PHASE I CLEAN LAKES PROJECT

DIAGNOSTIC AND FEASIBILITY STUDY OF

LAKE EUCHA

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DIAGNOSTIC AND FEASIBILITY STUDY OF LAKE EUCHA, OKLAHOMA

EXECUTIVE SUMMARY

Lake Eucha is a water supply reservoir located in Delaware County of northeastern Oklahoma. The lake=s tributaries include Spavinaw Creek, Beaty Creek, Brush Creek, Dry Creek, and Rattlesnake Creek. The lake and its tributaries are currently supporting their designated beneficial uses of Sensitive Water Supply (SWS), public and private water supply, cool water aquatic community, agriculture, primary recreation and aesthetics. However, excessive nutrient loading and eutrophication threaten these uses which would impact the Cities of Tulsa and Jay, Oklahoma who depend on the lake to supply their populations (approximately 370,000 people) with drinking water and recreation.

Eutrophication has been caused by elevated nutrient loading from Beaty Creek and Spavinaw Creek to Lake Eucha. It is estimated that Beaty Creek and Spavinaw Creek supply approximately 85% of the phosphorous entering the lake. Because Lake Eucha is phosphorous limited, increased phosphorous loads have resulted in eutrophication of the lake. The phosphorous in Beaty Creek likely originates from nonpoint source pollution resulting from agricultural practices associated with the poultry industry. The phosphorous in Spavinaw Creek likely originates from a combination of both point source pollution (Decatur WWTP) and nonpoint source pollution (agricultural practices associated with the poultry industry).

Other than the problems discussed above, the lake and its tributaries are generally in good shape. In fact, Lake Eucha ranks as one of the finest largemouth bass fisheries in the state and offers good channel catfish and crappie fishing. Fish flesh analysis revealed that the fish are free of notable levels of toxicants. The levels of pH, total alkalinity, total hardness, total suspended solids (TSS), turbidity, total dissolved solids (TDS), conductance, sulfate (SO_4) and chloride (Cl) in both the lake and streams were comparable to the levels found in the area. Lake water samples were also generally free of excessive levels of health threatening bacteria; although, excessive levels of bacteria were found in the tributaries. The elevated levels of bacteria in the tributaries are another indication of the impact of animal waste on water quality. The algal assemblage in Lake Eucha was typical of eutrophic lakes. Overall, the benthic macroinvertebrate community was in fair condition.

Based on the data presented and discussed in the diagnostic study, the major goal of restoration should be to prevent advancement of eutrophication of the lake. The most feasible alternative for accomplishing this is through source control of phosphorous loadings to the headwaters of Lake Eucha. Phosphorous loading can be reduced by application of best management practices throughout the watershed and implementing NPDES phosphorous limits at the wastewater treatment plants.

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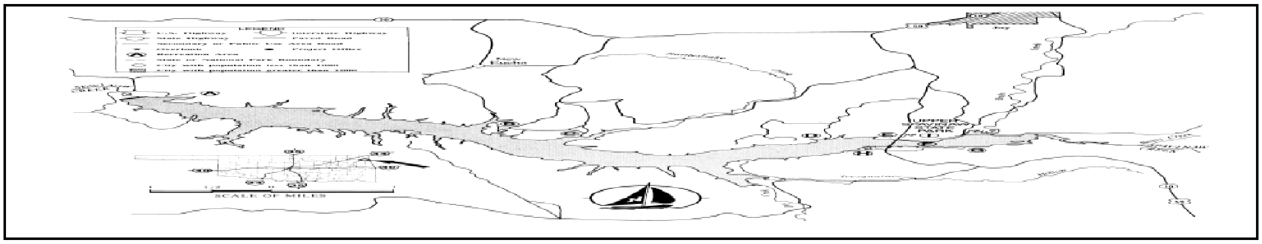
I. LAKE EUCHA DIAGNOSTIC STUDY

I.1 Lake Identification and Description

Lake Eucha (**Figure 1**) is located in Delaware County, Oklahoma. The approximate center of the lake is Latitude 36^{o}, 29' 00" and Longitude 94^{o}, 52' 30". The lake is owned and managed by the City of Tulsa, located approximately 80 miles west of the lake. Lake Eucha has a surface area of 2,860 acres and stores approximately 79,600 acre-feet of water at the normal pool elevation of 778 feet above mean sea level. It was constructed in 1952 by impounding Spavinaw Creek (OWRB 1990). Spavinaw Creek is a tributary to the Neosho River, which is a tributary to the Arkansas River. Other notable tributaries to Lake Eucha include Beaty Creek, Brush Creek, Dry Creek, and Rattlesnake Creek.



I.2 Description of Drainage Basin

The Lake Eucha watershed encompasses roughly 230,000 acres, with 60% located in Delaware County, Oklahoma and the remaider located in Benton County, Arkansas. Lake Eucha, Brush Creek, Dry Creek, Rattlesnake Creek, and the lower Beaty and Spavinaw Creek watersheds are located in Oklahoma. The upper Spavinaw and Beaty Creek watersheds are located in Arkansas. Elevation in the watershed ranges from approximately 778 to 1444 feet above mean sea level.

Climate

The study area has a temperate climate (Adamski et al. 1995). The mean annual temperature is 60^0F with monthly mean temperatures ranging from 38^0F in January to 82^0F in July. Temperatures greater than 100^0F occur on average 15 days per year, temperatures above 90^0F occur on average 71 days per year, and temperatures below freezing occur on average 85 days per year. The prevailing wind is southerly. Spring is the wettest season, with an average of 38% of all rainfall occurs. Winter is the driest season with an average of 16% of the total rainfall. Total annual precipitation averages approximately 45 inches. The average annual snowfall ranges from 5-7 inches. Annual lake evaporation averages about 48 inches, with 72% of evaporation occurring during the months of May through October (SCS 1970).

Ecoregions

Lake Eucha and its watershed are located in the Ozark Highlands and the Central Irregular Plains ecoregions. The Ozark Highlands ecoregion is characterized by oak/hickory or oak/hickory/ pine forest with some pasture land. The soils are primarily of the ultisol order. The Central Irregular Plains ecoregion is generally composed of a mosaic of bluestem prairie and oak/hickory forest. The soils are primarily of the mollisol soil order (Omernic 1987).

Soils

The ultisols in the Ozark Highlands, which formed under deciduous forest in the warm, humid climate, are generally depleted in organic matter and can be acidic (Adamski et al. 1995). They are moderately to strongly weathered and contain an abundance of kaolinite, illite, and iron and aluminum hydroxides. Soil thickness can range from less than a meter to several meters, but generally soils are thin. Intensive row-crop agriculture is not common because of the thin, deeply weathered soils. Soil permeability can be as much as 15.0 cm/hr resulting in a high potential for the leaching of dissolved constituents from the surface to ground water (Adamski and Pugh 1996). In general, ionic adsorption capacity of the ultisols of the Ozark Highlands is minimal. Thus, ionic constituents in infiltrating water are not readily absorbed by most soils and are easily flushed into nearby streams and shallow ground water (Adamski et al. 1995).

