source. The impairments for Cause Unknown and Pathogens are beyond the scope of this study and therefore will not be addressed in this report. The remaining pollutants, together with those in Table 2-1, are re-evaluated in this TMDL report.

TABLE 2-2. 2002 303(D) LIST FOR COBB CREEK WATERSHED

Waterbody ID	Name	Cause Unknown	Turbidity	Phosphorus	Low DO	Pathogens
OK310830060020_00	Fort Cobb Lake			9000		
OK310830060040_00	Lake Creek	9000	9000		9000	
OK310830060030_00	Willow Creek					9000

Fort Cobb Lake and all the streams in the watershed are designated in Oklahoma Water Quality Standards for the following beneficial uses:

- Public and Private Water Supply
- Warm Water Aquatic Community
- Agriculture
- Industrial & Municipal Process and Cooling Water
- Primary Body Contact Recreation
- Aesthetics
- Sensitive Public and Private Water Supply

In addition, the Fort Cobb watershed is also classified as a Nutrient Limited Watershed (NLW).

3. Applicable Water Quality Standards

3.1 Standards for Streams

3.1.a. Standards for nutrients

The Oklahoma Water Quality Standards (OWQS) do not have numerical criteria for nutrients that apply to the streams in the Cobb Creek Watershed. However, they contain the following narrative standard that applies to all streams and lakes in the state:

> "**785:45-5-19 (c) (2) Nutrients**. Nutrients from point source discharges or other sources shall not cause excessive growth of periphyton, phytoplankton, or aquatic macrophyte communities which impairs any existing or designated beneficial use".

The rules for implementation of Oklahoma's Water Quality Standards (OAC 785-46-15) [4] provide a framework that is used in assessing threats to waterbodies or impairments to beneficial uses by nutrients. The implementation rules describe a dichotomous process to be used in determining whether or not a stream is nutrient-threatened. If the dichotomous process indicates a stream is not threatened by nutrients, the stream will be considered not impaired by nutrients.

The dichotomous process uses the follow factors to determine if a stream is threatened by nutrients:

- Stream order
- Stream slope
- Total-Phosphorus (P) concentration
- Nitrate plus nitrite concentration
- Canopy shading
- Turbidity

The application of this dichotomous process to streams in Cobb Creek watershed was utilized to derive the threshold concentrations for Total-P and nitrate plus nitrite. If the mean value of Total-P and nitrate plus nitrite samples in a stream is below their corresponding threshold value, the stream is considered not threatened by nutrients. Table 3-1 shows stream order, slope and the threshold values for Total-P and nitrate plus nitrite for streams in the Cobb Creek watershed.

As shown in Figure 3-1, the stream order is determined using the BASINS rf3 reach file [9]. The stream orders given in Table 3-1 are for those segments where samples were taken.

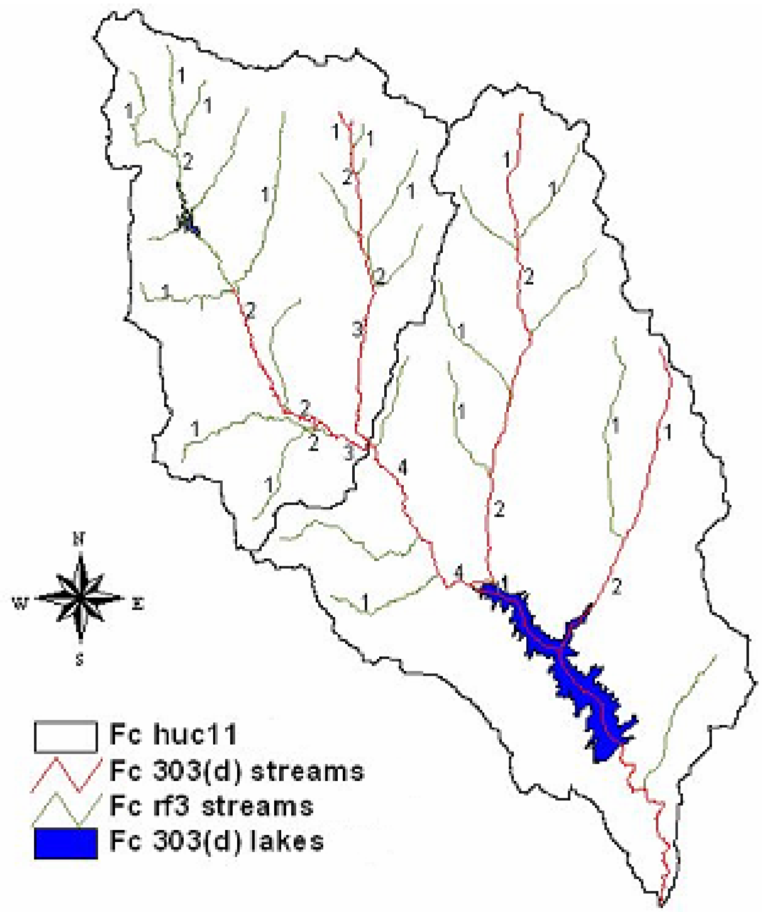


FIGURE 3-1. STREAM ORDER (COBB CREEK WATERSHED)

TABLE 3-1: THRESHOLD VALUES FOR STREAM TOTAL-P AND NO_2+NO_3

Stream	Stream Order	Slope (ft/mile)	Total-P (mg/L)	$NO_2 + NO_3$ (mg/L)
Willow Creek	2	<17	0.15	2.40
Lake Creek	2	<17	0.15	2.40
Trib to Lake Creek	1	≥ 17	0.24	4.95
Cobb Creek	4	<17	0.36	5.00

3.1.b. Standards for Dissolved Oxygen

The Oklahoma Water Quality Standards (OWQS) has the following criteria for dissolved oxygen:

Summer (Jun 16 – Oct 15): 4 mg/L

Seasonal (Oct 16 – Jun 15): 5 mg/L

The dissolved oxygen criteria must be maintained at all time.

3.2 Standards for Fort Cobb Lake

The Oklahoma Water Quality Standards do not contain numerical standards for nutrients and suspended solids; only narrative standards for nutrients and suspended solids can be found in the OWQS. However, it is very difficult to use narrative standards as the targets of this TMDL. The targets of a TMDL need to be numerical or quantified in some way.

Fort Cobb Lake and its watershed are classified in the OWQS as Nutrient-Limited Watershed (NLW). Nutrient-Limited Watershed, by definition, means a watershed of a waterbody with a designated beneficial use that is adversely affected by excess nutrients as determined by Carlson's Trophic State Index (using chlorophyll-a) of 62 or greater. According to the Implementation of Oklahoma's Water Quality Standards [4], the beneficial uses designated for Fort Cobb Lake are presumed to be fully supported but threatened. Since the lake is considered threatened when Carlson's Trophic State Index (TSI) is 62 or greater, a TSI value less than 62 was chosen as one endpoint of this TMDL.

In addition to TSI, dissolved oxygen criteria in the Oklahoma Water Quality Standards and the Implementation of Oklahoma's Water Quality Standards also apply to Fort Cobb Lake. The following endpoints are identified for this TMDL:

- Dissolved Oxygen (DO) for the surface water must meet the following requirements:
  - Summer (Jun 16 – Oct 15): 4.0 mg/L
  - Seasonal (Oct 16 – Jun 15): 5.0 mg/L
- Anoxic volume of water column in the lake must be less than 50%. The anoxic volume is defined as the vertical water column where the dissolved oxygen concentration is less than 2 mg/L.
- Carlson's Trophic State Index (TSI) must be less than 62. TSI can be calculated as follows:

$$TSI = 9.81 \times Ln\,(\text{chlorophyll-}a) + 30.6$$

The unit of chlorophyll-*a* is μg/L.

Dissolved oxygen criteria must be maintained at all times. Anoxic volume and TSI criteria could not be exceeded more than 10% of the time in order to achieve compliance.

3.3 Pesticide Standards

Because Alachlor and Aldicarb were detected in both surface water and streamside seepage samples, pesticides were identified in the1998 303(d) list as a cause of impairment.

To determine whether the surface water is actually impaired, water quality criteria for the surface water need to be checked. Review of the pesticide monitoring data for Lake Creek indicates that none of the pesticides tested exceeds any water quality standards. .

Oklahoma Water Quality Standards do not have any numerical criteria specifically for Alachlor or Aldicarb. The following requirements for toxic substances in general apply:

> "For toxicants not specified in Table 2 of Appendix G of this Chapter, concentrations of toxic substances with bio-concentration factors of 5 or less shall not exceed 0.1 of

published LC_{50} value(s) for sensitive representative species using standard testing methods …”.

“For toxicants not specified in Table 2 of Appendix G of this Chapter, concentrations of toxic substances with bio-concentration factors greater than 5 shall not exceed 0.01 of published LC_{50} value(s) for sensitive representative species using standard testing methods …”.

Both Alachlor and Aldicarb are not specified in Table 2 of Appendix G of the OWQS.

The technical fact sheets of EPA’s National Primary Drinking Water Regulations [12][13] indicate that the bio-concentration factors (BCF) for Alachlor and Aldicarb are 6 and 42, respectively. Since both BCF values are greater than 5, the target values for Alachlor and Aldicarb will be 0.01 of their published LC_{50} values.

Published LC_{50} values for Alachlor and Aldicarb were found from the following public resources:

- EXTOXNET, Extension Toxicology Network[15], which is a pesticide information project of Cooperative Extension Offices of Cornell University, Oregon State University, the University of Idaho, and the University of California at Davis and the Institute for Environmental Toxicology, Michigan State University. The USDA/Extension Service/National Agricultural Pesticide Impact Assessment Program provided major support and funding.
- Virginia Corporative Extension [14], Virginia Tech and Virginia State University.
- PAN Pesticides Database [8], derived from the U.S. EPA AQUIRE (AQUatic toxicity Information REtrieval) Database.

TABLE 3-2. PUBLISHED LC_{50} VALUES FROM DIFFERENT SOURCES

Reference	Chemical Name	LC_{50} (µg/L)		
		Fathead Minnow	Catfish	Common, mirror, colored, carp
EXTOXNET Extension Toxicology Network	Alachlor	-	6500	-
	Aldicarb	-	-	-
Virginia corporative Extension	Alachlor	-	-	-
	Aldicarb	-	-	-
U.S. EPA AQUIRE Database	Alachlor	5700	15700	5600
	Aldicarb	2700	23300	1000

Using the general methodology in the Oklahoma Water Quality Standards and the most stringent LC_{50} values in Table 3.2 for sensitive representative species, the target values for Alachlor and Aldicarb are calculated as 56.0 µg/L and 10.0µg/L, respectively.

3.4 Antidegradation Policy

Oklahoma antidegradation policy (OAC 785:45-3) requires protecting all waters of the state from degradation of water quality. The targets of this TMDL, resulting load reduction, and load allocations in this report were set with regard for all elements of the Oklahoma Water Quality Standards which includes the antidegradation policy. With the implementation of this TMDL, the water quality in Fort Cobb Lake and the streams in the watershed will be improving rather than degrading.

4. Impairment Assessment & TMDL Targets

Oklahoma's 2002 Water Quality Assessment Integrated Report has concluded that siltation and suspended solids impairments were listed in error for Cobb Creek, Lake Creek, Willow Creek and Fivemile Creek in the Oklahoma's 1998 303(d) list based on high flow high flow suspended solids and turbidity sampling. The siltation and suspended solids impairments for Lake Creek were corrected to turbidity impairment in the Oklahoma's 2002 303(d) list. Therefore, siltation and suspended solids will not be addressed in this report.

4.1. Status of Nutrient Impairment in Streams

Lake Creek, Willow Creek, Cobb Creek and Fivemile Creek are listed for nutrient impairment in the 1998 303(d) list. The Oklahoma Conservation Commission (OCC) conducted quarterly sampling on Lake Creek and its tributary during 1998 and 1999. The U.S. Geological Survey (USGS) sampled Fort Cobb Lake and its contributing streams during 2000 and 2001. These data are used to determine the status of nutrient impairment for Lake Creek, Willow Creek, and Cobb Creek

4.1.a. Data from OCC

The Oklahoma Conservation Commission sampled five (5) sites in Lake Creek from August 1998 to October 1999. Table 2 shows the legal descriptions of the five monitoring sites.

Samples were collected monthly at Sites 1 & 4 for nutrients and salt analysis which included nitrate/nitrite, total Kjeldahl nitrogen, total P, sulfate, total suspended solids, chloride, and hardness. Monthly field data were collected concurrently at all five sites. Field monitoring included flow rate, dissolved oxygen, temperature, pH, specific conductivity, turbidity, and alkalinity. In addition to regular monthly monitoring, two high flow events were sampled for water quality and field data at Site 1 on April 25, 1999 and June 21, 1999.

TABLE 4-1. OCC WATER QUALITY MONITORING STATIONS

Monitoring Sites	Latitude	Longitude	Legal	County
Lake Creek #1	35° 15' 30.4" N	98° 31' 54" W	S12, T9N, R13W	Caddo
Lake Creek #2	35° 18' 16.6" N	98° 31' 36.2" W	S36, T10N, R13W	Caddo
Lake Creek #3	35° 20' 01.2" N	98° 31' 36.2" W	S24, T10N, R13W	Caddo
Lake Creek #4	35° 21' 45.7" N	98° 30' 56.8" W	S7, T10N, R12W	Caddo
Lake Creek #5	35° 24' 21.9" N	98° 31' 14.5" W	S 25, T11N, R13W	Caddo

Sampling Site #1 was located on Lake Creek and Site #4 on a tributary to Lake Creek. Figures 4-1 and 4-2 show the total phosphorus (TP) and nitrogen (NO2 + NO3) data and the corresponding threshold values for Lake Creek and its tributary.

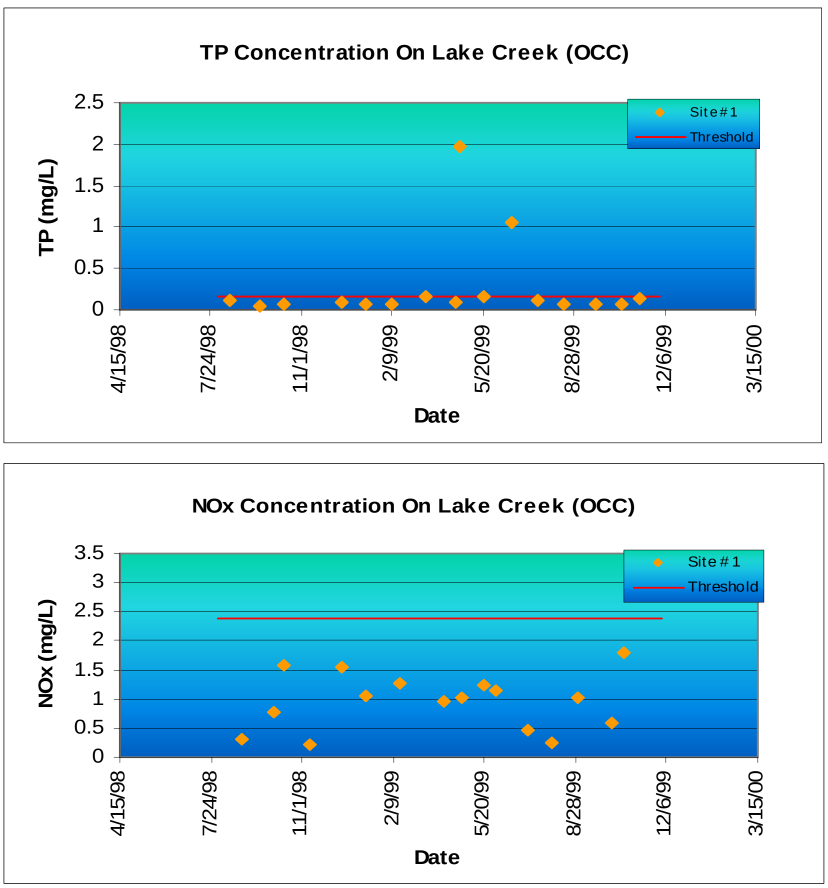
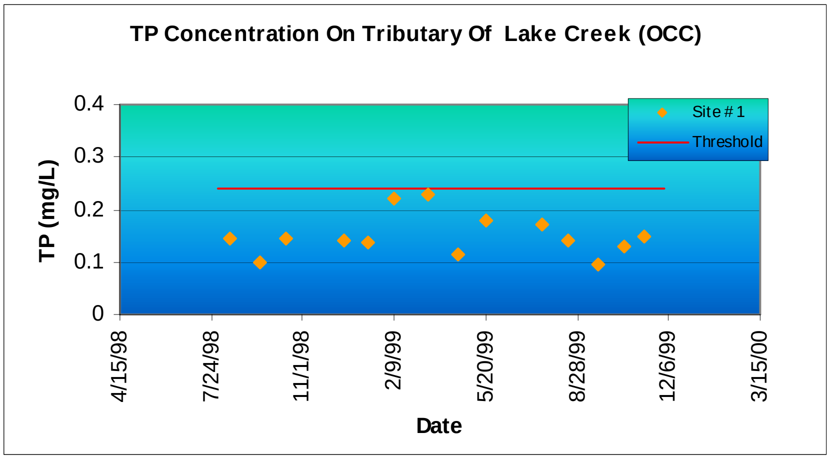


FIGURE 4-1. TOTAL-P, NO_3/NO_2 CONCENTRATION IN LAKE CREEK



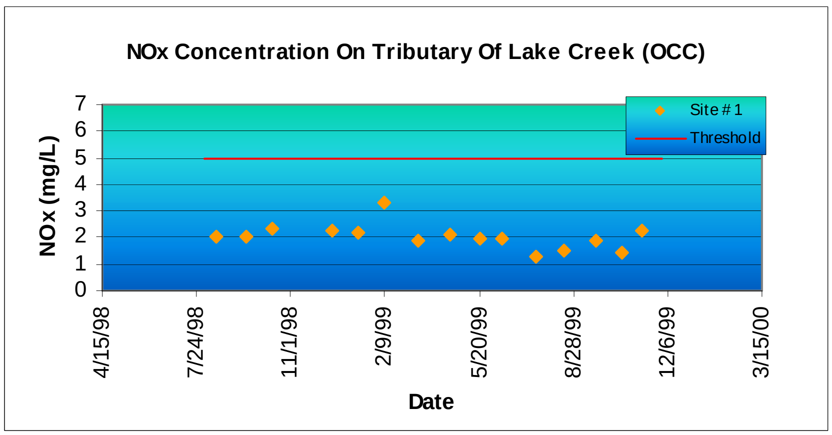


FIGURE 4-2. TOTAL-P, NO_3/NO_2 CONCENTRATION IN TRIBUTARY OF LAKE CREEK

If the mean of the samples does not exceed the threshold, according to the dichotomous process, the stream is not threatened by nutrients.

As shown in Figure 4-1 & 4-2, the mean values of TP or $NO_2 + NO_3$ of all samples are well below their corresponding threshold values. Both Lake Creek and its tributary are not nutrient-threatened so they are not nutrient-impaired.

4.1.b. Data from USGS

Bi-monthly monitoring was conducted from June 2000 to June 2002 at 26 sites (Figure 4-3). Sixteen sites are located in Fort Cobb Lake and ten sites in three major tributaries, namely Lake

Creek, Cobb Creek and Willow Creek. The sites in the lake were designed to characterize the spatial trend of the lake water quality. The sites in the tributaries were intended to determine the source and load of nutrients to the lake.

Parameters monitored included temperature, pH, DO, specific conductivity and Oxidation Reduction Potential (ORP), hardness, nitrate/nitrite, ammonia, total nitrogen, total phosphorus, Soluble reactive phosphorus (SRP), particulate organic carbon.

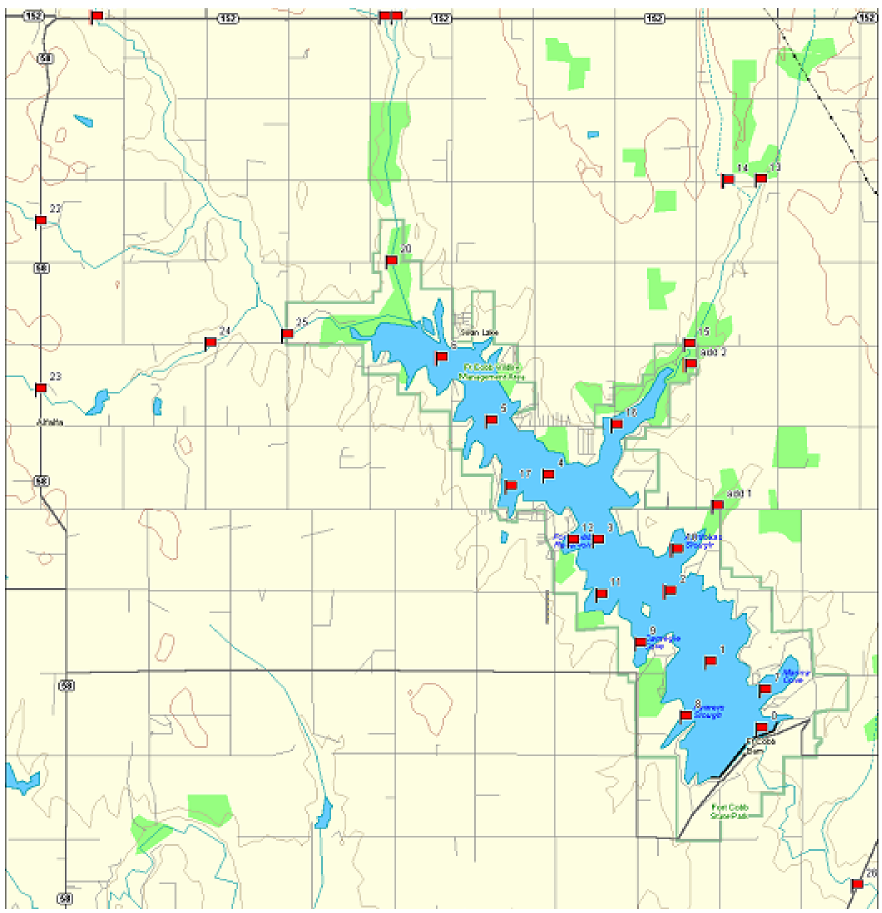
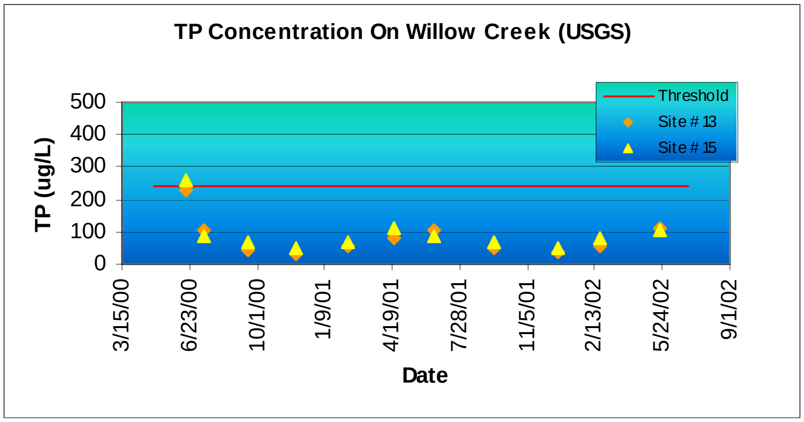


FIGURE 4-3. USGS MONITORING STATIONS (PROVIDED BY USGS)



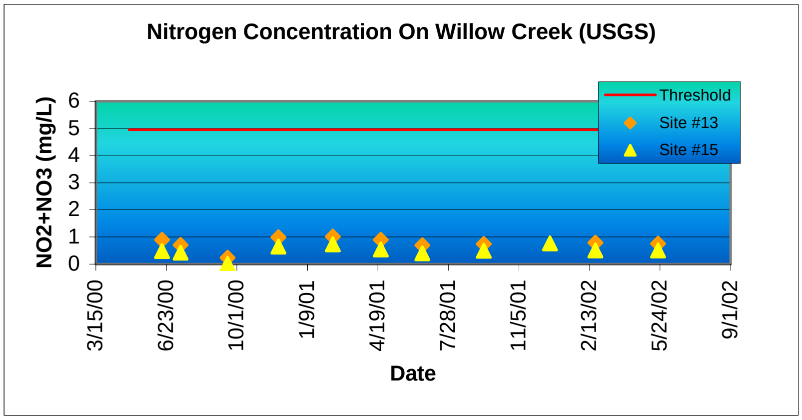
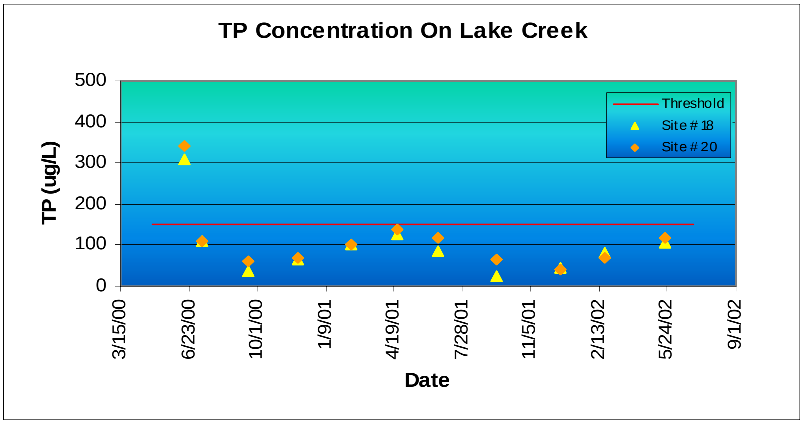


FIGURE 4-4. TOTAL-P, NO_3/NO_2 CONCENTRATION IN WILLOW CREEK



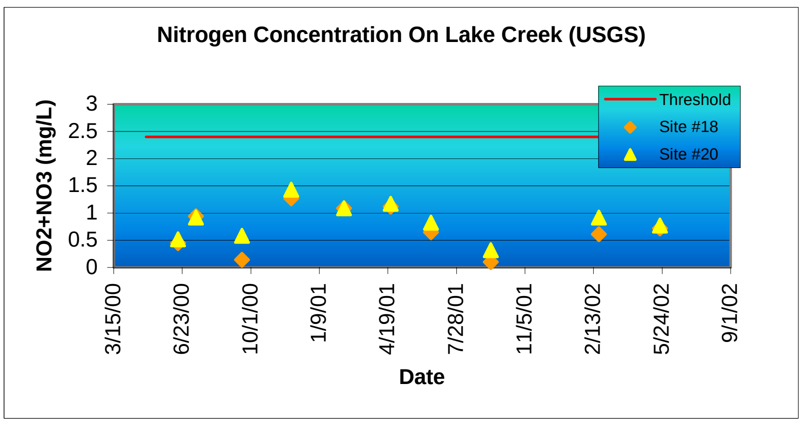


FIGURE 4-5. TOTAL-P, NO_3/NO_2 CONCENTRATION IN LAKE CREEK

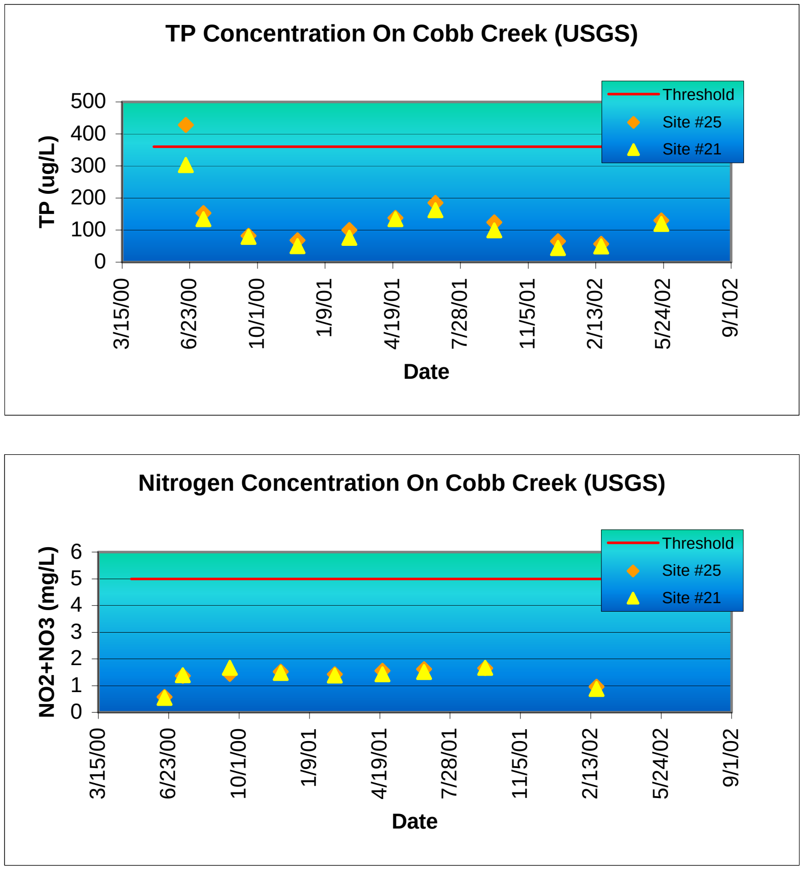


FIGURE 4-6. TOTAL-P, NO_3/NO_2 CONCENTRATION IN COBB CREEK

As shown in Figure 4-4, 4-5 & 4-6, the mean values of TP or NO_2 + NO_3 are well below their corresponding threshold values (Table 3-1). Cobb Creek, Lake Creek and Willow Creek are not nutrient-threatened and therefore are not nutrient-impaired.

There is not enough data on Fivemile Creek to assess the status of nutrient impairment. USGS collected only three samples on site 29 & 30. No samples exceeded TP or TN threshold values. In addition, the 2002 Water Quality Assessment Integrated Report [16] indicated that the nutrient impairment for Fivemile Creek was listed in error in the 1998 303(d) list.

4.2. Status of Nutrient Impairment in Fort Cobb Lake

In addition to the data collected by USGS in Fort Cobb Lake, Oklahoma Water Resources Board (OWRB) and U.S. Fish & Wildlife Service (USFWS) also conducted quarterly sampling in the lake. These data are used to determine the status of nutrient impairment for Fort Cobb Lake.

Fort Cobb Lake was not listed in the 1998 303(d) list for nutrient impairment but was included on the 2002 list. The available data support the listing.

Oklahoma Water Resources Board has conducted quarterly water quality monitoring at six sites in Fort Cobb Lake from July 1998 to July 1999. Figure 4-7 shows the six sampling sites. The monitored water quality parameters include NH_3, NO_2, NO_3, Total N, Organic N, TKN, Ortho-P, Total P, Settleable and Suspended Solids, Chloride, Chlorophyll-*a* and Turbidity. Field data include temperature, dissolved oxygen, pH, Conductivity, Total Dissolved Solid (TDS) and other parameters at different depths in the water column. USGS conducted bi-monthly water quality sampling on sixteen sites in Fort Cobb Lake, (Figure 4-3). The sampling started in June of 2000 and ended in June of 2002. Depth profiles of temperature, pH, DO, specific conductivity and Oxidation Reduction Potential (ORP) were conducted for sites in the lake. Water samples for laboratory analysis were collected as a surface composite and analyzed for nutrients (TN, TP, NO_2/NO_3, NH_3, SRP), Chlorophyll-*a*, particulate organic carbon (POC) and physical chemistry (pH, alkalinity, hardness, turbidity, conductivity, and total dissolved solids). In addition, samples were collected for algae taxonomy.

U.S. Fish & Wildlife Service, sponsored by U.S. Bureau of Reclamation, conducted quarterly water quality sampling on sixteen sites on Fort Cobb Lake, its tributaries and outflows (Figure 4-8). The sampling started in November of 1997 and ended in June of 2000 [11].

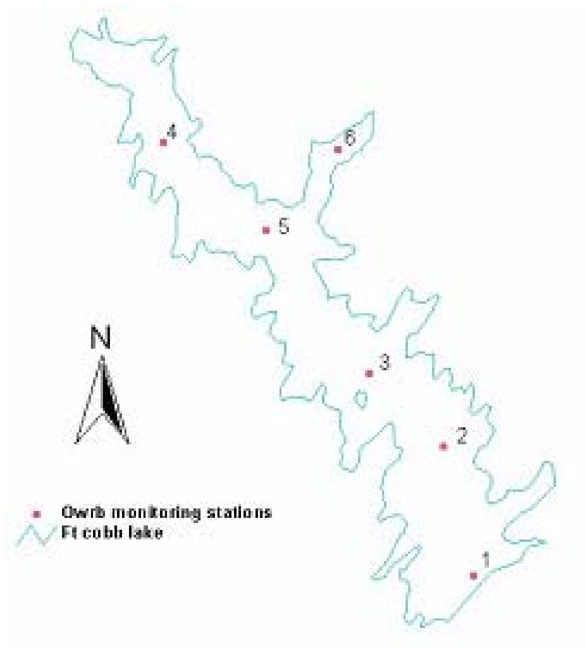


FIGURE 4-7. OWRB MONITORING STATIONS IN FORT COBB LAKE

The constituents analyzed include conductivity, turbidity, chlorophyll-*a*, COD, total phosphorus, soluble reactive phosphorus, total alkalinity, chloride, sulfate, total nitrogen, nitrate, nitrite and ammonia. In addition, other constituents such as metals etc. were also analyzed in water samples. However, these parameters are not in the scope of this TMDL. A review of the data for these parameters does not show any violations of water quality standards.

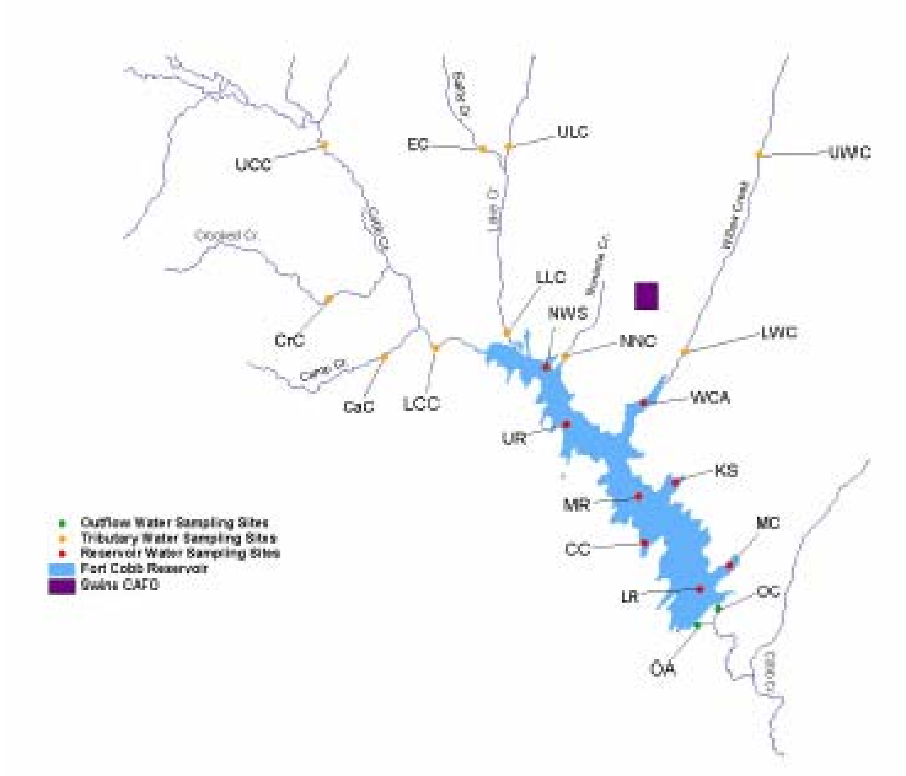


FIGURE 4-8. USFWS MONITORING STATIONS

The TSI data from USGS, OWRB and USFWS is summarized in Table 4-2. The aesthetics beneficial use for Fort Cobb Lake is considered not threatened with respect to nutrients if planktonic chlorophyll-*a* samples in the water column indicate a Carlson's Trophic State Index of less than 62.

