Lake Frederick
Diagnostic and Bathymetric Mapping Study

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EXECUTIVE SUMMARY

Lake Frederick is located approximately 4 miles east of Manitou and 14 miles northeast of the city of Frederick, Tillman County, Oklahoma. The dam is located at T1N R16WIM Sec.33 (34E30'/98E53'). Lake Frederick was constructed as a Soil Conservation Service project in 1974 for the purpose of water supply and flood control.

Lake Frederick is a 925-acre lake with a shoreline length of 18 miles, a spillway elevation of 1200 feet and a normal pool volume of 9,526 acre-feet (Oklahoma Water Atlas, 1990). The mean depth is 10.3 feet (3.14 meters) with an approximate maximum depth of 35 feet (11.5 meters). The lake is owned by the City of Frederick and serves as the sole drinking water supply for a population of approximately 5000 as well as serving other parts of Tillman County. The lake also provides recreational opportunities for the local populace to enjoy.

The Lake Frederick Watershed is located in the northern portion of Tillman County and is approximately 35,907 acres. The primary tributary and major outflow from the lake is Deep Red Creek. The land use in the Lake Frederick watershed consists primarily of mixed rangeland, herbaceous rangeland, cropland/pasture, shrub and brush rangeland, and other urban or built-up land. Soils in the watershed are very susceptible to erosion, which can be mitigated through terracing and contour tillage to reduce runoff and erosion by water.

Due to the lake's use as a municipal water supply reservoir and past and present drought conditions, the city of Frederick was concerned with sedimentation and current lake volumes. The expressed interest by the city resulted in the current diagnostic study of the lake. The purpose of this study is to create a current bathymetric map to examine current lake volumes and assess present water quality.

Overall water quality indicates conditions to be normal for Oklahoma lakes. The lake volume has not decreased. There are no outstanding measurements for any of the variables studied, however turbidity is excessive and consistently exceeds the Oklahoma Water Quality Standard. Nutrients are indicative of mesotrophic conditions. Nutrient levels are probably kept at bay due to the high turbidity and low light penetration into the water column.

INTRODUCTION

Lake Frederick was constructed in 1974 for the purpose of water supply and flood control. The lake is owned by the City of Frederick.

Presently, Lake Frederick serves as the sole drinking water supply for the city of Frederick. The city sells water to the Tillman County Water Development Authority (TCWDA) who in turn sells water to the cities of Davidson and Grandfield as well as the Tillman County Rural Water District No.1. Tipton and Manitou also buy water directly from the city of Frederick. The lake provides recreational activities for the local

residents to enjoy. These activities include fishing, boating and picnicking. Recreational activities in the past have been limited due to a lack of facilities. However this is slowly changing as more facilities have been developed as a result of 4th of July activities that take place at the lake.

Figure 6 shows land use in the watershed which consists of mixed rangeland (47%), cropland and pasture (37%), herbaceous rangeland (15%), shrub and brush rangeland (less than 1%), and other urban or built-up land (less than 1%) . This land use/land cover data was collected by the United States Geological Survey (USGS) and converted to ARC/INFO by the Environmental Protection Agency (EPA). This type of data is useful for environmental assessments of land use patterns with respect to water quality analysis, growth management, and other types of environmental assessments. Land use was mapped and coded using the Anderson classification system (Anderson et al. 1976) which is a hierarchical system of general (level 1) to more specific (level 2) characterization. The numbers obtained are estimates from the data sources used. The information was at a scale of 1:250,000 (which is very generalized for this size watershed) and the date of this data source is over 20 years old. Arc View 3.2 was used to generate the percent values listed.

Soils

Information on soils in the Lake Frederick Watershed was collected from the U.S. Department of Agriculture (USDA) Soil Surveys on Tillman County (SCS 1974). The predominant soil association in the lake watershed is the Vernon-Stamford association. The characteristics of this soil association are discussed below.