Soil types in the Lake Eucha watershed (**Appendix L**) were determined using the NRCS STATSGO database. Three soil mapping units are identified in the Lake Eucha watershed:

1) Clarksville-Noark-Nixa
2) Clarksville-Nixa-Captina

3) Craig-Dennis-Eldorado

The Clarksville-Noark-Nixa mapping unit encompasses 149,408 acres, or 66% of the watershed's area. The Clarksville-Nixa-Captina mapping unit encompasses 70,060 acres, or 31% of the watershed's area. The Craig-Dennis-Eldorado mapping unit encompasses 6,892 acres, or 3% of the watershed's area.

Each mapping unit contains numerous soil types. Nineteen soil types are included in the Clarksville-Noark-Nixa mapping unit. Clarksville series soils compose 30% of this mapping unit, while Noark series soils compose 28% and Nixa series soils compose 20%. Twenty-one soil types are included in the Clarksville-Nixa-Captina mapping unit. Clarksville series soils compose 20% of this mapping unit, while Nixa series soils compose 15% and Captina series soils compose 13%. Twenty-one soil types are included in the Craig-Dennis-Eldorado mapping unit. Craig series soils compose 16% of this mapping unit, while Dennis series soils compose 15% and Eldorado series soils compose 13%.

Erosion does not appear to be significant in the Lake Eucha watershed. The sediment load to the lake, which was calculated based on the TSS levels measured in the tributaries, indicate that the sediment load resulting from TSS was 7,058,581 kg during the study. This equates to only 68 pounds of soil eroded per acre in the watershed per year. Of course, this estimate does not take into account the bed load of eroded material carried by the stream. However, even if the sediment load indicated by the TSS levels equals only 10% of the total load, erosion would still be considered negligible. If the sediment load indicated by the TSS levels equals only 10% of the total load, then the total load would be 70,585,807 kg and equal 685 pounds of soil eroded per acre. It is generally accepted by the NRCS that from 1-5 tons may be eroded annually per acre of land to sustain crop production. The sediment load to Lake Eucha indicates that erosion in the watershed does not even approach levels considered significant according to NRCS standards.

Groundwater

Lake Eucha and its watershed lie within the Springfield Plateau, a section of the Ozark Plateaus Province. Karst features (e.g., caves, sinkholes, losing streams, and springs) are common in parts of the Sprinfield Plateau (Adamski and Pugh 1996). The extensive karst features of the Ozark Plateaus Province create an intricate ground water flow system, which results in rapid and complex interactions between ground and surface water.

The Springfield Plateau Aquifer consists of limestones and cherts of Mississippian age which crop out in the Springfield Plateau. Thickness of the sequence ranges from about 30 m to more than 120 m. The structure of the rocks is flat-lying with numerous local fractures and faults; regionally, the rocks gently dip to the west and south. The Springfield Plateau Aquifer is un-confined over much of the Springfield Plateau. Where it is unconfined, it is extensively used as a source of water for domestic purposes, which commonly yield 10 to 25 gal/min. The Springfield Plateau is separated from the underlying Ozark Aquifer by the Ozark confining unit, which consists primarily of shales of Devonian age (Adamski and Pugh 1996). Primary porosity and permeability generally are low for most of the rocks forming the Springfield and Ozark aquifers. Secondary porosity and permeability of the aquifers result from fracturing and dissolution of the carbonate rock. As a result, hydraulic conductivity can vary significantly even on a local scale. Fractures and solution openings, which can form extensive cave systems, together with the thin, permeable soils, allow rapid movement of water from surface- to ground-water and through the aquifer. The rapid recharge and movement are evident by the change of discharge, sediment load, and water quality of many springs during a rain (Adamski and Pugh 1996). Where secondary porosity is substantial, dissolved and particulate contaminants are rapidly transported through the aquifer with minimum removal by adsorption or filtering (Adamski et al. 1995).

Regionally, ground water flows from major topographic divides and discharges to major rivers. Locally, ground water flow can cross topographic divides; hence, determination of contributing areas for wells and recharge basins for springs can be very arduous (Adamski and Pugh 1996). In the Springfield Plateau Aquifer, the configuration of the potentiometric surface of unconfined areas generally reflects overlying topography. It is recharged primarily by precipitation locally; however, some recharge from losing streams does occur. Most of the length of perennial streams in the Springfield Plateau, as well as the Lake Eucha watershed, are gaining streams through ground water contributions. However, some intermittent streams and short reaches of perennial streams recharge the ground water system through losing stream channels. Sinkholes are not as important in the Lake Eucha watershed for ground water recharge as in other areas of the Ozarks, as sinkhole density is less than 1 per 100 square miles. Shallow ground water generally follows short (<10 mi), local, lateral flow paths terminating at springs and seeps along nearby streams. The springs that are rapidly recharged from precipitation and stream flow often respond to rain storms with increased discharge and elevated concentrations of nutrients, bacteria, and suspended solids, due to the rapid movement of these constituents from the surface into the spring system, as well as the ground water system (Adamski et al. 1995).

I.3 Lakes Public Access

Lake Eucha is easily accessible from U.S. Highway 412 via U.S. Highway 59/State Highway 10 and State Highway 20 (**Figure 1**). Highways 59/10 and 20 encircle the entire lake area and provide easy access to all lake facilities. The main recreational area is the Upper Spavinaw State Park (now called Lake Eucha State Park) which has numerous recreational facilities including picnic areas, trash receptacles, restrooms, playgrounds and group shelters. Other facilities on the lake include boat ramps, boat docks, fishing docks, campsites, camper parking, electrical hook-ups, grills, drinking water and concessions.

I.4 Size and Economic Structure of Population Using Lake

Lake Eucha is primarily used by the cities of Tulsa and Jay, Oklahoma for water supply and recreation (**Tables 1** and **2**). An average of 16% of all recreational users in 1993 and 1994 came from Tulsa. According to the 1990 census, Tulsa has a population of approximately 365,000. The median family income in Tulsa is $25,708 (USDC 1990). An average of 25% of all recreational users came from Jay. Jay has a population of approximately 2,200 with a median family income of $9,155. An average of 33% of all recreational users came from other in-state communities. Total in-state recreational users made up an average of 74% of all lake utilization, while out-of-state users made up an average of 26%.