TABLE 4-2. SUMMARY OF TSI DATA

Agencies	Median TSI	Min TSI	Max TSI	# Of TSI >= 62	Total # Of TSI	% Of TSI >= 62
OWRB	63.7	34.0	77.6	21	34	62%
USGS	61.2	38.8	85.2	67	158	42%
USFWS	61.8	41.7	78.8	34	72	47%

Data in Table 4-2 support the 303(d) status that Fort Cobb Lake does not support the Aesthetics beneficial use with respect to nutrients.

4.3. Status of Pesticide Impairment

Samples for organics and herbicides were taken by the OCC from August 1998 to June 1999. Immunoassays for pesticides (2,4-D, Alachlor, Aldicarb, Atrazine, Captan, Carbofuran, Chlorothalonil, Chlorpyrifos, Cyanazine, Metolachlor, Metribuzin, Paraquat, Picloram, and Triclopyr) were performed twice monthly during the spring & summer (March – October) and once monthly during fall and winter (November – February).

TABLE 4-3. LC-50 VALUES AND TARGET CRITERIA FOR PESTICIDES

Pesticides	LC-50 (µg/L)			Target Criteria (µg/L)
	Fathead Minnow	Channel Catfish	Common, mirror, colored, carp	
2,4-D	191500	7000	58271	70.0
Alachlor	5700	15700	5600	56.0
Aldicarb	2700	23300	1000	10.0
Atrzine	15000	4982	28467	49.8
Captan	155	78.3	250	0.78
Carbofuran	1264	629	1405	6.29
Chlorothalonil	-	81.5	110	0.82
Chlorpyrifos	178.5	457	76.9	0.77
Cyanazine	18630	12862	-	128.6
Metolachlor	8200	4900	-	490.0
Metribuzin	-	32540	-	325.4
Paraquat	-	100000	78500	785.0
Picloram	64033	13571		135.7
Triclopyr	NA for above species, but >1000 for all other tested species			10.0

Table 4-3 shows the target criteria for each pesticide. The target criteria are determined by multiplying the minimum LC_{50} by 0.01 for each pesticide. The LC_{50} values are derived from the U.S. EPA AQUIRE database.

The pesticide data collected by the OCC were compared with the criteria in Table 4-3 for each pesticide to determine the status of pesticide impairment for Lake Creek. Since no pesticide data exists for Cobb Creek and Fort Cobb Lake, the evaluation of the status of pesticide impairment relies on the comparison of the data for Lake Creek and the prediction of the Soil and Water Assessment Tool (SWAT) model performed by Oklahoma State University.

4.3.a. Lake Creek

OCC collected pesticide data on different sites of Lake Creek from August 1998 through October 1999. Alachlor and Aldicarb are the only two pesticides that were detected in both surface water and streamside seepage samples. We believe this is the reason that Alachlor and Aldicarb were listed in the 1998 303(d) list. Alachlor was detected in 13 of the 76 total samples and Aldicarb was detected in 19 of the 62 total samples. The highest concentration measured was 0.26 μg/L for Alachlor and 1.58 μg/L for Aldicarb. Both values are well below the corresponding target values.

Other pesticides were screened against the target criteria (Table 4-3). None of the measured data exceeds the corresponding target criteria. Therefore, it can be concluded that pesticides do not impair Lake Creek.

4.3.b. Cobb Creek

In addition to Lake Creek, Cobb Creek and Fort Cobb Lake are listed in the 1998 303(d) list for pesticide impairment. No monitoring data are available for either of the water bodies.

Oklahoma State University has performed a SWAT model to simulate nutrient and pesticide loadings from the Fort Cobb Watershed [17]. The model is calibrated for flow and nutrients, but it is not calibrated for pesticides because of limited pesticide data. The model is not suitable for predicting the actual pesticide mass loadings from the watershed but is adequate for comparison of the relative pesticide loadings from different sub-watersheds.

A comparison of land uses in Lake Creek sub-basin and Cobb Creek sub-basin are made in Table 4-4. Both sub-basins have a majority of land used for agricultural practices where pesticides are normally applied. The percentage of agricultural land in the Lake Creek sub-basin is slightly higher than that in the Cobb Creek sub-basin. The SWAT model was calibrated for pesticides based on data collected in Lake Creek. When the same calibrated parameters are applied to the Cobb Creek sub-basin, the model should give a conservative prediction of pesticides on a relative basis.

TABLE 4-4. LAND USE COMPARISON FOR COBB CREEK AND LAKE CREEK SUB-BASINS

Land Use Name	Land Use (%)	
	Cobb Creek Sub-basin	Lake Creek Sub-basin
Urban or Built-up Land	0.3%	0.5%
Agricultural Land	85.7%	92.2%
Forest Land	0.1%	1.8%
Range Land	13.6%	5.5%
Barren Land	0.0%	0.0%
Water	0.3%	0.0%

Pesticide loadings and concentrations from the Cobb Creek sub-basin and the Lake Creek sub-basin as predicted by the SWAT model are shown in Table 4-5.

TABLE 4-5. PESTICIDE LOADINGS (APRIL 1999 – AUGUST 1999)

	Pesticide Loading (kg)	Total Accumulative Flow (m^3)	Average Pesticide Concentration (µg/L)
Cobb Creek	394.9	1.42E+07	0.28
Lake Creek	300.4	9.78E+06	0.31

The pesticide loading in Table 4-5 is the loading from April 1999 to August 1999. The loading for other months of the year is negligible because little or no pesticides are applied in these months.

As shown in Table 4-5, the predicted pesticide concentration in Cobb Creek is even lower than that in Lake Creek. Because the observed pesticide concentrations in Lake Creek are well below the standards and the pesticide concentrations in Cobb Creek are relatively lower than those in

Lake Creek, we can conclude that the pesticide concentration in Cobb Creek is well below the standards. In other words, pesticides do not impair Cobb Creek.

4.3.c. Fort Cobb Lake

It is safe to assume that the only source of pesticides to Fort Cobb Lake is pesticides in stream flows of the tributaries to Fort Cobb Lake. Since none of Fort Cobb Lake's tributaries are impaired by pesticides, a simple mixing model can show that Fort Cobb Lake is not impaired by pesticides.

Assume :

V_i = volume from stream i, (i = 1,2,…n)

V = volume after mixing, $V = V_1 + V_2 + \ldots + V_n$

C_i = concentration in stream i, (i = 1,2,…n)

C_0 = critical concentration, $C_0 > C_i$ for i = 1,2,…n

C = concentration after mixing

Based on mass balance, we get:

$$V \cdot C = V_1 \cdot C_1 + V_2 \cdot C_2 + \ldots + V_n \cdot C_n$$

Substitute C_i with C_0:

$$V \cdot C < C_0 \cdot (V_1 + V_2 + \ldots + V_n)$$

Cancel volume on both sides:

$$C < C_0$$

Therefore, we can conclude that the water after mixing is not impaired if none of the tributaries is impaired.

4.4. Status of Dissolved Oxygen Impairment for Lake Creek

Dissolved oxygen for Lake Creek is not listed in 1998 303(d) list. However, it is listed in 2002 303(d) list (Table 4-5). Further inquiry showed that low DO for Lake Creek was added on the 2002 list based on data from Oklahoma Conservation Commission (OCC).

Oklahoma Conservation Commission measured dissolved oxygen on five sites in Lake Creek from May 1998 to October 1999. A total of 119 dissolved oxygen samples were taken. All measurements are above dissolved oxygen standards for streams. Therefore, Lake Creek is not impaired by low dissolved oxygen. We believe the low DO listing was listed in error in 2002 303(d) list.

4.5. Endpoint and Targets for Fort Cobb TMDL

This TMDL addresses turbidity impairment for Lake Creek and phosphorus impairment for Fort Cobb Reservoir. Since phosphorus is mostly found attached to sediment or TSS (which is closely related to turbidity), if phosphorus loading is reduced to meet water quality standards in Fort Cobb Lake, turbidity levels in the contributing streams, including Lake Creek, will also be reduced, thus meeting the turbidity standard.

This TMDL study consists of two modeling efforts: a watershed model to estimate non-point source loadings to Fort Cobb Lake and a lake model to simulate hydrodynamics and water quality conditions in the lake. Following are the selected endpoint targets of the TMDL:

- Trophic State Index (chlorophyll-*a* based) less than 62
- Dissolved Oxygen (surface water)
  - Summer (Jun 16 – Oct 15): 4.0 mg/L
  - Seasonal (Oct 16 – Jun 15): 5.0 mg/L
- Anoxic volume less than 50% of water column

5. Source Assessment

This TMDL report examined the major potential sources of nutrients in the Fort Cobb watershed. The source assessment was used as the basis for developing the modeling strategy and ultimate analysis of the TMDL allocation options. To evaluate sources, loads are characterized by the best available information, monitoring data, literature values, and local management activities. This section documents all the available information and interprets it for modeling analysis.

5.1. Assessment of Point Sources

There is currently no permitted wastewater discharge in Fort Cobb watershed. Regulated storm water discharges are also considered as point source pollution and must be addressed by the wasteload allocation component of a TMDL. In Oklahoma, storm water discharge permits are divided into two categories: industrial and construction. The database for storm water discharges (updated as of May of 2004) shows no permitted storm water discharge in the Fort Cobb watershed (Figure 5-1) and no regulated municipal separate storm sewer system discharge. This does not necessarily mean there will be no storm water permits in the watershed in the future. The conditions in storm water permits will be sufficient to protect waters in the watershed.

There are four Concentrated Animal Feeding Operation (CAFO) farms in the Fort Cobb watershed (Table 5-0). All four CAFOs are located in Caddo County.

TABLE 5-0. CAFO FACILITIES IN COBB CREEK WATERSHED

Name	Location	Farm Type	Total units
Harvey Farms	NE of S33, T11N, R13W	Cattle	2700
Terry Lierle	SE of S30, T11N, R13W	Swine	800
Maschhoff West Randolph sow & nursery	NW/SW/SW of S09, T11N, R13W	Swine	3096
Farmers F & F Farms Inc	SE/NE of S20, T08N, R12W	Cattle	750

A CAFO is an animal feeding operation that confines and feeds 1,000 animal units or more for 45 days or more in a 12 month period. An animal unit is a measure that is used to compare different animal species. According to the EPA, 1000 animal units is equivalent to 1000 cattle excluding mature dairy and veal cattle, 10,000 swine weighed 55 pounds or less, or 100,000 chickens.

The NPDES permit for CAFOs with less than 1000 animal units is encouraged but not required. Both Harvey Farms and Terry Leirle have a total retention permit. Overflows are allowed for these farms only under 25-year 24-hour storm events. The provisions in these NPDES permit are sufficient to protect the waters in the Cobb Creek watershed. No additional measures will be required for these CAFO farms. The animal waste produced by CAFOs is considered non-point pollution that is addressed in the following section.

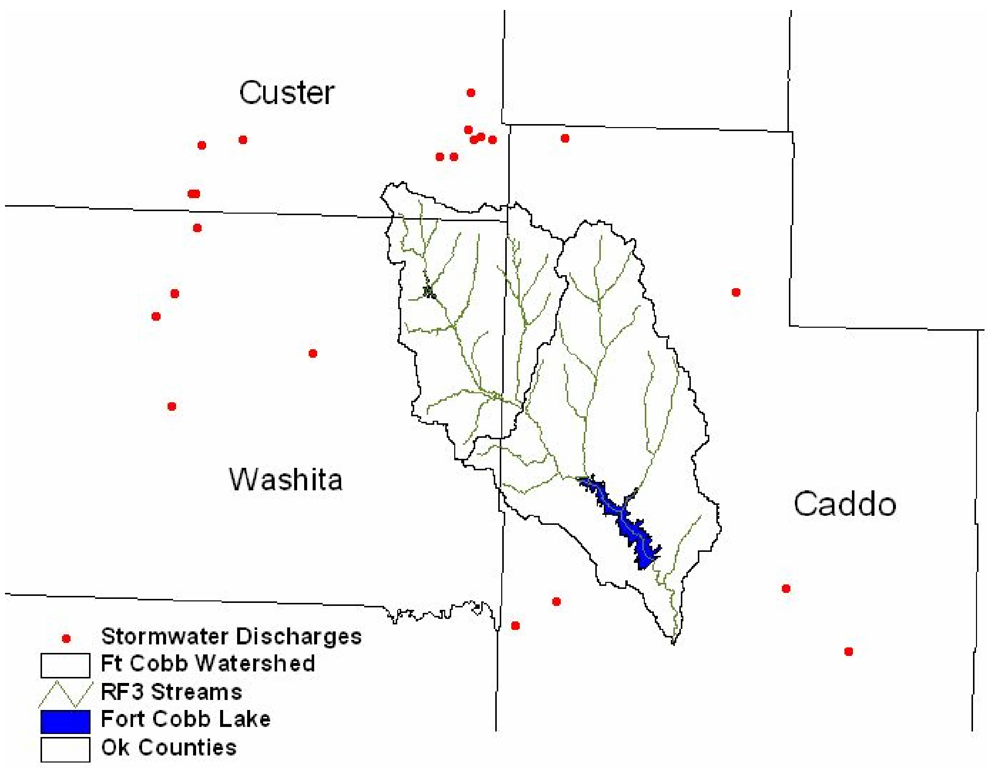


FIGURE 5-1 STORM WATER DISCHARGES

5.2. Assessment of Nonpoint Sources

Nonpoint sources of pollutants are typically separated into urban and rural categories. Surface storm runoff is an important source of loading in urban or residential settings with high amounts of paved, impervious areas. In rural settings, the amount of impervious area is usually much lower; but the sources of nutrients may include runoff of applied fertilizer and manure to agricultural land, runoff of animal wastes associated with the erosion of sediments in grazing fields, runoff from concentrated animal operations, failing septic tanks and contributions from wildlife.

5.2.a. Septic Systems

Septic systems are the most commonly used on-site treatment system in the United States. The system consists of the septic tank and soil absorption area (drainfield). In optimal operating conditions, septic systems treat domestic wastewater as well as, or even better than, mechanical treatment systems. In contrast to the highly mobile nitrate nitrogen, most phosphate reacts vigorously with soils. Phosphate ions are removed from the soil solution by several mechanisms, including adsorption, precipitation, plant uptake, and biological immobilization [22]. Effluent from septic tanks is not likely to reach surface water unless the systems are close to drainage ditches, streams, or lakes. A query of the complaint database at the Oklahoma Department of Environmental Quality shows a total of two incidences of surfacing sewage in the Cobb Creek watershed since 1994. In order to evaluate Total P loading from septic tanks, we need to estimate the number of septic tanks in the watershed.

Since there is no point source discharge in the watershed, we assume that all households in the watershed use a septic tank system for wastewater treatment. 2000 U.S Census data were used to estimate the number of people living in the Cobb Creek watershed. Table 5-1 shows population and number of persons per household for each census block and estimated population in the watershed. The estimated population is for the watershed area above the Fort Cobb dam. Figure 5-2 shows the census blocks in the watershed area.

TABLE 5-1. ESTIMATED POPULATION IN COBB CREEK WATERSHED

State ID	County ID	Tract	Blkgroup	Population	Persons Per Household	% Basin in Blkgroup	Estimated Population
40	15	9616	4	891	2.68	37.5%	334
40	15	9616	5	909	2.54	11.0%	100
40	15	9617	2	331	2.67	30.4%	101
40	15	9617	3	701	2.54	100.0%	701
40	15	9618	1	801	2.36	100.0%	801
40	15	9618	2	491	2.67	23.9%	117
40	15	9619	1	553	2.46	34.6%	191
40	39	9606	5	1354	2.54	15.2%	206
40	39	9607	1	1632	2.79	7.0%	114
40	149	9654	1	936	2.56	6.3%	59
40	149	9654	2	833	2.43	33.2%	277
				Average	**2.57**	**Total**	**3001**

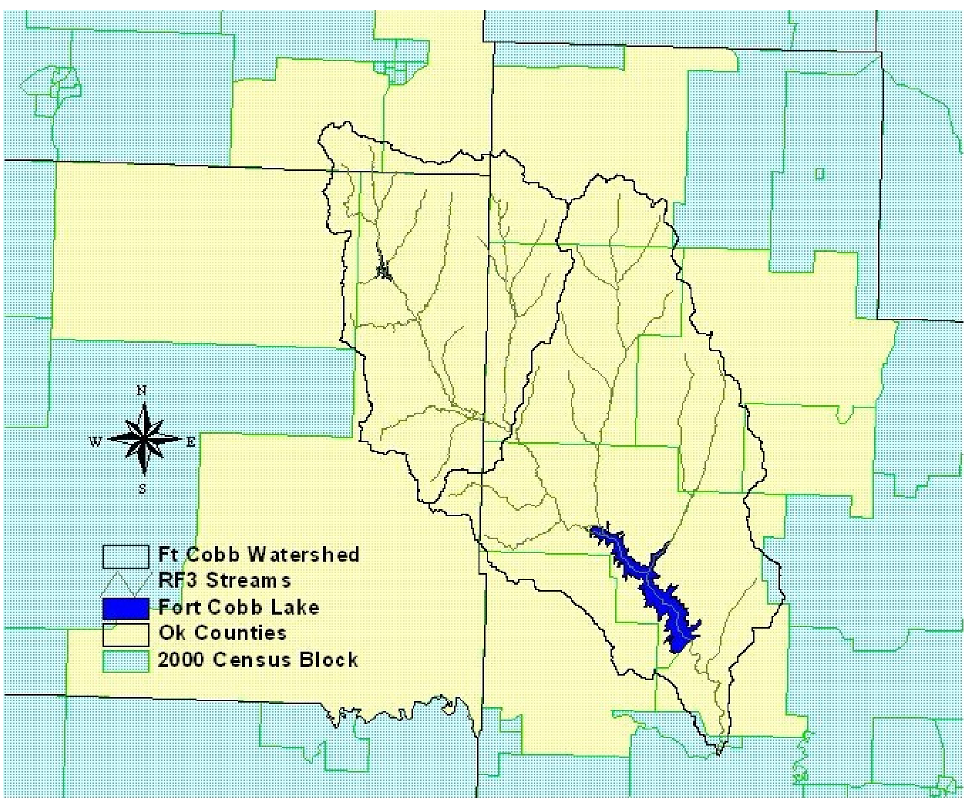


FIGURE 5-2. 2000 U.S. CENSUS BLOCKS IN COBB CREEK WATERSHED

First, phosphorus loading from septic tanks was estimated under the worst case scenario:

- All septic tanks failing
- Every household is assumed to have one septic tank system
- The total number of septic systems is estimated to be 1124
- Effluent from septic tanks drained directly to streams/lakes (drainfield not considered)
- Wastewater produced per person per day: 75 gallons
- Phosphorus concentration in septic tank effluent: 11.6 mg/L

Based on these assumptions, total P produced per person per year can be calculated as follows:

$$(75/1{,}000{,}000) \times 8.34 \times 11.6 \times 365 = 2.65 \text{ lbs/person/year}$$

Total P loading from septic tanks under the worst case scenario would be 3608 kg/year which is about 5% of the current average total P loading from all non-point sources as predicted by the SWAT model. In reality, this worst case scenario does not exist. The effluent from septic tanks is distributed into a drainfield. The effluent may reach groundwater and resurface in the stream banks or lakesides. Total P in the effluent may be adsorbed, precipitated, or removed by plant uptake. The direct contribution of total P to surface water from septic tanks in this watershed is much less than 5%, which is not significant. Any total P from septic tanks would contribute primarily to background loadings.

5.2.b. Migratory Birds

There are a large number of migratory birds (ducks & Canadian geese) staying in the Fort Cobb Lake in the winter. The concerns are that that direct defecation by waterfowl might be a significant nutrient input to the lake. An Integrated Assessment of the Trophic Status of Fort Cobb Reservoir by U.S. Bureau of Reclamation and USGS [23] also suggested that waterfowl might be a significant source of bacteria and ammonia.

To evaluate nutrient addition to Fort Cobb Lake by waterfowl, annual mid-winter waterfowl surveys were obtained from the U.S. Fish and Wildlife Service. Waterfowl in the lake are primarily ducks and small Canadian geese. According to the survey data, the average waterfowl population from 1998 to 2001 is 124,321.

The phosphorus loading to the lake was estimated in two ways: 1.) Average annual loading per waterfowl in other lake studies; 2.) P content in duck manure.

Method #1

The following table summarizes annual phosphorus loading to lakes from three studies. As shown in the table, when the size of the lake and the number of waterfowl increase, phosphorus addition to lakes per waterfowl decreases dramatically. For the same lake, when bird population increases, birds will need to go farther away from the lake to feed because the amount of food available in the lake does not increase with the number of birds.

TABLE 5-2. PHOSPHORUS LOADING TO LAKES FROM WATERFOWLS

References	Lake Size (ha)	# of waterfowl	Annual P (kg)	P (g/bird/year)
Manny et al (1975)[24]*	15	2,100	59	28.10
Manny et al (1994)[25]*	15	10,700	88	8.22
Marion et al (1994)[26]**	6300	1,021,600	2,000	1.96
Marion et al (1994)[26]**	6300	2,435,000	2,530	1.04
			Average	9.83

* Both studies were conducted on the same lake
** Study was conducted in two years.

We can see from Table 5-2 that the average phosphorus contribution to the lakes by each bird decrease as the bird population increases. This may be because the birds have to go farther away from lakes to feed so that they spend less time in the lakes.

Fort Cobb Lake is about 3806 acres or 1540 hectares. The average waterfowl population is 124,321. Average phosphorus loading to the lake can be estimated as follows:

TP loading = 9.83/1000*124,321 = 1,222 (kg/year)

The average total phosphorus loading to the lake from nonpoint sources is 70,000 kg/yr. The contribution from waterfowls is about 1.75% of total phosphorus loading.

Method #2

Manure characteristic tables from North Carolina State University Cooperative Extension and Michigan State University Extension show that the phosphorus content in fresh duck manure is 0.0038 lbs/day/bird in form of P_2O_5 [28]. For comparison purpose, the unit needs to be converted to lbs/day/bird as of P. The conversion factor is 0.4365.

The following assumptions were made in calculation of phosphorus loading to the lake:

- Waterfowls leave the lake to feed during the day and return to lake at night
- Waterfowls stay in the lake for three months a year

Defecation rate for Canadian geese and ducks varies significantly during the day and night. Manny et al. [25] made conservative estimates of Canadian geese defecation rate during the day and night equal to 1.96 and 0.37 droppings per goose per hour. This means that less than 16% of daily manure was directly added to the lake.

Based on the above assumptions and information, the phosphorus loading was calculated as follows:

P loading = 0.0038*0.4365*124,321*90*0.16*0.454 = 1378 (kg/year)

This estimated loading is only 1.97% of total phosphorus loading from nonpoint sources.

It is also worth noting that the surveys were conducted in the middle of the winter when waterfowl population is at its highest. In addition, the nutrient content for domestic ducks is believed to be higher than that for wild waterfowl. As a result, the above estimates are considered to be conservative.

The waterfowl phosphorus addition to the lake is relatively small (less than 2% of NPS loading) and occurs in the winter. Therefore, we believe that waterfowl will have little impact on algae growth in the summer.

5.2.c. SWAT model for Nonpoint Source Loadings

The Biosystems and Agricultural Engineering Department at Oklahoma State University (OSU) produced the nonpoint source loading analysis and estimates used to develop this TMDL. The Soil and Water Assessment Tool (SWAT) model was utilized in the assessment. The analysis and results are detailed in the report "Fort Cobb Basin – Modeling and Land Cover Classification [17]".

To spatially analyze nutrient loading, the Fort Cobb Lake watershed was divided into 90 sub-basins (Figure 5-3). The delineation of the 90 sub-basins was based on the 10-meter United States Geological Survey Digital Elevation Model (USGS DEM) data for the basin. The 30-meter land use data layer was created by Applied Analysis Inc. based on Landsat 7 ETM+ imagery collected on June 10, 2001. The follow seven land cover were defined with the imagery.

- Barren (Bare Soil)
- Forest
- Pasture
- Planted/Cultivated 1
- Planted/Cultivated 2
- Urban
- Water

Planted/Cultivated categories 1 & 2 differ by the amount of vegetation present. Figure 5-4 shows land use coverage throughout the Fort Cobb watershed. To adequately model the basin, a detailed survey was given in 2005 to Oklahoma State University (OSU) Cooperative Extension Service Agents and Specialists to gain an understanding of agricultural practices and land covers that occurred from 1996 to 2001. This survey went into great detail about the different types of crops in the basin along with different tillage practices, common double crops, fertilization rates, cattle stocking rates, and harvest dates. Based on the survey results, the planted/cultivated land cover was further divided into twelve separated agriculture land covers (Table 5-3).

Soil test phosphorus for common agricultural land covers was derived from OSU county level averages for the period 1995-1999. The number of cattle in the watershed was based on county level National Agricultural Statistics Service cattle estimates for the period 1996 – 2001 and the land cover data. Cattle were assumed to be evenly distributed across all agricultural land in each county.

TABLE 5-3. LAND USE COVERAGE IN THE FORT COBB LAKE WATERSHED

Land Use	Percentage of Basin (%)
Alfalfa	1.1
Bare Soil	0.2
Forest	6.2
Pasture	41
Peanut with Double Crop Winter Wheat (Conventional Tillage)	2.9
Peanut with Double Crop Winter Wheat (Conservation Tillage)	1
Peanut Winter Fallow	3.8
Rye (Conventional Tillage)	7.6
Rye (Conservation Tillage)	3.2
Grain Sorghum w/ Double Crop Winter Wheat	4.8
Grain Sorghum Winter Fallow	5.2
Urban	0.1
Water	2.4
Corn With Double Crop Winter Wheat	1.2
Winter Wheat for Grain (Conservation Tillage)	4.4
Winter Wheat for Grain (Conventional Tillage)	9.2
Winter Wheat for Pasture	5.6
Total	100.0%

The SWAT model was calibrated for flow for the period January 1995 through October 2001 and validated for flow in Cobb Creek for the period 1970 – 1989. Watershed loadings were calibrated for a longer period to cover a wider range of climatic and hydrologic conditions within the drainage area, allowing for a more representative analysis of source loading and in-stream conditions. The SWAT model was then calibrated for total phosphorus. The model was calibrated reasonably well for total phosphorus and but poorly for nitrogen. This is not considered to be a significant limitation for the current study because phosphorus is the limiting nutrient. The normal N:P ratio for algae is 7:1 which means that it takes about 7 nitrogen and 1 phosphorus to form algae cells. N:P ratio calculated from 1998-1999 OWRB data has an average of 30, maximum of 73. None of the calculated N:P ratio is less than 7. N:P ratio calculated from 2000-2001 USGS data shows an average of 17.5, and maximum of 43. Only four of 154 samples (2.6%) has N:P ratio less than 7 and all four samples are collected from sites near shoreline. No samples in main water body of the lake have the ratio less than 7. All data show that phosphorus is the limiting nutrient. In addition, blue-green is the dominant algae group in the lake. Blue-green algae can fix nitrogen through the air that supplies an unlimited source of nitrogen. Therefore, total phosphorus is much more important than total nitrogen in determining the trophic state of Fort Cobb Lake.

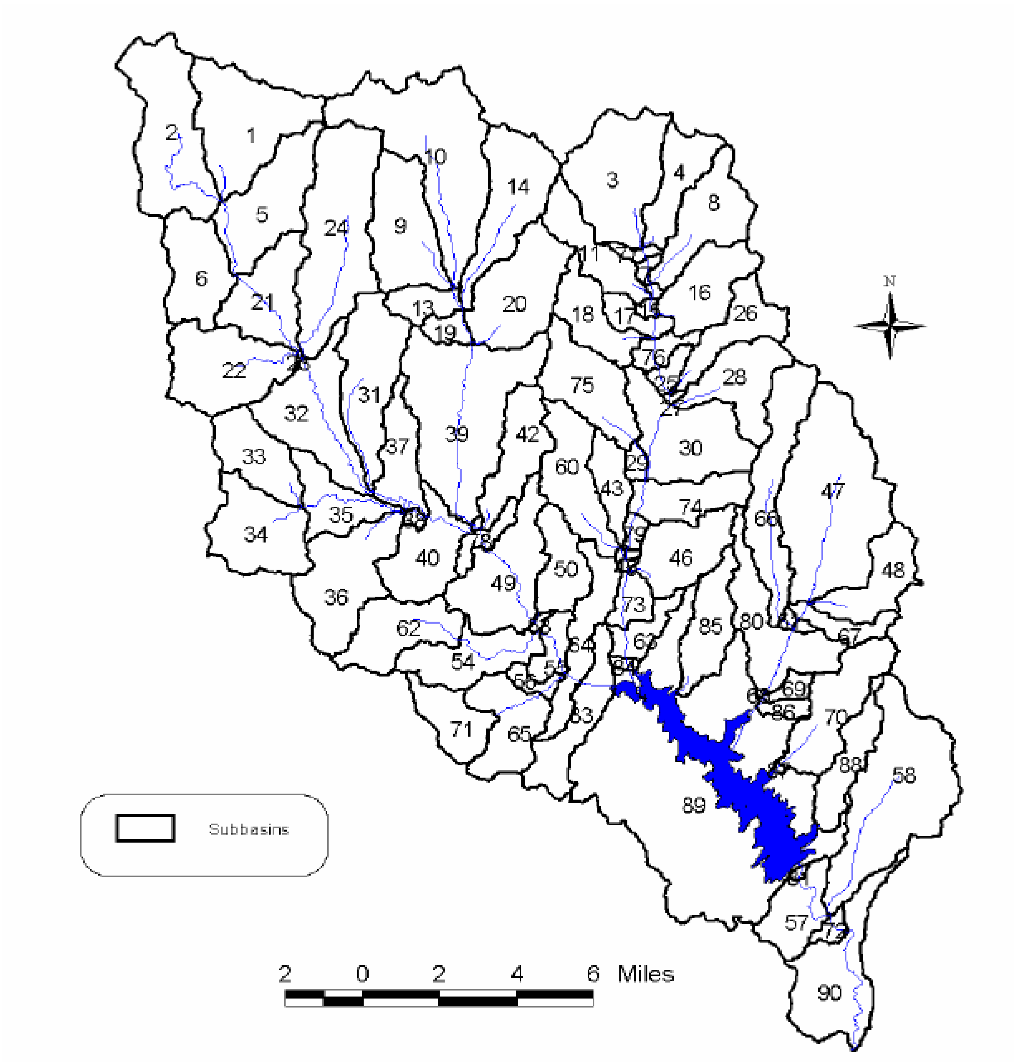


FIGURE 5-3. SUBBASIN LAYOUT USED IN THE COBB CREEK SWAT MODEL

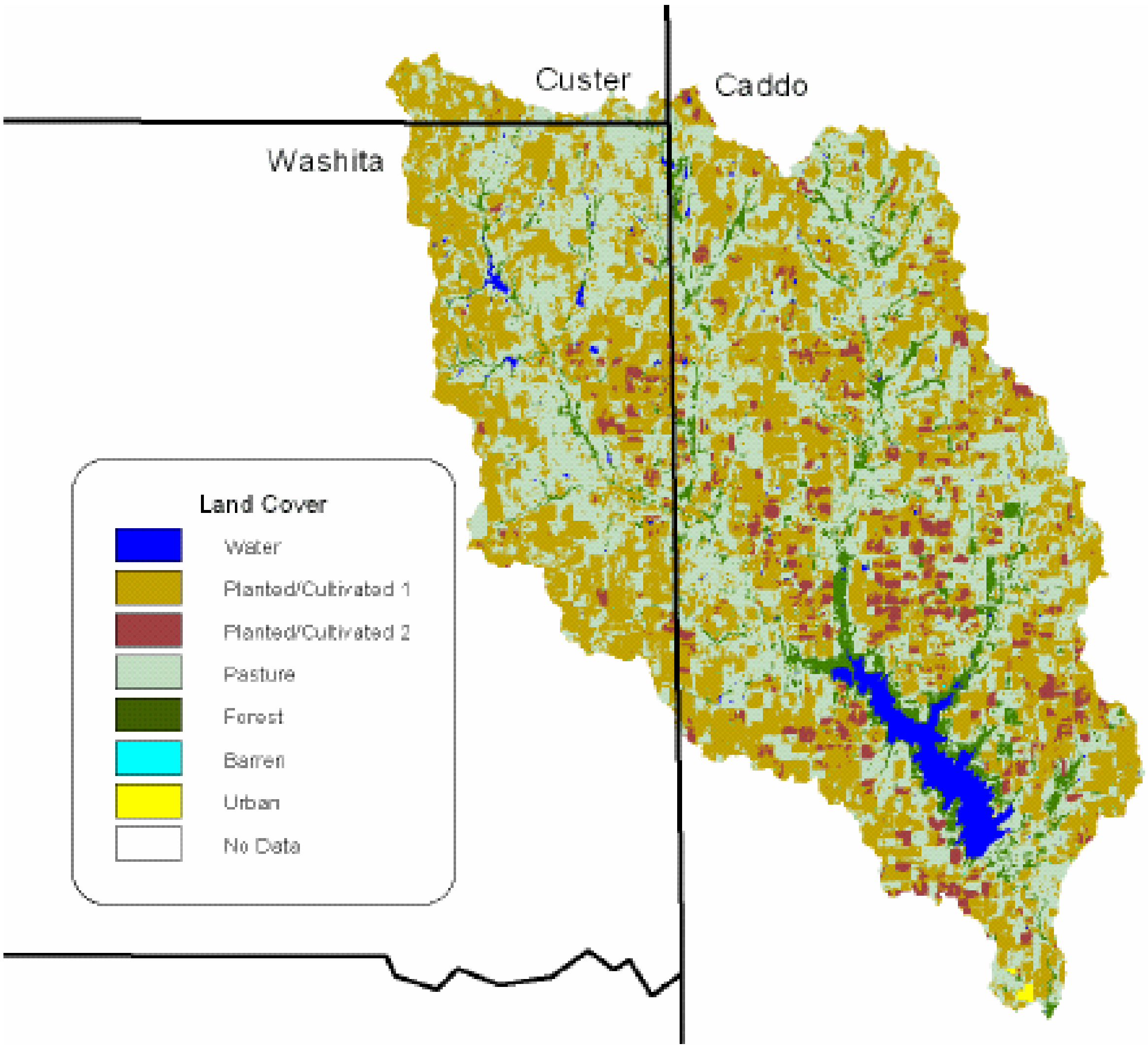


FIGURE 5-4. LAND USE COVERAGE BASED ON 2001 ETM IMAGERY

6. Model Development

The link between the Fort Cobb Lake water quality targets and identified source loads was established through sophisticated modeling techniques. This section discusses the model selection, setup, calibration and validation.

6.1. Model Selection

Lakes are usually stratified in the summer and mixed in the winter. Normally, the deeper a lake is, the more vertically stratified it gets. Fort Cobb Lake is well mixed for most of the year but is still stratified in the summer. Due to the lake's three-dimensional variability and seasonality, a three dimensional, time-dependent water quality model will best describe the system. The widely used models, which are also supported by the EPA, include the Environmental Fluid Dynamics Code (EFDC) and Water Quality Analysis Simulation Program (WASP). The EFDC model is a DOS-based program. All input files need to be compiled with a text editor. The WASP model is a windows-based program. It is more user-friendly than the EFDC model. However, the EFDC model was chosen for the study due to the following considerations:

- The WASP model is for modeling water quality only and the hydrodynamic inputs to WASP need to be generated by EFDC.

- WASP uses a one-dimensional array to represent computational cells, which makes it difficult to find the physical location of a cell in the lake. EFDC uses a three-dimensional array (i – row, j – column, k – layer) to reference grid and layers and users can easily pinpoint the location of a cell.