Vernon-Stamford association - This association is predominantly uplands with shallow to deep soils, which are very gently sloping to strongly sloping. The surface layer is composed of loam or clay and the subsoil is also loam or clay.

The Vernon soils are very gently sloping to strongly sloping with a surface layer of silty clay loam. The subsoil is composed of red clay, which extends downward 18 inches. The Vernon soils comprise approximately 63% of the association. These soils are well drained and have slow water permeability.

The Stamford soils are gently sloping with a surface layer composed of silty clay loam. The subsoil is composed of red clay extends downward approximately 36 inches. The Stamford soils comprise 11% of the association. These soils are also well drained and have slow water permeability.

Both soil types are prone to drought, as much of the rainwater is lost to runoff as a result of the high clay content and slow permeability. Erosion control is a concern for Vernon and Stamford soils with terracing and residue management recommended.

Historical Water Quality

The Oklahoma Water Resources Board (OWRB) studied Lake Frederick in both 1994 and 1997 as part of the Statewide Lake Water Quality Assessment (LWQA). Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction potential and salinity were performed at three study sites and water quality samples were collected to be analyzed for multiple parameters during each sampling event.

In 1994 the lake-wide turbidity was 65 nephelometric turbidity units (NTU), average chlorophyll-a value was 6.7 µg/l and average secchi disk depth was 14 centimeters. Figure 1 displays the turbidity values for each site for the sample year 1994. All turbidity values were well above the Oklahoma Water Quality Standard (OWQS) of 25 NTU (Plate1). The trophic state index (TSI), using Carlson's TSI (chlorophyll-a) was calculated using summer chlorophyll concentrations. This calculation is used to measure the productivity and indicate nutrient levels in lakes and reservoirs (Carlson, 1977). Lake Frederick had a calculated TSI of 48, which indicated the water body was mesotrophic in nature, indicative of moderate levels of primary productivity and nutrient conditions Figure 2. At the time of sampling the lake appeared to be well mixed and did not exhibit thermal stratification as oxygen levels remained above 3.0mg/L throughout the water column (Figure 3). In the 1994 LWQA Report, Lake Frederick was listed as experiencing a beneficial use impairment due to suspended solids and in violation of Oklahoma's Water Quality Standard (OWQS) for turbidity (25 NTU). The lake was also listed in the 319 Assessment Report as having non-point source concerns associated with agriculture in the watershed (Oklahoma Conservation Commission,1990).

In 1997 the lake-wide average turbidity was 99 NTU, average chlorophyll-a value was 7.5 µg/l, and average secchi disk depth was 16 centimeters. The calculated TSI was 50, which is indicative of a mesotrophic to eutrophic water body with possibly threatened water quality due to moderate to high primary productivity and in-lake nutrient levels (Plate 2). At the time of sampling the lake exhibited weak thermal stratification at the 5-6 meter depth. Anoxic conditions were present from 9 meters to the bottom at 10.3 meters (Figure 4). This is not a concern for the beneficial use of fish and wildlife propagation as the majority of the water column was oxic in nature. In the 1999 Beneficial Use Monitoring Program Report, Lake Frederick was listed as being in violation of the OWQS for turbidity. This suggests potential beneficial use threats or impairments were present at the time of sampling.

In summary, Lake Frederick experienced periods of high inorganic turbidity with values approaching or exceeding 100 nephelometric turbidity units (NTU). Due to light limitations driven by high turbidity, low to moderate primary productivity values were detected based upon chlorophyll-a values collected in the summers of 1994 and 1997. Excessive amounts of suspended solids detected in the lake in 1994 and 1997 also indicated the potential presence of sedimentation concerns. The lake is also listed on

Oklahoma's 303 (d) list of impaired and threatened waters in need of a TMDL, as required by EPA for all lakes which fail to meet the state's established water quality standards. The primary concern with Lake Frederick is the high concentration of suspended solids and the continual exceedance of the OWQS for turbidity.