Month	Tulsa	Jay	Other	In-State	Out-of-Sta
Jan	5	19	62	**86**	**14**
Feb	13	35	37	**85**	**15**
Mar	7	37	25	**69**	**31**
Apr	17	17	28	**62**	**38**
May	22	7	57	**85**	**15**
June	18	20	48	**86**	**14**
July	19	16	41	**76**	**24**
Aug	34	26	30	**89**	**11**
Sep	21	20	30	**71**	**30**
Oct	34	13	23	**71**	**30**
Nov	0	57	14	**71**	**29**
Dec	29	36	14	**79**	**21**
Mean	18	25	34	**77**	**23**

I.5 Historical Lake Uses and Trends in Use

The designated beneficial uses of Lake Eucha and its watershed are: public and private water supply, cool water aquatic community, agriculture, primary recreation and aesthetics. The lake has also been designated a sensitive public and private water supply (SWS). Sensitive public and private water supplies are prohibited from having new point source discharges or increased loading from existing point sources without approval from the Oklahoma Water Resources Board. In addition, BMP's for control of Non-Point Source pollution should be implemented in watersheds of water bodies designated SWS (OWRB 1995).

Lake Eucha was constructed in 1952 as a drinking water reservoir for the population of Tulsa, Oklahoma. The water intake for Tulsa is located in Spavinaw Lake, approximately 4 miles downstream from the Lake Eucha dam. Although Tulsa doesn't take its drinking water directly from Lake Eucha, it is dependant on the storage capacity of Lake Eucha for providing a continuous, dependable water source. Tulsa draws an average of 65-70 million gallons per day (mgd) from Spavinaw Lake which serves a portion of its population. In drought conditions, Tulsa draws up to 100 mgd (Hamlett 1995), which is the highest possible rate for the intake system. Future use is not expected to exceed this limit.

Tulsa has a 1938 water use permit issued by court decreed right through the Oklahoma Planning and Resources Board. The permit, now handled by the Oklahoma Water Resources Board, allows the use of Spavinaw Creek water which flows into Lake Eucha and ultimately Spavinaw Lake. The permit originally allowed the use of 29 mgd and an additional 132.5 mgd for future use. The *Report on Future Water Supply* dated May, 1955, and *Supplement to Report of May 1955* dated October, 1957, established that the drought period April, 1952 to May, 1957 resulted in a safe dependable yield for the Spavinaw Creek System of 59 mgd.

Tulsa can rely on other water sources besides Spavinaw Creek as water demand increases in the future. Tulsa began drawing water from Oologah Lake in July, 1977 at a rate of approximately 33 mgd, and is now drawing an average of 40 mgd. This is well under the maximum daily intake rate of 128 mgd according to the permit issued by the Oklahoma Water Resources Board (OWRB). Up to 143,707 acre-ft per year can be drawn from this source according to the permit. Tulsa has a contract with the Grand River Dam Authority (GRDA) for a 31 mgd emergency water source which is drawn from Lake Hudson. Tulsa has another contract with the GRDA which gives them the right to as much as 100 mgd from the GRDA pump back reservoir. However, this source can not be used until a pipe-line/reservoir system is completed in 2010 (Hannon 1995, Limes 1995). With these alternative sources, it is unlikely that Tulsa will ever need to expand their water intake and pump system on Spavinaw Creek to exceed its 100 mgd capacity. There are no plans to expand the intake and pump system in the future to increase the intake capacity (Chichester 1995).

Jay, Oklahoma also depends on Lake Eucha as a source for its drinking water. The City of Jay purchases water from Tulsa and does not hold a separate water right. The intake for Jay is located on the north shore of the lake approximately 0.25 miles west of the U.S. Highway 59 bridge, between Valerius Cove and Bolton Cove. This intake also serves Rural Water District 1 (RWD) which provides drinking water for approximately 250 households near Jay, along State Highway 20. Together, RWD 1 and Jay use an average of 1 mgd (Chichester 1995).

A small water intake, east of the bridge on the south shore, serves the Upper Spavinaw State Park, the City of Tulsa offices, and the south shore campground area east of the U.S. Highway 59 bridge. These facilities use an average of 100,000 gallons/month (Chichester 1995).

The Lake Eucha water level is maintained at the spillway level. At this level the lake can best fulfill its function as a storage reservoir. Excess water is allowed to go over the spillway. As little as 2 inches of flow over the spillway is enough to match normal Tulsa water demand. If, because of lack of rainfall , the lake level is below the spillway, floodgates are opened enough to meet the daily Tulsa water use. This amount and no more is allowed through until water levels rise back to just at or above the spillway level (Chichester 1995).

In the past, Tulsa was more dependant on Spavinaw Lake as a water source, because it had fewer alternative water sources. Because of this, there could be no deviation from the way water levels were managed. However, Tulsa can now rely on Oologah Lake as an alternative source and is now less dependant on Spavinaw Lake. So now, in some cases, Tulsa can deviate from these management goals and allow extra water through the Lake Eucha floodgates even if water levels are below the spillway level. One such case is when extra water is allowed through to maintain water levels in Lake Spavinaw for recreational purposes. During holidays such as Memorial Day and the 4^{th} of July weekend, it is important to keep water levels in Spavinaw Lake above the spillway for water quality and aesthetic reasons. Even if Lake Eucha water levels are below the spillway, extra water can be allowed through the floodgates if it is determined that this will not diminish the ability of Lake Eucha to serve its function as a storage reservoir (Chichester 1995).

In 1980, there were serious drought conditions where Lake Eucha received very little inflow while Tulsa water demands were high. Lake Eucha water levels were below the spillway so the flood gates were opened. Water levels in Lake Eucha continued to recede and eventually dropped below the flood gates, which is 20 feet below normal pool elevation. A sluice at lower release point was opened and Lake Eucha water levels dropped to 25 feet below normal pool elevation. This is the lowest pool level in the history of the lake. This is an example of the primary purpose of Lake Eucha as a storage reservoir having priority over all other functions such as aesthetics, fishing, and other recreational activities (Chichester 1995).

Tulsa voluntarily maintains a minimum flow of 11 cubic feet per second (cfs) in Spavinaw Creek below the Lake Eucha dam for the purpose of protecting the aquatic community (Chichester 1995). This minimum flow was determined using the "Montana" method which has been modified for Oklahoma streams (Orth and Maughan 1981).

This modified method suggests a flow of 10% of the average flow during July through December and 30% of the average flow during January through June as the minimum flow is required to prevent degradation. This minimum flow for the protection of the aquatic community was also mentioned when a plan was considered to use the Lake Eucha dam to produce hydro-electric power. It is a concern that if the Lake Eucha dam is ever used to produce hydro-electric power, low flows during the period of July through December would be detrimental to the aquatic community (Hensley 1995). If such a plan is ever implemented, the minimum flow requirements of 11 cfs would be mandatory (Chichester 1995). The OWRB has no minimum flow requirements for fish as part of their permit for Lake Eucha (Robertson 1995).

I.6 Lake User Population Impacted by Lake Degradation

The greatest impact of lake degradation would be to the cities of Tulsa and Jay, Oklahoma. Tulsa depends on the lake to supply its population of over 365,000 with drinking water. Jay and RWD 1 also rely on the lake as a source of drinking water for its population of over 2,000.