- EFDC has a much shorter running time. Each EFDC model run took approximately 16 to 18 hours. If the WASP model were used, the running time would be much longer. As a result, the time needed to calibrate the model would be increased dramatically.

The EFDC model was used to simulate water quality processes in Fort Cobb Reservoir. EFDC is a state-of-the-art hydrodynamic water quality model that has evolved over the past two decades to become one of the most widely used and technically defensible hydrodynamic models in the world [18]. EFDC has also been used in other TMDL projects in Oklahoma, such as Lake Tenkiller and Lake Eucha.

6.2. Model Setup

6.2.a. Watershed Representation

The watershed representation is both a conceptual and a mathematic definition of the drainage area contributing to the waterbody. The SWAT model developed by Oklahoma State University was used to calculate nonpoint source pollutant loadings based on meteorological data, land cover and land use distribution, soil characteristics, and pollutant dynamics in the watershed.

6.2.b. Lake Representation

The setup of the EFDC model required evaluation of the lake's physical and chemical characteristics, including bathymetry, outflow, temperature, and water quality. The EFDC model configuration involved the construction of a horizontal grid for Fort Cobb Lake, the development of EFDC input files, and compilation of the FORTRAN source code with appropriate parameter specification of array dimensions. EFDC was set up for dynamic scenario modeling of hydraulics and water quality constituents. The hydrodynamic variables of the EFDC model included velocity, water surface elevation, temperature and mixing. The following were considerations for setting up the EFDC model:

- Linkage to the watershed model: Pollutant loads entering the lake were represented by the watershed model. Watershed loadings were carried into the lake model in the form of daily average flows and daily total loading from four inflow cells representing Cobb Creek, Lake Creek, Willow Creek, and two tributaries, respectively. The watershed model generated output values for Chlorophyll-*a*, CBOD, Nitrate, Organic N, Mineral P and Organic P. These quantities were further subdivided into carbon, nitrogen species, and phosphorus species and then directly streamed into the lake model. Twenty-one water quality state variables were simulated in the lake model, including DO, algae, carbon, nitrogen, and phosphorus. The EFDC hydrodynamic variables included velocity, water surface elevation, and temperature.

- Computational grid: As part of the model development, the lake area was divided into a grid of discrete cells. To ensure that the grid conformed closely to the actual lake geometry, an orthogonal mapping procedure was used to represent the horizontal surface of the lake as a two-dimensional grid domain. The bathymetric data for Fort Cobb Lake were interpolated to further define the lake in three dimensions. The bathymetric data were obtained from the U.S. Bureau of Reclamation (USBR). The numerical grid consisted of 179 total cells. Since Fort Cobb Lake is only stratified shortly in the summer and stays well mixed most of the year, five vertical layers were chosen to represent the vertical structure of temperature and DO profiles in the lake. As a visual check, the EFDC model grid was overlaid on an aerial photo of Fort Cobb Lake and surrounding area (Figure 6-1). The surface area and lake volume of the model were also calculated and compared with the actual surface area and volume of the lake. Table 6-1 shows the comparison results.

TABLE 6-1. SURFACE AREA AND VOLUME OF FORT COBB LAKE

	Model	Actual	Difference (%)
Surface Area (Acres)	3747	3806	1.56%
Volume (Acre-ft)	73752	73833	0.11%

6.2.c. Selection of Model Simulation Period

The time period used for calibration and verification of the EFDC model for Fort Cobb Lake was determined according to available data. The OWRB collected water quality data in Fort Cobb Lake in 1998 and 1999. The USGS collected data in 2000 and 2001. The USFWS also collected some data from 1998 to 2000. Data collected in 1998-1999 was used to calibrate the model and data collected in 2000–2001 was used to validate the model.

Annual precipitation for the watershed was plotted in Figure 6-0. The average annual precipitation from 1975 to 2001 was 31.8 inches. The annual rainfall for 1998 was 24.2 inches and the annually rainfall for 2000 was 33.1 inches.

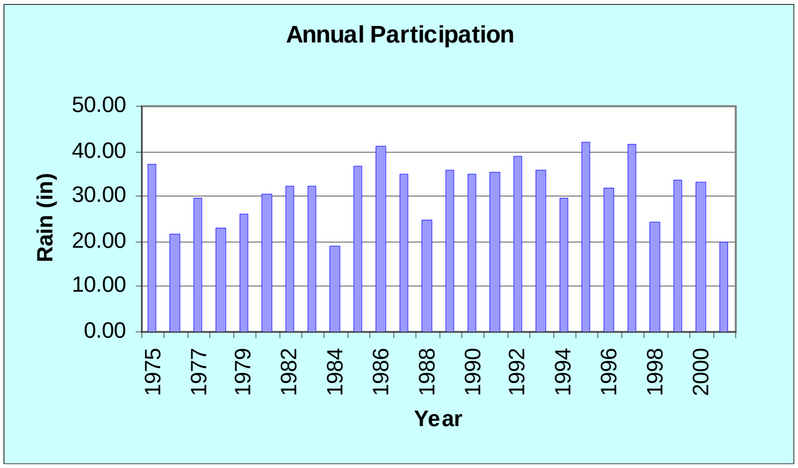


FIGURE 6-0. ANNUAL PRECIPITATION FOR FORT COBB WATERSHED

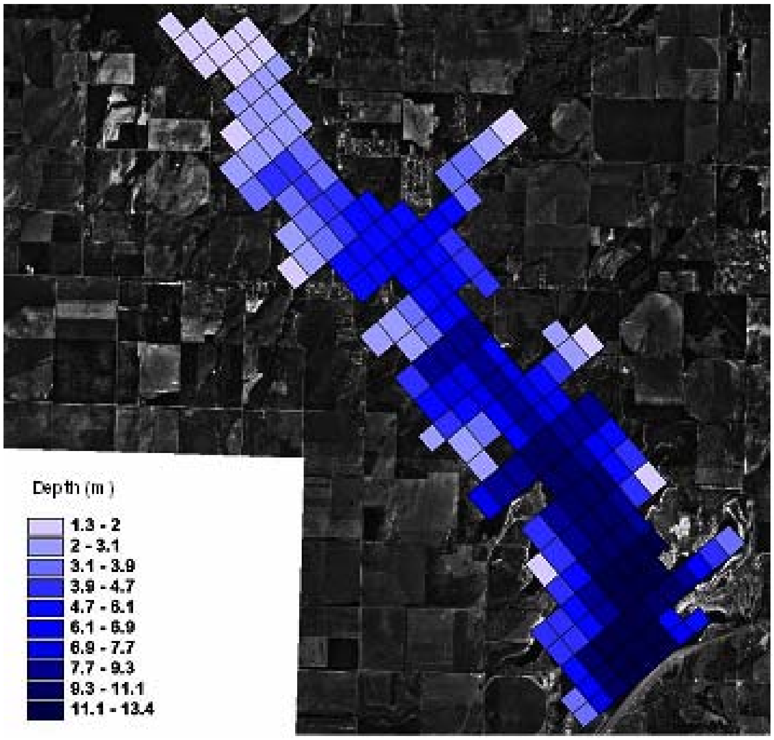


FIGURE 6-1. BATHYMETRIC AND COMPUTATIONAL GRID OVERLAY - FORT COBB LAKE

6.2.d. Model Inputs

The inputs of the EFDC model for Fort Cobb Lake include hourly weather data, daily flow data, and daily loadings to the lake.

The weather data for the model was obtained from Oklahoma Mesonet for the Fort Cobb station. The data includes hourly atmosphere pressure, air temperature, wind speed and direction, relative humidity, rainfall and, solar radiation. Since the weather station is close to the lake, the data provides a good representation of the weather conditions being modeled.

The hydraulic data was downloaded from Army Corps of Engineer's web site (http://www.swt-wc.usace.army.mil/FCOBcharts.html). The data include daily inflow, release, pool elevation, and evaporation.

Flows to the lake were input in four cells:

(12, 37) ----- Cobb Creek and Lake Creek
(15, 33) ----- unnamed tributary to the lake
(21, 26) ----- Willow Creek
(18, 18) ----- unnamed tributary to the lake

Flows were evenly distributed in all five layers because the average water temperature in streams is very close to the water temperature in the lake. Using USGS's temperature data, we calculated average water temperature on all tributaries and compared that to site #6 (upper lake). The average water temperature in streams is only 0.4 degrees lower than that in the lake.

The loadings to Fort Cobb Lake were simulated with the SWAT watershed model developed by OSU. The output parameters of the SWAT model include flow, CBOD, Nitrate and Nitrite, Organic N, Mineral P, Organic P, and sediment. These quantities were further subdivided into carbon, nitrogen species, and phosphorus species based on literature values or regression relationships from the data. Portions of nitrogen and phosphorus species were treated as calibration parameters and were further adjusted in the calibration process.

In addition to loadings predicted by the SWAT model, the atmospheric deposition of nutrients was considered in the EFDC model for Fort Cobb Lake. The annual data for Oklahoma was downloaded from National Atmospheric Deposition Program's web site. The data from 1998 to 2001 was downloaded and the average of the downloaded data was input in the EFDC model.

Sediment input to the lake was assumed because reliable sediment loading was not available. Sediment was introduced to the lake primarily during high flow events which normally occur in the spring. Most sediment (in the form of TSS) has been settled out of water column by the summer. Fort Cobb Lake does not have any turbidity problems according to monitoring data, which indicates a low TSS concentration in the water column.

To obtain the sediment chemical concentrations, the EFDC model was run repeatedly for the calibration period. Approximately 10 years worth run was performed. Then the resulting sediment chemical concentrations were used in the model calibration.

6.3. Model Calibration

The EFDC model was calibrated for hydrodynamics and water quality to simulate actual conditions in the lake. Calibration is the process of modifying the input parameters in the EFDC model until the output from the model matches an observed set of data.

6.3.a. Hydrodynamics

Hydrodynamic calibration is needed to properly characterize the nature, behavior, and patterns of water flow within the modeled geometry of the lake. Modeled versus observed water surface elevations near the dam were compared to verify the lake's hydrodynamic behavior. As shown in Figure 6-2, modeled surface elevation is very close to that observed except for the period from the middle of October to December 15, 1998. The observed lake elevation had a sudden change on December 15, 1998. The rainfall data was checked to see if there was a rainfall event to cause the sudden elevation change. No rainfall event was found on or a week before December 15, 1998. This effort proves to some extent that the predicted lake elevation is likely to be correct. Then, the lake elevation data was carefully reviewed for its accuracy and possible errors. It was found that an adjustment to the stage gauge accounts for the apparent elevation change. The magnitude of the adjustment was approximately the same as the difference between the modeled and observed surface elevation. After the gauge adjustment, the modeled elevation matches the observed very well. Therefore, we have enough reason to believe that the elevation data from the middle of October to December 15, 1998 were not accurate. A simple regression was performed between the modeled and observed elevations (Figure 6-2). The slope of 1.00 and R^2 of 0.96 indicate an excellent match. The R^2 value could have been even higher if the stage gauge did not drift prior to December 15, 1998.

Temperature is a good indicator of hydrodynamic behavior. A temperature profile will show if the lake is mixed or vertically stratified. Because temperature influences algal growth and dissolved oxygen, an accurate temperate calibration is also very important to the success of water quality modeling. The results of temperature calibration are shown in Figure 6-3.

In Figure 6-3, the red and orange points are observed data by OWRB and USFWS and the lines are modeled temperature at different depths. The modeled temperature fits the observed data very well. Observed temperatures were also plotted against predicted temperatures at the depth where temperatures were observed. A regression line with slope of 1.0 and R^2 of 1.0 indicates a perfect match between the modeled and observed. For the temperature prediction in Fort Cobb Lake, the slope is 1.04 and R^2 is 1.00, which shows the EFDC model predicts water temperatures extremely well.

6.3.b. Water Quality

Water quality conditions in the lake vary at different locations. Measured data show that the upper part of the lake has a higher chlorophyll-*a* concentration than the lower part of the lake. To better reproduce the water quality conditions for Fort Cobb Lake the model predictions were compared with the measured data at three locations upper, middle, and lower parts of the lake.

Since the targets of this TMDL are TSI or chlorophyll-*a*, DO, and anoxic volume, the calibration is focused on these parameters. Figures 4 through 15 show the comparison of the prediction to the available data. The observed data is plotted in points and the model prediction is plotted in lines.

Overall, the calibrated model makes good predictions on Chlorophyll-*a*, dissolved oxygen and anoxic volume. The observed data indicates dissolved oxygen and anoxic volume criteria were not violated in the lake. However, most measured TSI values were higher then the target value of 62. As a result, the TSI target becomes the controlling factor for TMDL development. The model predictions also show that dissolved oxygen and anoxic volume meet water quality standards all the time. The model predicts chlorophyll-*a* or TSI very well.

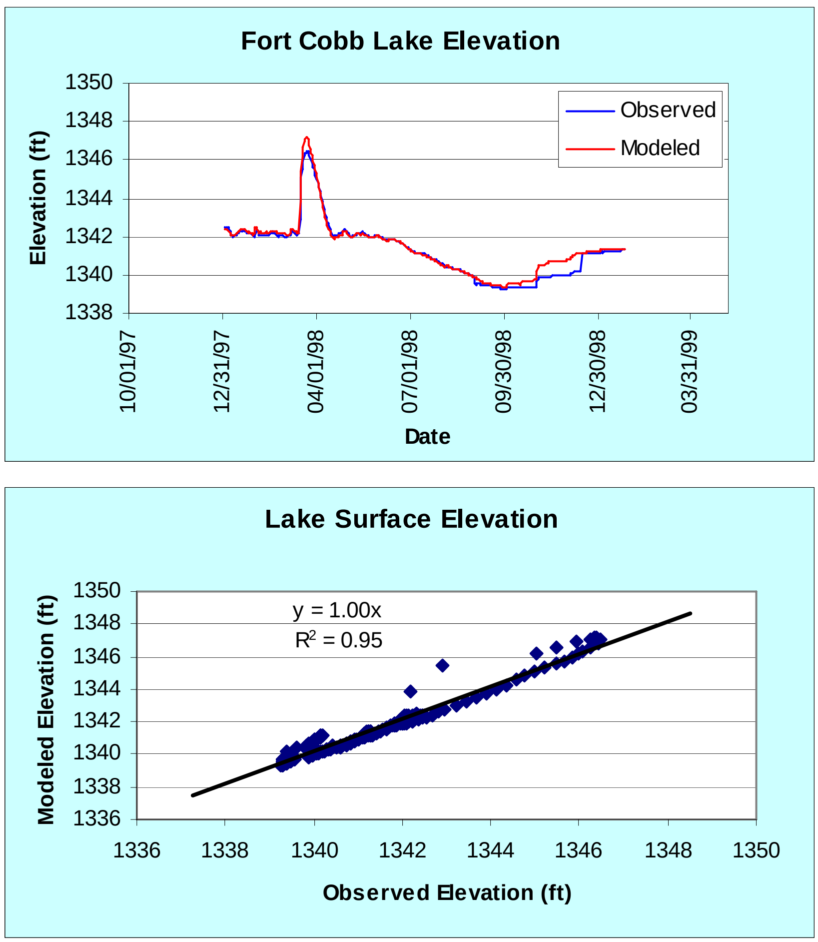
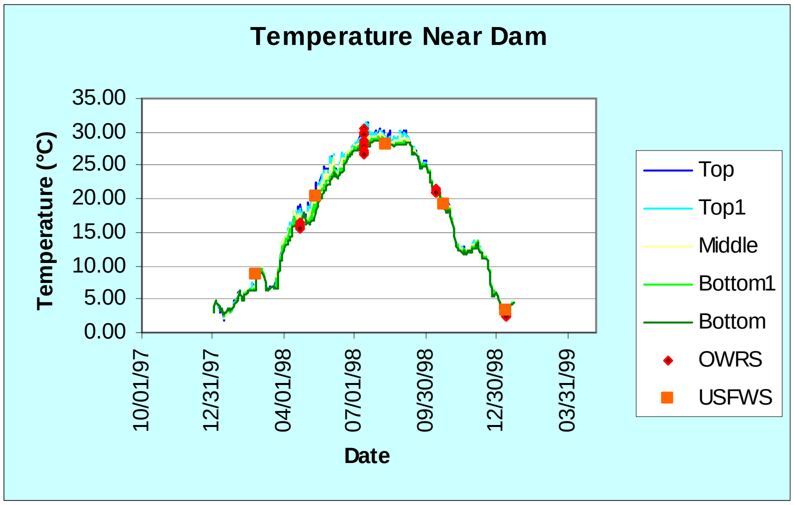


FIGURE 6-2. COMPARISON OF MODELED AND OBSERVED LAKE ELEVATION



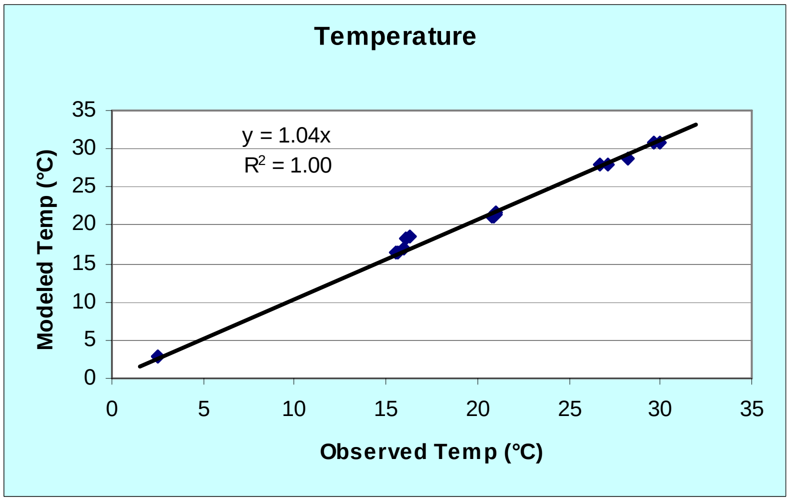


FIGURE 6-3. TEMPERATURE PROFILE NEAR THE DAM

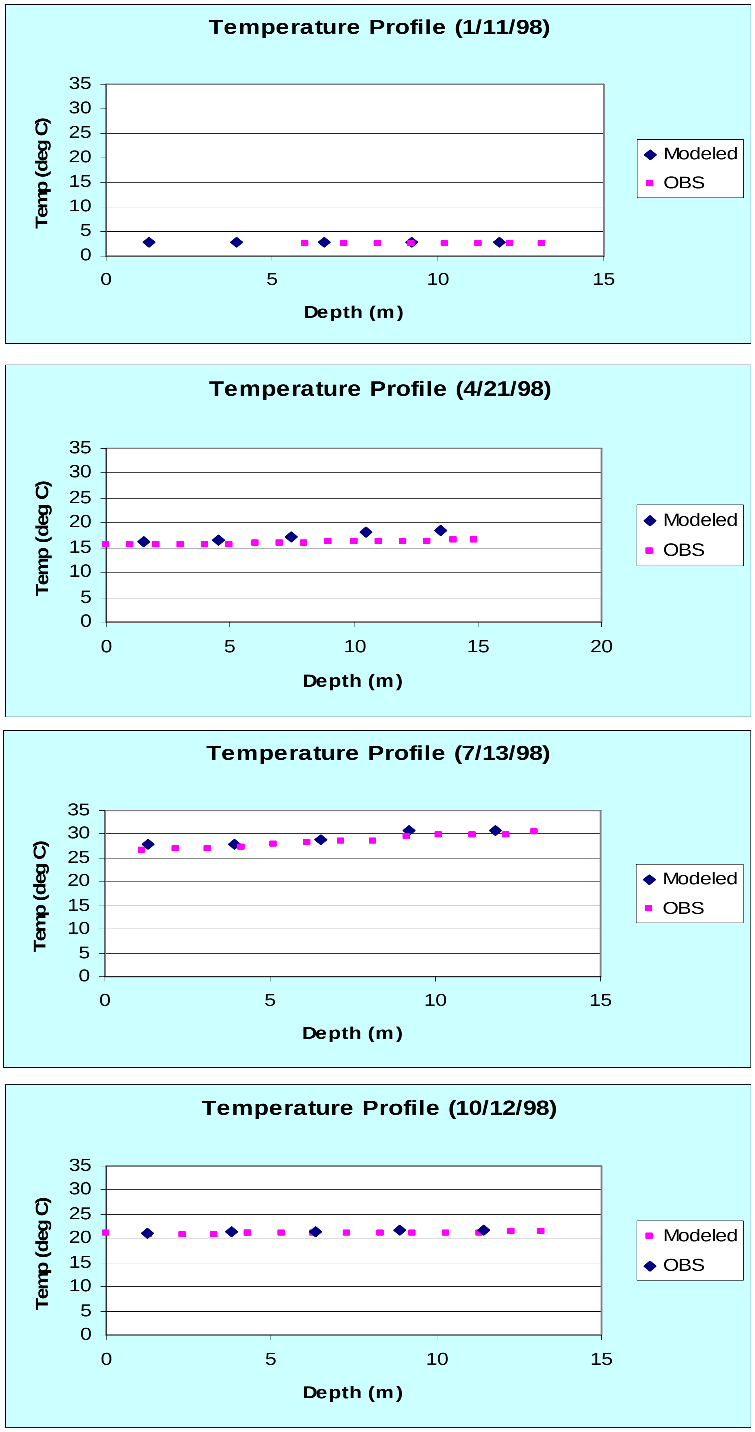


FIGURE 6-3A. TEMPERATURE PROFILE NEAR THE DAM

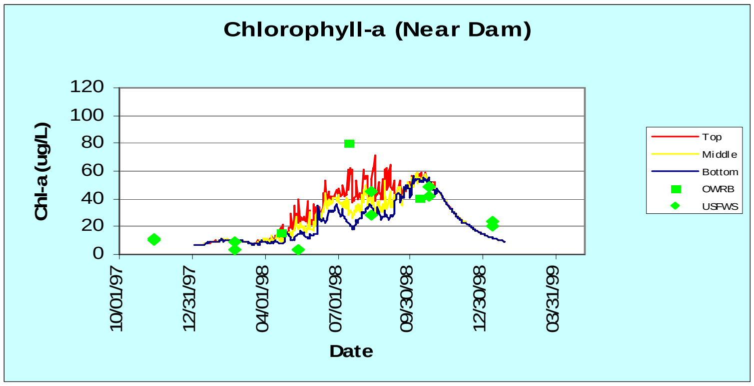


FIGURE 6-4. CHLOROPHYLL-A CONCENTRATION NEAR THE DAM

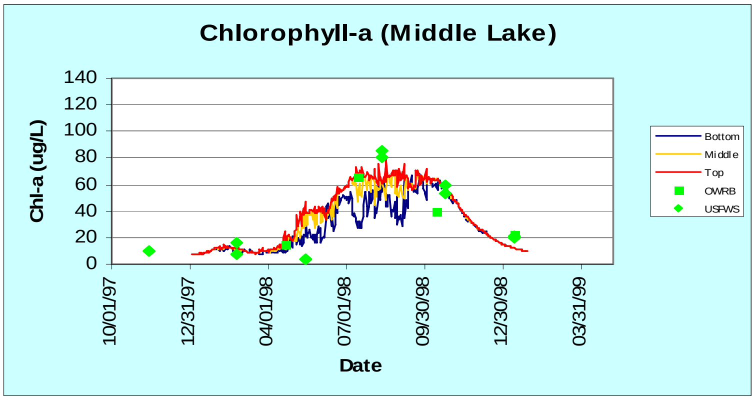


FIGURE 6-5. CHLOROPHYLL-A IN THE MIDDLE PART OF THE LAKE

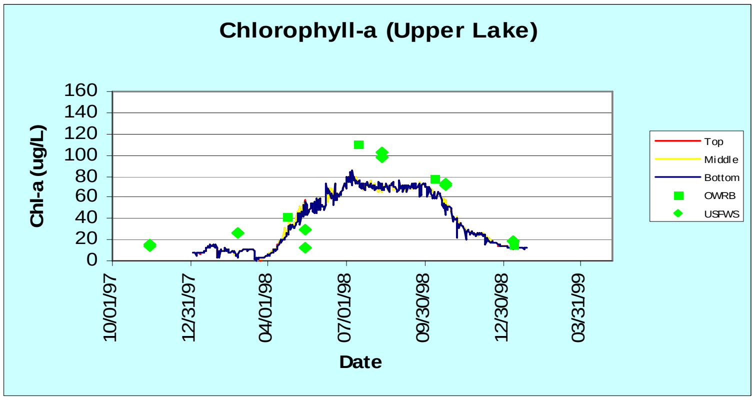


FIGURE 6-6. CHLOROPHYLL-A IN THE UPPER PART OF THE LAKE

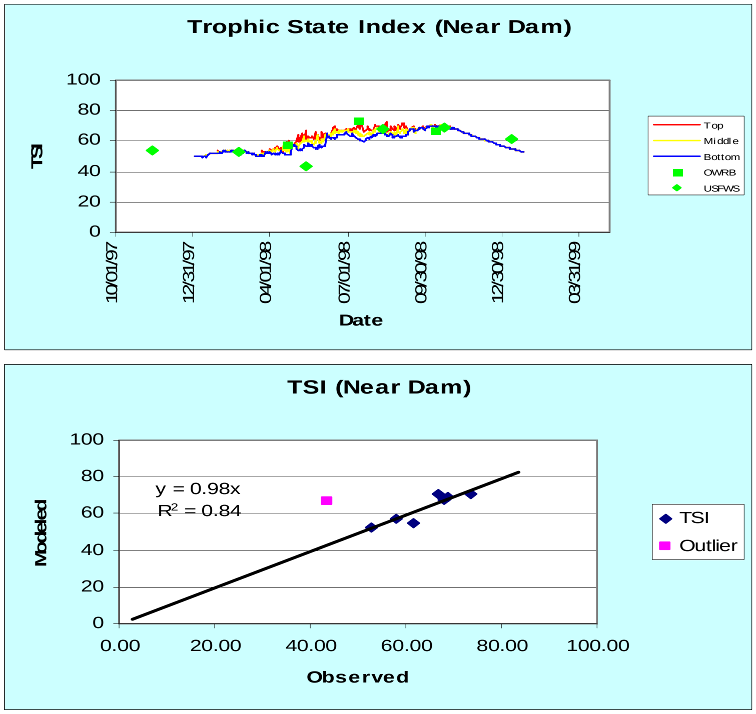


FIGURE 6-7. TROPHIC STATE INDEX NEAR THE DAM

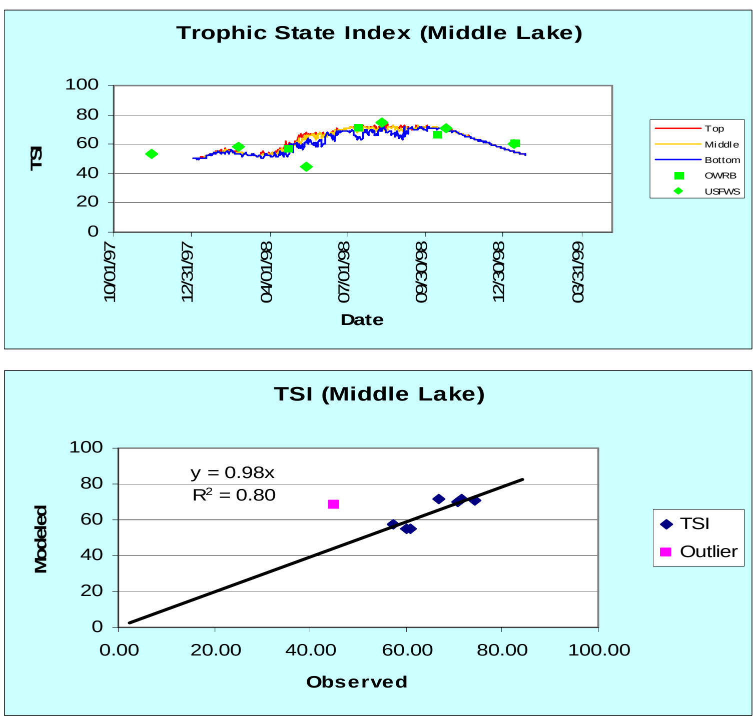
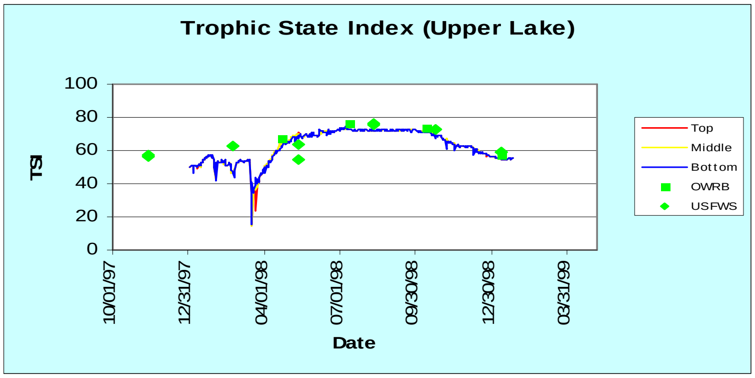


FIGURE 6-8. TROPHIC STATE INDEX IN THE MIDDLE PART OF THE LAKE



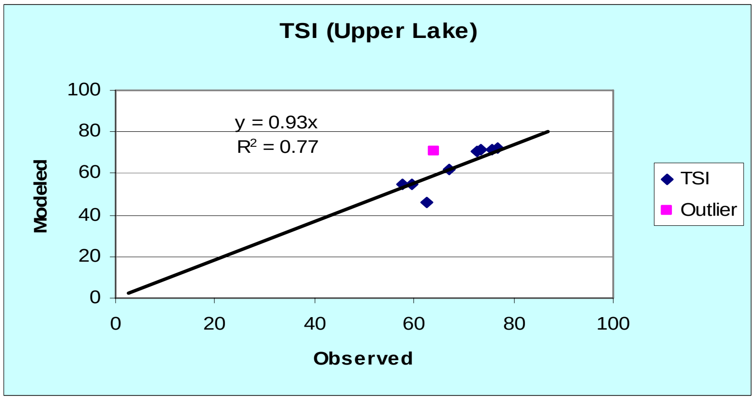


FIGURE 6-9. TROPHIC STATE INDEX NEAR IN THE UPPER PART OF THE LAKE

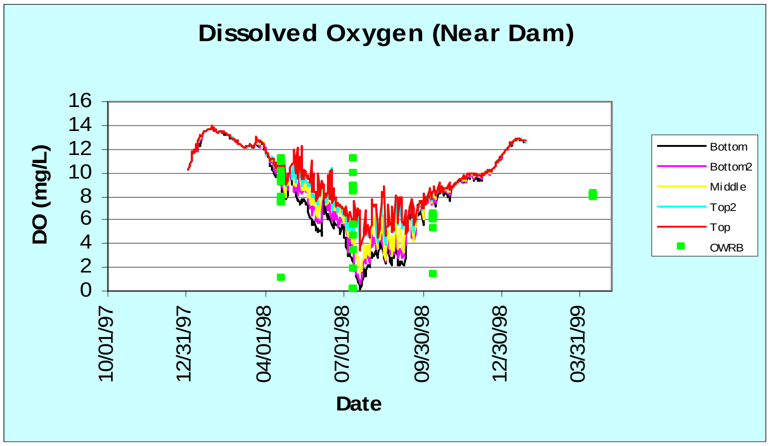


FIGURE 6-10. DISSOLVED OXYGEN NEAR THE DAM

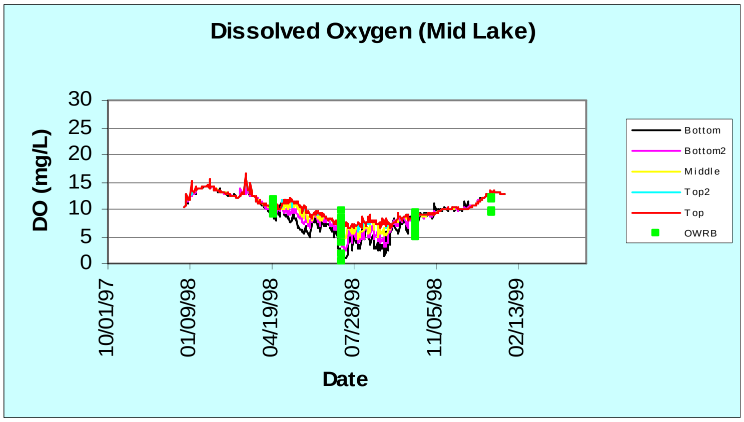


FIGURE 6-11. DISSOLVED OXYGEN IN THE MIDDLE PART OF THE LAKE

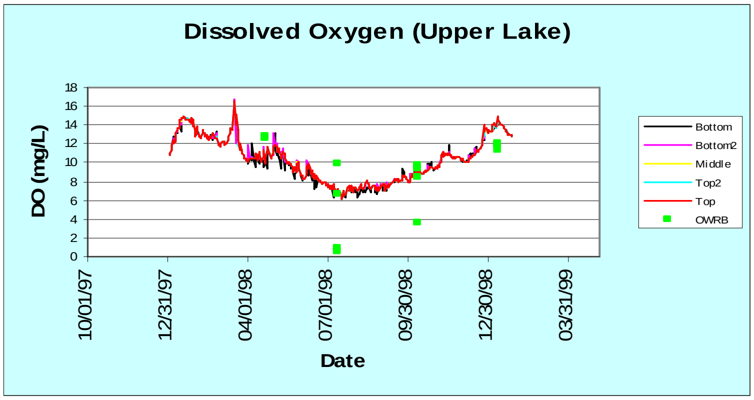


FIGURE 6-12. DISSOLVED OXYGEN IN THE UPPER PART OF THE LAKE

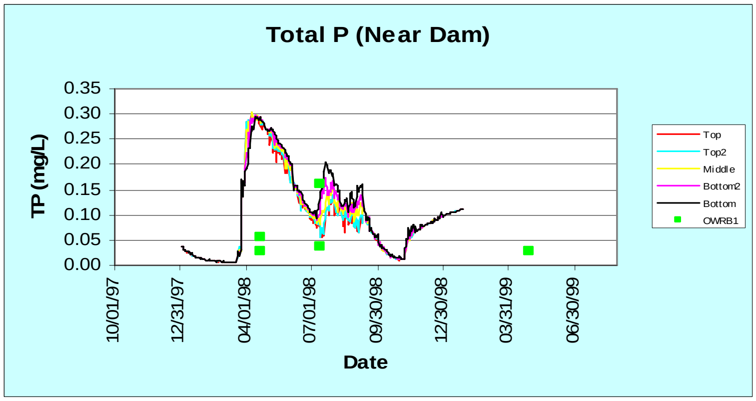


FIGURE 6-13. TOTAL-P NEAR THE DAM

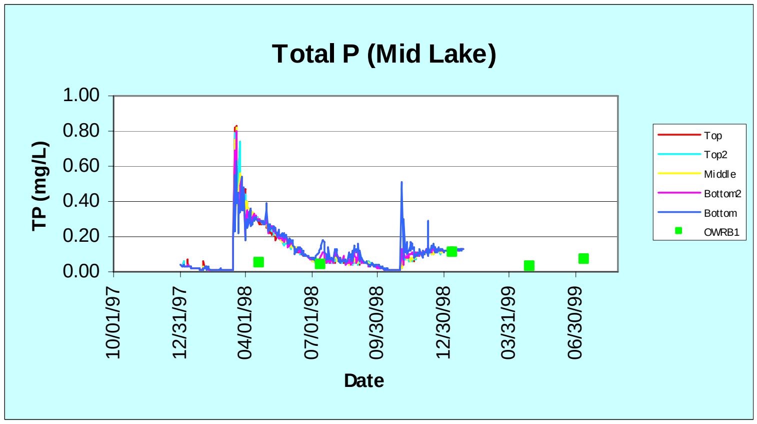


FIGURE 6-14. TOTAL-P IN THE MIDDLE PART OF THE LAKE

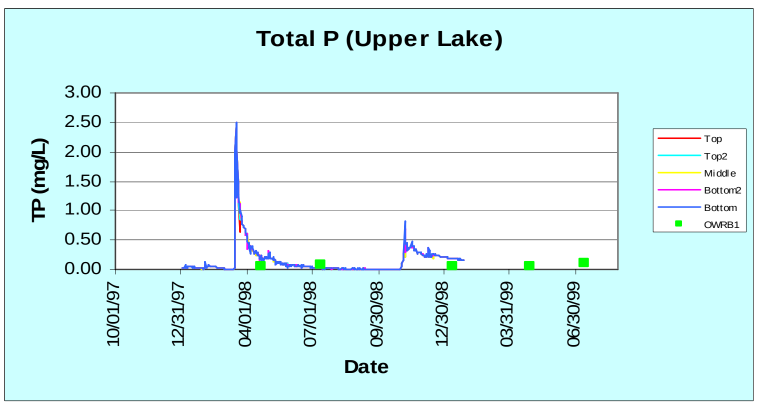


FIGURE 6-15. TOTAL-P IN THE UPPER PART OF THE LAKE

Data from both the OWRB and USFWS were used in the Chlorophyll-*a* (Figures 6-4 through 6-6) and TSI calibration (Figures 6-7 through 6-9). The chlorophyll-*a* concentration is significantly higher in the upper part of the lake than the lower part of the lake. The chlorophyll-*a* concentration predicted by the model matches the data well at the upper, middle and lower parts of the lake. The predicted TSIs were plotted against the data at the upper, middle and lower parts of the lake. The R^2 ranges from 0.77 to 0.84 and the slope ranges from 0.93 to 0.98 which indicates a very good fit for a natural system. Both the model and data show that the TSI target was exceeded in May through October. The TSI target of 62 was met in Fort Cobb Lake during the winter months.