SAMPLE METHODS

Water Quality

As part of this study, Lake Frederick was sampled in June of 2000 for numerous water quality chemical and biological parameters. Vertical profiles for dissolved oxygen, pH, temperature, specific conductance, oxidation-reduction, and salinity were performed at all sample sites using a Hydrolab Minisonde multiprobe unit. These parameters were recorded in situ from the surface to the bottom of the lake in one-meter intervals. Water quality samples were collected at three sites to represent the riverine, transition, and lacustrine zones of the reservoir. Samples were collected at the lake surface and at 0.5 meters from the lake bottom at all sites. Water samples were preserved for analysis of the following parameters: ammonia (NH_4^+), nitrate nitrogen (NO_3), nitrite nitrogen (NO_2), kjeldahl nitrogen, total nitrogen, organic nitrogen, ortho-phosphorus, total phosphorus, suspended solids, hardness, alkalinity, and chlorides. Each water sample was collected in two ½ gallon polyethylene bottles, one preserved with sulfuric acid (H_2SO_4) and both were stored on ice (4°C). The Oklahoma Department of Environmental Quality (DEQ) State Environmental Laboratory performed the sample analysis.

Water samples were also collected in 1-quart containers to determine turbidity and chlorophyll-a values. Nephelometric turbidity was determined through use of a HACH Portalab Turbidimeter. In general, at least 300 ml of sample water are filtered through a millipore filter, which is then ground with a mortar and pestle, and preserved with acetone in a test tube and refrigerated until delivery to the Oklahoma City-County Health Department laboratory for analysis. All equipment calibrations were performed prior to sampling and in accordance with the manufacturer's instructions. All sample collections, preparation, and analyses were made in accordance with Standard Methods for the Examination of Water and Wastewater (1995).

Bathymetric Mapping

The primary objective of the study was to conduct a bathymetric survey of the reservoir in order to generate a current bathymetric map and current lake volume calculations. A description of this procedure is discussed in the following sections.

Bathymetric Mapping is the process utilized to determine the storage capacity of reservoirs. The process utilizes a differential global satellite positioning system (DGPS)[1], an acoustic depth sounder (Echosounder)[2], and Coastal Oceanographic software[3]. The implementation of this technology in bathymetric mapping has allowed the surveying process to become more efficient and accurate. This mapping process was utilized to survey Lake Frederick in June of 2000.

The process of conducting a bathymetric survey consists of three successive procedures. These procedures include setup, field surveying, and post-processing of collected data. In the first procedure setup, Hypack software from Coastal Oceanographic is used to create virtual track lines that are laid across a digital rendering of the reservoir that has GPS coordinates. These virtual track lines are spaced between 300 to 400 feet apart. The determination of the spacing is related to the accuracy that is required for the surveying project. The closer the virtual lines are together the more data that will be collected in the surveying process. The data directories for which the collected data will be stored are also created in the setup procedure. The next step in the surveying process is field surveying.

Field Surveying consists of the actual data collection. Once the destination reservoir has been reached the equipment is setup on the boat (Carolina Skiff) and networked together. The equipment is then tested to ensure that the individual components are working properly together. The echosounder is calibrated to the salinity concentration of the reservoir to provide accurate depth readings. Once on the lake, each virtual line is followed across the reservoir until the entire navigable surface area of the reservoir has been covered. A DGPS (XY) point and a depth reading (Z) are collected every one to three seconds (depending on desired accuracy) while navigating on each virtual line that cuts across the reservoir. The raw data is collected in State Plane 1983 Geodetic Parameters. In this mode the XYZ coordinates are collected in feet. The Coastal Oceanographic Hypack software is used to display the map of the reservoir, the virtual lines, and store all data points that are logged while on the reservoir. After the field surveying has been completed the mapping process continues back in the office where post-processing takes place.