Together, visitors from Tulsa and Jay, OK account for over 40% of all lake recreational use. Therefore, these two communities would feel the greatest impact from any negative effects on water supply as well as activities such as fishing, boating or to the overall aesthetic value of the lake. Visitors from the surrounding counties and other in-state areas, which account for 33% of all recreational use, and out of state visitors, which account for 26% of all recreational use, would also be impacted by lake degradation.

The economic impact due to lake degradation should be considered. Lower visitation and the resulting loss of revenue would have negative effects on the local economy. **Table 3** shows the visitation to the Lake Eucha (formerly Upper Spavinaw) State Park from 1987 through 1991. This does not include visitation to other areas of the lake but can be used to indicate the large number of people visiting the Lake Eucha area in a given year. It is estimated that $12-$15 is spent by each daily visitor and $25 for overnight visitors (Hawthorne 1995). Further lake degradation and lower visitation would mean fewer recreational dollars for local merchants that depend on Lake Eucha for business.

Year	**Visitors**	**Estimated Revenue**
1987	28,732	$344,784
1988	16,082	$192,984
1989	25,382	$304,584
1990	22,792	$273,504
1991	24,238	$290,856

I.7 Comparison of Lake Use to Other Lakes in 80 km Area

In Oklahoma, twelve lakes with known public access are located within an 80 km radius (50 mile) of Lake Eucha (**Table 4**). In addition, eight lakes in Arkansas are located within 80 km of Lake Eucha. Arkansas lakes within the 80 km radius include Beaver Lake (28,200 acres), Bobb Kidd Lake (200 acres), Crystal Lake (60 acres), Elmdale Lake (180 acres), Fayetteville Lake (196 acres), Sequoyah Lake (500 acres), Swepco Lake (531 acres), and Weddington Lake (102 acres). For comparative purposes, only the lakes owned by Oklahoma cities (Lakes Claremore, Eucha, Spavinaw, Stillwell, and Yahola) will be examined in the following narrative.

Lake Eucha was constructed to provide water supply for the City of Tulsa, as well as a recreational facility for surrounding areas. Nine recreation areas are located on the lake (OWRB 1990). In the OWQS, the following beneficial uses are listed for Lake Eucha: public and private water supply, cool water aquatic community, Class I agriculture irrigation, primary body contact recreation, and aesthetics. In addition, Lake Eucha has been designated a *Sensitive Water Supply* (OWRB 1995). According to the *1994 Oklahoma Water Quality Report to Congress* [305(b) Report], the support status for the cool water aquatic community and primary body contact recreation beneficial uses were fully supporting. The support status for the drinking water supply and agriculture beneficial uses were not assessed (DEQ 1994).

Lake	County	Owner	Legal Location	Year Built	Surface Area (Ac)	Storage (Ac-ft)
Brushy Creek	Sequoyah	State of Oklahoma	12-T12N-R23E	1964	358	3,258
Claremore	Rogers	Claremore	3-T21N-R16E	1930	470	7,900
Eucha	**Delaware**	**Tulsa**	**22-T22N-R22E**	**1952**	**2,860**	**79,600**
Ft. Gibson	Cherokee	Corps of Engineers	18-T16N-R20E	1953	19,900	365,200
Grand	Mayes	GRDA	14-T23N-R21E	1940	46,500	1,672,000
Greenleaf	Muskogee	State of Oklahoma	10-T13N-R20E	1939	920	14,720
Oologah	Rogers	Corps of Engineers	2-T22N-R15E	1963	29,460	553,400
Spavinaw	Mayes	Tulsa	15-T22N-R21E	1924	1,584	38,000
Stillwell	Adair	Stilwell	24-T15N-R24E	1965	188	3,110
Tenkiller	Sequoyah	Corps of Engineers	14-T13N-R21E	1952	12,900	654,100
W.R. Holway	Mayes	GRDA	31-T21N-R21E	1968	712	48,000
Webber Falls	Muskogee	Corps of Engineers	34-T13N-R20E	1970	11,600	170,100
Yahola	Tulsa	Tulsa	16-T20N-R13E	1948	431	6,445

Lake Claremore was constructed to provide water supply and recreation for the City of Claremore. One recreational area is located on the lake (OWRB 1990). In the OWQS, the following beneficial uses are listed for Lake Claremore: public and private water supply, warm water aquatic community, agriculture, industrial and municipal process and cooling water, primary body contact recreation, and aesthetics. In addition, Lake Claremore has been designated a *Sensitive Water Supply* (OWRB 1995). According to the *1994 Oklahoma Water Quality Report to Congress*, the support status for the warm water aquatic community, primary body contact recreation, aesthetics, and Sensitive Water Supply beneficial uses were fully supporting but threatened. The support status for the drinking water supply, agriculture, and industrial and municipal process and cooling water uses were not assessed (DEQ 1994).

Spavinaw Lake was constructed to provide water supply for the City of Tulsa, recreation, and fish and wildlife habitat. Five recreational facilities are located on Spavinaw Lake (OWRB 1990). In the OWQS, the following beneficial uses are listed for Spavinaw Lake: public and private water supply, cool water aquatic community, Class I agriculture irrigation, primary body contact recreation, and aesthetics. In addition, Spavinaw Lake has been designated a *Sensitive Water Supply* (OWRB 1995). According to the *1994 Oklahoma Water Quality Report to Congress*, the support status for the cool water aquatic community and primary body contact recreation beneficial uses were fully supporting. The support status for the drinking water supply, Sensitive Water Supply, and agriculture beneficial uses were not assessed (DEQ 1994).

Lake Stillwell (Sallisaw Creek Site 18) was constructed to provide water supply for the City of Stillwell, flood control, and recreation. One recreational area is located on the lake (OWRB 1990). In the OWQS, the following beneficial uses are listed for Lake Stillwell (Sallisaw Creek upstream from U.S. Highway 64): public and private water supply, cool water aquatic community, Class I agriculture irrigation, industrial and municipal process and cooling water, primary body contact recreation, and aesthetics. In addition, Lake Stillwell has been designated a *High Quality Water* (OWRB 1995). According to the *1994 Oklahoma Water Quality Report to Congress*, Stillwell Lake is fully supporting all its designated beneficial uses (DEQ 1994).

Lake Yahola was constructed to provide water and recreation for Tulsa. Two recreational areas are located on the lake (OWRB 1990). In the OWQS, the following beneficial uses are listed for Lake Yahola: public and private water supply, warm water aquatic community, Class I agriculture irrigation, industrial and municipal process and cooling water, primary body contact recreation, and aesthetics. In addition, Lake Yahola is designated a *Sensitive Water Supply* (OWRB 1995). According to the *1994 Oklahoma Water Quality Report to Congress*, the lake is not supporting its warm water aquatic community use. The support status of the Sensitive Water Supply designation was determined to be fully supporting but threatened. The support status for the primary body contact recreation, drinking water supply, aesthetics, agriculture, and industrial and municipal process and cooling water uses were not assessed (DEQ 1994).