Figures 6-10 through 6-12 show the comparison of dissolved oxygen in the upper, middle and lower part of the lake. There are three measured dissolved oxygen profiles at each monitoring site in 1998. The predicted DO matches the data well in overall trend and vertical profile. The observed surface DO is generally higher because the predicted DO is a daily average while samples are taken during the day. Both data and the model show that the lake is stratified near the dam and the anoxic volume is about 40%.

The model predicted an unusual DO spike in the upper and middle part of the lake in March of 1998. The DO load to the lake and other input files were reexamined for accuracy. No errors were found. The DO spike is coincident with the only high-flow event. After consulting with experts in the EFDC model, we believe that the DO spike occurs because the model is not stable during the high-flow event. We tried to increase the number of time steps to the maximum allowed by our version of EFDC. No noticeable changes were observed. The model recovered in about a week and was stable in the rest of simulation period. The DO spike which occurred months before the critical period will not have much impact on the results of the TMDL. Therefore, it is not a significant concern for the model predictions.

Total phosphorus (TP) concentration in the lake is important for algae growth. When TP concentration is lower than a threshold number, it limits algae growth in the lake. On the other hand when algae have enough phosphorus for growth, additional phosphorus will not necessarily promote more algae growth. Comparisons of the predicted and observed TP are shown in Figures 6-13 through 6-15. The observed data for TP on July 13, 1998 is not available and the ortho-P data was used in plots for this date. The predicted TP concentrations match observed data reasonably well in the middle and upper part of the lake but miss the observed data collected on April 21, 1998 near the dam. Since TP data are only available on three dates, it is really not sufficient to judge the quality of TP calibration. In the model verification section, more data will be used to justify the TP calibration.

Comparing the peaks of lake elevation and TP plots, it is clear that a significant amount of TP is delivered to the lake during storm events.

After the EFDC model was calibrated, the data collected in 2000 and 2001 were used to verify the model calibration. The calibrated model input files (WINEFDC.inp & WQWIN.inp) were attached in Appendix A of this report.

6.4. Model Verification

Model verification is a process in which the calibrated model is applied to the same system for a different period of time to see if it still can reproduce observed conditions. Model verification is also a confidence building process. Once the model is verified, it can be used to predict load reduction with more certainty.

6.4.a. Hydrodynamics

The modeled water surface elevation and temperature profiles were compared with the measured data near the dam (Figures 6-16 & 17). Both lake surface elevation and water temperature matched the observed data well.

6.4.b. Water Quality

As in the calibration phase, Trophic State Index (TSI), chlorophyll-*a*, dissolved oxygen, and TP are plotted against the observed data. During the verification process, parameters in the calibrated model stayed the same.

The comparison of model output and observed data are shown in Figure 6-18 through Figure 6-29. Overall, the calibrated model for Fort Cobb Lake reproduces the observed water quality conditions reasonably well at different parts of the lake and for all of the calibrated parameters.

As in the model calibration, several dissolved oxygen spikes in the upper and middle part of the lake were predicted by the model. Some of the DO spikes occurred at the bottom layer of the model. Model instability during high-flow events was believed to the cause of those DO spikes. We tried to increase the number of time steps to the maximum allowed by our version of EFDC. No noticeable changes were observed. Fortunately, all the DO spikes occurred only in the spring which is not the critical period of time of the model and the EFDC model recovered quickly after high-flow events. Therefore, these DO spikes will not have much impact on the results of this TMDL. We believe that the DO spikes, although unreal, are not a significant concern for the model.

From the lake elevation and TP plots, it can clearly be seen that the phosphorus loadings to the lake are directly related to the storm events. Most sediments and nutrients are washed off to the lake during storm events. Because of the close tie between sediment and nutrients, if the sediments to the lake are effectively reduced, the nutrients to the lake will also be reduced.

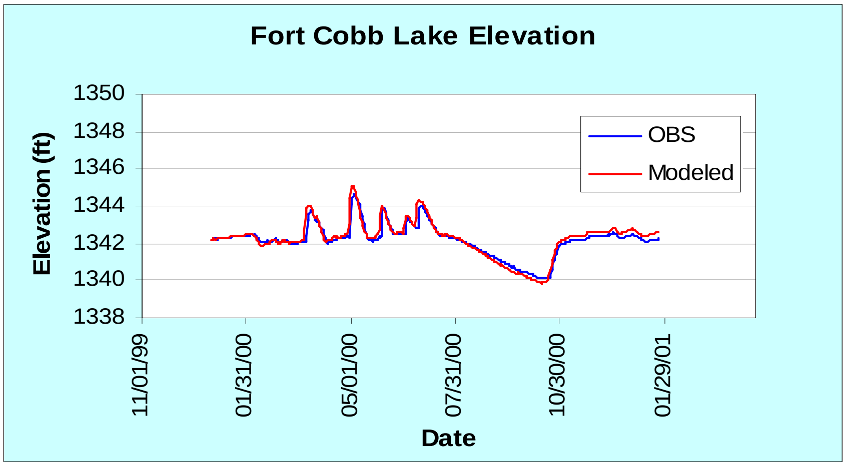


FIGURE 6-16. LAKE ELEVATION (2000)

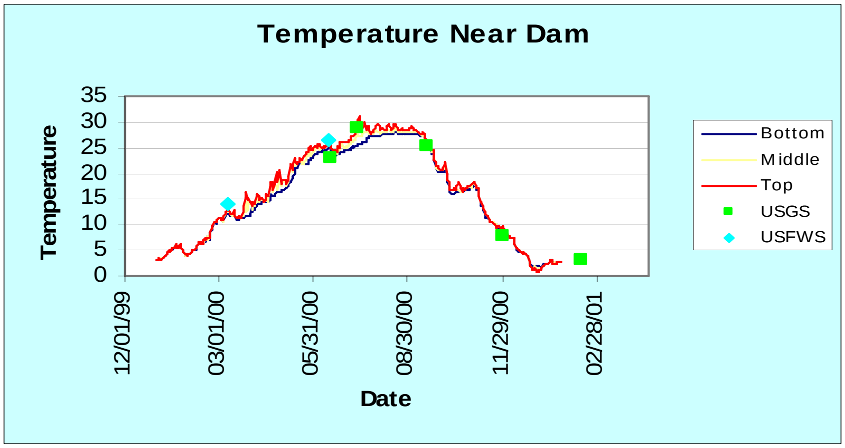


FIGURE 6-17. WATER TEMPERATURE NEAR THE DAM (2000)

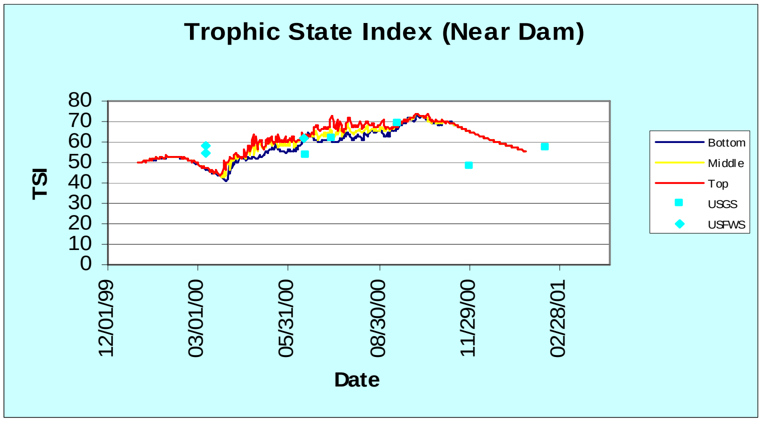


FIGURE 6-18. TROPHIC STATE INDEX NEAR THE DAM (2000)

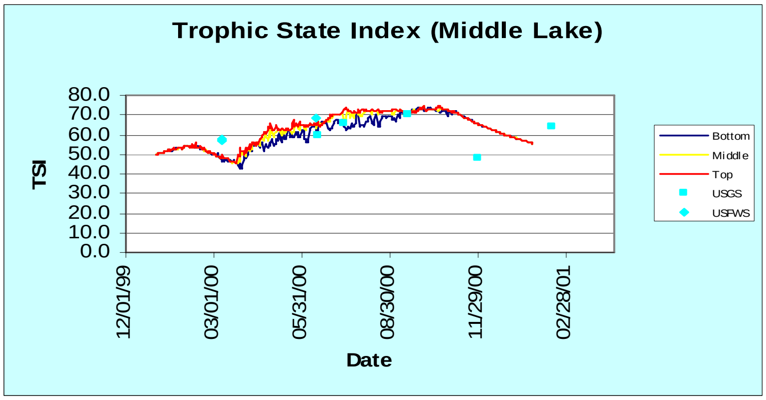


FIGURE 6-19. TROPHIC STATE INDEX IN THE MIDDLE PART OF THE LAKE (2000)

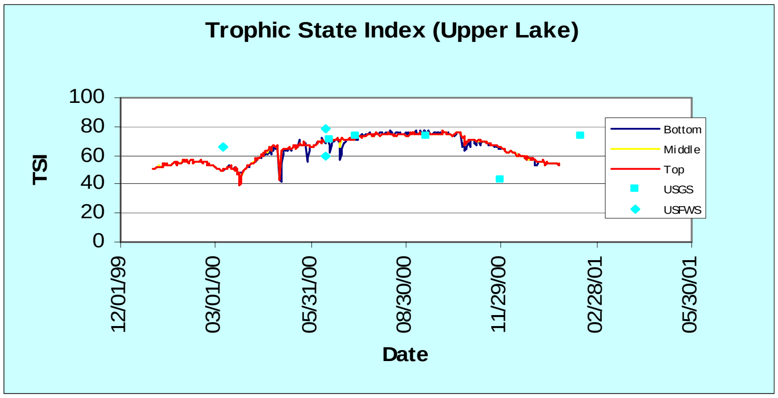


FIGURE 6-20. TROPHIC STATE INDEX IN THE UPPER PART OF THE LAKE (2000)

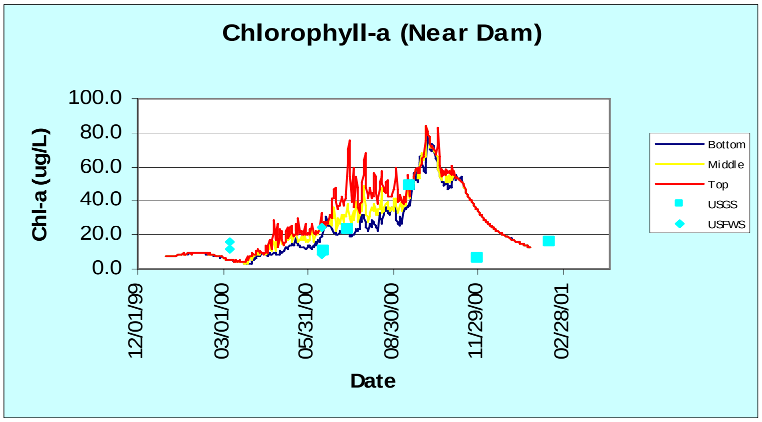


FIGURE 6-21. CHLOROPHYLL-*a* NEAR THE DAM (2000)

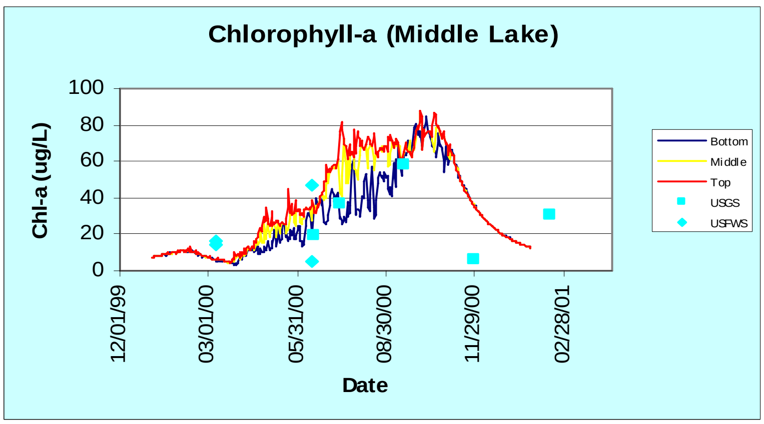


FIGURE 6-22. CHLOROPHYLL-*a* IN THE MIDDLE PART OF THE LAKE (2000)

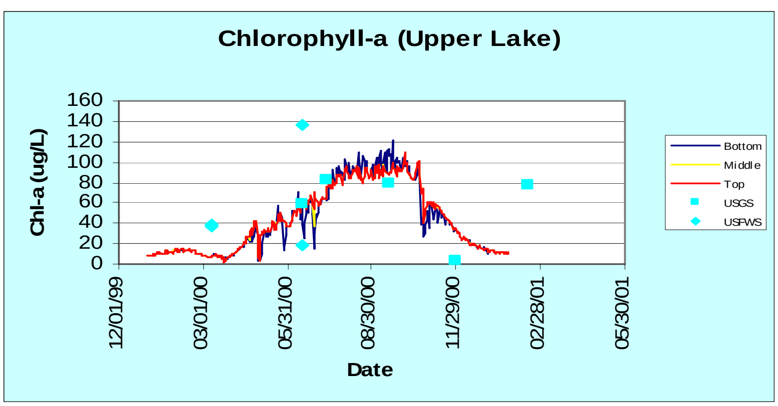


FIGURE 6-23. CHLOROPHYLL-*a* IN THE UPPER PART OF THE LAKE (2000)

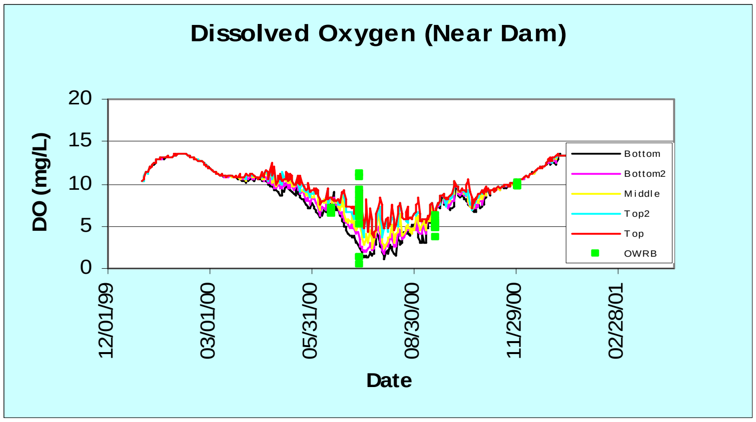


FIGURE 6-24. DISSOLVED OXYGEN NEAR THE DAM (2000)

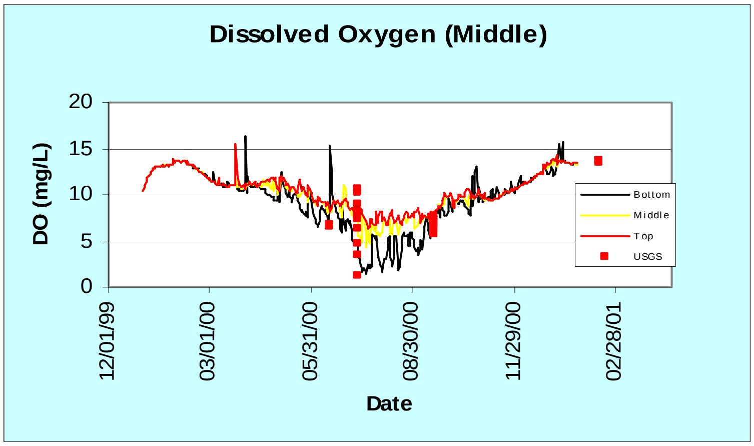


FIGURE 6-25. DISSOLVED OXYGEN IN THE MIDDLE PART OF THE LAKE (2000)

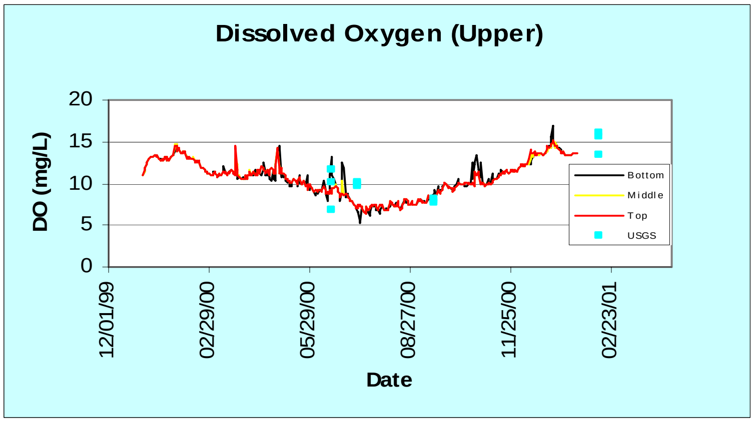


FIGURE 6-26. DISSOLVED OXYGEN IN THE UPPER PART OF THE LAKE (2000)

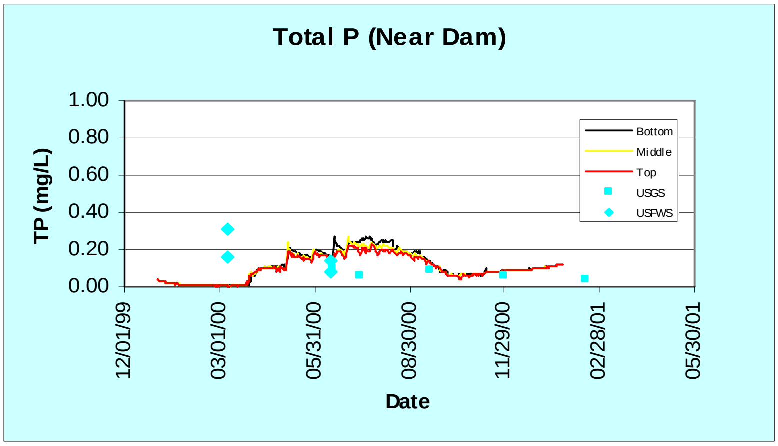


FIGURE 6-27. TOTAL-P NEAR THE DAM (2000)

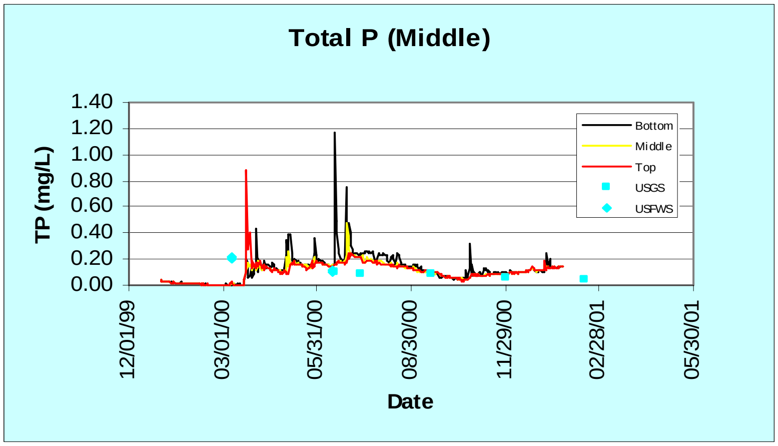


FIGURE 6-28. TOTAL-P IN THE MIDDLE PART OF THE LAKE (2000)

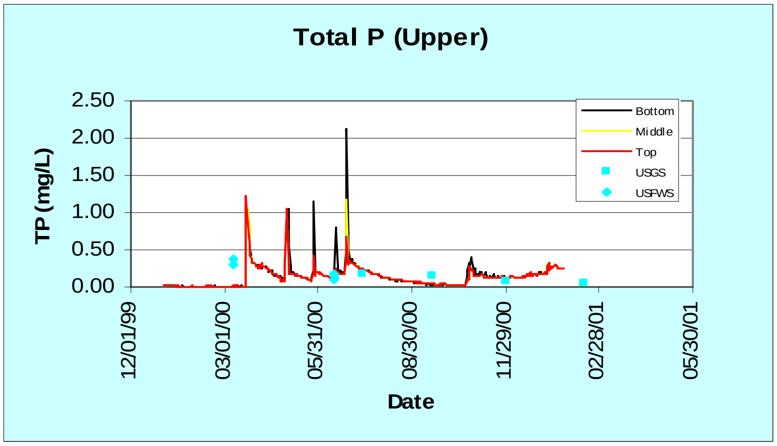


FIGURE 6-29. TOTAL-P IN THE MIDDLE PART OF THE LAKE (2000)

7. Nutrient Reduction

7.1. Load Reduction

Using the calibrated and verified model, reduction scenarios were evaluated to determine the nutrient load reductions required to reach the selected target endpoints. It is important to understand the impact of nutrients on the water quality conditions in the lake. In this study, the influence of nitrogen and phosphorus loadings were studied numerically using the calibrated and verified model for the Cobb Creek watershed. Though Fort Cobb Lake is phosphorus limited and eutrophication in the lake is more sensitive to changes in phosphorus loadings, both nitrogen and phosphorus loadings were reduced at the same percentage in the load reduction simulations. The nutrient reduction would come from various Best Management Practices (BMPs). Some BMPs remove more phosphorus and some BMPs remove more nitrogen. For example, converting some of the worst cultivated land to pasture would remove more nitrogen [17] and nutrient management plan would remove more phosphorus [21]. Without any knowledge what BMPs will be implemented in the watershed and the degree of implementation, we believe that the most reasonable assumption would be for phosphorus and nitrogen to have the same reduction rate.

Iterative model runs with progressively larger reductions were used to determine the reduction in lake loading required to meet the water quality standards. Since the dissolved oxygen and anoxic volume criteria are met currently without any load reduction, the reductions calculated are required to meet the target for Carlson's TSI of 62. The TSI target is considered to be met if the average number of days at three sites (near dam, mid-lake and upper-lake) with TSI greater than 62 is less than 36 days in a year. This assessment method is consistent with that used by Oklahoma Water Resources Board in the BUMP report in the sense that all data from the lake were put together to make an overall assessment.

For the calibration period, the TSI target was not met at 65% nutrient reduction but was met at 70% reduction. Therefore, the required reduction rate should be between 65% and 70% for the calibration period. However, this is not the final reduction goal because we still need to check if the TSI target is met at this reduction rate for the verification period. Iterative model runs with progressive load reductions showed that a 78% load reduction was required to meet the TSI target for the verification period. This reduction rate was chosen as the reduction rate for this TMDL study. Since the verification period is the critical condition, modeling results were shown for this period only. Figures 7-1 through 7-12 show the model predictions on TSI, chlorophyll-a, DO and TP after 78% load reduction. Table 7-1 shows TSI information at three locations of the lake resulting from different reduction rates.

Fort Cobb Lake is rarely stratified. The lake was stratified for only about two weeks in the calibration period and was not stratified at all in the verification period. Because the lake is well mixed and aerated, nutrient flux from the sediment is at minimum and is not likely to have a significant impact on the reduction rate. Ignoring the impact of internal nutrient loads would add implicitly to the margin of safety of the TMDL.

TABLE 7-1. NUTRIENT REDUCTION RATE

Reduction Rate	Location	TSI		Days (TSI ≥ 62)	Average Days (TSI ≥ 62)
		Max	Median		
0%	Near Dam	74.1	61.5	187	216
	Mid Lake	74.5	64.1	225	
	Upper Lake	76.6	66.0	235	
70%	Near Dam	69.7	51.0	48	76
	Mid Lake	71.1	53.5	83	
	Upper Lake	72.1	55.6	97	
75%	Near Dam	68.3	50.2	23	62
	Mid Lake	69.8	51.8	74	
	Upper Lake	70.9	54.6	89	
78%	Near Dam	65.9	48.9	2	32
	Mid Lake	67.4	49.8	29	
	Upper Lake	69.2	52.2	64	

It is worth noting that the reduction goal of 78% was determined based on the land use information in 1998 through 2000 when the data were collected. The land uses in the model do not reflect the current condition. Oklahoma State University updated the SWAT model with 2005 land use coverage. The model with the most recent land covers indicates that 20% total phosphorus reduction has been achieved since 2001. One dominant factor for the reduction could be the dramatic change in land use. Many farmers are shifting from row crops to wheat and pasture in the basin. After 2001, peanut acreage dropped by 61%, a 9500 acre reduction [29].

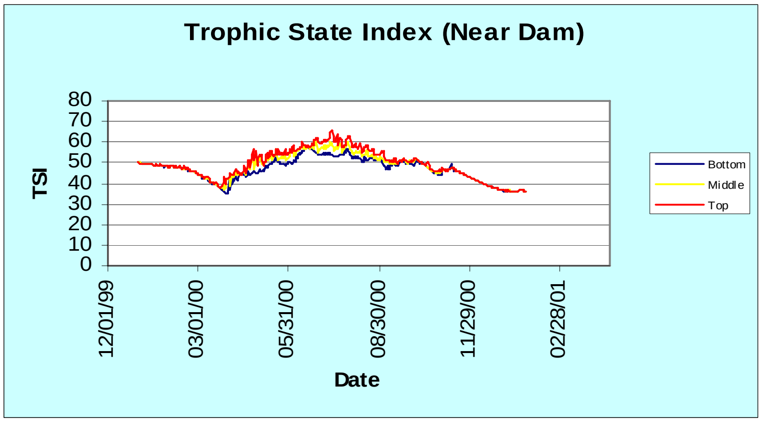


FIGURE 7-1. CARLSON'S TSI NEAR THE DAM (REDUCTION)

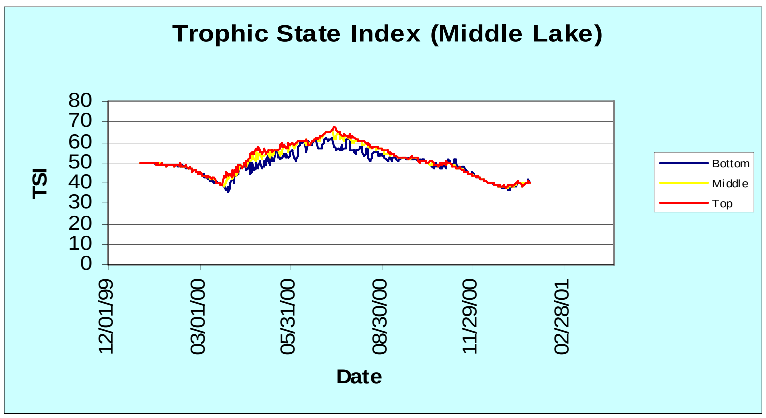


FIGURE 7-2. CARLSON'S TSI IN THE MIDDLE PART OF THE LAKE (REDUCTION)

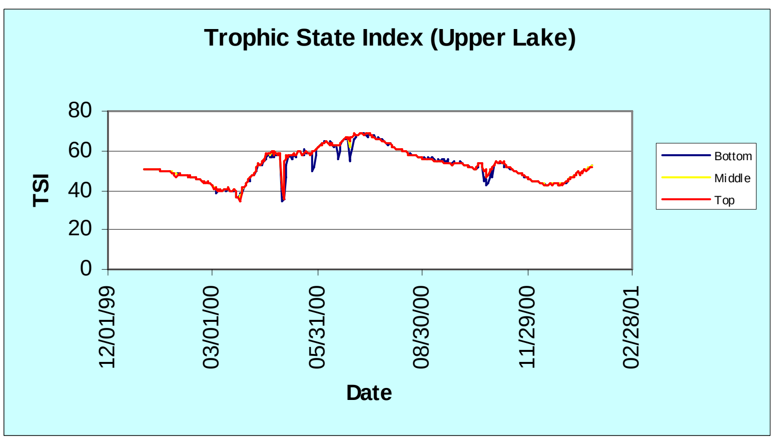


FIGURE 7-3. CARLSON'S TSI IN THE UPPER PART OF THE LAKE (REDUCTION)

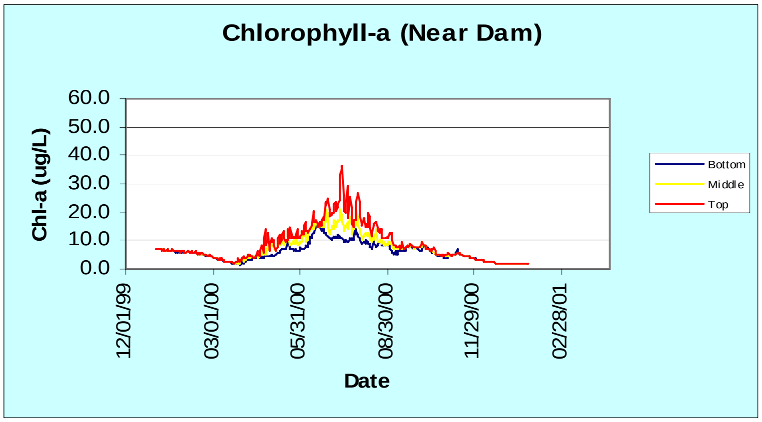


FIGURE 7-4. CHLOROPHYLL-A NEAR THE DAM (REDUCTION)

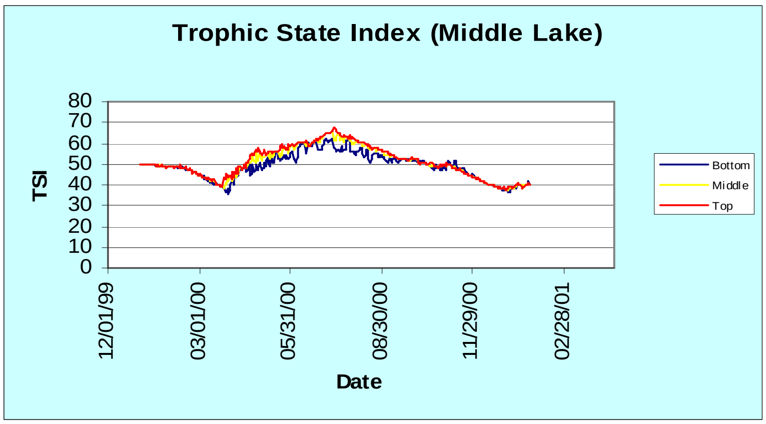


FIGURE 7-5. CHLOROPHYLL-A IN THE MIDDLE PART OF THE LAKE (REDUCTION)

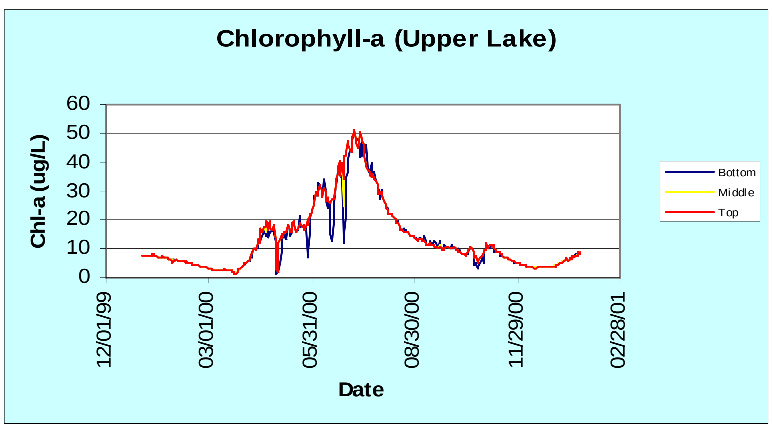


FIGURE 7-6. CHLOROPHYLL-A IN THE UPPER PART OF THE LAKE (REDUCTION)

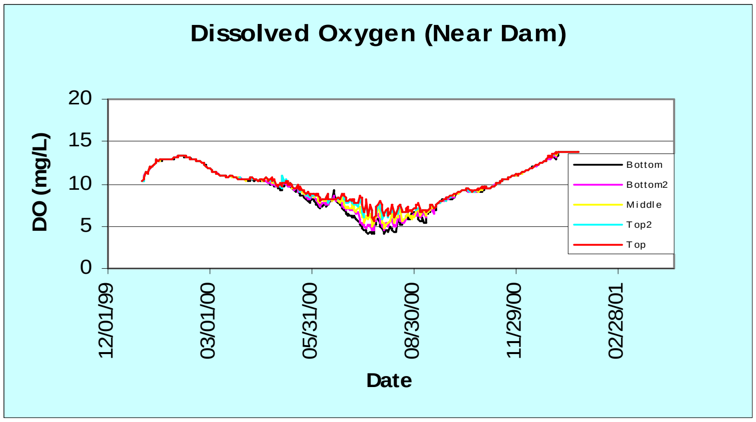


FIGURE 7-7. DISSOLVED OXYGEN NEAR THE DAM (REDUCTION)

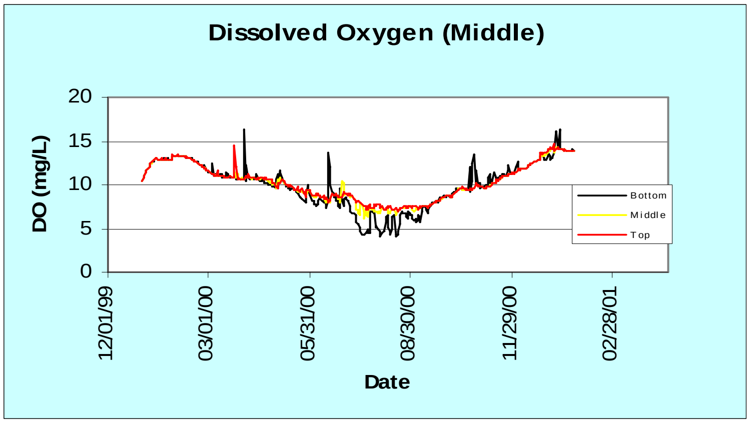


FIGURE 7-8. DISSOLVED OXYGEN IN THE MIDDLE PART OF THE LAKE (REDUCTION)

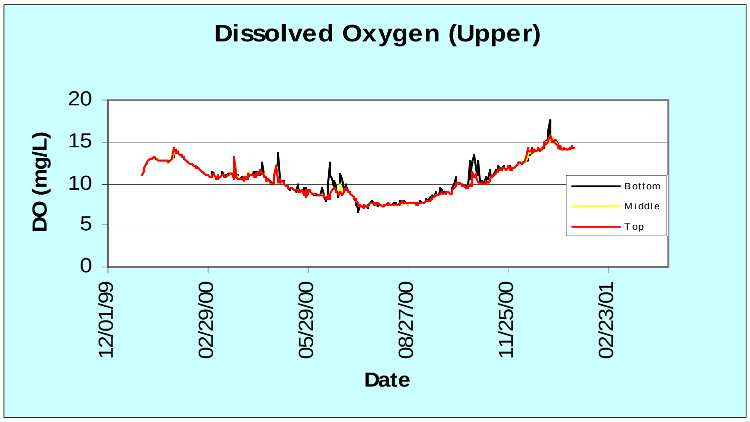


FIGURE 7-9. DISSOLVED OXYGEN IN THE UPPER PART OF THE LAKE (REDUCTION)

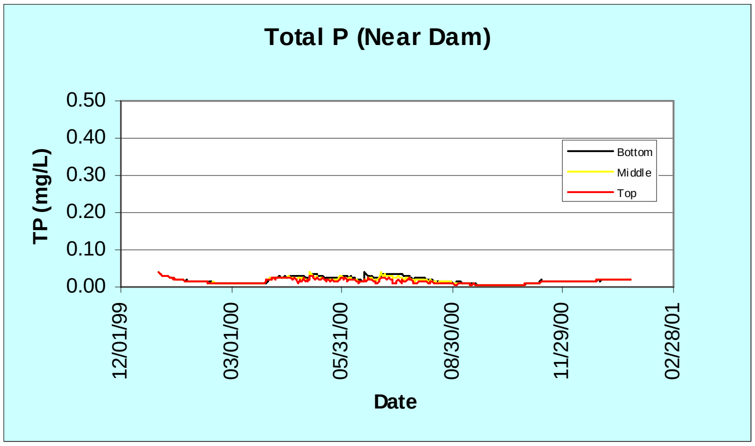


FIGURE 7-10. TOTAL-P NEAR THE DAM (REDUCTION)

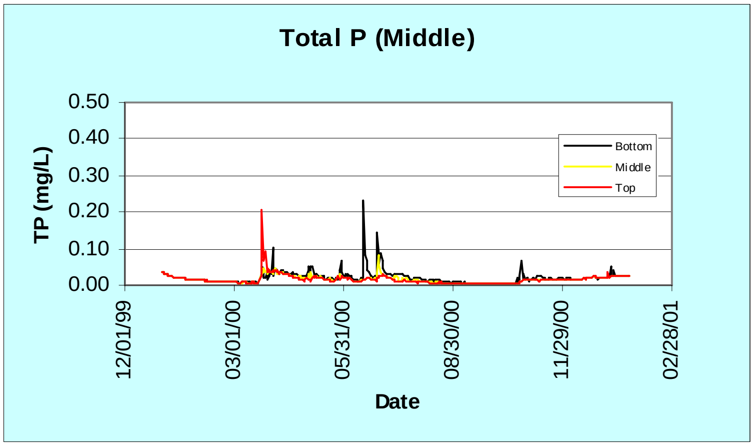


FIGURE 7-11. TOTAL-P IN THE MIDDLE PART OF THE LAKE (REDUCTION)

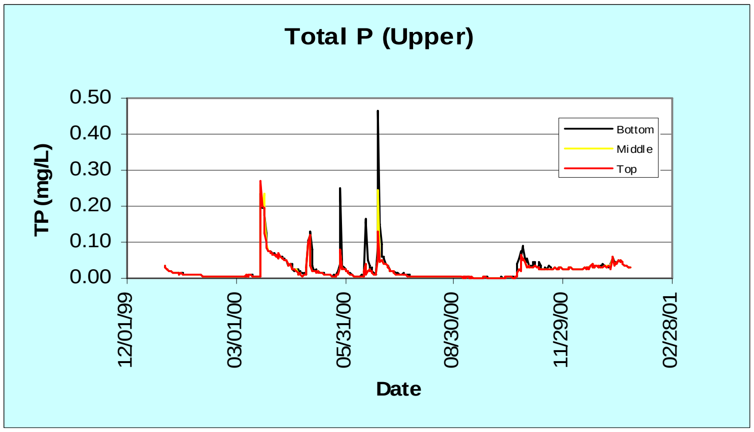


FIGURE 7-12. TOTAL-P IN THE UPPER PART OF THE LAKE (REDUCTION)

7.2. Margin of Safety and Load Allocation

Since the model is calibrated and verified, a 5% margin of safety (MOS) is recommended to satisfy the TMDL requirements. The model predicted a reduction in nutrients of 78% is necessary. In other words, 22% of the current nutrient load is allowed in order to achieve the targets of this TMDL. After applying the 5% margin of safety, only 17% of current load will be allocated as background load, wasteload, reserved load and non-point source load.