The last procedure in the bathymetic mapping process is the post-processing. The raw data collected in the field is brought back to the office. Utilizing the Hypack Software the raw data is reviewed. The reason for reviewing the data is that when surveying in the field there is always the possibility that the equipment has processed a false reading, whether it is a DGPS reading or echosounder reading. The raw data is viewed using the Hypack Single Beam Editing program. The Editing program allows staff to see a virtual line and the data collected on that line. Each virtual line is reviewed individually. In the process of reviewing a line, each XYZ point collected on that line is examined to ensure that it is an accurate value. XYZ Coordinate points on the line that are not accurate are corrected to closely match other accurate surrounding points. The day to day fluctuations in lake levels are also adjusted in the raw data during this process. This is done by recording the lake levels on the days that the surveying takes place and then this data is used to adjust the raw Z coordinate values. Once the raw data has been corrected the data is sorted. The Sort program can eliminate conflicting data points based on either a Radius or DX-DY distances. With a Radius, which is preferred, the program eliminates any other data record, which is within the radial distance of the accepted point. The smaller the accepted point the less edited data is rejected and a larger accepted value results in more edited data that is rejected. The

Sort program then saves the edited data to an ASCII XYZ data file with the .XYZ extension. Once the edited data has been sorted it can be rendered in a map, such as a contour map, or some other form of graphical representation to satisfy the needs of the project.

[1]Trimble, AgGPS122
Sub meter accuracy
DGPS antennae

[2]Raytheon Depth Sounder Precision Surveying Fathometer
Model: DE719D MK2
Range 500' or 150m
Resolution 0.1 units
Accuracy +/- 0.5% of indicated depth (ft or m)

[3]Coastal Oceanographics, Inc. Hypack for Windows
(Bathymetric surveying, dredging maintenance, construction, and general navigation software.)

RESULTS AND DISCUSSION

All water quality data collected by the OWRB are compared to the Oklahoma Water Quality Standards (OAC 785:45) and the Use Support Assessment Protocols (USAP) (OAC 785:46-15) documents in order to determine if a lake is meeting the beneficial use assigned to it by the state. The OWQS specify numerical and narrative criteria necessary to maintain and protect beneficial uses.

In June of 2000 the lake-wide turbidity value was 102 NTU's (Plate 3) and average lake-wide secchi disk depth was 14 centimeters. Figure 1 displays the turbidity values per site at the time of sampling. All turbidity values were well above the OWQS standard of 25 NTU. The trophic state index, using Carlson's TSI (chlorophyll-a) was calculated and resulted in a value of 45 (Plate 3). This value is slightly lower than those of previous year's (48 and 50), but still indicates the water body to be mesotrophic in nature. The trophic state categories are displayed in Table 1.

Table 1. Lake Trophic State categories.

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

Salinity values for Lake Frederick were consistently 0.2 parts per thousand (ppt), which are consistent with values seen in most Oklahoma reservoirs. Readings for specific conductance ranged from 0.384mS/cm to 401mS/cm, which indicate the presence of high concentrations of electrical current conducting compounds (i.e. salts) in the lake. In general, pH values were found to be neutral to slightly alkaline with values ranging from 7.14 to 8.13. Low secchi disk depths and visual observations indicate the lake was highly colored at the time of sampling. The oxidation-reduction potential ranged from 85mV to 341mV which is indicative of an absence of reducing compounds. Lake Frederick was thermally stratified at site 1, the dam between 3-4 meters in depth (Figure 5). At this depth, dissolved oxygen values fell below 3.0 mg/L creating anoxic conditions for over half of the water column. Anoxic conditions could potentially be a problem in this water body during the summer months.

Water quality samples were analyzed for nutrients, including total nitrogen and total phosphorus, and suspended solids, although there are currently no numerical OWQS in place at this time. The total nitrogen at the surface ranged from 0.83mg/L to 2.78mg/L and from 0.78mg/L to 1.08mg/L at the lake bottom. Total phosphorus had a range of

0.098mg/L to 0.125mg/L at the surface and 0.091mg/L to 0.121mg/L at the lake bottom. The nitrogen to phosphorus ratio (TN:TP) was 12:1 for the sample year 2000. This value is higher than 7:1, characterizing the lake as phosphorus limited (Wetzel, 1983). These nutrient values generally indicate the Lake Frederick is not experiencing enrichment.