I.8 Inventory of Point Source Pollutant Discharges

There are two permitted point source pollutant dischargers in the Lake Eucha watershed, the cities of Gravette and Decatur, Arkansas. Gravette, Arkansas has a population of 1412. Its waste water treatment plant is an aerated lagoon with a design discharge of 0.56 million gallons per day (mgd). Its permit requirements are listed in **Table 5**.

Parameter	QUANTITY OR LOADING		QUALITY OR CONCENTRATION			
	Monthly _	Units	Min.	Monthly _	Max. (7 day _)	Units
pH	N/A	N/A	6.0	N/A	9.0	S.U.
TSS	93	lbs/day	N/A	20	30	mg/l
Ammonia	19	lbs/day	N/A	4	6	mg/l
Fecal Col.	N/A	N/A	N/A	1000	2000	#/100 ml
BOD	93	lbs/day	N/A	20	30	mg/l

The receiving stream for Gravette's effluent is Railroad Hollow located directly southwest of the city (SW 1/4 Section 14, T20N, R33W). Railroad Hollow is a losing stream which flows southwest from Gravette approximately 2 miles before it discharges into Spavinaw Creek. Results of the discharge monitoring reports for Gravette from March, 1993 through February, 1994 and September, 1995 through August, 1996 are listed in Tables 6 and 7, respectively.

As **Tables 6** and **7** indicate, Gravette does not discharge continuously. Based on the data in **Table 6**, it was calculated that Gravette discharged 55,298,992 gallons from March, 1993 through February, 1994. Based on the data in **Table 7**, it was calculated that Gravette discharged 28,507,545 gallons from September, 1995 through August, 1996. This amounts to only 27% of the design discharge (204,400,000 gallons per year) during the 1993-94 period and 14% during the 1995-96 monitoring period. The 1993-94 monitoring reports indicate that no permit requirement exceedances occurred. The 1995-96 monitoring reports indicate that the maximum pH requirement was exceeded twice and the TSS monthly average requirement was exceeded once. The nutrient loading from the Gravette facility will be discussed in Section I.10.I.

Month-Year	_ Discharge (mgd)	_ TSS (mg/l)	_ Ammonia (mg/l)	_ Fecal Col. (#/100 ml)	_ BOD (mg/l)
Mar-93	0	0	0	0	0
Apr-93	0.416603	12	0.45	1	5
May-93	0.392368	4	0.26	1	4
Jun-93	0	0	0	0	0
Jul-93	0	0	0	0	0
Aug-93	0	0	0	0	0
Sep-93	0	0	0	0	0
Oct-93	0.330131	6	<0.10	1	1
Nov-93	0.352493	4	0.21	0	2
Dec-93	0.317053	9	<0.10	0	4
Jan-94	0	0	0	0	0
Feb-94	0	0	0	0	0

Month-Year	_ Discharge (mgd)	_ TSS (mg/l)	_ Ammonia (mg/l)	_ Fecal Col. (#/100 ml)	_ BOD (mg/l)
Sep-95	0	0	0	0	0
Oct-95	0	0	0	0	0
Nov-95	0.332861	11.0	<0.10	<2	4.33
Dec-95	0	0	0	0	0
Jan-96	0	0	0	0	0
Feb-96	0	0	0	0	0
Mar-96	0	0	0	0	0
Apr-96	0.309514	21.3	0.28	3	4.67
May-96	0.297945	3.7	<0.13	6	2.00
Jun-96	0	0	0	0	0
Jul-96	0	0	0	0	0
Aug-96	0	0	0	0	0

Decatur, Arkansas has a population of 918. Its waste water treatment plant not only treats the municipal sewage, but also the waste from the poultry processing plant located in Decatur. The Decatur facility has a design discharge of 1.6 mgd and uses an activated sludge system along with diffusion aeration to treat the waste water. Its permit requirements are listed in **Table 8**.

The receiving stream for Decatur’s effluent is Columbia Hollow via Decatur Branch directly west of the city (NW1/4 Section 11, T19N, R33W). Decatur Branch flows into Spavinaw Creek roughly 5 miles east of Decatur’s discharge.

Parameter	QUANTITY OR LOADING		QUALITY OR CONCENTRATION			
	30 day _	Units	Min.	30 day _	Max. (7 day _)	Units
pH	N/A	N/A	6.0	N/A	9.0	S.U.
TSS	200.2	lbs/day	N/A	15	23	mg/l
Ammonia (July-Feb)	200.2	lbs/day	N/A	15	23	mg/l
Ammonia (Mar-June)	133.4	lbs/day	N/A	10	15	mg/l
Nitrate-N	133.4	lbs/day	N/A	10	15	mg/l
Chlorine	N/A	N/A	N/A	N/A	0.1	mg/l
Fecal Col.	N/A	N/A	N/A	200	400	#/100 ml
BOD	133.4	lbs/day	N/A	10	15	mg/l

Discharge monitoring results for Decatur from March, 1993 through February, 1994 and October, 1995 through September, 1996 are listed in **Tables 9** and **10**, respectively. As **Tables 9** and **10** indicate, Decatur has a continuous discharge. Based on the data in **Tables 9** and **10**, it was calculated that Decatur discharged 323,000,000 gallons from March, 1993 through February, 1994 and 411,600,000 gallons from October, 1995 through September, 1996. This amounts to 55% of the design discharge (584,000,000 gallons per year) in 1993-94 and 70% during the 1995-96 period. The discharge monitoring reports indicated that Decatur's effluent exceeded the permit requirements on numerous occasions. The ammonia-nitrogen permit requirement was exceeded eight times between April 1 and June 30, 1993. The nitrate-nitrogen permit requirement was exceeded once in November, 1993. The effluent for the July-September period failed the 7 day *pimephales* toxicity test. From October, 1995 through September, 1996, the permit requirement was exceeded nine times for TSS, ten times for ammonia-nitrogen, seven times for nitrate-nitrogen, twice for the 7 day *ceriodaphnia* toxicity test, and once for the 7 day *pimephales* toxicity test. During the 1995-96 period, most of the exceedances occurred between April and September, 1996. Nutrient loading from Decatur is discussed in Section I.10.I.