The Total Maximum Daily Load can be described as follows:

TMDL = BA + WLA + LA + MOS

Where

BA = Background Allocation

WLA = Wasteload Allocation (point source discharges)

LA = Load Allocation (non-point sources)

MOS = Margin of Safety

There is no wastewater discharge in the Cobb Creek watershed. There are two CAFO farms in the watershed. The NPDES permits for the CAFOs are total retention. The provisions in these permits are sufficient to protect waters in the Cobb Creek watershed. No wasteload allocation is assigned to the CAFOs.

There is currently no stormwater permit in the watershed. Therefore, no wasteload allocation is assigned for stormwater permits either. This does not mean that stormwater permits in the watershed cannot be issued in the future. A reserved load is allocated to accommodate any future stormwater discharges. The provisions in the stormwater permits are stringent enough to protect waters in the watershed.

The background allocation is established based on data collected under low flow conditions. Daily stream flows are sorted from low to high and three flow regimes are defined as follows:

Let Q_i represent daily stream flow

High Flow: if $Q_i \geq 75$ percentile

Normal Flow: if 25 percentile $\leq Q_i < 75$ percentile

Low Flow: if $Q_i < 25$ percentile

Monitoring data for total phosphorus under low flow conditions were separated and used to calculate the mean concentration for TP. This concentration was selected as the background concentration. The background concentration was calculated to be 0.069 mg/L. Average low flow was also calculated to be 0.38 cfs using flow data from 1998 through 2000. Then, the multiplication of background TP concentration and average low flow produced the background load to the lake.

BA = 23.5 kg/year.

The load allocation accounts for non-point source contributions. Since most of the total P load comes from non-point sources, it depends largely on rainfall and runoff events. The EFDC model predicts that a 78% reduction rate would bring Fort Cobb Lake into compliance for both calibration and verification periods. The average annual total P load from 1998 to 2000 predicted by the SWAT model is about 70,000 kg/year. Applying the 78% load reduction, the maximum allowable load is 15,400 kg/year. The load assigned for margin of safety (5%) is 3500 kg/year.

TABLE 7-2. LOAD ALLOCATIONS

Maximum Annual Load (kg/year)	Background Load (kg/year)	Wasteload Allocation (kg/year)	Load Allocation (kg/year)	Reserved Load (kg/year)	Margin of Safety (kg/year)
15400	24	0.0	11856	20	3500

Since there is no point discharge in the watershed, nothing is assigned to the wasteload allocation. To accommodate potential growth in the watershed, an annual load of 20 kg/year is reserved for storm water permits.

7.3. Best Management Practices

The Best Management Practices discussed in this section are intended to show with a reasonable assurance how nutrient reduction may be achieved in Fort Cobb watershed. The implementation of Best Management Practices is not a requirement of this TMDL report. Reduction of nonpoint source pollutant loadings relies on voluntary programs.

7.3.a. Effectiveness of Best Management Practices

The calibrated SWAT model was used to predict sediment and nutrient load from different land uses. Table 7-3 shows the simulated average annual sediment and nutrient loads for various land uses in the basin.

Forest (6% of the entire watershed) accounts for only 0.1% of total P load. Pasture or range (41.4%) accounts for 8.3% of total P load. Croplands (peanuts, sorghum, wheat for grains and grazeout wheat), which are about 50.4% of the total land in the watershed, account for 90.4% of total P load. Among the croplands, peanuts, sorghum and grazeout wheat fields (19.6%) are the major sources of total P contributing 65% of total P load. Therefore, load reduction efforts should focus on reducing nutrient load from cropland. Establishing riparian buffers, no-till cultivation, winter cover for row crops, conversion of cultivated land to pasture, grade stabilization structures, diversions, and terraces are examples of effective Best Management Practices (BMP) to reduce sediment and nutrient load to Fort Cobb Lake.

TABLE 7-3. SIMULATED ANNUAL LOADS BY LAND USE FOR THE FORT COBB BASIN FOR THE PERIOD 1990-2000

Land Use	Fraction of Basin (%)	Sediment (Mg/ha)	Total N (Kg/ha)	Total P (Kg/ha)
Forest	6.0%	0.01	2.20	0.01
Pasture-Range	41.4%	1.61	3.60	0.62
Peanut	7.1%	4.06	7.74	1.87
Sorghum	2.8%	3.16	6.95	1.20
Urban	0.1%	0.05	1.20	0.09
Water	2.1%	0.00	0.00	0.00
Wheat for Grain	30.8%	5.88	9.90	1.91
Grazeout Wheat	9.7%	5.16	8.69	1.81

Using the calibrated SWAT model for the Cobb Creek watershed, Oklahoma State University evaluated several Best Management Practices (BMPs) [17]. The scenarios evaluated are as follows:

- Winter cover crops on row crops
- No-till wheat and row crops
- Conversion of selected highly erodible crop to permanent pasture.

The impacts of each practice on sediment and nutrient reduction are summarized in Table 7-4.

It is estimated that approximately one third of wheat fields are currently moldboard plowed. The reduction in sediment load we would expect if everyone quit moldboard plowing would be 28.6% * 0.33 = 9.5%. Certain farmers were considering changing their peanut production to cotton production. This change as predicted by the SWAT model would increase sediment and nutrient load and therefore should be discouraged.

TABLE 7-4. LOAD REDUCTIONS FOR DIFFERENT BMPS

Practice	% Reduction In Total Basin Load		
	Sediment	Total N	Total P
Calibrated Model*	0.00%	0.00%	0.00%
Notill wheat and row crops	-51.10%	-42.80%	-34.40%
No winter cover on row crops	9.20%	11.10%	6.80%
Worst 1% of cultivated land to pasture	-6.00%	-3.20%	-4.40%
Worst 2.5% of cultivated land to pasture	-11.50%	-8.10%	-8.00%
Worst 5% of cultivated land to pasture	-18.00%	-13.90%	-12.30%
Worst 7.5% of cultivated land to pasture	-23.00%	-18.30%	-15.50%
Worst 10% of cultivated land to pasture	-26.50%	-21.40%	-17.90%
Worst 15% of cultivated land to pasture	-33.00%	-27.10%	-22.10%
Worst 20% of cultivated land to pasture	-37.50%	-31.10%	-25.10%
Worst 25% of cultivated land to pasture	-41.50%	-34.70%	-27.70%
Worst 35% of cultivated land to pasture	-48.00%	-40.40%	-32.00%

* Calibrated model assumes conventional tillage without moldboard plow and small grains winter cover on all row crop

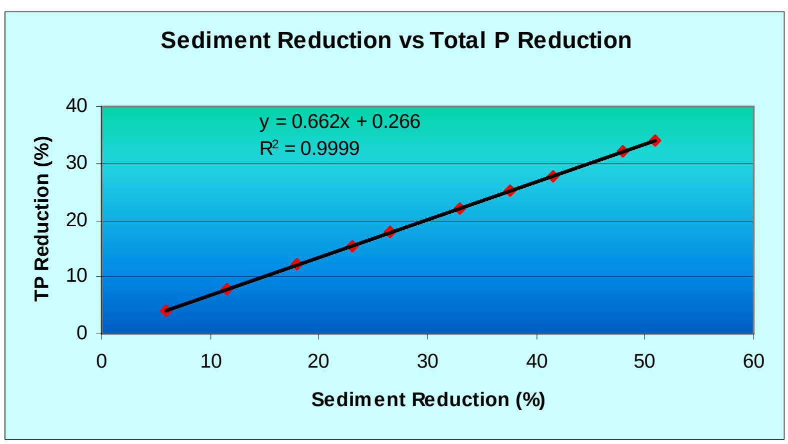


FIGURE 7-13. SEDIMENT REDUCTION VS. TOTAL-P REDUCTION

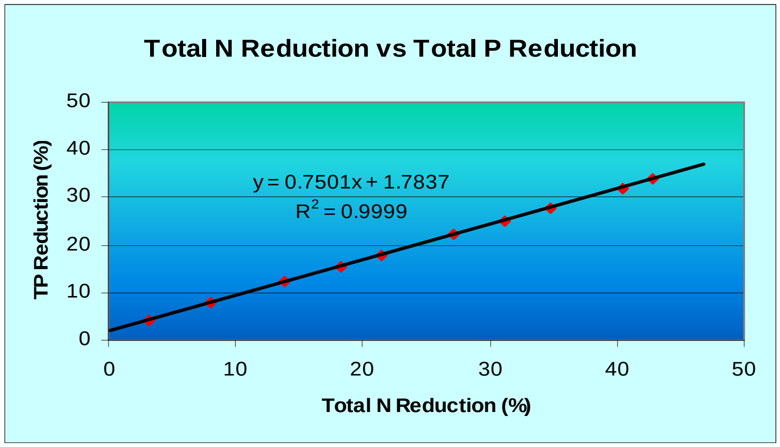


FIGURE 7-14. TOTAL N REDUCTION VS. TOTAL-P REDUCTION

Reduction rates for sediment, total P and total N have a linear relationship between each other as shown in Figure 7-13 and 7-14. For every percent (1.0%) reduction in total P, 1.33% reduction in total N and 1.5% reduction in sediment would be achieved. These reduction rates and relationships were predicted by the calibrated SWAT model for converting some of the worst cultivated land to pasture and no-till wheat and row crops. The reduction rates for other types of management practices will be different. Figure 7-15 shows the relationship between sediment load reduction and conversion of cultivated land to pasture [17].

More details on the impacts of the listed scenarios can be found in the OSU's "Fort Cobb Basin - Modeling and Land Cover Classification" report [17].

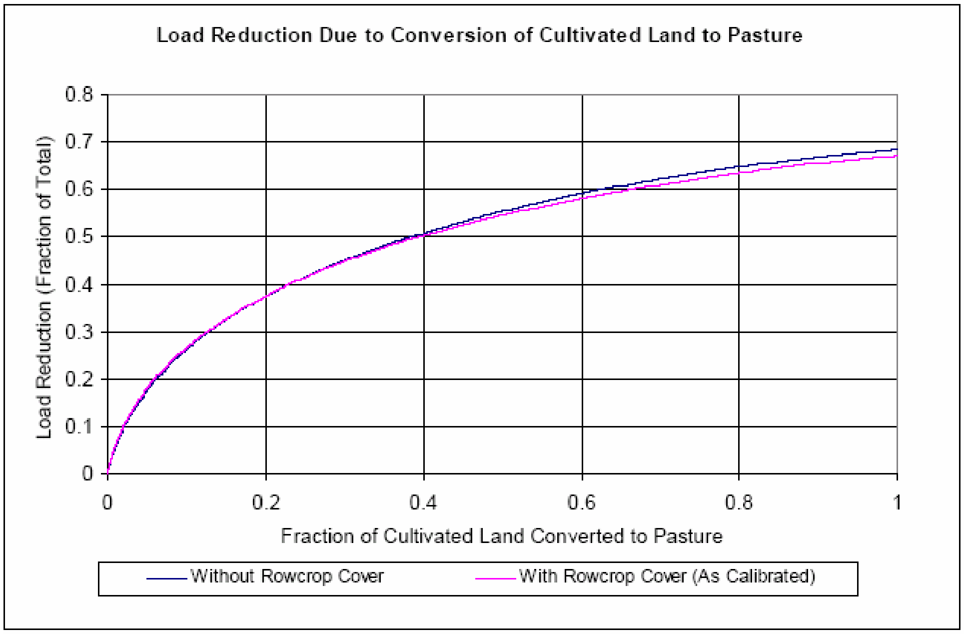


FIGURE 7-15. SEDIMENT LOAD REDUCTION DUE TO CONVERSION OF CULTIVATED LAND TO PASTURE

The highest sediment reduction rate through the BMPs evaluated by OSU is 65.8%, which is equivalent to 44.0% reduction in TP. To achieve this reduction rate, 100% no-till on all crops is required and 100% cover-crops need to be used on all row crops. These practices are almost impossible to implement in reality. This tells us that 65% reduction in total P cannot be achieved through no-till and row crop and the conversion of worst cultivated land to pasture alone. Other practices will be needed to help reduce sediment and nutrient load to Fort Cobb Lake. These practices include riparian buffer restoration, limiting access to creeks for cattle, nutrient management plans, grade stabilization structures, and education on fertilizer application.

Riparian buffers are an effective way to reduce sediment and nutrient load from agricultural fields. Riparian buffers slow and disperse flow of surface runoff, and promote settling of sediment. Riparian buffers are especially good for filtering larger-sized sediment such as sand, soil aggregates, and crop residue, but are generally less effective for clay sediments. Riparian buffers are good for removal of sediment-attached nutrients but are less effective on dissolved nutrients. Riparian buffers along agricultural lands benefit the farmer and the stream in many ways. However, due to the limitation of the SWAT model, OSU did not simulate the impact of riparian buffers.

A buffer can hold 50 to 80% of nutrients in the soil, keeping them out of the stream where they can cause algal blooms and degrade water quality. A sufficient buffer can also help trap 75-90% of sediment before it leaves the farm [19]. Charles J. Barden and Kyle R Mankin et al [20] studied the effectiveness of three types of riparian buffer vegetation for filtering agricultural field runoff, namely fallow, plum & native grass, and plum & fallow. Total P reduction is above 40% for all vegetation and ranges from 40% to 60%. Reduction in TSS concentration is over 90% for all vegetation types.

The goal of nutrient management is to minimize edge of field delivery of nutrients and minimize leaching of nutrients from the root zone. Pollution prevention through nutrient management is achieved by developing a nutrient budget for the crop, applying nutrients at the proper time, and applying only the types and amounts of nutrients necessary to produce a crop. A summary of the literature findings regarding the effectiveness of nutrient management in controlling nitrogen and phosphorus is given in the following table [21].

TABLE 7-5. RELATIVE EFFECTIVENESS OF NUTRIENT MANAGEMENT

Practice [a]	Percent Change in Total Phosphorus Loads	Percent Change in Total Nitrogen Loads
Nutrient Management [b]	-35	-15

[a] Most observations from reported computer modeling studies
[b] An agronomic practice related to source management; actual change in contaminant load to surface and ground water is highly variable.

According to the Oklahoma Conservation Commission, gully erosion is common and significant in the Cobb Creek watershed. The implementation of structural BMPs, such as grade stabilization structures and diversions could be critical in some areas. Grade stabilization structures will prevent formation or advance of gullies and trap sediment, nutrients and other chemicals, thus improving downstream water quality. Without the structural BMPs, other management practice such as riparian buffer, grasses or tillage practices may not be as effective due to erosion already ongoing. Though the structural BMPs are vital to the success of non-point source project in the watershed, it is very difficult to estimate the effectiveness of such structures in reduction of sediments and nutrients.

With the combination of riparian buffer, no-till and row crop, conversion of worst cultivated land to pasture, nutrient management plan, bank stabilization, grade stabilization structures and other BMPs, it is likely the required reduction in sediment and nutrients can be achieved. Due to the complexity of the water quality system and the inherit uncertainties in the watershed and lake models, it is difficult to quantify the actual reduction in sediment and nutrient. More monitoring and study will be needed to evaluate the actual effectiveness of the proposed BMPs.

Table 7-6 summarizes the estimated reduction rates for sediment and nutrients for various Best Management Practices.

TABLE 7-6. REDUCTION RATE FOR SEDIMENT AND NUTRIENTS FOR VARIOUS BMPS

Best Management Practices	Sediment (%)	Total nitrogen (%)	Total P (%)
Notill wheat & row crops [17]	-51	-43	-34
Convert up to 20% worst cultivated land to pasture [17]	~ -38	~ -31	~ -25
Riparian Buffer [19][20]	75 ~ 90	35-55	40 ~ 60
Nutrients management plan [21]	NA	-15	- 35
Grade stabilization structures	Unknown	Unknown	Unknown

When several BMPs are implemented at the same time, we assume that the reduction on sediment and nutrients will be additive. Following example is used to show how the overall reduction of several BMPs is calculated:

- Assume no-till wheat and row crop and riparian buffer is implemented in the watershed. The reduction rate on total P for no-till wheat and row crop and riparian buffer is 34% and 50%, respectively.
- After no-till wheat and row crop is implemented, 34% of total P is removed from current loading. In other word, the percentage of total P remaining is (1–0.34) = 66%.
- When riparian buffer is implemented, there is another 50% reduction in total P which leaves 0.66 × (1-0.5) = 33% total P remaining.
- The overall reduction will be (1 – 0.33) = 67%.

This procedure can keep going when more BMPs are implemented. In reality, different BMPs may interact with each other and the actual reduction rate may not be additive. However, this procedure provides the best estimate on overall reduction we can possibly have without any monitoring.

7.3.b. Options for Implementing BMPs

There are many combinations of different BMPs. The most feasible combination will depend on a number of factors such as the degree of implementation for each BMP, number of land owners who will participate the proposed BMPs, costs and incentives for each BMP, public education, etc. In this section, we are trying to give a few examples on options to achieve reduction rate of 78% in total P through a combination of BMPs.

Option #1:

- No-till wheat and row crop: 34%
- Convert 20% worst cultivated land to pasture: 25%
- Riparian buffer: 50%
- Nutrient Management Plan: 35%
- Grade stabilization structures: unknown

The overall reduction rate in total P is calculated to be 84%. This is the potential reduction rate that may be achieved in the watershed through the proposed BMPs. However, this reduction rate may be unrealistic because it assumes that the above BMPs are fully implemented.

Option #2:

- 60% No-till wheat and row crop: (0.34 * 0.65) = 22.1%
- Convert 20% worst cultivated land to pasture: 25%
- 90% Riparian buffer: (0.5 * 0.9) = 45%
- 90% Nutrient Management Plan: (0.35 * 0.9) = 31.5%
- Grade stabilization structures: unknown

The overall reduction in total P would be 78% for this option.

These BMP options only serve as examples of what might be done to achieve the TMDL reduction goal. We recognize this TMDL reduction goal may be difficult to achieve because the extent of reduction required and the implementation of nutrient reduction BMPs are voluntary. The BMPs may not be unrealistic related to the required extent to achieve the goal of the TMDL, but are not necessarily readily agreeable to farmers given current programs in the watershed. Additional support to help implement these practices will likely be necessary.

As noted in Section 7.1, the TMDL reduction goal was determined using the land cover when the data was collected. Since then, approximately 20% reduction has been achieved according to OSU's SWAT model with 2005 land cover information. Although this reduction is still far short from reaching the TMDL reduction goal, it is a big step forward. For those who are interested in BMPs recently implemented in the watershed, please refer to the Watershed Based Plan for the Fort Cobb Watershed report by Oklahoma Conservation Commission [30].

8. Public Participation

This report has been submitted to EPA for technical review and technical approval was received in November 2004. The TMDL report was open for public review on November 24, 2004 and the public review period ended on February 25, 2005. A public meeting was held in the Town of Fort Cobb on January 13, 2005. It was estimated that more than 60 persons attended the public meeting and 45 attendants registered. The attendants include farmers and stakeholders living in or near the Fort Cobb watershed, representatives from West Caddo Conservation District, Farm Bureau and their consultants, USGS, USDA, OCC, and Oklahoma Department of Agriculture etc. A brief presentation about the TMDL was given in the public meeting followed by questions and answers. All questions except specific technical questions from Farm Bureau's Consultants were answered. OCC and USGS also helped to clarify some of the questions. We stayed until all questions were answered and all meeting attendants left.

To address the unanswered technical questions, we committed an additional meeting with Farm Bureau and their consultants. That meeting was held on February 8, 2005 in the DEQ office. Farm Bureau and their consultants, DEQ and OSU attended the meeting.

At the end of public review period, five comments were received. All comments were considered, formally responded and included as an appendix of this report. As a result of public comments, Oklahoma State University refined or recalibrated the SWAT model. Since the TP load to the Fort Cobb Lake predicted by the SWAT model changed significantly from year to year although the overall annual average loading stayed almost the same, we recalibrated the EFDC model based on the new TP load to the lake. Due to a significant increase in TP load in 2000, the required reduction rate went up from 65% to 78%. The TMDL allocation was changed accordingly. The TMDL report was also revised to reflect all changes resulting from public comments.

The second public comment period was open on May 24, 2006 for the revised TMDL report and the public comment period ended on June 23, 2006. No comments were received during this public comment period.