CONCLUSION

The purpose of this study was to assess the current water quality and determine current volume by creating a bathymetric map of the lake. GIS analysis of the data collected determined the total volume to be 9,663 acre-feet with a total surface area of 878 acres. This value varies from the information in Oklahoma Water Atlas (OWA), which indicates the volume to be 9,526 acre-feet with a total surface area of 925 acres resulting in a difference of 137 acre-feet. At this time it is not known where the OWA statistics were taken from or how they were calculated. Results of the bathymetric mapping indicate that sedimentation is not a problem for the reservoir.

In summary, Lake Frederick continues to be classified as a mesotrophic waterbody, indicative of moderate primary productivity with moderate nutrient levels (Plate 3) consistent with other reservoirs in the region. The most immediate concern or impairment associated with Lake Frederick continues to be the excessive turbidity values. The lake-wide turbidity average of 102 NTU greatly exceeded the OWQS of 25 NTU. Although anoxic conditions were present at site 1 (the dam) at the time of sampling it is difficult to predict if this is truly an impairment since the lake is fairly shallow in many places and may be well mixed in these areas. Data collected in June 2000 was similar to that of the 1994 and 1997 LWQA, therefore water quality conditions seem to be consistent over time, although turbidity values have increased slightly. Lake Frederick has been placed on the 2000/2001 BUMP lake assessment list and will be sampled for a full calendar year, collecting data quarterly. More data collection and analysis will allow a clearer picture of the actual behavior of the lake.

Figure 1. Turbidity Values for Lake Frederick for three sample years

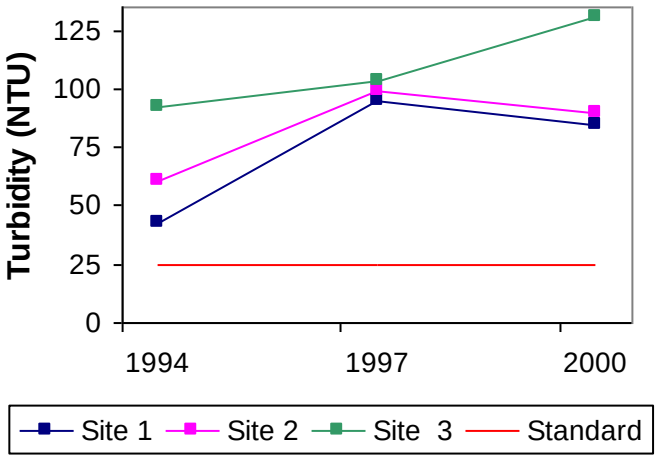


Figure 2. Trophic State Index (TSI) for Lake Frederick for three sample years.

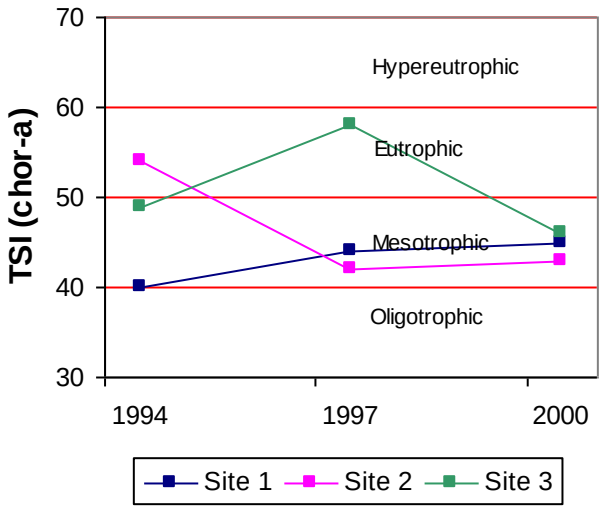


Figure 3. Vertical profile of Lake Frederick, summer 1994.