Month-Year	_ Discharge (mgd)	_ TSS (mg/l)	_ NH_3-N (mg/l)	_ NO_3-N (mg/l)	_ Fecal Col. (#/100 ml)	_ BOD (mg/l)
Mar-93	0.8	6.3	4.7	3.8	3	8.0
Apr-93	0.8	10.2	28.2	2.1	3	9.4
May-93	0.8	6.3	20.9	6.6	3	10
Jun-93	0.9	6.7	14	2.9	18	10
Jul-93	1.1	4.5	5.5	2.3	26	6.5
Aug-93	0.8	2.9	6.6	2.8	1.3	4.2
Sep-93	0.95	3.4	7.7	3.0	1.1	4.3
Oct-93	0.9	4.3	7.8	3.5	0	5.4
Nov-93	1.0	6.1	7.8	10	1.8	6.0
Dec-93	0.9	4.5	11.6	9.8	3.2	5.9
Jan-94	0.8	4.7	8.7	9.0	1.6	8.1
Feb-94	0.9	6.3	10.2	6.1	1	7.9

Month-Year	_ Discharge (mgd)	_ TSS (mg/l)	_ NH_3-N (mg/l)	_ NO_3-N (mg/l)	_ Fecal Col. (#/100 ml)	_ BOD (mg/l)
Oct-95	0.8	5.9	6.3	1.6	9.5	1.5
Nov-95	0.8	10.3	6.0	6.2	4.9	2.2
Dec-95	0.9	6.6	9.3	5.9	3.2	1.7
Jan-96	1.1	---	12.5	5.0	---	---
Feb-96	1.1	13.4	12.9	3.9	35.7	3.1
Mar-96	1.1	10.0	10.0	8.1	42.4	2.8
Apr-96	1.2	13.3	19.6	3.9	8.5	2.3
May-96	1.1	16.3	25.0	13.4	25.0	3.2
Jun-96	1.2	23.2	34.7	8.6	58.5	6.8
Jul-96	1.2	15.0	19.0	14.6	42.4	5.0
Aug-96	1.5	11.3	10.3	10.0	82.0	2.8
Sep-96	1.5	21.0	22.0	11.9	71.9	3.1

I.9 Watershed Landuse and Watershed Production

Landuse in the watershed is primarily forest and pasture. Oak and hickory forest is the predominant forest type in the watershed. Cropland and urban areas are insignificant. Much of the watershed (>50%) is in agricultural production. The major agricultural commodity produced in the watershed is poultry. Hog operations and cattle operations also contribute significantly to agricultural production in the watershed. There are also a number of dairies in the watershed.

The 1992 Census of Agriculture shows that poultry production in Benton County, Arkansas and Delaware County, Oklahoma increased drastically between 1982 and 1992 (**Table 11**). This is a good indication of the growth of the poultry industry in the Lake Eucha watershed. The 1992 Census indicates that hog and pig production has increased significantly in Delaware County, Oklahoma; however, no trend was observed in hog and pig production in Benton County, Arkansas. Cattle production in both counties has remained fairly consistent. The number of dairies has decreased in both counties.

Ag Product Sold	County, State	1982	1987	1992
Cattle & calves	Delaware County, OK	28,236	30,291	30,830
Hogs & pigs	Delaware County, OK	39,936	72,875	85,007
Broilers & chickens	Delaware County, OK	10,798,137	16,461,839	26,359,308
Cattle & calves	Benton County, AR	48,032	56,312	50,465
Hogs & pigs	Benton County, AR	165,933	280,575	141,200
Broilers & chickens	Benton County, AR	53,914,589	68,896,889	93,596,018

A recent survey of chicken, hog, and turkey production in the Lake Eucha watershed was performed by the Oklahoma Conservation Commission under contract for the City of Tulsa during the spring of 1996 (OCC 1996). The survey found that 714 chicken houses, 57 hog houses, and 5 turkey houses are currently in operation. The survey also estimated that a total of 8,259,600 pounds of nitrogen and 2,585,540 pounds of phosphorous would be excreted by confined animals in the Lake Eucha watershed during 1996. It is important to note that this is an estimate of the nutrients excreted, not the amount entering streams. Only a small fraction of the excreted nutrients reach the streams. **Table 12** displays the estimated amounts of nutrients produced in each watershed based on the 1996 survey results.

A large number of houses were not in production during the survey. If all houses were in production, it is estimated that 10,184,600 pounds of nitrogen and 3,180,540 pounds of phosphorous would be produced in the Lake Eucha watershed per year.

Waste generated by these confined animal operations is usually land applied. Under normal conditions, only a small fraction of the nutrients ever reach the water. A large portion of the

STREAM	NITROGEN (LBS/YR)	PHOSPHOROUS (LBS/YR)
Beaty Creek	1,183,600	365,840
Brush Creek	327,800	101,320
Dry Creek	88,000	27,200
Rattlesnake Creek	44,000	13,600
Spavinaw Creek	6,616,200	2,077,580
Unassessed area	0	0
TOTAL	8,259,600	2,585,540

nitrogen is lost to the atmosphere. Plants take much of the rest leaving only a small fraction of the original quantities of nitrogen to become a potential water pollutant. Phosphorous, although not volatile, often binds tightly with soil particles leaving only a small portion of the original quantities of phosphorous to become a potential water pollutant. However, because phosphorous levels in poultry waste are present in greater amounts than plants need in relation to nitrogen, phosphorous tends to accumulate on and near the soil surface. Phosphorous eventually becomes a water pollutant wherever poultry waste is used as a fertilizer year after year (OCC 1996). For more information on this subject, the report *Confined Animal Inventory: Lake Eucha Watershed August, 1996* should be reviewed (OCC 1996).

It should be noted that because most of the feed for the confined animal operations originates from outside of the watershed, a net increase in the amounts of nutrients in the watershed results.

Cattle operations were not addressed in the confined animal inventory conducted in 1996. Many poultry producers also have cattle operations. Much of the waste produced by the confined animal operations is applied to pasture land on which producers often keep cattle. Therefore, the waste excreted by these cattle does not represent the introduction of additional nutrients to the watershed, only the assimilation of nutrients already present there. However, when these cattle have free access to streams, they can provide an effective delivery system of these nutrients to waterbodies.

When high nitrogen and phosphorus levels are detected in water quality samples, the waste generated by poultry and livestock should be considered.

I.10 Lake Limnology

A. Investigative Approach

Seasonal sampling by the Oklahoma Conservation Commission from 1987 to 1992 indicated that Lake Eucha was eutrophic. Impairment of the recreational and water supply uses were recognized as potential results of the high trophic state. While the lake is currently supporting an outstanding sports fishery, potential oxygen depletions resulting from massive algal blooms threaten the aquatic community. Based on these data, the limnological objectives of this investigation were to: 1) assess the lake water quality, physical conditions, and trophic state, 2) evaluate the watershed effects on the lake, and 3) identify lake problems and their causes.

B. Experimental Procedures

1. Lake Location and Sampling Sites

Lake Eucha is located approximately 6 miles south of Jay, Oklahoma. Three representative sampling sites were established on Lake Eucha for assessment of the lake water quality. Lake sampling sites were located near the dam (1), Sawmill Point (2), and the Highway 10 Bridge (3). Additional sampling sites were established on Beaty (6), Brush (5), Dry (7), and Rattlesnake (4) Creeks as well as three sites on Spavinaw Creek (8-10). **Figure 2** shows the location of the lake and tributary sampling sites.