9. References

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10. Appendix A

EFDCWIN.inp

```
C******************************************************************************
C
C Efdcwin.inp is the new master input file of the EFDC model. It is the simplified
C version of the original master input file efdc.inp, and is created for the
development of
C the sediment toolkit. Similar to efdc.inp, efdcwin.inp contains the major
C parameters of the EFDC's hydrodynamic, temperature, salinity, sediment and
C toxic submodels. What not covered in efdcwin.inp are the parameters of the
C water quality submodel. The EFDC model reads efdcwin.inp right after efdc.inp
C is read, therefore the parameters in efdcwin.inp override the corresponding
C parameters in efdc.inp and the EFDC model can work normally without the existance
c of efdcwin.inp.
c
c For most applications, a user needs to adjust the parameters in efdcwin.inp
c only and to treat efdc.inp like a dummy file. For some special applications or
C for the several advanced EFDC users, changes to the original efdc.inp file might
C be needed.
c
c Efdcwin.inp is still in the process of testing. A file similar to efdcwin.inp,
c called wqwin.inp, will be created for the EFDC model's water quality submodel.
C For now, please use the original parameter input files wq3dwc.inp and wq3dsd.inp
c for water quality modeling applications.
c
C******************************************************************************
C1     1. Submodel Selection
C
C      SAL   =ISTRAN(1): Salinity submodel=(0,1)
C      TEM   =ISTRAN(2): Temperature submodel=(0,1)
C      DYE   =ISTRAN(3): Dye submodel=(0,1)
C      WQ    =ISTRAN(8): Water quality submodel=(0,1)
C      NSED9->ISTRAN(6): Cohesive sediment submodel=(0,N)
C      NSND9->ISTRAN(7): Non-cohesive submodel=(0,N)
C      NTOX9->ISTRAN(5): Toxicant submodel (NTOX9 is an integer, NOT just On/Off)
C                        NTOX=TOX:  NUMBER OF TOXIC CONTAMINANTS(0 -> any positive
integer)
C                        =(0,N)
c
C1     SAL    TEM    DYE    WQ     NSED9  NSND9  NTOX9
       0      1      0      1      1      0      0
C ------------------------------------------------------------------------------
C2     2. Major Parameters
C
C      ISRESTI: 1 FOR hot start, READING INITIAL CONDITIONS FROM  restart.inp
C               0 for cold start
C      NTC:     Number of simulation days
C      NTSPTC:  Number of time setps per day
C      TBEGIN:  Beginning day of simulation
C      ZBRADJ:  Variable roughness height in meters
C      Alati    Domain latitude in Deg
C      TEMO:    Reference, initial, equilibrium and/or isothermal
C               tempreature in Deg C
c      RKDYE:  FIRST ORDER DECAY RATE FOR DYE VARIABLE IN 1/SEC
c
c  Card 8, 9 10 should be modified to be consistant with (or
c  independent from) NSED9, NSND9, & NTOX9, 7/30/99
c
c            Total NTC= 181 + 92 + 92 = 365 days
```

```
C
C2     ISRESTI  NTC   NTSPTC  TBEGIN  ZBRADJ  Alati   TEMO   RKDYE
       0         390   3456    0.0     0.03       35.0    25.0   0.0
C ------------------------------------------------------------------------------
C3     3. Vertical Layers
C
C   Layer #:         Layer number, 1=bottom layer
|
C   Layer Thickness: Thickness of each vertical layer
C                     Layer thickness must sum to 1.0
C
C
C3     Layer #      Layer Thickness
       1      0.2
       2      0.2
       3      0.2
       4      0.2
       5      0.2
C ------------------------------------------------------------------------------
C4     4. Harmonic Tides
C
C      NPFOR:      Forcing number
C      SYMBOL:     Forcing symbol (heer for refeernce only)
C      AMPLITUDE:  Amplitude in M (Pressure divided by RHO*G)
C      PHASE:      Forcing phase relative to tbegin in seconds
c
c when no tides, c4 must not have data, otherwise PFPH(0,...) will cause problem at
c RAD=PI2*PFPH(NPFORw,M)/TCP(M), when npserw=0. MTIDE=0 will skip this do loop
c
C4     NPFOR  SYMBOL AMPLITUDE    PHASE
C ------------------------------------------------------------------------------
C5     5. Point Sources
C
C
C      IQS:      I CELL INDEX OF VOLUME SOURCE/SINK
C      JQS:      J CELL INDEX OF VOLUME SOURCE/SINK
c      QSSE:     CONSTANT INFLOW/OUTFLOW RATE IN M*M*M/S
C      NQSERQ:   ID NUMBER OF ASSOCIATED VOLUMN FLOW TIME SERIES
C      NSSERQ:   ID NUMBER OF ASSOCIATED SALINITY TIME SERIES
C      NTSERQ:   ID NUMBER OF ASSOCIATED TEMPERATURE TIME SERIES
C      NDSERQ:   ID NUMBER OF ASSOCIATED DYE CONC TIME SERIES
C      NTXSERQ:  ID NUMBER OF ASSOCIATED TOXIC CONTAMINANT CONC TIME SERIES
C      NSDSERQ:  ID NUMBER OF ASSOCIATED COHEASIVE SEDIMENT CONC TIME SERIES
C      NSNSERQ:  ID NUMBER OF ASSOCIATED NONCOHEASIVE SED CONC TIME SERIES
c
c   wqpsl.inp should be changed to make it consistant with qser.inp, i.e. to include
c   0.0 0.0 0.0 0.0 1.0
c   at the beginning, to specify discharging layer(s)
C
C
C5     IQS    JQS    QSSE   NQSERQ  NSSERQ  NTSERQ     NDSERQ  NTXSERQ  NSDSERQ  NSNSERQ
NWQ
       12     37     0.0    1        0        1  0        0         1   0         0
      15    33    0.0   2       0       1       0       0        1        0        0
      21    26    0.0   3       0       1       0       0        1        0        0
      18    18    0.0   4       0       1       0       0        1        0        0
C ------------------------------------------------------------------------------
C6     6. Controlled Flows
C
C      IQCTLU:   I INDEX OF UPSTREAM OR WITHDRAWAL CELL
C      JQCTLU:   J INDEX OF UPSTREAM OR WITHDRAWAL CELL
```

```
C       IQCTLD:   I INDEX OF DOWNSTREAM OR RETURN CELL
C       JQCTLD:   J INDEX OF DOWNSTREAM OR RETURN CELL
C       NQCTYP:   FLOW CONTROL TYPE
C                 = 0  HYDRAULIC STRUCTURE: INSTANT FLOW DRIVEN BY ELEVATION
C                      OR PRESSURE DIFFERCENCE TABLE
C                 = 1  ACCELERATING FLOW THROUGH TIDAL INLET
C       NQCTLQ:   ID NUMBER OF CONTROL CHARACTERIZATION TABLE
C
C An utility program is needed to make NQCTLQ tables (qctl.inp)
C  and to make withdraw time series (qwrs.inp)
c qctl.inp should be replaced by a subroutine, so user does not have to supply it
c
C6      IQCTLU JQCTLU IQCTLD JQCTLD NQCTYP NQCTLQ
C -----------------------------------------------------------------------------
C7      7. Flow Withdrawals
C
c       IWRU:     I INDEX OF UPSTREAM OR WITHDRAWAL CELL
c       JWRU:     J INDEX OF UPSTREAM OR WITHDRAWAL CELL
c       KWRU:     K INDEX OF UPSTREAM OR WITHDRAWAL LAYER
c       IWRD:     I INDEX OF DOWNSTREAM OR RETURN CELL
c       JWRD:     J INDEX OF DOWNSTREAM OR RETURN CELL
c       KWRD:     K INDEX OF DOWNSTREAM OR RETURN LAYER
c       QWRE:     CONSTANT VOLUME FLOW RATE FROM WITHDRAWAL TO RETURN IN M*M*M/s
c       NQWRSERQ: ID NUMBER OF ASSOCIATED VOLUMN WITHDRAWAL-RETURN FLOW AND
c                    CONCENTRATION RISE TIME SERIES
c       SAL:   SALTINITY RISE
c       TEM:   TEMPERATURE RISE
c       DYE:   DYE CONCENTRATION RISE
c       TOX#:  NTOX TOXIC CONTAMINANT CONCENTRATION RISES
c       SED#:  NSEDC COHESIVE SEDIMENT CONCENTRATION RISE
c       SND#:  NSEDN NONCOHESIVE SEDIMENT CONCENTRATION RISE
c
C7      IWRU   JWRU   KWRU   IWRD   JWRD   KWRD   QWRE   NQWRSERQ     SAL    TEM    DYE
        TOX#   SED#   SND#
        11     7      5      11     6      1      0.0    1            0.0    0.0    0.0
        0.0    0.0    0.0
C -----------------------------------------------------------------------------
C8      8. Cohesive Sediment
C
C      ISEDINT: 0 FOR CONSTANT INITIAL CONDITIONS GIVEN ON C36 AND C37 of efdc.inp
C               1 FOR SPATIALLY VARIABLE WATER COLUMN INITIAL CONDITIONS
C               2 FOR SPATIALLY VARIABLE BED INITIAL CONDITIONS
C               3 FOR SPATIALLY VARIABLE WATER COL AND BED INITIAL CONDITIONS
C               ALL spatial variable INITIAL CONDITIONS FROM FILE sedb.inp
C       SEDO:    INITIAL SEDIMENT CONC IN FLUID PHASE (mg/liter=gm/m**3)
C       SEDBO:   INITIAL SEDIMENT PER UNIT AREA OR BOTTOM SURFACE (gm/sq meter)
C       WSEDO:   CONSTANT OR REFERENCE SEDIMENT SETTLING VELOCITY
C                IN FORMULA WSED=WSEDO*( (SED/SEDSN)**SEXP )
C       TAUD:    BOUNDARY STRESS BELOW WHICH DEPOSITION TAKES PLACE ACCORDING
C                TO (TAUD-TAU)/TAUD
C       WRSPO:   REF RESUSPENSION RATE (COHESIVE SED TRANS ONLY) IN FORMULA
C                WRSP=WRSP0*( ((TAU-TAUR)/TAUN)**TEX ) (gm/m**2-sec)
C       TAUR:    BOUNDARY STRESS ABOVE WHICH RESUSPENSION OCCURS (m/s)**2
C
C        1CM THICKNESS BED WITH N=.6,.5 GIVES SEDBO 1.E4, 1.25E4
C
C
C                            Ziegler, 94, Fig.3's WSEDO
C8      ISEDINT      SEDO   SEDBO  WSEDO  TAUD   WRSPO  TAUR
        0      4.0   30000.0       0.0020 0.0020 0.0060 0.0024
C -----------------------------------------------------------------------------
```

```
C9     9. Non-cohesive Sediment
C
C       SEDO:    INITIAL SEDIMENT CONC IN FLUID PHASE (mg/liter=gm/m**3)
C       SEDBO:   INITIAL SEDIMENT PER UNIT AREA OR BOTTOM SURFACE (gm/sq meter)
C       WSEDO:   CONSTANT OR REFERENCE SEDIMENT SETTLING VELOCITY
C       SEDN:    MAX MASS/TOT VOLUME IN BED (NONCOHESIVE SED TRANS) (gm/m**3)
C       SEXP:    DIMENSIONLESS RESUSPENSION PARAMETER GAMMA ZERO
C       TAUD:    DUNE BREAK POINT STRESS
C       WRSPO:   NOT USED
C       TAUR:    CRITICAL SHIELDS STRESS  IN (m/s)**2
c       TEX:     CRITICAL SHIELDS PARM (NONCOH SED)                            |
c
c   Morro Bay Projects indicated that SND model has problems when wet/dry is on
c     see rdump1.for code, the section caculates tbsed
C                               1.8E6
C9     SEDO   SEDBO  WSEDO  SEDN   SEXP   TAUD   WRSPO  TAUR   TEX
C ------------------------------------------------------------------------------
C10    10. Toxicant Parameters
C    USER MAY CHANGE UNITS OF WATER AND SED PHASE TOX CONCENTRATION
C    AND PARTIATION COEFFICIENT ON C38 - C40 BUT CONSISTENT UNITS MUST
C    MUST BE USED FOR MEANINGFUL RESULTS
C
C      NTOXN:    TOXIC CONTAMINANT NUMBER ID (1 LINE OF DATA BY DEFAULT)
C     ITXINT:    0 FOR SPATIALLY CONSTANT WATER COL AND BED INITIAL CONDITIONS
C                1 FOR SPATIALLY VARIABLE WATER COLUMN INITIAL CONDITIONS
C                2 FOR SPATIALLY VARIABLE BED INITIAL CONDITIONS
C                3 FOR SPATIALLY VARIABLE WATER COL AND BED INITIAL CONDITION
C    ITXBDUT:    SET TO 0 FOR INITIAL BED CONDITION TOTAL TOX (ugm/litr)
C                SET TO 1 FOR INITIAL BED CONDITION MASS TOX/MASS SED(mg/kg)
C    TOXINTW:    INIT WATER COLUNM TOT TOXIC VARIABLE CONCENTRATION (ugm/litr)
C    TOXINTB:    INIT SED BED TOXIC CONC SEE ITXBDUT
C    DIFTOX:   DIFFUSION COEFF FOR TOXICANT IN SED BED PORE WATER (M**2/S)
C
C10    NTOXN  ITXINT ITXBDUT      TOXINTW      TOXINTB      DIFTOX
C ------------------------------------------------------------------------------
C11    11. Tox-Sed Parameters
C
C     NTOXC: TOXIC CONTAMINANT NUMBER ID.  NSEDC+NSEDN LINES OF DATA
C              FOR EACH TOXIC CONTAMINANT (DEFAULT = 2)
C  NSEDN/NSNDN: FIRST NSED LINES COHESIVE, NEXT NSND LINES NON-COHESIVE.
C            REPEATED FOR EACH CONTAMINANT
c
c   NTOXC & NSEDN/NSNDN are not used, and should be removed, 8/16/99
c
C   ITXPARW: EQUAL 1 FOR SOLIDS DEPENDENT PARTITIONING (WC) GIVEN BY
C            TOXPAR=toxparw*(CSED**CONPARw),
C   TOXPARW: WATER COLUMN PARO (ITXPARW=1) OR EQUIL TOX CON PART COEFF BETWEEN
C            EACH TOXIC IN WATER AND ASSOCIATED SEDIMENT PHASES (liters/mg)
C   CONPARW: EXPONENT IN  TOXPAR=PARO*(CSED**CONPARW) IF ITXPARW=1
C   ITXPARB: EQUAL 1 FOR SOLIDS DEPENDENT PARTITIONING (BED)
C   TOXPARB: SEDIMENT BED PARO (ITXPARB=1) OR EQUIL TOX CON PART COEFF BETWEEN
C            EACH TOXIC IN WATER AND ASSOCIATED SEDIMENT PHASES (liters/mg)
C   CONPARB: EXPONENT IN  TOXPAR=PARO*(CSED**CONPARB) IF ITXPARB=1
C                 1       0.8770  -0.943          0.025
C11    ITXPARW      TOXPARW      CONPARW      ITXPARB      TOXPARB      CONPARB
       Comment
C ------------------------------------------------------------------------------
C12    12. South OBC
C
C       ICBS:    I CELL INDEX
C       JCBS:    J CELL INDEX
```

```
C       ISPBS:   1 FOR RADIATION-SEPARATION CONDITION
C                0 FOR ELEVATION SPECIFIED
C       NPFORS:    APPLY HARMONIC FORCING NUMBER NPFORS
C       NPSERS:    APPLY TIME SERIES FORCING NUMBER NPSERS
C       NSSERS:  SOUTH BOUNDARY CELL SALINITY TIME SERIES ID NUMBER
C       NTSERS:  SOUTH BOUNDARY CELL TEMPERATURE TIME SERIES ID NUMBER
C       NDSERS:  SOUTH BOUNDARY CELL DYE CONC TIME SERIES ID NUMBER
C       NTXSERS: SOUTH BOUNDARY CELL TOXIC CONTAMINANT CONC TIME SERIES ID NUM.
C       NSDSERS: SOUTH BOUNDARY CELL COHESIVE SED CONC TIME SERIES ID NUMBER
C       NSNSERS: SOUTH BOUNDARY CELL NONCOHESIVE SED CONC TIME SERIES ID NUMBER
C       NTSCRS:  NUMBER OF TIME STEPS TO RECOVER SPECIFIED VALUES ON CHANGE
C                TO INFLOW FROM OUTFLOW
C
C12    ICBS   JCBS   ISPBS  NPFORS NPSERS NSSERS NTSERS NDSERS NTXSERS      NSDSERS
       NSNSERS       NTSCRS
C ---------------------------------------------------------------------------
C13    13. West OBC
C
C       ICBW:    I CELL INDEX
C       JCBW:    J CELL INDEX
C       ISPBW:
C       NPFORW:
C       NPSERW:
C       NSSERW:  WEST BOUNDARY CELL SALINITY TIME SERIES ID NUMBER
C       NTSERW:  WEST BOUNDARY CELL TEMPERATURE TIME SERIES ID NUMBER
C       NDSERW:  WEST BOUNDARY CELL DYE CONC TIME SERIES ID NUMBER
C       NTXSERW: WEST BOUNDARY CELL TOXIC CONTAMINANT CONC TIME SERIES ID NUM.
C       NSDSERW: WEST BOUNDARY CELL COHESIVE SED CONC TIME SERIES ID NUMBER
C       NSNSERW: WEST BOUNDARY CELL NONCOHESIVE SED CONC TIME SERIES ID NUMBER
C       NTSCRW:  NUMBER OF TIME STEPS TO RECOVER SPECIFIED VALUES ON CHANGE
C                TO INFLOW FROM OUTFLOW
C                    Harmo  Pser
C13    ICBW   JCBW   ISPBW  NPFORW NPSERW NSSERW NTSERW NDSERW NTXSERW      NSDSERW
       NSNSERW       NTSCRW
C ---------------------------------------------------------------------------
C14    14. East OBC
C
C       ICBE:    I CELL INDEX
C       JCBE:    J CELL INDEX
C       ISPBE:
C       NPFORE:
C       NPSERE:
C       NSSERE:  EAST BOUNDARY CELL SALINITY TIME SERIES ID NUMBER
C       NTSERE:  EAST BOUNDARY CELL TEMPERATURE TIME SERIES ID NUMBER
C       NDSERE:  EAST BOUNDARY CELL DYE CONC TIME SERIES ID NUMBER
C       NTXSERE: EAST BOUNDARY CELL TOXIC CONTAMINANT CONC TIME SERIES ID NUM.
C       NSDSERE: EAST BOUNDARY CELL COHESIVE SED CONC TIME SERIES ID NUMBER
C       NSNSERE: EAST BOUNDARY CELL NONCOHESIVE SED CONC TIME SERIES ID NUMBER
C       NTSCRE:  NUMBER OF TIME STEPS TO RECOVER SPECIFIED VALUES ON CHANGE
C                TO INFLOW FROM OUTFLOW
C
C14    ICBE   JCBE   ISPBE  NPFORE NPSERE NSSERE NTSERE NDSERE NTXSERE      NSDSERE
       NSNSERE       NTSCRE
C ---------------------------------------------------------------------------
C15    15. North OBC
C
C       ICBN:    I CELL INDEX
C       JCBN:    J CELL INDEX
C       ISPBN:
C       NPFORN:
C       NPSERN:
```

```
C      NSSERN:  NORTH BOUNDARY CELL SALINITY TIME SERIES ID NUMBER
C      NTSERN:  NORTH BOUNDARY CELL TEMPERATURE TIME SERIES ID NUMBER
C      NDSERN:  NORTH BOUNDARY CELL DYE CONC TIME SERIES ID NUMBER
C      NTXSERN: NORTH BOUNDARY CELL TOXIC CONTAMINANT CONC TIME SERIES ID NUM.
C      NSDSERN: NORTH BOUNDARY CELL COHESIVE SED CONC TIME SERIES ID NUMBER
C      NSNSERN: NORTH BOUNDARY CELL NONCOHESIVE SED CONC TIME SERIES ID NUMBER
C      NTSCRN:  NUMBER OF TIME STEPS TO RECOVER SPECIFIED VALUES ON CHANGE
C               TO INFLOW FROM OUTFLOW
C
C15    ICBN   JCBN   ISPBN  NPFORN NPSERN NSSERN NTSERN NDSERN NTXSERN      NSDSERN
       NSNSERN       NTSCRN
C ------------------------------------------------------------------------------
C16    16. Variable Save
C      IGrADS:  =0  Save output in ASCII format only (*.out files)
C               =1  Save output in GrADS format only (hysdtx1.bin,hysdtx2.bin)
C               =2  Save output in both format (*.out,hysdtx1.bin,hysdtx2.bin)
C
C               When IGrADS is on, try to minimize LCM,KCM, & NTXM in EFDC.PAR
C               to minimize output hysdtx2.bin's size
C
C    Any of the following paramters =0=No, =1=Yes
C
C    IDUMPe  = elevation time series,
C    IDUMPu  = U-velo.   time series,
C    IDUMPv  = V-velo.   time series,
C    IDUMPw  = W-velo.   time series,
C    IDUMPs  = Salinity  time series,
C    IDUMPt  = Temperat. time series,
C    IDUMPd  = Dye       time series,
C    IDUMPc  = Cohe S.   time series,
C    IDUMPn  = Noncohe S time series,
C    IDUMPx  = Toxicants time series,
C    IDUMPb  = Bed       time series,
C    IDUMPfx = flow rate in x-direction
C    IDUMPfy = flow rate in y-direction
C
C16 IGrADS  IDUMPe  IDUMPu  IDUMPv  IDUMPw  IDUMPs  IDUMPt  IDUMPd  IDUMPc  IDUMPn
IDUMPx  IDUMPb  IDUMPfx IDUMPfy
    2       1       1       1          0       0       1       0       0       0
0       0       0       0
C ------------------------------------------------------------------------------
C17    17. Station Save
C
C   ILTMSR:    I CELL INDEX
C   JLTMSR:    J CELL INDEX
C   CLTMSR:    LOCATION Name AS A CHARACTER VARIABLE
C17    ILTMSR JLTMSR CLTMSR
       10     7      'ST1'
       13     13     'ST2'
       13     18     'ST3'
       12     31     'ST4'
       13     25     'ST5'
       20     26     'ST6'
C ------------------------------------------------------------------------------
C18    18. 3D Save
C     3D data (hy3d.bin) for GrADS
C
c    For time series (hyts.bin)
C    SaveTS  : Time series saving frequency in hours,
c              if savets<=0,=> save every time step
c
```

```
c    For 3D results (hy3d.bin)
C    StartDay: Start day from TBEGIN for saving 3D arrays
C    EndDay  : End day from TBEGIN for saving 3D arrays
C    AVER3D :  = 3D results average period in hours
C    SAVE3D = 3D results saving frequency in hours, AVER3D<=SAVE3D
c              if save3D<=0,=> save every time step
c
c Notes: Itimes=NTSPTC*SaveTS/24=Number of time steps used in hyts.bin saving.
c Itimes must be even number to save WQ time series in the same way as hydro,
c because WQ is calculated at every even steps!!
C
C18    SaveTs StartDay     EndDay AVER3D ISAVE
       24.0   0.0          9999.9 12.0   24
C ------------------------------------------------------------------------------
```

Wqwin.inp

```
C******************************************************************************
C
C Wqwin.inp is the new master input file of the EFDC water quality submodel. It is
c the simplified version of the original master input file wq3dwc.inp, and is
c created for the development of the sediment toolkit. Similar to wq3dwc.inp,
c wqwin.inp contains the major parameters of the EFDC's water quality submodel.
C The EFDC model reads wqwin.inp right after wq3dwc.inp is read, therefore the
c parameters in wqwin.inp override the corresponding parameters in wq3dwc.inp
c and the EFDC model can work normally without the existance of wqwin.inp.
c Paremeters that should can be determined in the hydrodynamic model are given
c in efdcwin.inp.
c
c For most applications, a user needs to adjust the parameters in wqwin.inp
c only and to treat wq3dwc.inp like a dummy file. For some special applications or
C for the several advanced EFDC users, changes to the original wq3dwc.inp file might
C be needed.
c
c C1-C6 for WQ model and C25-C26 for sediment diagenesis model likely change from
project
c to project, so they can be modified by the wizard and the treeview. The rest of the
c cards are not controlled by wizard, they are controlled by the treeview only.
c
c Each card in wqwin.inp can have arbitrary number of comment lines between the
comment
c lines Cxx and Cxx (where xx is the card number), as long as each comment line's
first
c character is character C or c and the second character is not a numeric.
c
c Jeff Ji, 9/9/99
c Tetra Tech, Inc.
c Fairfax, VA
c
c Updated on 9/9/99
c
c Notes:
c
c 1. The WQ point source loadings time series IDs are given in efdcwin.inp, and
c    k location is given in the new wqpsl.inp, 9/13/99
c
C-----------------------------------------------------------------------------
C1 Benthic flux and reaeration
C
C   IWQBEN  = benthic flux model switch (0=specified flux; 1=predictive flux)
c
C Constant benthic flux rates (g/m^2/d)
C   FPO4 = benthic flux rate of phosphate
C   FNH4 = benthic flux rate of ammonia nitrogen
C   FNO3 = benthic flux rate of nitrite+nitrite nitrogen
C   FSAD = benthic flux rate of silica
C   FCOD = benthic flux rate of chemical oxygen demand
C   SOD = sediment oxygen demand rate in m/m**2/day=-4=near wwts, =-2.0 others, Mike &
Ji, 8/12/99
C
C   IWQKA   = reaeration option switch
C           = 0, constant reaeration (WQKRO), no wind reaeration
C           = 1, constant reaeration (WQKRO) plus wind reaeration
C           = 2, use O'Connor-Dobbins (1958) formula
C           = 3, use Owens & Gibbs (1964) formula
```

```
C   KRO     = reaeration constant (3.933 for OConnor-Dobbins; 5.32 for Owen-Gibbs)
C
c1  IWQBEN  FPO4    FNH4    FNO3    FSAD    FCOD    SOD    IWQKA  KRO
    1       0.001   0.050   0.002   0.048   2.00    -2.0    0      1.50
C------------------------------------------------------------------------------
C2 Constant initial conditions in (g/m^3): TAM(mol/m^3), FCB(MPN/100mL)
C
C   Bc = cyanobacteria
C   Bd = algae diatoms
C   Bg = algae greens
C RPOC = refractory particulate organic carbon
C LPOC = labile particulate organic carbon
C  DOC = dissolved organic carbon
C RPOP = refractory particulate organic phosphorus
C LPOP = labile particulate organic phosphorus
C  DOP = dissolved organic phosphorus
C PO4t = total orthophosphate
C RPON = refractory particulate organic nitrogen
C LPON = labile particulate organic nitrogen
C  DON = dissolved organic nitrogen
C  NH4 = ammonia nitrogen
C  NO3 = nitrite + nitrate nitrogen
C   SU = unavailable silica
C   SA = available biogenic silica
C  COD = chemical oxygen demand
C   DO = dissolved oxygen
C  TAM = total active metal
C  FCB = fecal coliform bacteria
C
C  Bc      Bd      Bg      RPOC    LPOC    DOC
C  RPOP    LPOP    DOP     PO4t    RPON    LPON    DON
C2 NH4     NO3     SU      SA      COD     DO      TAM     FCB
   0.10    0.20    0.10    0.055   0.024   1.200
   0.010   0.010   0.010   0.010   0.050   0.050   0.070
   0.100   0.200   0.100   1.200   4.280   10.00   0.1     3.030
C------------------------------------------------------------------------------
C3 SOUTH OPEN BOUNDARY
C
c  (I, J) = should come from efdcwin.inp
c  TIME SERIES ID'S FOR EACH STATE VARIABLE
C
C  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
C          c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A   C
C                   O  O  C  O  O  P  4  O  O  N  4  3        D     M
C3                  C  C     P  P     t  N  N
C------------------------------------------------------------------------------
C4 WEST OPEN BOUNDARY
C
c  (I, J) = should come from efdcwin.inp
C  TIME SERIES ID'S FOR EACH STATE VARIABLE
C
C  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
C          c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A   C
C                   O  O  C  O  O  P  4  O  O  N  4  3        D     M
C4                  C  C     P  P     t  N  N
C------------------------------------------------------------------------------
C5 EAST OPEN BOUNDARY
C
c  (I, J) = should come from efdcwin.inp
C  TIME SERIES ID'S FOR EACH STATE VARIABLE
C
```

```
C  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
C          c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
C                   O  O  C  O  O  P  4  O  O  N  4  3        D     M
C5                  C  C     P  P     t  N  N
C-----------------------------------------------------------------------------
C6 NORTH OPEN BOUNDARY
C
c  (I, J) = should come from efdcwin.inp
C  TIME SERIES ID'S FOR EACH STATE VARIABLE
C
C  I   J   B  B  B  R  L  D  R  L  D  P  R  L  D  N  N  S  S  C  D  T  F
C          c  d  g  P  P  O  P  P  O  O  P  P  O  H  O  U  A  O  O  A  C
C                   O  O  C  O  O  P  4  O  O  N  4  3        D     M
C6                  C  C     P  P     t  N  N
C----------------------------------------------------------------------------
C----------------------------------------------------------------------------
C7 Half-saturation parameters for ALGAE (see Table 3-1)
C
C    KHNc = nitrogen half-saturation for cyanobacteria (mg/L)
C    KHNd = nitrogen half-saturation for algae diatoms (mg/L)
C    KHNg = nitrogen half-saturation for algae greens algae (mg/L)
C    KHNm = nitrogen half-saturation for macroalgae (mg/L)
C    KHPc = phosphorus half-saturation for cyanobacteria (mg/L)
C    KHPd = phosphorus half-saturation for algae diatoms (mg/L)
C    KHPg = phosphorus half-saturation for algae greens algae (mg/L)
C    KHPm = phosphorus half-saturation for macroalgae (mg/L)
C     KHS = silica half-saturation for algae diatoms (mg/L)
C    STOX = salinity at which microsystis growth is halved for cyanobacteria
C
C7  KHNc    KHNd    KHNg    KHNm    KHPc    KHPd    KHPg    KHPm     KHS    STOX
    0.05    0.05    0.05    0.05    0.002   0.002   0.002   0.002   0.025    1.0
C-----------------------------------------------------------------------------
C8  Parameters for ALGAE (see Table 3-1)
C
C   KeTSS = light extinction for total suspended solids (1/m per g/m3)
C   KeCHL = light extinction for total suspended chlorophyll (1/m per g/m3)
C     Note: if KeCHL is negative, the Riley (1956) formula is used to
C           compute the extinction coefficient due to chlorophyll:
C             KeCHL = 0.054*CHL^0.6667 + 0.0088*CHL
C             where CHL = total chloryphyll concentration (ug/L)
C   CChlc = carbon-to-chlorophyll ratio for cyanobacteria (mg C / ug Chl)
C   CChld = carbon-to-chlorophyll ratio for algae diatoms (mg C / ug Chl)
C   CChlg = carbon-to-chlorophyll ratio for algae greens (mg C / ug Chl)
C   CChlm = carbon-to-chlorophyll ratio for macroalgae (mg C / ug Chl)
C      I0 = initial solar radiation (Langley/day) at water surface
C   IsMIN = minimum optimum solar radiation (Langley/day)
C      FD = fraction of day that is daylight
C         0.041
C8 KeTSS  KeChl   CChlc   CChld   CChlg    CChlm      I0   IsMIN      FD
   0.015  0.041   0.040   0.065   0.060    0.100   350.00  40.000   0.500
C-----------------------------------------------------------------------------
C9  Lower-upper Optimal temperature parameters for ALGAE (see Table 3-1)
C    TMc1 = lower optimal temperature for cyanobacteria growth (degC)
C    TMc2 = upper optimal temperature for cyanobacteria growth (degC)
C    TMd1 = lower optimal temperature for algae diatoms growth (degC)
C    TMd2 = upper optimal temperature for algae diatoms growth (degC)
C    TMg1 = lower optimal temperature for algae greens growth (degC)
C    TMg2 = upper optimal temperature for algae greens growth (degC)
C    TMm1 = lower optimal temperature for macroalgae growth (degC)
C    TMm2 = upper optimal temperature for macroalgae growth (degC)
C    TMp1 = lower optimal temperature for diatom predation (degC)
```

```
C    TMp2 = upper optimal temperature for diatom predation (degC)
C                            18.0   24.0                 2.0   29.0
C9  TMc1  TMc2   TMd1   TMd2   TMg1   TMg2   TMm1   TMm2   TMp1   TMp2
    23.0  32.0   17.0   23.0   20.0   25.0   18.0    24.0  12.0   25.0
C------------------------------------------------------------------------------
C10 Sub-super optimal temperature parameters for ALGAE (see Table 3-1)
C
C   KTG1c = suboptimal   temperature effect coef. for cyanobacteria growth
C   KTG2c = superoptimal temperature effect coef. for cyanobacteria growth
C   KTG1d = suboptimal   temperature effect coef. for algae diatoms growth
C   KTG2d = superoptimal temperature effect coef. for algae diatoms growth
C   KTG1g = suboptimal   temperature effect coef. for algae greens growth
C   KTG2g = superoptimal temperature effect coef. for algae greens growth
C   KTG1m = suboptimal   temperature effect coef. for macroalgae growth
C   KTG2m = superoptimal temperature effect coef. for macroalgae growth
C   KTG1p = suboptimal   temperature effect coef. for diatom predation growth
C   KTG2p = superoptimal temperature effect coef. for diatom predation growth
C
C10 KTG1c  KTG2c   KTG1d   KTG2d   KTG1g   KTG2g  KTG1m    KTG2m   KTG1p   KTG2p
  0.0200   0.001  0.0001  0.0050  0.0050  0.0050  0.0050   0.0050  0.0050  0.0050
C------------------------------------------------------------------------------
C11  Parameters for CARBON (1) (see Table 3-2)
C
C    FCRP = carbon distribution coef. for algae predation: refractory POC
C    FCLP = carbon distribution coef. for algae predation: labile POC
C    FCDP = carbon distribution coef. for algae predation: DOC
C    FCDc = carbon distribution coef. for cyanobacteria metabolism
C    FCDd = carbon distribution coef. for algae diatoms metabolism
C    FCDg = carbon distribution coef. for algae greens metabolism
C    KHRc = half-sat. constant (gO2/m3) for cyanobacteria DOC excretion
C    KHRd = half-sat. constant (gO2/m3) for algae diatoms DOC excretion
C    KHRg = half-sat. constant (gO2/m3) for algae greens  DOC excretion
C
C11 FCRP    FCLP    FCDP    FCDc    FCDd    FCDg    KHRc    KHRd    KHRg
    0.35    0.55    0.10    0.00    0.00    0.00    0.50    0.50    0.50
C------------------------------------------------------------------------------
C12 Parameters for CARBON (2) (see Table 3-2)
C
C     KRC = minimum dissolution rate (1/day) of refractory POC
C     KLC = minimum dissolution rate (1/day) of labile POC
C     KDC = minimum dissolution rate (1/day) of DOC
C  KHORDO = oxic respiration half-sat. constant for D.O. (gO2/m3)
C   KHDNN = half-sat. constant for denitrification (gN/m3)
C   AANOX = ratio of denitrification rate to oxic DOC respiration rate
c                   0.750   0.1
C12 KRC     KLC     KDC     KHORDO  KHDNN   AANOX
    0.005   0.075   0.010   0.5     0.1     0.5
C------------------------------------------------------------------------------
C13 Distribution parameters for PHOSPHORUS (1) (see Table 3-3)
C
C    FPRP = phos. distribution coef. for algae predation: refractory POP
C    FPLP = phos. distribution coef. for algae predation: labile POP
C    FPDP = phos. distribution coef. for algae predation: DOP
C    FPIP = phos. distribution coef. for algae predation: Inorganic P
C    FPRc = phos. distribution coef. of RPOP for cyanobacteria metabolism
C    FPRd = phos. distribution coef. of RPOP for algae diatoms metabolism
C    FPRg = phos. distribution coef. of RPOP for algae greens metabolism
C    FPLc = phos. distribution coef. of LPOP for cyanobacteria metabolism
C    FPLd = phos. distribution coef. of LPOP for algae diatoms metabolism
C    FPLg = phos. distribution coef. of LPOP for algae greens metabolism
C Note, the following must sum to 1.0:
```

```
C         FPRP + FPLP + FPDP + FPIP = 1.0
C         FPRc + FPLc + FPDc + FPIc = 1.0
C         FPRd + FPLd + FPDd + FPId = 1.0
C         FPRg + FPLg + FPDg + FPIg = 1.0
C  0.30   0.30   0.20   0.20   0.30   0.30   0.30   0.20   0.20   0.20
C13 FPRP  FPLP   FPDP   FPIP   FPRc   FPRd   FPRg   FPLc   FPLd   FPLg
   0.10   0.20   0.50   0.20   0.30   0.30   0.30   0.30   0.30   0.30
C-------------------------------------------------------------------------------
C14 Distribution parameters for PHOSPHORUS (2) (see Table 3-3)
C
C    FPDc = phosphorus distribution coef. of DOP for cyanobacteria metabolism
C    FPDd = phosphorus distribution coef. of DOP for algae diatoms metabolism
C    FPDg = phosphorus distribution coef. of DOP for algae greens metabolism
C    FPDm = phosphorus distribution coef. of DOP for macroalgae metabolism
C    FPIc = phosphorus distribution coef. of P4T for cyanobacteria metabolism
C    FPId = phosphorus distribution coef. of P4T for algae diatoms metabolism
C    FPIg = phosphorus distribution coef. of P4T for algae greens metabolism
C    FPIm = phosphorus distribution coef. of P4T for macroalgae metabolism
C   KPO4p = partition coefficient for sorbed/dissolved PO4
C
C Notes, the following must sum to 1.0:
C         FPRc + FPLc + FPDc + FPIc = 1.0
C         FPRd + FPLd + FPDd + FPId = 1.0
C         FPRg + FPLg + FPDg + FPIg = 1.0
C   0.40  0.40   0.40   0.40   0.10   0.10   0.10   0.10   0.04
C14 FPDc  FPDd   FPDg   FPDm   FPIc   FPId   FPIg   FPIm   KPO4p
    0.30  0.30   0.30   0.30   0.10   0.10   0.10   0.10   0.04
C-------------------------------------------------------------------------------
C15 Hydrolysis rate for PHOSPHORUS (see Table 3-3)
C
C     KRP = minimum hydrolysis rate (1/day) of RPOP
C     KLP = minimum hydrolysis rate (1/day) of LPOP
C     KDP = minimum hydrolysis rate (1/day) of DOP
C                 0.05
C15 KRP    KLP    KDP
    0.010  0.075  0.100
C-------------------------------------------------------------------------------
C16 Distribution parameters for NITROGEN (1) (see Table 3-4)
C
C    FNRP = nitrogen distribution coef. for algae predation: RPON
C    FNLP = nitrogen distribution coef. for algae predation: LPON
C    FNDP = nitrogen distribution coef. for algae predation: DON
C    FNIP = nitrogen distribution coef. for algae predation: Inorganic N
C    FNRc = nitrogen distribution coef. of RPON for cyanobacteria metabolism
C    FNRd = nitrogen distribution coef. of RPON for algae diatoms metabolism
C    FNRg = nitrogen distribution coef. of RPON for algae greens  metabolism
C    FNLc = nitrogen distribution coef. of LPON for cyanobacteria metabolism
C    FNLd = nitrogen distribution coef. of LPON for algae diatoms metabolism
C    FNLg = nitrogen distribution coef. of LPON for algae greens  metabolism
C
C16 FNRP    FNLP    FNDP    FNIP    FNRc    FNRd    FNRg    FNLc    FNLd    FNLg
  0.3000  0.5000  0.1000  0.1000  0.2000  0.2000  0.2000  0.4000  0.4000  0.4000
C-------------------------------------------------------------------------------
C17 Distribution parameters for NITROGEN (2) (see Table 3-4)
C
C    FNDc = nitrogen distribution coef. of DON for cyanobacteria metabolism
C    FNDd = nitrogen distribution coef. of DON for algae diatoms metabolism
C    FNDg = nitrogen distribution coef. of DON for algae greens  metabolism
C    FNDm = nitrogen distribution coef. of DON for macroalgae    metabolism
C    FNIc = nitrogen distribution coef. of DIN for cyanobacteria metabolism
C    FNId = nitrogen distribution coef. of DIN for algae diatoms metabolism
```

```
C    FNIg = nitrogen distribution coef. of DIN for algae greens  metabolism
C    FNIm = nitrogen distribution coef. of DIN for macroalgae    metabolism
C    ANCc = nitrogen-to-carbon ratio for cyanobacteria
C    ANCd = nitrogen-to-carbon ratio for algae diatoms
C    ANCg = nitrogen-to-carbon ratio for algae greens
C    ANCm = nitrogen-to-carbon ratio for macroalgae
C
C17 FNDc  FNDd   FNDg   FNDm   FNIc   FNId   FNIg   FNIm   ANCc   ANCd   ANCg   ANCm
  0.200  0.200  0.200  0.200  0.200  0.200  0.200  0.200  0.167  0.176  0.176  0.088
C-----------------------------------------------------------------------------
C18 Parameters for NITROGEN (3) (see Table 3-4)
C
C   rNitM = maximum nitrification rate (gN/m3/day)
C   KNit1 = suboptimal   temperature effect constant for nitrification
C   Knit2 = superoptimal temperature effect constant for nitrification
C     KRN = minimum hydrolysis rate (1/day) of RPON
C     KLN = minimum hydrolysis rate (1/day) of LPON
C     KDN = minimum hydrolysis rate (1/day) of DON
C   0.99                                    0.020
C18 rNitM   KNit1   KNit2   KRN     KLN     KDN
    0.20    0.0045  0.0045  0.005   0.075   0.020
C-----------------------------------------------------------------------------
C19 Parameters for SILICA (see Table 3-5)
C
C    FSPP = silica distribution coef. for diatom predation
C    FSIP = silica distribution coef. for diatom predation
C    FSPd = silica distribution coef. for diatom metabolism
C    FSId = silica distribution coef. for diatom metabolism
C    ASCd = silica-to-carbon ratio for algae diatoms
C    KSAp = partition coef. for sorbed/dissolved SA
C     KSU = dissolution rate (1/day) of particulate silica (PSi)
C
C19 FSPP    FSIP    FSPd    FSId    ASCd    KSAp    KSU
    1.0     0.0     1.0     0.0     0.36    0.16    0.05
C-----------------------------------------------------------------------------
C20 Decay parameters for COD & DO (see Table 3-6) and TAM & FCB (see Table 3-7)
C
C     KCD = COD decay rate (per day)
C   KTCOD = temperature rate constant for COD decay
C    KFCB = first-order fecal coliform bacteria decay rate (1/day)
C    TFCB = temperature effect constant for KFCB decay rate
C
C20 KCD    KTCOD   KFCB    TFCB
    1.00   0.041   0.5     1.07
C-----------------------------------------------------------------------------
C21 spatially/temporally ALGAL PARAMETERS (/d except Keb in /m)
C
C    PMc = max. growth rate for cyanobacteria (1/day)
C    PMd = max. growth rate for algae diatoms (1/day)
C    PMg = max. growth rate for algae greens  (1/day)
C    PMm = max. growth rate for macroalgae    (1/day)
C   BMRc = basal metabolism rate for cyanobacteria (1/day)
C   BMRd = basal metabolism rate for algae diatoms (1/day)
C   BMRg = basal metabolism rate for algae greens  (1/day)
C   BMRm = basal metabolism rate for macroalgae    (1/day)
C   PRRc = predation rate on cyanobacteria (1/day)
C   PRRd = predation rate on algae diatoms (1/day)
C   PRRg = predation rate on algae greens  (1/day)
C   PRRm = predation rate on macroalgae    (1/day)
C    Keb = background light extinction coefficient (1/m)
C   0    0     1.8        0.05        0.01        0.28  0.10  0.1
```

```
C21 PMc  PMd   PMg   PMm  BMRc  BMRd  BMRg  BMRm  PRRc  PRRd  PRRg  PRRm   Keb
   1.60  1.50  1.80  2.0  0.04  0.01  0.01  0.10  0.01  0.10  0.10  0.33  0.475
C------------------------------------------------------------------------------
C22 spatially/temporally constant SETTLING VELOCITIES (m/d)
C
C    WSc = settling velocity for cyanobacteria (m/day)
C    WSd = settling velocity for algae diatoms (m/day)
C    WSg = settling velocity for algae greens  (m/day)
C   WSrp = settling velocity for refractory POM (m/day)
C   WSlp = settling velocity for labile POM (m/day)
C    WSs = settling velocity for particles sorbed to TAM (m/day)
C   REAC = reaeration adjustment factor
C           0.25    0.25
C22 WSc     WSd     WSg     WSrp    WSlp    WSs    REAC
    0.01    0.25    0.10    1.00    1.00    1.00   1.00
C------------------------------------------------------------------------------
C23 Dry Atmospheric Deposition (g/m2/day; MPN/m2/day)
C
c   Bc        Bd        Bg        RPOC      LPOC      DOC
C   RPOP      LPOP      DOP       PO4t      RPON      LPON      DON
C23 NH4       NO3       SU        SA        COD       DO        TAM       FCB
    0.0       0.0       0.0       0.000387  0.000387  0.000773
    0.0       0.0       0.000054  0.000019  0.000530  0.000530  0.000771
    0.000214  0.000393  0.0       0.000247  0.0       0.0       0.0       1.0e07
C------------------------------------------------------------------------------
C24 Wet Atmospheric Deposition concentrations (mg/L; MPN/L)
C
c  NH4 & NO3 might be available at http://nadp.sws.uiuc.edu/default.html
c
C   Bc        Bd        Bg        RPOC      LPOC      DOC
C   RPOP      LPOP      DOP       PO4t      RPON      LPON      DON
C24 NH4       NO3       SU        SA        COD       DO        TAM       FCB
    0.0       0.0       0.0       0.325     0.325     0.650
    0.0       0.0       0.045     0.016     0.0       0.0       0.848
    0.35      1.070     0.0       0.0       0.0       0.0       0.0       0.0
C-----------------------------------------------------------------------------
C---Sediment Diagenesis Model Parameters -----------------------------------
C-----------------------------------------------------------------------------
C25 SM Initial Conditions (I)
C
C    iICI2= initial conditions switch
c          =0, determined by efdcwin.inp C2's ISRESTI automatically
C          =1, ICs ALWAYS read from restart file WQSDRST.INP,
c              no matter efdcwin.inp is cold or hot start.
c
C   CPON1 = Conc. Particulate Org. Nitrogen in G-class 1 (g/m3)
C   CPON2 = Conc. Particulate Org. Nitrogen in G-class 2 (g/m3)
C   CPON3 = Conc. Particulate Org. Nitrogen in G-class 3 (g/m3)
C   CPOP1 = Conc. Particulate Org. Phosphorus in G-class 1 (g/m3)
C   CPOP2 = Conc. Particulate Org. Phosphorus in G-class 2 (g/m3)
C   CPOP3 = Conc. Particulate Org. Phosphorus in G-class 3 (g/m3)
C   CPOC1 = Conc. Particulate Org. Carbon in G-class 1 (g/m3)
C   CPOC2 = Conc. Particulate Org. Carbon in G-class 2 (g/m3)
C   CPOC3 = Conc. Particulate Org. Carbon in G-class 3 (g/m3)
C
C25 iICI2 CPON1 CPON2   CPON3    CPOP1  CPOP2   CPOP3  CPOC1   CPOC2   CPOC3
     1   50.00  150.00  250.00   20.00  100.00  150.00 1000.00 3000.00 5000.00
C-----------------------------------------------------------------------------
C26 Initial Conditions (II)
c
C   C1NH4 = Conc. NH4-N in layer 1 (g/m3)
```

```
C   C2NH4 = Conc. NH4-N in layer 2 (g/m3)
C   C2NO3 = Conc. NO3-N in layer 2 (g/m3)
C   C2PO4 = Conc. PO4-P in layer 2 (g/m3)
C   C2H2S = Conc. Sulfide (H2S) in layer 2 (g/m3)
C    CPSi = Conc. Particulate biogenic silica in layer 2 (g/m3)
C    C2Si = Conc. Dissolved available silica in layer 2 (g/m3)
C
C26 C1NH4   C2NH4   C2NO3   C2PO4   C2H2S   CPSi    C2Si
    2.00    4.00    1.0     250.00  250.00   5000.0  500.00
C-----------------------------------------------------------------------------
C27 Split depositional fluxes to Gi classes
C
C   FNBc1 = fraction of PON,POP & POC from Cyanobacteria routed to G1 class
C   FNBc2 = fraction of PON,POP & POC from Cyanobacteria routed to G2 class
C   FNBc3 = fraction of PON,POP & POC from Cyanobacteria routed to G3 class
C           Note:  FNBc1 + FNBc2 + FNBc3 = 1.0
C   FNBd1 = fraction of PON,POP & POC from diatom algae group routed to G1 class
C   FNBd2 = fraction of PON,POP & POC from diatom algae group routed to G2 class
C   FNBd3 = fraction of PON,POP & POC from diatom algae group routed to G3 class
C           Note:  FNBd1 + FNBd2 + FNBd3 = 1.0
C   FNBg1 = fraction of PON,POP & POC from green algae group routed to G1 class
C   FNBg2 = fraction of PON,POP & POC from green algae group routed to G2 class
C   FNBg3 = fraction of PON,POP & POC from green algae group routed to G3 class
C           Note:  FNBg1 + FNBg2 + FNBg3 = 1.0
C
C27 FNBc1   FNBc2   FNBc3   FNBd1   FNBd2   FNBd3   FNBg1   FNBg2   FNBg3
    0.60    0.30    0.10    0.60    0.30    0.10    0.60    0.30    0.10
C-----------------------------------------------------------------------------
C28 Decay parameters for diagenesis
C
C   KPON1 = Decay rate of PON at 20 degC in Layer 2 for G1 class (1/day)
C   KPON2 = Decay rate of PON at 20 degC in Layer 2 for G2 class (1/day)
C   KPON3 = Decay rate of PON at 20 degC in Layer 2 for G3 class (1/day)
C   KPOP1 = Decay rate of POP at 20 degC in Layer 2 for G1 class (1/day)
C   KPOP2 = Decay rate of POP at 20 degC in Layer 2 for G2 class (1/day)
C   KPOP3 = Decay rate of POP at 20 degC in Layer 2 for G3 class (1/day)
C   KPOC1 = Decay rate of POC at 20 degC in Layer 2 for G1 class (1/day)
C   KPOC2 = Decay rate of POC at 20 degC in Layer 2 for G2 class (1/day)
C   KPOC3 = Decay rate of POC at 20 degC in Layer 2 for G3 class (1/day)
C
C28 KPON1   KPON2   KPON3   KPOP1   KPOP2   KPOP3   KPOC1   KPOC2   KPOC3
    0.035   0.0018  0.0     0.035   0.0018  0.0     0.05    0.0045  0.0001
C-----------------------------------------------------------------------------
C29 Temperature adjustment parameters and silica parameters
c
C   ThKN1 = Constant for temperature adjustment for KPON1, KPOP1, & KPOC1 (unitless)
C   ThKN2 = Constant for temperature adjustment for KPON2, KPOP2, & KPOC2 (unitless)
C   ThKN3 = Constant for temperature adjustment for KPON3, KPOP3, & KPOC3 (unitless)
c
C     KSi = First order dissolution rate for particulate biogenic silica
C           (PSi) at 20 degC in layer 2 (1/day)
C    P2Si = Partition coefficient for Si in Layer 2, controls sorption
C           of dissolved silica to solids (L/Kg)
c
C29 ThKN1   ThKN2   ThKN3  KSi    P2Si
    1.1     1.15    1.0    0.5    100.0
C-----------------------------------------------------------------------------
C30 Partition coefficients & reaction velocities
c
C   P1NH4 = Partition coefficient, ratio of particulate to dissolved NH4
C           in layer 1 (L/Kg)
```

```
C   P2NH4 = Partition coefficient, ratio of particulate to dissolved NH4
C           in layer 2 (L/Kg)
C   P2PO4 = Partition coefficient, ratio of particulate to dissolved PO4
C            in layer 2 (L/Kg)
C   P1H2S = Partition coefficient for H2S in Layer 1 (L/Kg)
C   P2H2S = Partition coefficient for H2S in Layer 2 (L/Kg)
C  KH2Sd1 = Reaction velocity for dissolved sulfide oxidation in
C           Layer 1 at 20 degC (m/day)
C  KH2Sp1 = Reaction velocity for particulate sulfide oxidation in
c           Layer 1 at 20 degC (m/day)
c                 100.00
C30 P1NH4   P2NH4 P2PO4   P1H2S   P2H2S    KH2Sd1  KH2Sp1
    1.00    1.00  100.00  100.00  100.00    0.60    1.20
C-----------------------------------------------------------------------------
C31 Spatially varying parameters: physical and rate velocity
C
C    Hsed = Layer 1 sediment thickness (meters)
C      W2 = sediment burial rate (cm/year)
C      Dd = diffusion coefficient in pore water (m2/day)
C      Dp = apparent diffusion coefficient for particle mixing (m2/day)
C    KNH4 = optimal reaction velocity for nitrification at 20 degC (m/day)
C   KNO31 = reaction velocity for denitrification in layer 1 at 20 degC (m/day)
C   KNO32 = reaction velocity for denitrification in layer 2 at 20 degC (m/day)
C  DP1PO4 = factor to enhance sorption of PO4 in layer 1 when DO is
C           greater than DOcPO4 (unitless)
C SODmult = factor to enhance magnitude of sediment oxygen demand (unitless)
c Psload10= p loading parameter (<=0.0, ignored)
C                                                                 400.00
65.68584
C31  Hsed       W2       Dd       Dp     KNH4    KNO31    KNO32   DP1PO4  SODmult
psload10
   0.1500   0.5000   0.0030   0.0003   0.1400   0.1250   0.2500  400.000   1.0000
65.68584
C-----------------------------------------------------------------------------
C32 Spatially varying parameters: distribution coefficients for RPOM
C
C   FNRP1 = fraction of water column refractory PON routed to G-class 1
C   FNRP2 = fraction of water column refractory PON routed to G-class 2
C   FNRP3 = fraction of water column refractory PON routed to G-class 3
C           Note:  FNRP1 + FNRP2 + FNRP3 = 1.0
C   FPRP1 = fraction of water column refractory POP routed to G-class 1
C   FPRP2 = fraction of water column refractory POP routed to G-class 2
C   FPRP3 = fraction of water column refractory POP routed to G-class 3
C           Note:  FPRP1 + FPRP2 + FPRP3 = 1.0
C   FCRP1 = fraction of water column refractory POC routed to G-class 1
C   FCRP2 = fraction of water column refractory POC routed to G-class 2
C   FCRP3 = fraction of water column refractory POC routed to G-class 3
C           Note:  FCRP1 + FCRP2 + FCRP3 = 1.0
C                                 0.7300  0.1700
C32 FNRP1 FNRP2   FNRP3   FPRP1   FPRP2   FPRP3   FCRP1   FCRP2   FCRP3
  0.1000  0.8000  0.1000  0.1000  0.7300  0.1700   0.1000  0.8300  0.0700
C------------------------------------------------------------------------------
C------------------------------------------------------------------------------
C------------------------------------------------------------------------------
```