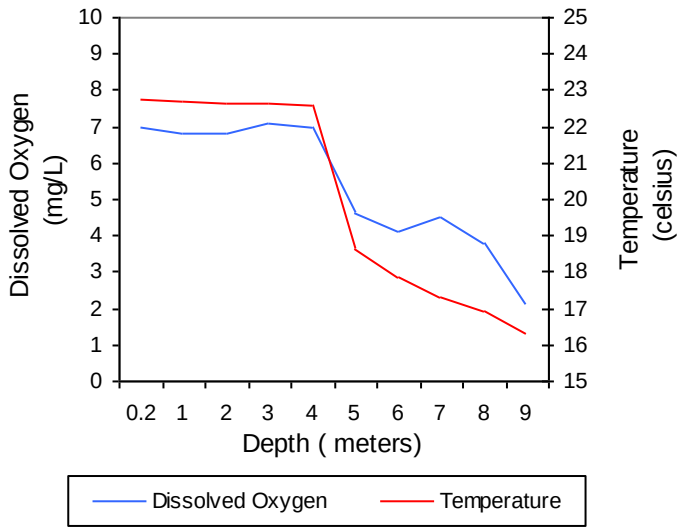


Figure 4. Vertical profile of Lake Frederick, summer 1997.

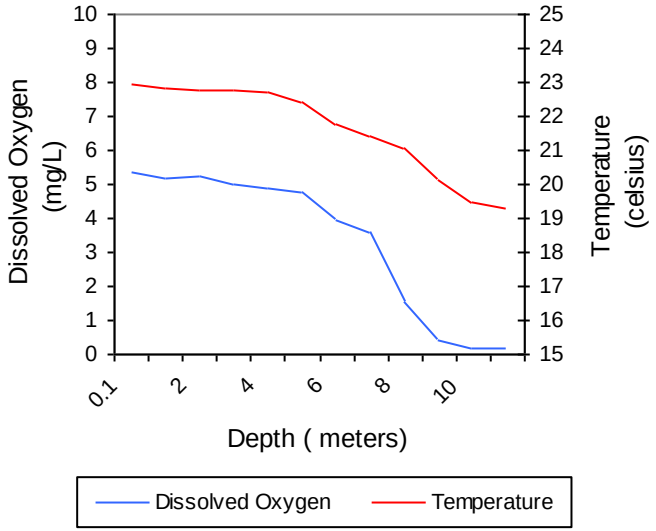
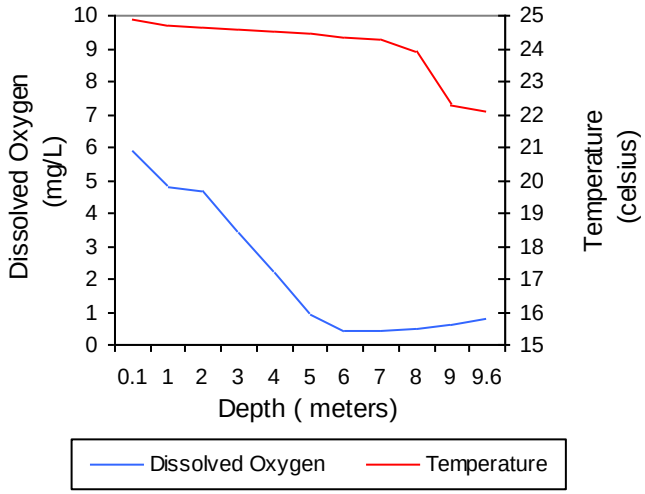
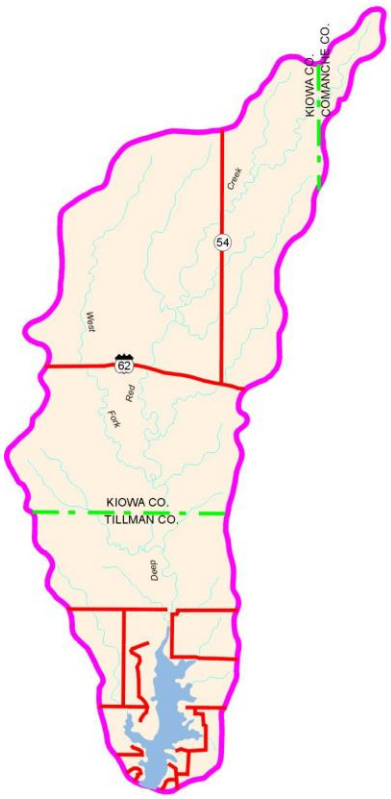