2. <u>Lake and Tributary Sampling</u>

The lake and its tributaries were first sampled by the OCC in March 1993 and were sampled at least monthly through February 1994. Semi-monthly samples were taken at these lake and tributary sites from May 1993 through September 1993. All water quality sampling was carried out according to Standard Operating Procedures on file at the Oklahoma Conservation Commission or as written in the project work plan. A brief summary of these follows.

Water temperature, pH, conductivity and dissolved oxygen profiles were taken in situ at all lake sites. Profiles were established by taking readings at 1 m increments from the surface to the bottom of the lake. Grab samples were collected at 0.10 m below the surface and 0.5 meters above the bottom of the lake. These water quality samples were analyzed for alkalinity, turbidity, hardness, chloride (Cl), total dissolved solids (TDS), total suspended solids (TSS), ammonia (NH_3-N), nitrite (NO_2-N), nitrate (NO_3-N), total Kjeldahl nitrogen (TKN), sulfate (SO_4), total phosphorus, and ortho-phosphate phosphorus. Chlorophyll samples were collected on all lake sites and water transparency was measured with a 20 cm Secchi disk. Sediment samples were collected from all lake sites using a Ponar Dredge on September 2-3, 1993 for analyses of nutrients and metals.

At the stream sites, temperature, dissolved oxygen, conductivity, and pH were taken in situ concurrently. Grab samples were collected and analyzed for alkalinity, turbidity, hardness, chloride (Cl), total dissolved solids (TDS), total suspended solids (TSS), ammonia (NH_3-N), nitrite (NO_2-N), nitrate (NO_3-N), total Kjeldahl nitrogen (TKN), sulfate (SO_4), total phosphorus (TP), and ortho-phosphate phosphorus. Samples were also collected from the tributaries during high flow events throughout the course of the study. High flow samples were taken using stage activated Manning automatic samplers. Samples were drawn at hourly intervals. Gross composites of each event were analyzed for total hardness, Cl, TDS, TSS, SO_4, and nutrients. Pesticides were measured twice in high flow samples collected by the autosamplers.

Semi-monthly bacteria samples were collected at all lake and tributary sites from May through September of 1993. The samples were sent to the City of Tulsa's Mohawk Lab to be analyzed for fecal coliforms, E. Coli., Fecal strep., and Enterococcus.

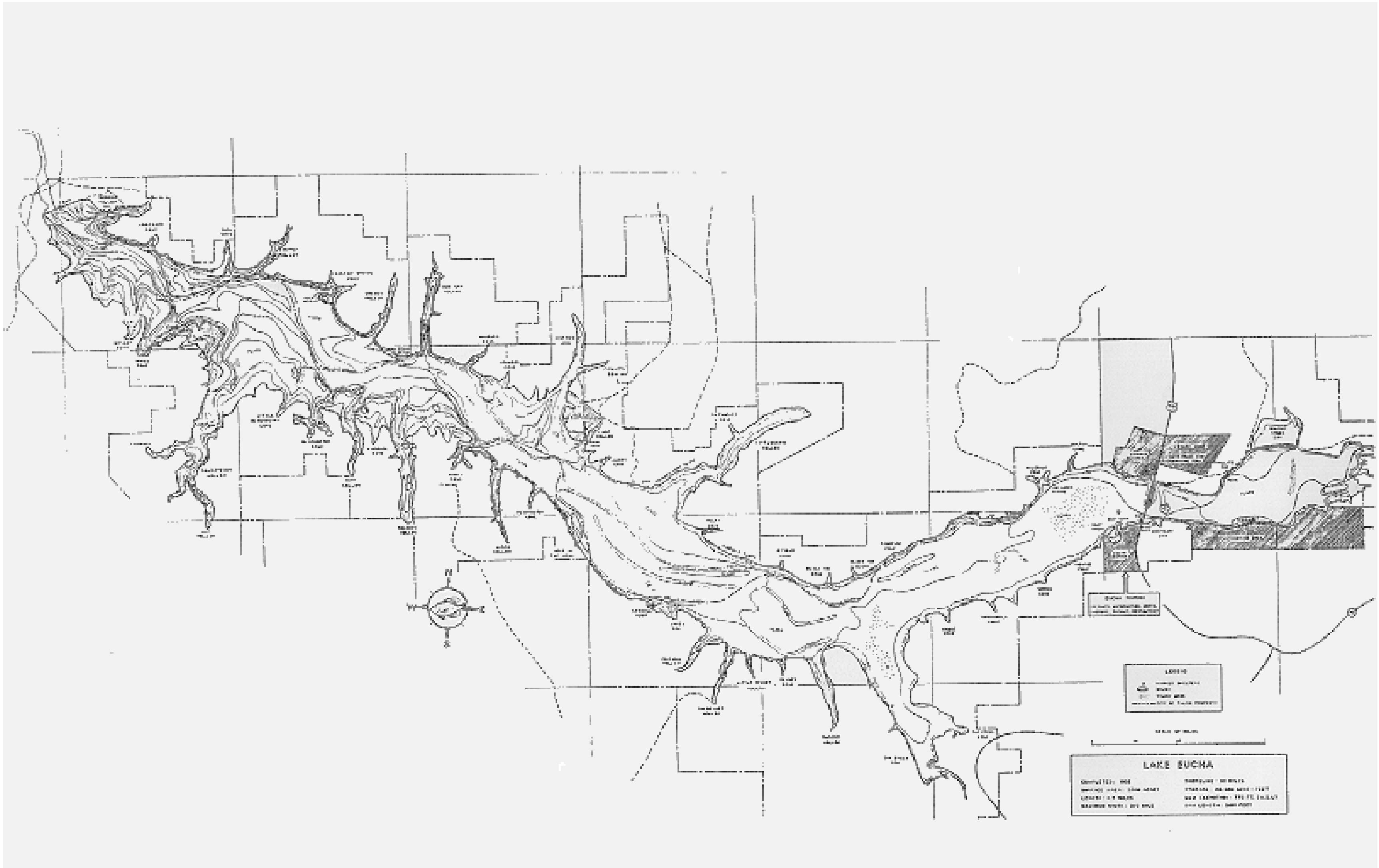
Zooplankton were collected 3 times during the study near the dam with a single bottom to surface vertical tow with a Wisconsin net. Four surface grab samples from the dam were collected for analysis of phytoplankton. The samples were sent immediately to the lab for taxonomic identification and enumeration. Benthic macroinvertebrates were collected at 30 sites in the lake along 3 transects using a ponar dredge. Ten samples were taken at each of the 3 transects which are shown in **Appendix A**. The samples were washed in a #30 mesh sieve, preserved in ethanol, and delivered to the City-County Health Department Laboratory of Oklahoma City for identification and enumeration. Fish were collected by Oklahoma Department of Wildlife Conservation (ODWC) and City of Tulsa personnel, during a May 1995 electrofishing survey.