10. Appendix B

Response to Comments from Farm Bureau

Comment #1: The public hearing at Ft. Cobb was a technical disaster with an unseeable power point presentation, audio problems, and handouts left at the office.

Recommendation: we would like to see staff come to public hearings prepared to answer questions, regardless of the time lapsed between the TMDL completion date and the public hearing. Time is our most precious commodity. The public deserves the opportunity to ask questions and have them answered in a public setting. Also, we were paying for our consultant to attend the meeting the overview of the TMDL should have been limited to a short amount of time, with the majority of the meeting time allotted to respond to questions.

Response #1: *we apologize for the equipment problems during our presentation because we assumed all equipments provided at the meeting site would work properly. We will be well prepared in the future. As for the time allocation at the public hearing, we believe we had enough time to answer all questions from the local public. We also committed to have a separate meeting to discuss the technical questions regarding water quality modeling. We did not leave the public hearing until all questions were answered and public participants had left.*

Comment #2: Recommendation: With regard to the SWAT model performed by Oklahoma State University, there was a need for peer review, and perhaps, departmental review, of the work performed, prior to submission to the ODEQ. A couple of phone calls to other university personnel to check assertions about fertilizer rate usage and watershed farming practices would have been prudent. Previous SWAT land use models preformed for the Lake Tenkiller TMDL and Lake Eucha have not undergone any useful public review. The Lake Eucha land use model, performed by Oklahoma State University, was used in the City of Tulsa's litigation against the poultry industry. That litigation resulted in a settlement which placed environmental restrictions on the poultry growers in the Lake Eucha watershed.

Response#2: *We believe the SWAT calibration for the Fort Cobb watershed is adequate given the available flow data. However, improvement to the calibration can still be made. OSU performed a new extensive survey in the watershed, collected the most recent land use information, and recalibrated the SWAT model.*

Comment #3: We would like to see the SWAT model rerun by the contractor at no addition cost to the taxpayers, with appropriate inputs and peer review, and resubmitted to the ODEQ.

Response #3: *Please refer to response #2.*

Comment #4: We urge ODEQ to consider and follow all of the recommendations made in the comments submitted by Quantitative Environmental Analysis on behalf of the various agricultural organizations. This includes gathering some additional data, and rerunning the SWAT and EFDC models.

Response #4: *see response to comments from Quantitative Environmental Analysis for details.*

Comment #5: We'd like to see the ODEQ consider development of watershed plans for so-call "impaired" watersheds, in lieu of TMDLs. It is our understanding this is acceptable under the Clean Water Act. We believe it would be a more prudent expenditure of taxpayers' dollars, rather than doing a TMDL and then doing a watershed plan. We urge coordination on this issue with the Oklahoma Conservation Commission.

Response#5: *The Oklahoma's 303(d) list contains only impaired stream and lakes but not watershed. When a stream or lake is listed as impaired, the state is required to develop a TMDL for the impaired waterbody. We are coordinating with Oklahoma Conservation Commission on BMPs in the watershed. A watershed management plan is not an option for this watershed. Besides, determining load reduction is also a requirement of a watershed management plan.*

Response to Comments from QEA

1. The basis for listing Fort Cobb Lake is not explicitly documented in the TMDL.
Recommendation #1. We recommend that the TMDL explicitly document and/or reference (to publicly available documents) the listing process, the nutrient impairment study, the basis for establishing phosphorus limitation that is assumed for the lake, and the basis for the TMDL target (i.e., fewer than 10% of samples exceeding a Trophic State Index (TSI) of 62). For example, how does the designation of a Nutrient Limited Watershed (NLW) lead to the designation of a "threatened" water body and subsequently a listing on the state's 303(d) list for impairment due to total phosphorus?

Response #1*: The Oklahoma's 2002 303(d) list is part of the State of Oklahoma 2002 Water Quality Assessment Integrated Report which details the assessment methodology for all designated beneficial uses. Under the new terminology, there is no "threatened" category anymore. A beneficial use is either "attained" or "not attained". A "threatened" beneficial use is considered as "not attained".*

2. The phosphorus limitation assumed in Fort Cobb Lake should be documented and supported with unequivocal data.
This TMDL is predicated on the conviction that Fort Cobb Lake is phosphorus limited and will remain phosphorus limited. The TMDL and the Nutrient Impairment of Fort Cobb Lake analysis (Derichsweiler 2005) both cite 1998-1999 OWRB data that indicate an annual average N:P ratio of 25:1. The sites from which this average was calculated appear to be located in the pelagic (open water) zone of the lake. More recent data (2001-2002), cited in the Oklahoma Water Resources Board (OWRB) Beneficial Use Monitoring Program (BUMP) – Lake Sampling 2002-2003 Draft Final Report (OWRB 2003) and presumably collected at the same six locations, indicate a lower N:P ratio of 13:1. In addition, the highest surface total phosphorus values were reported in the summer, suggesting the possibility of a lower N:P ratio in the summer time than the average of 13:1. Another, more recent, report by the United States Geological Survey (USGS 2004) cites a growing season average N:P ratio of 10.7:1, which increased to 25.8:1 during the senescent season, for an overall average across all dates and sites of 17.6:1. These USGS data were collected in both pelagic and littoral (shoreline) areas. Collectively, these studies indicate wide, but not unusual, spatial and temporal variations in N:P ratios in Fort Cobb Lake.

The Redfield ratio of N:P in marine algae is 7.2:1 (by weight), suggesting that where nutrients are available at a ratio greater than 7.2:1, marine algae will tend to be phosphorus limited. The TMDL uses this Redfield ratio as a "bright-line" cutoff to conclude that since Fort Cobb Lake exhibits an annual average N:P ratio higher than 7.2:1, nitrogen never limits algae growth. However, there is wide variability in the stoichiometry, nutrient uptake rates, and optimal N:P resource ratios of freshwater algae (Bowie et al. 1985, Wetzel 2001, Stumm and Morgan 1996, Reynolds 1984, Sterner and Elser 2002). For example, Hecky and Kilham (1988, as cited in Sterner and Elser 2002) observed optimal N:P ratios from 7:1 to 87:1 and Downing and McCauley (1992) observed nitrogen limitation in lake experiments at N:P ratios below 31:1. While it is widely assumed that most North American lakes are phosphorus limited, this assumption has been called into question (Elser et al. 1990). Recent literature also suggests that the high energetic cost of nitrogen fixation by cyanobacteria limits the importance of the atmosphere as a source of nitrogen (Ferber et al. 2004). Based on these literature studies, it is not appropriate to simply assume a single nutrient limitation based strictly on a comparison of the Redfield ratio and the average annual nutrient ratio.

Recommendation #2. Based on the variability and uncertainty associated with nitrogen and phosphorus concentrations in Fort Cobb Lake and the stoichiometry of the algal community, we recommend that the TMDL either provide unequivocal evidence to demonstrate that Fort Cobb Lake is phosphorus limited at all locations and times or consider that the lake may also be nitrogen limited, at certain locations and times.

Response #2: *N:P ratio calculated from 1998-1999 OWRB data has an average of 30, maximum of 73. None of the calculated N:P ratio is less than 7. N:P ratio calculated from 2000-2001 USGS data shows an average of 17.5, and maximum of 43. Only four of 154 samples (2.6%) has N:P ratio less than 7 and all four samples are collected from sites near shoreline. No samples in main water body of the lake have the ratio less than 7.*

The Redfield ratio (C/N/P) in marine algae is 106/16/1 in moles (41/7.2/1 in weight). The C:P ratio for freshwater algae has big difference from marine algae. The N:P ratio is actually close. Although there are some reference suggesting different stoichiometry, there are many more supporting the N:P ratio. It is widely recognized that phosphorus is most likely the limiting nutrient in lakes and ponds. As the N:P ratio of algae suggests, it would take about 7 nitrogen and 1 phosphorus to form algae cells. When the N:P ratio in the water column is greater than 7, there are more nitrogen available than phosphorus and phosphorus will become the limiting factor for algae growth. OWRB has been using the N:P ratio of 7:1 in BUMP monitoring reports for years to determine if a lake is phosphorus or nitrogen limited.

In Fort Cobb Lake, the observed N:P ratios in water column are greater than 7 at all sites located in the middle of main waterbody. There is more nitrogen than phosphorus in the lake to grow algae. In addition, there is a significant amount of blue algae present in the lake. Blue algae is known to be able to fix nitrogen from the air where nitrogen is unlimited. We could not see how nitrogen will become limited in the lake.

3. The TMDL does not accurately incorporate current farming practices on the watershed. Long-term phosphorus predictions by the watershed model used for the TMDL will be a function of fertilizer application rates. Soils in the Fort Cobb watershed typically have significant quantities of phosphorus, obviating the need for the high fertilizer application rates provided in Table 3.2 of Storm et al. (2003). The rates shown in Table 3.2 are above those recommended by Oklahoma State University (OSU; Zhang et al. 1998), considering the Soil Test Phosphorus (STP) values typically measured in this watershed (Appendix D of Storm et al. 2003). Although these discrepancies may have little impact on the short term modeling results, long term modeling results can be impacted by these application rates. In addition, the general perception of the models and information used in the TMDL development would improve if the ODEQ ensured the use of the most up-to-date and representative data for model simulations.

Recommendation #3. As a result of these concerns, we recommend that the TMDL combine an open dialog with the farming community in the watershed along with a review of the OSU guidelines and county STP data to provide the best available information with which to specify phosphorus application rates in the model. These new application rates should then be used to guide long-term loading changes in the watershed.

***Response #3**: The model was intended to simulate conditions when the water quality data were collected and it would not necessarily represent the current condition.*

Recommendation #4. We recommend that the TMDL also incorporate management operation information from the farming community in order to supplement the information provided by Monty Ramming (e.g., tillage practices currently in use in the watershed). This information should be used to specify more accurate inputs and realistic future options (e.g., Best Management Practices; BMPs).

***Response #4**: The ODEQ recognizes that an implementation plan is not a required component of a TMDL. The proposed BMPs in the report are offered to show the likelihood of achieving the proposed phosphorus reduction if everyone involved is willing to do whatever it takes. The actual implementation of phosphorus reduction is beyond the scope of this TMDL report.*

4. The implementation of the TMDL is unclear in the report.
The implementation plan outlined in the TMDL is vague and based on a very rough estimate of loading reductions, calculated via a linear method of combining a number of BMPs in a "series" (i.e., applied to the watershed in a linear fashion). The scenarios presented result in significant confusion for the stakeholders in that it is unclear what they are to expect upon implementation of this TMDL. For example, Figure 7-15 of the TMDL indicates that all of the cultivated land would have to be converted to pasture to approach (but still not achieve) the reductions (70%, including 5% for the margin of safety) outlined in the load allocations of the TMDL. This scenario is unrealistic and results in stakeholders having limited faith or "buy in" to the TMDL implementation. Although the TMDL states that the conversion to pasture would occur simultaneously with other management practices, the actual implementation that is planned is unclear.
Recommendation #5. We recommend that further clarification of the implementation plans be included with the TMDL so that stakeholders have a clearer picture of the management being proposed for their watershed.

***Response #5**: the phosphorus reduction options listed in the TMDL report are only shown as examples as for what BMPs might be done to possibly achieve the proposed reduction. Given that the implementation of phosphorus reduction is beyond the scope of this TMDL report and the purpose of the loading reduction calculation is to show the feasibility of the proposed reduction, we believe the loading reduction calculation method and proposed BMP options are logical and reasonable. We recognize any BMP alone will not be able to achieve the proposed phosphorus reduction. A combination of various BMPs will be needed. The actual BMP implementation options are open. The proposed BMPs options in the TMDL report may not be realistic since they are not necessarily readily agreeable to farmers.*

Recommendation #6. We recommend that the implementation of the TMDL consider current practices and existing plans for changes on the watershed.

***Response #6**: the proposed options are not actual TMDL implementation plan. See response #5 for more information.*

Recommendation #7. We recommend that the implementation plan incorporate input from local stakeholders and the farming community.

***Response #7**: Please refer to response #6.*

5. The impacts of management practices should be simulated with the available models.

The combined load reduction over a watershed due to a series of BMPs is not linear. In addition, it is common to observe that management practices implemented near receiving waters have a much greater impact on the loading than management practices implemented farther away from the receiving waters. Given these nonlinear effects and the fact that a watershed model of the system exists, it is more credible and accurate to consider modeling the potential load reductions for different combinations of management practices, as opposed to applying the linear model that is used in Section 7.3.b of the TMDL.

Recommendation #8. The ODEQ should consider modeling proposed implementation plans with a re-calibrated SWAT model (see Comments Concerning the Modeling for the TMDL), as opposed to applying the method currently used in Section 7.3.b.

In addition, the SWAT model was calibrated to conditions that do not represent the best available information with respect to winter cover crops and moldboard plow usage (pg. 30, Storm et al. 2003). Following calibration, actual management practices with respect to these issues were incorporated as linear reductions in sediment load, totaling 14%. It is more appropriate to calibrate a model to the best available information than to calibrate a model using simplified inputs and then change the outputs to reflect reality. It is recognized that incorporating more detailed management practices increases the complexity of the model and that trade-offs must be made. However, a change in sediment load of 14% seems large enough to warrant explicit modeling instead of linear, post-hoc adjustments to model outputs.

***Response #8**: The purpose of this TMDL is to identify the maximum allowable load to the Fort Cobb Lake. The development of an implementation plan for the load reduction is not a requirement of the TMDL. Therefore, we do not intend to model the various BMPs with the SWAT model. The reduction rates for Riparian Buffer and Nutrients Management Plan are based on literatures. The effectiveness of these BMPs may vary with locations and the level of the implementation. In addition, the SWAT cannot model riparian buffers and nutrient management plans without a detailed nutrient management plan being developed for the watershed.*

Recommendation #9. We recommend that the TMDL be based on a SWAT model that is recalibrated to the best available information including, but not limited to, winter cover crops and moldboard plow usage. The SWAT model should then be used to estimate reductions in loadings due to changes in these management practices.

Response #9*: OSU has performed a new survey in the watershed and collected the most recent land use data. The SWAT model was recalibrated to the best available information.*

Please also refer to response #8.

II. COMMENTS CONCERNING THE MODELING FOR THE TMDL

The TMDL applied the United States Department of Agriculture supported model, SWAT, to simulate nutrient loads from the watershed to Fort Cobb Lake and the United States Environmental Protection Agency supported model, EFDC, to simulate water quality in the lake. Both of these models are complex and require significant data for model development and proper calibration. The watershed model is important because it represents the current practices on the watershed and estimates the nutrient loads entering Fort Cobb Lake. For this watershed, accurate representation of the non-point source loadings is critical because there are no point sources in this basin. The lake model is important because the TMDL target is based on the modeled response of the lake (i.e., chlorophyll-a concentrations) to nutrient loads. Consequently, accurate development and calibration of both SWAT and EFDC are needed for a realistic TMDL and proper load reduction scenarios. The following section includes comments on both models.

1. The available data do not justify the application of complex models such as SWAT and EFDC.

Highly complex models such as SWAT and EFDC need to be constrained by site-specific data. Without such data, calibrated parameters are ill-defined and future projections are subject to substantial uncertainty. Given the data limitations on this system (e.g., no suspended sediment data, no storm event data, relatively few in-lake data points, one gauged tributary), less sophisticated and more transparent models should have been employed to develop the TMDL. **Recommendation #10.** We recommend that the TMDL: 1) states the rationale for selecting SWAT and EFDC and, 2) discusses the limitations and uncertainties associated with applying such complex models to so few data.

Response #10*: Selection of the models for this project is defined largely by the problem itself. Fort Cobb Lake is listed in Oklahoma's 2002 303(d) list for phosphorus because the chlorophyll-a concentration is too high. The applicable Water Quality Standards in the lake are dissolved oxygen, anoxic volume and Carlson's TSI. To capture the anoxic volume in the lake, a three-dimensional model is required. EFDC is a widely used water quality model and is supported by the EPA. We had some knowledge/experiences on the EFDC model. We believe other simpler water quality models would not satisfy the TMDL goals in this project.*

The SWAT model was designed specifically for ungaged basins. SWAT is a physically based model that was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use management conditions. Please see model documentation for additional details. The only *issue with applying SWAT with limited or no calibration and validation data is that it increases the level of uncertainty in its predictions.*

As in any other water quality modeling, the observed data is never enough. Certain improvements can always be made to a model if more data becomes available. We wish we had more data to calibrate our models. At the same time, we also believe that we have adequate data for the TMDL development. For the Fort Cobb Lake, we have data for chlorophyll-a, nutrients, turbidity, temperature, dissolved oxygen etc at various sites across the lake so that we could capture and spatial characteristics of the lake. Temperature and dissolved oxygen data in water column are also available which allow us to evaluate the vertical profiles of the lake. These data are collected from 1998 through 2001. For the tributaries contributing to the lake, Oklahoma Conservation Commission collected extensive samples in Lake Creek, including a couple of high flow events. U.S. Geological Survey and U.S. Fish and Wildlife Services also collected extension nutrient data in Cobb Creek, Lake Creek and Willow Creek. In sum, we believe that the current available data are adequate though more data would be beneficial.

2. The calibration of the SWAT model used for developing non-point source loadings to Fort Cobb Lake is weak and biased high, resulting in an overestimation of the loading reductions required to meet the TMDL target.

The Nash-Sutcliffe value, which is a measure of model performance, ranges from below 0 to 1.0; a value approaching 1.0 indicates a perfect fit between the simulated and measured data, while a value less than 0.0 indicates that the model is predicting no better than the mean of the actual data. The negative Nash-Sutcliffe values for the hydrologic calibration of the SWAT model presented in Table 4.4 of Storm et al. (2003) indicate that the mean of the data is a better model than the simulation model itself for the total flow during the calibration period and the baseflow during both the calibration and validation periods. In addition, SWAT underestimates flow rates during low flow events and overestimates flow rates during high flow events (pg. 17, Figure 4.5 of Storm et al. 2003). This discrepancy between the model and data was characterized by the authors as relatively unimportant, as demonstrated by the sentence "This limitation mainly effects [sic] short term stream flow and should not significantly impact long-term averages" (pg. 17, Storm et al. 2003). While this statement may be true from an overall flow balance perspective, a key output of the SWAT model for TMDL development is phosphorus loads, and phosphorus concentrations tend to be correlated with flow rate (due to increased sediment carrying capacity; this correlation is not shown in the report). Because the phosphorus concentration is likely to be positively correlated with flow rate, underestimating low flow rates and overestimating high-flow rates, as the SWAT model does, may lead to substantial long-term (accumulating) errors in phosphorus loading.

Visually, SWAT appears to over-predict phosphorus concentrations (Figure 4.8 of Storm et al. 2003). Statistics describing this bias, or lack thereof, are not provided beyond the presented slope of the best-fit line (1.2299) which, because it is greater than one and the intercept is very close to zero, suggests that the model over predicts phosphorus concentrations. In addition, the SWAT model was calibrated to water quality data primarily collected during baseflow conditions (the highest recorded flow rate concurrent with a phosphorus measurement was 0.94 m^3/sec, Appendix B of Storm et al. 2003), indicating that data do not exist with which to calibrate phosphorus concentrations at high flow rates. However, with non-point source loading, it is typically the high flow events that carry the majority of the loading (Benaman and Shoemaker 2004). In fact, for the Fort Cobb system, the TMDL (pg. 49) states that a "significant amount of TP is delivered to the lake during storm events". At the public meeting in Fort Cobb (January 3, 2005), Paul Yue estimated this percentage to be 90%. The actual percentage is less important than the conclusion: the phosphorus loading estimates to Fort Cobb Lake have not been constrained by adequate high-flow data. This adds to uncertainty of the model parameters. Overall, the SWAT model calibration appears weak for both flow and phosphorus. Historically, SWAT tends to perform relatively well for simulating flow rates, as shown by other applications of SWAT (Santhi et al. 2001, Srinivasan et al. 1998, Benaman et al. 2005, Arnold et al. 1995). However, the performance measures shown for the Fort Cobb watershed calibration (Table 4.4 of Storm et al. 2003) are well below the Nash-Sutcliffe values determined in these other referenced applications (all above 0.7).

These combined weaknesses and uncertainties present a substantial limitation to the TMDL development. An overestimation of loadings from the watershed will result in a bias in the lake model, as well. This bias will affect the TMDL development because a high bias in the loadings and consequently the water quality results of the lake model will result in overestimations of needed load reductions in order to meet the TMDL target.

Recommendation #11. We recommend that flow rates be recalibrated at multiple gauging stations to provide an unbiased prediction of flow rates during both low-flow and high-flow events (and statistics presented to demonstrate the lack of bias).

Response #11 *Please refer to response #15.*

Recommendation #12. We recommend that phosphorus concentrations be recalibrated to provide an unbiased prediction of phosphorus concentrations (and statistics presented to demonstrate the lack of bias).

Response #12 *Please refer to response #15.*

Recommendation #13. We recommend that Nash-Sutcliffe values for the nitrogen and phosphorus calibrations be presented.

Response #13 *Please refer to response #15.*

Recommendation #14. We recommend that a discussion on the utility of the model for TMDL development be provided, taking into consideration the goodness of fit measures (i.e., Nash-Sutcliffe values) computed.

Response #14 *Please refer to response #15.*

Recommendation #15. Because of the intensive data needs for SWAT model calibration and the significant uncertainty in the current calibration, we recommended that these recalibration steps take place after the collection of additional data.

Response #15*: Due to time and resource constraints, one of the limitations of the current SWAT model for the Ft Cobb basin is the upstream reservoirs were not included. This dramatically influenced the calibration of the surface and baseflow components. These reservoirs were input into SWAT as ponds, and in order to improve the flow calibration they need to be incorporated into the SWAT model as reservoirs. Pond option was added to the recalibrated SWAT model to improve the quality of flow calibration.*

It should be noted that flow was calibrated on relative error and not Nash-Sutcliff. A very important point is that the SWAT model is doing an adequate job of estimating surface runoff, which is the primary transport mechanism for phosphorus from upland areas. Without additional water quality data, more detailed phosphorus and nitrogen calibration efforts are not justified.

3. Lack of sediment calibration of the SWAT model leads to uncertainty in the non-point source loadings determined from the model.

Phosphorus loads typically correlate to sediment loads (Sharply and Smith 1990). Based on this, the TMDL suggests numerous BMPs that reduce erosion. However, the SWAT model was not calibrated to sediments (Storm 2005) and hence, the SWAT predictions of sediment are likely to be highly uncertain. In the absence of TSS data, the SWAT model should be checked against TSS surrogates: secchi depth and turbidity data. The USGS data set with which phosphorus and nitrogen were calibrated contains secchi depth and turbidity data. The trends predicted by the model should roughly match the trends in the turbidity data, and should be the inverse of trends in the secchi depth data.

Recommendation #16. We recommend that the model be recalibrated, considering sediment transport and loading after the execution of a TSS sampling program; or, at a minimum, the text, figures, and tables in the TMDL report be modified to clearly reflect that sediments were not calibrated.

Response #16*: Sediment was not calibrated. Data are not available.*

Recommendation #17. We recommend that the TMDL present suspended sediment model predictions versus secchi depth and turbidity. While this will not provide a quantitative calibration of the suspended sediment model predictions, these checks will establish some confidence in the SWAT suspended sediment model results.

Response #17*: please refer to response #16.*

4. Documentation of the SWAT model development is incomplete in the TMDL report.

There are a number of processes that occur in the watershed that the TMDL report does not discuss, including bank erosion and in-stream nutrient processes. An understanding of how and whether they were considered in the TMDL development is important when considering potential implementation programs.

Recommendation #18. We recommend that the TMDL report clearly state whether stream bank erosion is important in this watershed and whether it was considered in modeling suspended sediments in the watershed.

***Response #18**: Due to the complexity of accurately estimating stream bank erosion, the model did not account for stream bank erosion.*

Recommendation #19. In-stream nutrient processes can be important for determining the available nutrients that reach Fort Cobb Lake. We recommend that the TMDL report discuss whether in-stream nutrient processes were modeled and how their inclusion or exclusion impacts the final results of the TMDL.

***Response #19**: The instream nutrient processes were not modeled.*

Recommendation #20. We recommend that the inputs to the watershed model be documented in the TMDL report. These include maps and/or tables of soils data, hydrologic soils groups, and curve numbers.
Another area of the SWAT model that requires further explanation and clarification is the use of phosphorus and nitrogen data during calibration. There are 101 total phosphorus and 104 total nitrogen samples listed in Appendix B of the SWAT model; however, the model used 60 phosphorus and 62 nitrogen data points for calibration.

***Response #20**: Only 60 phosphorus and 62 nitrogen data points could be used for calibration since SWAT predicted zero flow for the remaining samples.*

Recommendation #21. We recommend that the TMDL report state the basis for using only 60 of 101 total phosphorus data points and 62 of 104 total nitrogen data points for calibration of the SWAT model.

***Response #21**: Please refer to response #20.*

Recommendation #22. We recommend that the TMDL report explicitly state why the Willow Creek and Lake Creek USGS gauge stations were not used to calibrate the SWAT model for watershed loading predictions.

***Response #22**: USGS daily stream flow period of record for Lake Creek is 1969 to 1978, and 1970 to 1978 for Willow Creek. Our landcover was developed from a June 10, 2001 satellite image. The landcover may have been significantly different 30 years prior to our satellite image and thus adding uncertainty to our calibration. The model did utilize the flow data from Lake Creek and Willow Creek to justify applying the Cobb Creek calibration to other parts of the watershed. Please see Table 4.1 and related text in the OSU report.*

5. Justification of certain SWAT model parameters should be provided and an understanding of their impact on the model results should be discussed in the TMDL.
The SWAT model prevents grazing when the available biomass is less than the BIOMIN parameter. Past experience with the model has shown that erosion and subsequent phosphorus loadings are sensitive to this number (Benaman 2003). The model used a BIOMIN value of 1000 kg/hectare for pasture and 800 kg/hectare for wheat in wheat/peanut operations (Storm 2005).

Recommendation #23. Due to the sensitivity of the model to the value of BIOMIN, we recommend that justification of this number for the Fort Cobb watershed be provided in the TMDL report, as well as a discussion of the impact of this parameter on the model results.

***Response #23**: The model used a BIOMIN parameter of 1000 for pasture and 800 for wheat. These are numbers that represent conditions that are properly utilized and not overgrazed.*

The stated value for variable PPERCO (phosphorus percolation coefficient) is 1.0 m^3/Mg (pg. 24 of Storm et al. 2003); however, this number is outside of the range of expected values as indicated by the SWAT Users Manual (Neitsch et al. 2002).
Recommendation #24. We recommend that justification for the use of 1.0 m^3/Mg for PPERCO and an explanation of the physical meaning of this value be discussed in the TMDL.