Figure 5. Vertical profile of Lake Frederick, summer 2000.





Frederick Lake and Watershed

Frederick Lake Location

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

Turbidity 1994

Trophic State 1994

Plate 1

Lake Water Quality for

Frederick Lake

Frederick Lake and Watershed

Frederick Lake Location

Turbidity 1997

Trophic State 1997

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

Plate 2

Lake Water Quality for

Frederick Lake

Frederick Lake and Watershed

Frederick Lake Location

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

Turbidity 2000

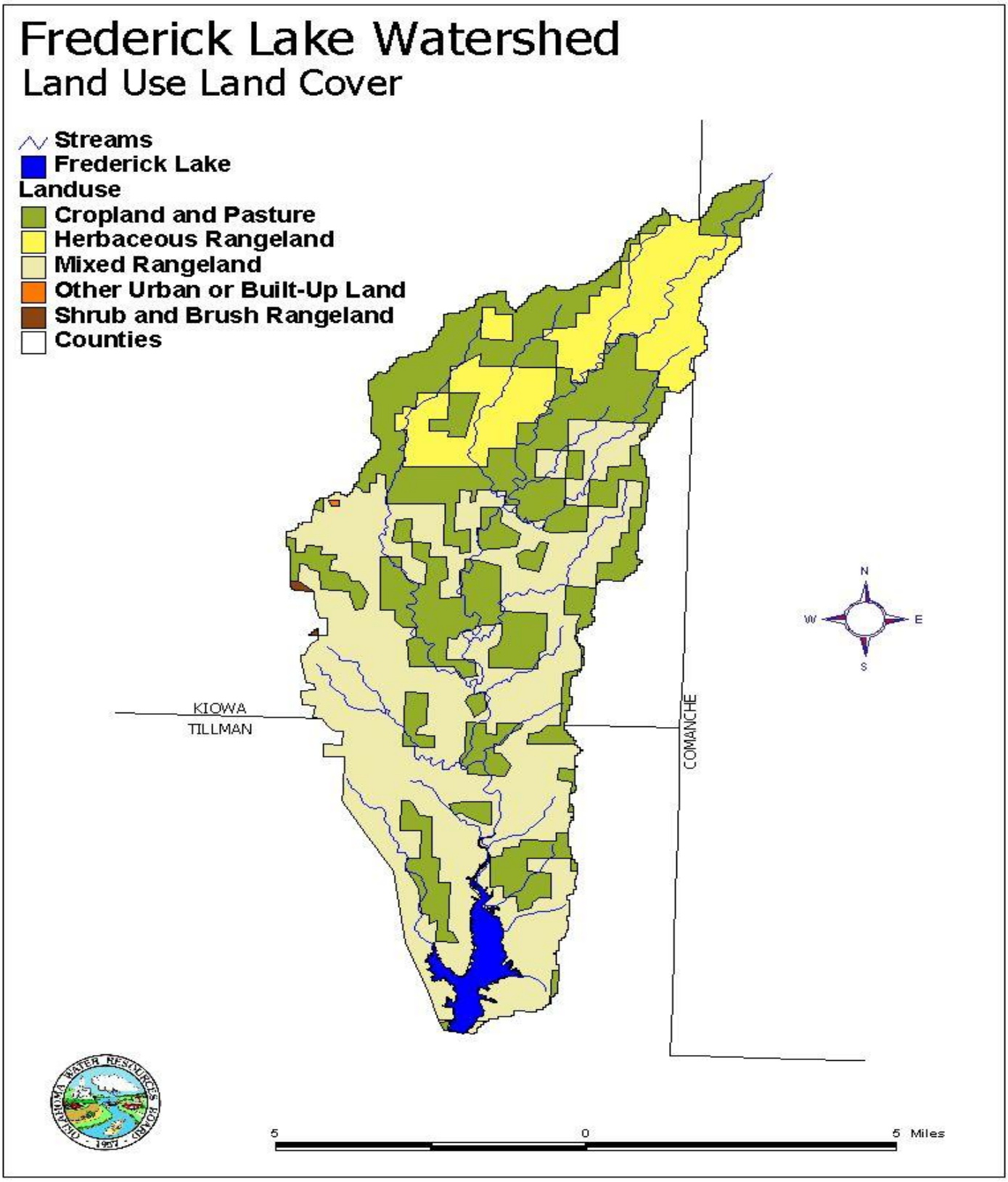
Trophic State 2000

Plate 3

Lake Water Quality for

Frederick Lake

Figure 6. Land use map for Lake Frederick watershed



LITERATURE CITED

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

Oklahoma Conservation Commission. 1990 319 Report. Oklahoma City, Oklahoma

OWRB. Oklahoma Water Atlas. 1990. Oklahoma City, Oklahoma, Publication No. 135

Wetzel, R.G., 1983 Limnology pp. 285-288

APPENDIX A
GIS BATHYMETRIC MAPPING ANALYSIS

Lake Frederick GIS Bathymetric Survey Report

Procedures:

1) Create the Lake Boundary
   a) Digital Orthophotos
      The lake boundary was created by on-screen digitizing from aerial photo graph images called digital orthophoto quarter-quadrangles (DOQQs). There were two DOQQs that covered the extent of Lake Frederick. They were the Southeast corner of the Manitou quad and the Southwest corner of the Indiahoma quad. The DOQQs were obtained from the ONENET FTP site (ftp://okmaps.onenet.net) . The DOQQs were originally produced by the USGS.

   b) ArcView GIS
      ArcView is a Geographic Information System (GIS) software that allows the user to work with maps in a digital format. This GIS was used to view the DOQQs to create a lake boundary. Using the DOQQs as a backdrop, the lake's shoreline could easily be seen and mapped. The boundary was digitized at a scale of 1:3000

2) Working With the Collected Survey Data
   a) Importing the Survey Data Into the GIS
      The survey point data was imported into the GIS and convert to a point coverage.

3) Creating a Depth Surface
   a) Using the collected survey data, a surface model was created to show the depths across the lake. The survey data points were collected along parallel transects that were 300 foot apart. These points were used to interpolate an ARCINFO GRID. The grid is made up of 10 foot by 10 foot cells covering the extent of the lake. Each cell has a depth assigned to it based on the TOPOGRID interpolation process. The grid is used to calculate the lake volume and to create contours.

4) Creating Depth Contours
   a) The depth grid was used to create 5 foot depth contours across the lake.

Results:

1) Volume and Area Statistics
   The total surface area of Lake Frederick was calculated to be 878 acres. This area was calculated from the digitized lake boundary.

   The volume of Lake Frederick was computed from the depth grid. Using the CUTFILL volume tool in ARCINFO the total volume was determined to be 9,663 acre-feet.

Compared to the Oklahoma Water Atlas:

Total surface area from OWA: 925ac
Total surface area from Study: 878ac
Difference: -47ac

Total volume from OWA: 9,526ac-ft
Total volume from Study: 9,663ac-ft
Difference: +137ac-ft

At this time it is not known where the OWA statistics where taken from or how they were calculated.