***Response #24**: The SWAT user manual provides guidelines and not absolute ranges. A value of 1.0 was used to obtain a reasonable calibration.*

6. The calibration and documentation of the EFDC model is weak and should be reevaluated.
There is no indication of the quality of the EFDC model calibration (statistical measures of fit). Visually, the model appears to be biased high with respect to chlorophyll-a. The TMDL should report statistical measures of fit and bias for both the calibration and verification results of all state variables.
As currently shown in the TMDL report, the calibration and verification results:

- illustrate only 3 of the 21 EFDC water quality state variables (chlorophyll-a, dissolvedoxygen, and total phosphorus);
- do not present all of the data from all of the agencies (e.g., USFWS chlorophyll-a data arepresented in the calibration figures, but total phosphorus data are not);
- do not permit an evaluation of vertical profiles in water quality or temperature data;
- illustrate the results for only three lake zones (upper lake, middle lake, and near dam), which are composed of an unspecified combination of the 179 model cells and are then compared to an unspecified combination of the 16+ sites where data are available.

Recommendation #25. We recommend that the TMDL present results from the other 18 state variables, or state why such results are unimportant to the model predictions of chlorophyll-a and dissolved oxygen. These model results should be presented, even where there is a general lack of data, because the model behavior can be evaluated, semi-quantitatively, without data.

***Response #25**: It is not common for all state variables to be evaluated in an EFDC application because not all state variables are important and the resources are limited. For the Fort Cobb Lake, chlorophyll-a and dissolved oxygen, the TMDL targets, are the parameters of concern. Nutrients directly affect the growth of algae. Since the lake is clearly phosphorus limited, total nitrogen is not important to the model results. Other state variables such as silica, total active metal and fecal coliform bacteria etc. would have little or no impacts on the model output for the parameters of concern. We received our version of EFDC from Tetra-Tech who developed the EFDC model. Our version of EFDC does not have outputs for every state variable. Tetra-Tech used the same version of EFDC model on other project they developed for other lakes with the similar parameters of concern.*

Model outputs are too long to be included in the TMDL report as an appendix and will only increase the length of the report. The model results are available on electronic form upon request.

Recommendation #26. We recommend that the TMDL present, in the appropriate figures, all of the relevant data from the three datasets described (OWRB, USGS, USFWS). Data that are omitted from figures should be identified and described. The reservoir water quality zones (near dam, middle lake, and upper lake) should be explicitly described, as should the water quality sampling sites and model cells that are used to represent each zone.
On page 39 of the TMDL, a water balance is used to justify the statement that "This effort proves to some extent that the model is calibrated correctly." There is much more to a hydrodynamic model than a water balance. The model-data comparison provides evidence that the model does not erroneously gain or lose water to a large degree. However, this model-data comparison offers little evidence that water velocities or directions are adequately calculated. While the available water temperature data suggest that the lake is rarely stratified, the model-to-data comparison is difficult to gage from Figures 6-3, and 6-17, because of the presentation style of the data and the lack of symbology denoting data from different depths. The calibration and verification results for dissolved oxygen and chlorophyll-a indicate that the model frequently does not match the measured vertical stratification in these parameters (e.g., Figures 6-10, 6-23, 6-24).

Response #26*: Three monitoring sites in the upper, middle and lower parts of the lake were chosen to represent the general water quality of the lake. OWRB, USGS and USFWS collected water quality samples in the lake. However, because the monitoring was designed for different purposes for each agency, at only three sites all agencies have monitoring data. These three sites were chosen in calibration and verification. No data for these three sites were omitted.*

The model-data comparisons in lake elevation and temperature show that the model is doing a good job in predicting hydrodynamics. There is no water velocity data in the lake. Therefore, water velocities (u & v components) were just observed to see if they are reasonable in the process of calibration. However, since the water velocity directly affects the mixing of the lake which in turn will affect temperature profile in the lake, if the model predicted water velocity wrong it would not give correct prediction in water temperature profile.

We believe that the model makes good predictions for both chlorophyll-a and dissolved oxygen. Plots in the TMDL report were updated for better labels and easier comparisons between plots.

Recommendation #27. The presentation should be modified to more clearly establish the adequacy of the hydrodynamic model and resulting vertical dynamics in water quality.

Response #27*: plots on vertical profiles were added to provide a clear view on vertical mixing of the lake.*

Recommendation #28. The EFDC model was used to simulate TSS (Yue 2005a). Given the importance of TSS on light alteration and consequently, phytoplankton growth, we recommend that the TMDL document TSS inputs to the lake model, document how TSS was modeled, and present the model-predicted TSS results for both the calibration and verification timeframes. To corroborate the TSS model results, we recommend that the TMDL include a comparison to inlake turbidity and secchi depth data.

Response #28*: The cohesive sediment sub-model in the EFDC was turned on. Since there is no reliable TSS load to the lake, the TSS concentrations in the lake may not be correct during the wet season. However, critical condition occurs in the summer, the dry season. Sediment delivered to the lake from tributaries should have settled out of water column. As a result, the TSS concentration should have little impacts on algae growth during the critical period of time. Low turbidity measurements show that there is not much TSS in the lake.*

Figure 6-12 includes an unrealistically high dissolved oxygen value of over 25 mg/L. This is over 10 mg/L greater than saturation and corresponds to a period where no corresponding spike in chlorophyll-a is predicted by the model. Similar spikes also appear in Figures 6-11, 6-25, 6-26, 7-8, and 7-9 (i.e., 6 of the 9 dissolved oxygen plots in the TMDL report). Several of these spikes are predicted in the bottom model layer, but not the middle or top layers.
Recommendation #29. We recommend that the TMDL report document the basis for these seemingly unrealistic dissolved oxygen predictions.

Response #29*: We reevaluated these dissolved oxygen spikes in the upper and middle parts of the lake and found out all the spikes are coincident with high flow events. We believe that the model was not stable during those high flow events. We tried to increase the number of time steps to the maximum allowed by our version of EFDC. No noticeable changes were observed. Fortunately, all high flow events did not occurred in the critical period of time and the model recovered quickly after each event. We believe that the DO spikes will not have much impact on the model results.*

Recommendation #30. The EFDC model was not calibrated to nitrogen species (*personal communication*, TMDL public meeting, February 8, 2005). We recommend that the TMDL clearly state this fact and discuss the impact of this exclusion on the conclusions.

Response #30*: Please refer to response #2.*

Recommendation #31. We recommend that the TMDL present model results from the three individual phytoplankton groups to establish the reasonableness of the EFDC predictions of group dominance throughout the simulations. Overall, the calibration of the lake model seems relatively weak and biased high for chlorophyll-a. The data available for model calibration are limited, presenting significant uncertainty in the ability of the model to simulate water quality in the lake.

***Response #31**: the EFDC model handles the three algae group internally and only output chlorophyll-a concentrations. Efforts were made to ensure all parameters that controls algae growth are within the normal range. We agree that the data available for model calibration are limited and we wish we had more data. However, the calibrated model captured the spatial and temporal characteristics of the algae growth in the lake. The model predicted chlorophyll-a reasonably well in all three sites across the lake under critical conditions.*

Recommendation #32. As a result of these limitations, we recommend that the EFDC model be recalibrated after recalibration of the SWAT model and collection of additional data necessary to support the use of such a highly complex model as EFDC.

***Response #32**: OSU has recalibrated the SWAT model. As a result, the EFDC model was recalibrated to reflect the change in nutrient load to Fort Cobb Lake.*

Recommendation #33. We recommend that the TMDL expressly indicate the limitations in the model results, given the available data and important processes in the lake.

***Response #33**: the report contains both positives and negatives of the model. We believe that the available data are adequate for the development of this TMDL though more data will be helpful.*

Recommendation #34. We recommend that the TMDL report provide the final set of EFDC calibration coefficients for all components of the model.

***Response #34**: the final EFDC control files will be included in Appendix to the report.*

7. The TMDL documentation should demonstrate that algae growth in the model is limited by phosphorus, rather than nitrogen, as per the phosphorus limitation assumption.

The TMDL is predicated on the belief that the system is phosphorus limited at all locations and times (see Comment #2 on page 1). This belief is the justification for not calibrating the model to nitrogen. Given that the model is not calibrated to nitrogen and simulated nitrogen concentrations are not presented, it is important to demonstrate that the model does not mistakenly simulate nitrogen limitation. This can be evaluated through the examination of the following nitrogen and phosphorus limitations terms:

$$\frac{NH_4 + NO_3}{KHN_x + NH_4 + NO_3} \quad and \quad \frac{PO_4 d}{KHP_x + PO_4 d}$$

Recommendation #35. We recommend that the TMDL report provide plots and/or statistics of the above equations to demonstrate that algae growth in the model is not mistakenly limited by nitrogen. This evidence should consider all model cells, the entire calibration, verification, and projection (reduction) periods and all three algae species. The nitrogen limitation term should always be greater than the phosphorus limitation term. These results will provide a check that the model is not limiting algal growth due to insufficient nitrogen.

***Response #35**: We calculated the recommended equations. The minimum value for nitrogen limitation is 0.965 which indicates nitrogen limitation does not exist in the entire modeling period. The minimum value for phosphorus limitation is 0.352. Although the nitrogen term is occasionally smaller than the phosphorus term, this only occurs when both values are above 0.99. The calculations indicate that the model did not mistakenly predict nitrogen limitation.*

8. The impacts of nutrient flux from the sediment bed should be discussed within the TMDL development.

The flux of nutrients from the sediment bed can be an important source of nutrients to the water column, particularly in eutrophic systems with a large sediment-water interfacial area to volume ratio. In fact, in many systems, nutrient release from the sediments has dramatically slowed the perceived rate of improvement in water quality (e.g., Seo and Canale 1999). Because of the potential importance of sediments as a source of nutrients, the TMDL should document several aspects of the sediment diagenesis model.

Recommendation #36. We recommend that the final set of parameter values used in the sediment diagenesis model be documented in the TMDL report.

***Response #36**: the final set of parameters will be included in Appendix to the report.*

Recommendation #37. We recommend that the procedure used to “spin-up” the sediment chemical concentrations be documented in the TMDL report.

***Response #37**: the TMDL report will be modified to include the procedure.*

Recommendation #38. We recommend that raw results and/or statistics quantifying the model predictions for oxygen, orthophosphate, and ammonia fluxes to/from the sediment bed be presented in the TMDL report. Additionally, we recommend that these fluxes be compared to results from similar systems to establish the reasonableness of the predicted fluxes.

***Response #38**: Because the lake is well mixed and rarely reaches anoxic at the bottom according to monitoring data and model prediction, the sediment nutrient flux should be very small and are considered unimportant. The predicted nutrient fluxes in the Fort Cobb Lake were compared to those in Tenkiller Lake EFDC model which was performed by Tetra-Tech. They are about two magnitude smaller than those predicted in the Tenkiller Lake.*

Recommendation #39. We recommend that a mass balance around the water column during the summer season be calculated to quantify the percentage of growing season phosphorus load that originates in the sediments. We also recommend that this calculation be projected into the future to describe how the percentage is expected to change as external inputs decrease.

***Response #39**: As far as the lake stays well mixed and the lake bottom stays aerobic, nutrient flux from sediment can be neglected comparing to loadings from the watershed.*

9. The future scenarios presented in the TMDL lack sufficient detail.
The EFDC model load reduction projections (upon which the load reduction requirements are based, Figures 7-1 through 7-12) present results for January 1998 to February 1999. However, the projections were performed for both the calibration and verification periods (four years total; Yue 2005b).
Recommendation #40. We recommend that the reduction projection figures include all of the model results used. Future compliance is based on model results from fours years of simulation. There is no indication of whether these are wet years, dry years, average years, or a mixture. Therefore, it is difficult to judge if compliance within this four-year window equates to compliance over the long term.

Response #40*: The entire model results were included in reduction projections. The reduction rate was projected in calibration period. The same reduction rate was checked during the verification period to ensure all TMDL targets were met.*

Recommendation #41. We recommend that the TMDL report discuss the representativeness and appropriateness of the four-year simulation period for establishing future, long-term compliance.

Response #41*: The average annual participations from 1975 to 2001 is 31.8 inches. The annual rainfall for 1998 was 24.2 inches and the annually rainfall for 2000 was 33.1 inches.*

10. Additional information on the lake model development should be provided in the TMDL.
Recommendation #42. We recommend that the TMDL clearly state the specific locations (e.g., model cells) at which direct runoff was input to the lake and the percentage of the direct runoff assigned to each location. Additionally, we recommend that the TMDL state the rationale for these locations and percentages.

Response #42*: In the EFDC model, flow was input at four locations: Cobb Creek, Willow Creek, and two tributaries, or at four cells (12, 37), (21, 26), (18, 18) and (15,33). The direct runoff represents 8.2% of the total flow input to the lake. The direct runoff was evenly distributed to cells (21, 26), (18, 18) and (15,33).*

Recommendation #43. We recommend that the TMDL report explains that all tributaries enter the lake model evenly distributed (vertically) across all model layers. We also recommend that the TMDL state the rationale for this decision.

Response #43*: the average water temperature in the tributaries is close to the temperature in the lake. Using USGS's temperature data, we calculated average water temperature on all tributaries and compared to that in site #6 (upper lake). The average water temperature in streams is only 0.4 degrees lower than that in the lake. Since the lake is well mixed, we believe the best way for flow input to the lake is evenly distributed across all model layers.*

As indicated during the February 8, 2005 meeting with the ODEQ, Figures 7-13 and 7-14 are graphical representations of the values in Table 7-4. However, the values in Table 7-4 are from a grid-based modeling effort (not the SWAT model) and the nitrogen and phosphorus loading reductions for the cultivated land to pasture conversions were estimated using a ratio of nitrogen or phosphorus loadings to sediment loading (Storm 2005). As a result, the perfect correlations shown in Figures 7-13 and 7-14 are merely a product of the assumptions made to produce the values presented in Table 7-4.

Recommendation #44. We recommend that the TMDL explain the basis for Table 7-4 and how Figures 7-13 and 7-14 were generated. In addition, we recommend that the conclusions drawn from these figures be re-evaluated and potentially adjusted, given the above information. Most of the calibration, verification, and projection (reduction) figures in the TMDL report have mislabeled x axes. For example, in Figure 6-4 the first three (equally spaced) x ticks are September 1997, January 1998, and April 1998. There are three months between September and January, but only two months between January and April.

***Response #44**: The TMDL report for this section was modified to reflect this comment.*

None of x axes was mislabeled. The x axes may not be clearly labeled because they were labeled only to month instead of date. All labels in figures were adjusted to show dates and x ticks were evenly spaced for 91 days or approximately three months.

Recommendation #45. We recommend that the figures be modified to clearly show x-axis values. We also recommend that, to the extent possible, the figures be similarly formatted to facilitate comparisons among figures (e.g., Figures 6-10, 6-11, and 6-13 show model and data results from the same time period, but all have different x scales).

***Response #45**: Time Scales in these Figures were adjusted for easy comparisons.*

USGS (2004, pg. 2) suggests that migratory waterfowl can be a significant source of *E. coli* and ammonia in the winter.
Recommendation #46. We recommend that the TMDL include a discussion and quantification of phosphorus from waterfowl and how its exclusion from the model affects the lake model results.

***Response #46**: We obtained waterfowl population survey data from U.S. Fish and Wildlife Services and estimated the phosphorus load to the lake from the waterfowls. The total phosphorus load to the lake is less than 2% of phosphorus load from the watershed. Besides, this load from waterfowls was added in the winter times. Therefore, we believe nutrient additions from waterfowls should have minimum impact on our TMDL conclusions. The TMDL report was modified to include the detailed estimates for nutrient addition to the lake from waterfowls.*

Recommendation #47. We recommend that the TMDL cite the sources of the information presented in Table 7-6. It is unclear how the percent anoxia (40%) was determined. The model calibration figures indicate two (of five) layers briefly dropping below the 2.0 mg/L threshold at the "Near Dam" site. However, the model does not appear to predict anoxia at the "Middle" or

"Upper" stations, indicating that on a lake-wide basis, the percent anoxic volume is considerably less than 40%.

Response #47*: The sources of the information were added to the table. The anoxic volume was evaluated at each of the three sites (upper, middle and lower part of the lake). A 40% anoxic volume was estimated only at the site near the Fort Cobb Lake dam. This prediction matches the observed dissolved oxygen profile at this site. For the upper and middle parts of the lake, the lake relatively shallow and mixed and no anoxic volume was predicted by the model. The estimate of 40% anoxic volume is for the monitoring site near the dam instead of the whole lake.*

Recommendation #48. We recommend that the TMDL clearly state how the percent of anoxic volume was determined.

Response #48*: The model has five layers. The anoxic volume was calculated using predicted DO concentrations for each layer.*

Recommendation #49. We recommend that Figure 7-6 show chlorophyll-a in the upper part of the lake, as the title indicates, rather than chlorophyll-a in the middle of the lake.

Response #49*: the error was corrected in the report.*

Response to Comments from Dale Beerwinkle

1) TMDL Report fails to recognize proactive efforts of farmers in the watershed.

Through specific treatments available through past and present 319 projects and NRCS programs, and from the farmers' pockets, much cropland has been planted or committed to grass, grazing practices improved, riparian areas are being restored and protected, and structures put in place to slow and divert water flows. There is increasing use of no-till and other conservation farming. Mow-board plowing is practiced less and less because of labor restraints (time) and fuel cost. Fertilizer use has been reduced. Changes in government programs have decreased row crop acreages. These conservation and environmental commitments of the farmers should be acknowledged in the report. Such proactive efforts by farmers could be a factor why many of the impairments for the lake's tributaries in the 1998 303(d) listing were proven wrong by quantitative measure.

***Response #1**: OSU recently conducted an extensive survey to get the accurate information on farming practices in the watershed. The most recent land use data was also obtained. The SWAT model indicated that about 20% nutrient reduction has been achieved since 2001.*

2) Report lacks cost estimates and other obstacles to implement proposed BMP's

In 2003, perhaps more than ½ of the peanut acres on my commute to work were no-tilled or ro-tilled. Shortcomings of irrigation to incorporate pre-emerge herbicide and ALS resistant amaranth has reversed that trend, which was growing rapidly. Farmers are aware of *potential* economic benefits of no-till, but there is little research *in this locale* by universities or companies to *help realize this potential*. Fence building materials and other inputs have increased near two fold in the last year. What are the establishment costs and expense/income factors for planting cropland to grass? Aren't economic considerations supposed to be part of structuring TMDLs?

***Response #2**: The purpose of this TMDL is to figure out a nutrient reduction rate needed to restore Fort Cobb Lake to meet water quality standards. Economic consideration is not a requirement for a TMDL.*

3) Number of CAFOs in watershed

The TMDL report appears materially incorrect in reference to the number of CAFOs in the watershed (pages 4, 27, 66). Besides the units listed, it appears three CAFOs are omitted. There is a large CAFO in section 9-11N-13W, including capacity of over 5600 adult swine and an 8,000 head nursery. There is a smaller CAFO (approximately 2600 adult swine) located at the very head of the Lake Creek drainage in section 2-11N-13W (at the very apex of southern/northern drainage between the Washita and Canadian Rivers). There is also a swine finishing facility south of Highway 152 between Lake Creek and Willow Creek. These omissions might undermine confidence in TMDL report. *They should be properly researched and noted*.

***Response #3**: There are four CAFOs in the Cobb Creek watershed. However, only two were permitted. The report was modified to reflect the change.*

4) Use of Alachlor and Aldicarb

The report uses Alachlor and Aldicarb on all SWAT modeled peanut and grain sorghum acres. While presumably for pesticide load modeling, and selected to model because of earlier contamination reports, it should be pointed out that Alachlor is not used anymore on peanuts. Aldicarb is used principally on peanut acres with nematode infestation, and is cost prohibitive in most producers' minds, especially under non-quota peanut pricing. The presentation in the TMDL paper leaves the impression these products were and are being used indiscriminately by producers, which is untrue.

***Response #4**: Alachlor and Aldicarb were used in the SWAT model because they were detected in the water samples and because they were the reasons the streams and Fort Cobb Lake were listed in Oklahoma's 1998 303(d) list. The TMDL report has concluded that Alachlor and Aldicarb are not a problem.*

5) Nutrient impairment of Five Mile Creek

On page 18 of the TMDL Report, it is stated that there is *no data* to assess the status of nutrient impairment of Five Mile Creek, stating simply that it was listed in error in the 1998 303(d) list. However, in Figures 37 through 41 (pages 84 through 88), the USGS study on Trophic Status of Fort Cobb Lake graphs quarterly monitoring from 2001 on sites 29 and 30 from Five Mile Creek. In each category these sites had less or comparable concentrations of nutrients than sampling sites 21 and 25 on Cobb Creek, "included for spatial comparison". This data should be noted in the TMDL report. In particular, the locations showed less concentrations of NO_3+NO_2 , less total P, and much less soluble P. Since these sample sites were in stream orders 1 and 2, and had fewer nutrients than from down stream samples of Cobb Creek, it could be inferred that Five Mile Creek is not nutrient impaired. This data offers support of the fact Five Mile Creek was listed on the 1998 303(d) by mistake. If the data may be insufficient, that could be discussed.

***Response #5**: USGS collected only three samples on sites 29 and 30. There is not enough data to assess the nutrient impairment for Five Mile Creek. The TMDL report was modified.*

6) Discouragement of cotton as an alternative to peanuts

Page 70 of the TMDL report states: "Certain farmers were considering changing their peanut production to cotton production. This change as predicted by the SWAT model would increase sediment and nutrient load and therefore should be discouraged." This statement is not necessarily true if cotton might lend itself better to ro-till or no-till rotations. Cotton has been a successful partner in conservation cropping schemes here and in other parts of the state. Transgenic seeds are available that make environmentally friendly and no-till friendly herbicides the herbicides of choice. These seed choices and the boll weevil eradication program greatly reduce insecticide usage. A tap rooted crop, cotton is known to respond to deep placed phosphorus when phosphorus is needed, out of the 10 mm depth modeled in SWAT for phosphorus run off.

***Response #6**:* *It is commonly recognized that erosion from cotton fields is much worse than that from peanut field.*

7) Road Sediment

While not a part of the final DEQ TMDL paper, the OSU final report to DEQ has a section presenting a study conducted to determine the contribution of the watershed's road system to sedimentation. This section is far from transparent as to how ground-truth information was adapted to the WEPP:road model, as terminologies are different. There are several areas where it would appear that road contributions could be higher than estimated:

Road width – Standard county right of way is 66 ft (20 meters). While variable, ditches and traveled way most often occupy the entire width. *Assuming a road width of 10 meters appears to underestimate erodible area by ½.*

Flow length for road segment– Roads (especially dirt and graveled roads) in the watershed are usually cut surface (rather than fill) from both sides for very long segments. Road surfaces are often flat. Runoff may not be able to escape from road or ditch at assumed cross drainages. Dirt and graveled roads are most often rutted, according to the WEPP:road description. Actual flow length and effective flow length may be substantially longer than anticipated by the methods used by the researchers.

Soil types for dirt roads - Ground observers were told to classify the road soil as "sand, deep sand, clay, or bedrock". WEPP:road uses "clay loam, silt loam, sandy loam, and loam" for input choices. Most soil types in the area are loamy fine sands, fine sandy loams, or silty loams, and deeper horizons are finer textured yet. *Depending on flow length and slope, mischaracterization of soil type for modeling would add to error in the study.*

Contributing P? – It could be argued that the sediment from road erosion is probably low in P, especially if it is from deeper soil horizons as suggested in this discussion. However, it can be noted that these soils, even if entirely mineral, have been submitted to intensive fallow weathering, including mechanical disturbance, and it might be interesting to know the soil test P in these potential sediments.

***Response #7**:* *sediment load from county roads is only about 5% of total sediment load from the watershed. The nutrient load from county road is already lumped into the load from nonpoint sources predicted by the SWAT model.*

8) Sediment calibration

What objective measure is sediment calibrated against in the SWAT model? The lone parameter adjusted for sediment calibration was the factor for supportive conservation practice, which was adjusted to 0.8 in the universal soil loss equation in the SWAT model. How does a land manager relate this adjusted value to the expense he and the operator have put into terrace and grassed waterway construction, repair, and upkeep? Or relate it to the onsite supportive conservation factor value if USLE is applied to his field, which is considerably less than this number? What is the contribution of in-channel erosion to sediment in the model as applied?

***Response #8**: Sediment is not considered as calibrated in the SWAT model and bank erosion is not modeled. The amount of sediment is not a important factor in determining the nutrient reduction goal in this TMDL study because the critical time is in the summer while most high storm events occur in the spring*

9) **Nutrient Loading – phosphorus - wildlife**

In *5.2 Assessment of Nonpoint Sources* (page 28), the report elucidates the possible nonpoint pollution sources in rural settings. However, the paper and supporting modeling work do not address all these sources. Fort Cobb Reservoir is continual home for a small Canadian goose flock and transient home for many migrating waterfowl. The waterfowl provide direct transport of nutrients, field feeding on peanuts and growing wheat, and returning to the refuge of the lake to roost on the water. Given a range of estimates of residency rates, size, feeding habits, defecation rates, and defecation schedule, estimates could be made for waterfowl P added *directly* to the lake (without benefit of runoff) from 2,500 kg to levels much higher, levels more than 100 fold higher the 23.5 kg background rate estimated from low flow conditions in the report. This would seem to be important, given the low dilution capabilities implied by the trophic state of the lake.

***Response #9**: The impact of waterfowl on the water quality of Fort Cobb Lake was studied and added to this TMDL report. Please refer to section 5.2.b for details.*

10) **Lack of transparency in modeling**

In the OSU application of the SWAT model, it is not thoroughly discussed as to how soil test phosphorus levels *in the watershed* are inferred from *countywide data* and/or input budgets presented. The conceptual linkage to such information and its effects on the SWAT model and estimating a TDML is vague. Other concepts not readily understandable from the report include parameter changes in calibration (Why increase or decrease values? In what direction or magnitude where parameters changed from original assumptions? How did these changes affect the modeled outcome?). What are the relative contributions of the various distributions of P to total P in the water? Such transparency is lacking throughout the modeling report. Perhaps the researchers did not realize that the final audience would include layman stakeholders in the watershed, and the modeling report was worded for those with a thorough understanding of the SWAT model and its application in this process.

***Response #10**: How soil test phosphorus levels were used in the model and how the model was calibrated are all technical issues which are difficult to understand for those without related professional trainings.*

Response to Comments from E. Glen Price

I, E. Glen Price, make this written statement for the record concerning the various remedies for the classification of Ft. Cobb Lake as an impaired body of water. It is my understanding that the determination was made because of high phosphorus in the main body of the lake. along with turbidity in one of its contributing streams, Lake Creek. Such phosphorous reportedly contributes to an unusually high amount of green algae growth that peaks in warmer seasons and depletes oxygen levels when it dies off in the fall. This condition reportedly renders the lake less desirable for fishing and swimming. These were considered uses when the dam was envisioned and constructed under the guidance of the US Bureau of Reclamation in 1958.

I am 60 years old and have lived in Caddo County all my life except for University studies ('62-'68 BS, MS Agronomy OSU; 71-73, PhD agronomy, U of Illinois and active military service ('69-'71, Soils Analyst, Army corps of Engineers). I was born in upper end of the watershed. I use Ft. Cobb Lake for recreation in many ways now and enjoyed the area covered by the lake prior to the dam's construction (Lemmon's recreation area for instance). My sons and I particularly like to fish in Ft. Cobb for the different, and changing, species found there, but especially like to pursue largemouth bass. My sons finished their education at Anadarko and every one of my immediate family has worked or still works in Anadarko, a city relying on Ft. Cobb Lake for its municipal water supply. I presently operate farms and graze cattle in this watershed, though I do not own land there. I am president of the Hinton Chamber of Commerce and a member of the Caddo county Industrial Authority. I am concerned that the right solutions need to be found that are in the best interest of all in the region.

It is my concern that the remedies mentioned were limited to prevention of phosphorous entering the upstream water of Ft. Cobb Lake. Opportunity exists to remove any existing or future excess phosphorous through methods that would add to the economy instead of placing a burden on contributors to the regions wealth. In particular, I find that any additional costs to agriculture would be hazardous to the entire economy as we depend heavily on it for our base. Agriculture operators have made many strides in the economical use and retention of fertilizer and the agencies responsible for preventing erosion and protecting the water also have made substantial gains since the data were collected for your determination of impairment. These alone will not solve the problem of phosphorous in the water as one of the main cause is the added time and surface exposure allowing evaporation to concentrate any existing nutrient load. If all water were blocked from entering or leaving the lake by stream the lake would become more saline in short order. The water is partially impaired by evaporation alone, but this can be mitigated through management of water surface area or other techniques.

Another apparent problem with the lake is that the algae grow in a virtual monoculture environment, with limited competition for the phosphorous in the water and the algae have temperature ranges narrower than what ft. Cobb experiences. The addition of higher plant life would concert some of the phosphorous to these species which could be removed from the waters much as crops. Such species could be determined by experimentation, but should be well known to biological students of the state. Algae might be removed from the lake for beneficial purposes as well, using simple vortex or filtration methods. These would have multiple benefits to the lake and temper expense and economic activity restrictions above it in the watershed and partially be offset by the use of the protein containing green matter removed.

Catfish are fun to catch, but the real economic boost is associated with bass fishermen and their high percentage of boating, etc. A few year back – possibly 20 – there were many active bass clubs that utilized the lake for tournaments. It was predicted by fish and game officials that Ft. Cobb, one of the best for largemouth bass, might produce a state record size trophy. But, vegetation was considered excessive and action taken to remove milfoil and other water plants from the bio-system. The vegetation was lost and bass fishing went with it. There plants provide cover and shade for the fish, filter silt and clay sized particles form the water, regulate water movement, provide oxygen through photosynthesis on a broad temperature range, and lock up nutrients from the water. Like crops, the growth removes nutrients form the soil and water, depositing these in their tissues which may provide food for other higher life forms, beauty, and protection as estuaries for hatching fishes and other organisms for more diverse food chains. Rich waters make for rich harvests if there is diversity of life forms present to utilize them.

Swimming in the lake has been impaired in part by the success of one of the wildlife department programs – geese. I know these are federally regulated "migratory fowl", but some of these birds only leave Ft. Cobb to feed. They live in the area year round and are joined by ducks, geese, pelicans, etc. from time to time, peaking in numbers in winter months when algae are not actively growing in the lake. This allows the phosphorous to build during this time and allows for a bloom once the waters warm in spring. More liberal hunting of these fowls would show net reduction of phosphorous from the lake as the geese harvest or glean many pounds of phosphorous bearing plant tissue daily and deposit their wastes directly into the lake, mostly at night. There is potential increase in the economy directly associated with the increased harvest. The numbers of geese could be drastically decreased without impairing the quality of the flocks for future use. They can be a part of the solution to a problem to which they contribute, unmeasured because their waters are mostly absent in the streams above the lake.

There is no mention of the form in which phosphorous exists in the waters of Ft Cobb Lake. Phosphorous held by colloidal particles will be held tightly and not go into solution easily. These particles hold most of the phosphorous measured in the watershed above the lake. The various forms of phosphorous held in organic matter may be more available for the algae. I am aware of no report this in the worrisome finding of impairment of the lake. Sediments in waters provide a function of algae prevention by blocking out the sunlight necessary for algae to photosynthesize. The amount of rainfall received in the watershed has an influence on the amount of silt and clay in the water. This might have offsetting effects on phosphorous measurements and algae growth. Colloidal particles are aggregated and removed by gravity in the presence of calcium. Fertilization with lime and gypsum can help maintain clarity of the water and measure of phosphorous in water samples.

I have mentioned "cropping" the phosphorous from the lake by harvest of vegetation. This vegetation could be dried, and used as mulch for bare ground within the watershed itself, thus limiting the need bring organic or inorganic forms from outside its borders. It would appear that local governmental agencies could use this mulch for bare soil created when roads are constructed, bridges cleared during construction, etc. The dried vegetation might also be used for animal rations, also limiting the requirement by agriculturalists to import nutrients for their various operations. There have been many systems, more nearly closed, researched for third world country producers by recycling proteins from downstream back into their watersheds. These primarily were for handling wastes from poultry and animal feeding pens into ponds with fish being harvested there as protein source for food and feed, but also for fertilizer in fields of plants to be fed these animals. Such cycles could be arranged for Ft. Cobb Lake. Basically, the Wildlife Department farms the lake now (not a natural environment) as the fish species are there on a "put and take" basis. Rough fish may lend themselves to this program more readily than game fish species. Any increased harvest of fish would decrease the phosphorous from the waters in which they developed. Many of the fish are sterile hybrids, just as were the tilapia in the instances mentioned about. They are not native fish species. Harvest is not done by the same entity that placed then in the lake, but they are harvested. Again, increased harvests would mean faster reduction of phosphorous. The Epcot center at Kissimmee, Florida, has developed a closed system waster water purification and recycling based on harvest of vegetation from water plants. We can learn much from these prototypes by study and emulation. Research and adaptation of these promising plans seem to be a rational approach to a complex problem. Source and use of nutrients should be on the management table just as the more common source and use of funds analysis. Management is simplified through this process. Many in government believed that the economy is improved by research efforts alone, regardless of the productive outcome of the subject matter studied. Certainly, this would appear to be restriction of nonpoint source addition by streams, these removal procedures should adapted and utilized to solve the impaired water condition.

Support for a diverse solution including both sides of the equation should receive broad based support from universities, along with national, state and local governments. The critical part would be the probable direct interest from fishing and hunting enthusiasts, suppliers, and tourists as well as agriculturalists. Oklahoma should lead the way for the nation. We can show what heartland common sense can do. Recycling has always been a major part of our economy. Our state was born with the idea of economy of resources. We know their origin. We know their worth.

***Response**: We agree that establishing vegetation in Fort Cobb Lake will help settle and filter fine particles in water columns, regulate water movement, provide cover and shade for fish and promote more diverse life forms. Harvesting vegetation will remove nutrient from the lake. We also agree that lime, gypsum or alum can help reduce turbidity in the water column. We would welcome and encourage these activities in Fort Cobb Lake. However, these practices are beyond the scope of this TMDL.*

The impact of migratory bird on Fort Cobb Lake was evaluated based on middle winter surveys by U.S. Fish and Wildlife Services. This section was added to the TMDL report.

In the EFDC (Environmental Fluid Dynamic Code) model, total phosphorus was break up into inorganic form (PO_4) and organic form. The organic form of phosphorus was further divided *into dissolved organic phosphorus (DOP), labile particulate organic phosphorus (LPOP) and refractory particulate organic phosphorus (RPOP). The details on the EFDC model are available to public upon request.*

Response to Comments from US Bureau of Reclamation

The comments from US Bureau of Reclamation were summarized as follows:

Comment #1: We suggest if allowed under EPA, Total Maximum Daily Load (TMDL report guidelines, sections of the draft report prepared by the Oklahoma Conservation Commission "Watershed Based Plan for the Fort Cobb Watershed" be incorporated into the TMDL report. Useful and informative discussion sections in the watershed report would compliment and provide an overall improved TMDL report product. Specifically, these include discussions on incentive programs, current progress in meeting BMP's time frames, etc.

***Response #1**: BMP implementation is not required in a TMDL report. However, a reference to the Oklahoma Conservation Commission report was added in the TMDL report. For those who are interested in the BMPs implemented in the Fort Cobb watershed and related information, please refer to the OCC's Watershed Based Plan for the Fort Cobb Watershed report for details.*

Comment #2: We noticed the reference list does not include a Bureau of Reclamation sponsored and funded water quality monitoring report. The investigation was completed in cooperation with U.S. Geological Survey, Columbia Environmental Research Center, and is titled "An integrated Assessment of the Trophic Status of Fort Cobb Reservoir, Oklahoma" (2004). We suggest your review of study results, discussions and conclusions may provide additional information that could be utilized in the TMDL report. At a minimum, the USGS study should be included as a reference source document.

***Response #2**: When this TMDO report was first drafted, the USGS report was not available yet. Some discussions and reference were added to the TMDL report.*