C. Morphological and Hydrological Characteristics of the Lake

1. Lake Morphology

Figure 3 illustrates the bathymetric map of Lake Eucha. The morphological characteristics of Lake Eucha are listed in **Table 13**.

Parameter	Value	Units
Surface Area	2,860.0	Acres
Storage Capacity	79,600.0	Acre/feet
Maximum Depth	84.0	Feet
Mean Depth	27.8	Feet
Length	8.5	Miles
Maximum Width	0.7	Miles
Shoreline Length	49.0	Miles
Shoreline Development	5.5	


LAKE EUCHA

2. Lake Hydrology

Outflow from the lake is recorded by the City of Tulsa. Average outflow from Lake Eucha for the years 1993 and 1994 was 266,608 acre-feet per year. Inflow was estimated by adding outflow, water volume lost through evaporation, and water used for municipal drinking water, and then subtracting water volume gained from rainfall onto the lake surface. Using this method it was estimated that the annual inflow was 268,452 acre-feet per year. Rainfall onto the lake was estimated by multiplying the average precipitation of 45 inches per year (SCS 1970) by the lake surface area. Lake evaporation was estimated by multiplying the average annual lake evaporation for the area (48 inches per year) by the lake surface area. The mean water usage of Jay, RWD 1, the City of Tulsa offices, and the State Park for 1993-1994 was used to estimate the output for water supply. This figure does not include City of Tulsa water which is taken from Spavinaw Lake. Residence time, which was calculated by dividing storage capacity by outflow, was approximately 0.296 years or 3.6 months. **Table 14** displays Lake Eucha's hydrologic budget.

Input	**Volume (Ac-ft/yr)**
Inflow	268,452
Rainfall	10,800
Output	
Lake Evaporation	11,520
Water Supply	1,124
Outflow	266,608

By taking this inflow volume and dividing it by the watershed acreage, the annual runoff for the area can be calculated. Estimates indicate that annual runoff from the Lake Eucha watershed is approximately 1.2 acre-feet per acre which agrees well with USGS estimates of 1.0-1.25 acre-feet per acre for the area (Linsley et al. 1975).

From USGS gauging data, it was determined that approximately 35% of total annual discharge results from base flow and 65% of total annual discharge was from storm flow. In addition, it was calculated from watershed size and annual runoff that Spavinaw Creek contributes 57% of total runoff, Beaty Creek contributes 17%, Brush Creek contributes 9%, Dry Creek contributes 6%, Rattlesnake Creek contributes 2%, and the remaining 9% is runoff from the unassessed area around the lake. It is likely that springs discharge ground water directly into the lake, as they are common in the area. However, none are mapped and there is no data available to determine their hydrologic contribution to the lake. These springs are not considered to be major contributors to the total inflow to the lake.

D. Water Quality of the Lake

Water quality in Lake Eucha and its tributaries was monitored from March 1993 through February 1994. This involved semi-monthly sampling from May to September 1993 and monthly sampling during the remaining 7 months.

1. Thermal Structure of the Lake

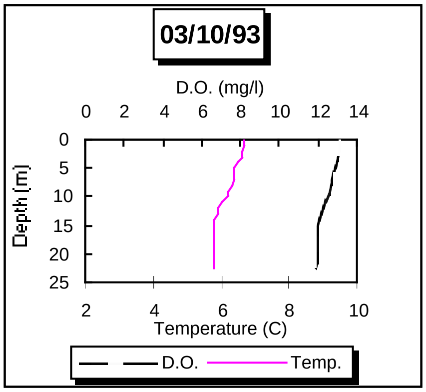
Temperature profiles can be seen in **Appendix B**. Thermal stratification was evident at the dam (**Figure 4**) and Sawmill Point from May 12 through October 27, 1993. Thermal stratification was also evident at the Highway 10 Bridge on March 10, April 13, and May 26 through September 22, 1993. By mid-summer, the surface of the thermocline reached the depth of 2 m below the surface of the water. The maximum temperature differences between the top and bottom of the profile during stratification was 9ºC at the Highway 10 Bridge, 16ºC at Sawmill Point, and 18.7ºC at the dam. This indicates that the strength of the thermal stratification at the Highway 10 Bridge was not as strong as the stratification at the dam and Sawmill Point. Turnover occurred in November 1993 and the lake remained unstratified for the rest of the sampling period.

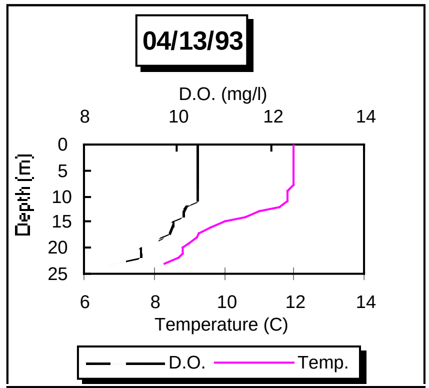
Surface temperatures ranged from 3^0C in mid-January to 31^0C in August. However, bottom temperatures remained below 24ºC at the Highway 10 Bridge, 14ºC at Sawmill Point, and 12.9ºC at the dam. The cooler bottom temperatures at the dam and Sawmill Point result from the strong thermal stratification which prevents mixing with the warm surface waters (epilimnion).

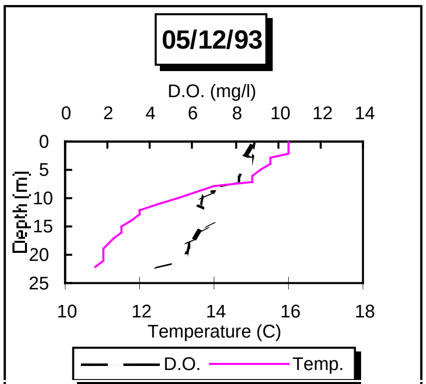
2. Dissolved Oxygen

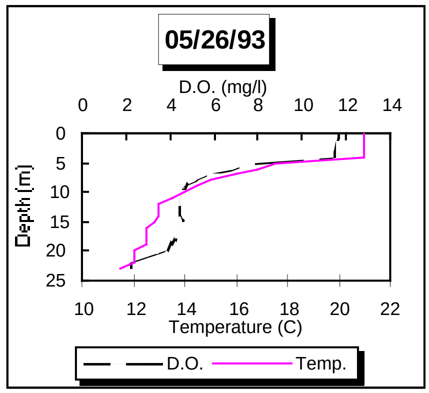
Appendix B also shows the dissolved oxygen (D.O.) profiles. Dissolved oxygen concentrations were compliant with the OWQS throughout the lake from March to May 1993 and from November to the end of the study in February 1994. However, clinograde oxygen profiles (**Figure 4**) were present at all lake sites during thermal stratification. Decomposition of high levels of organic matter results in hypolimnetic D.O. depletion and the resulting clinograde oxygen profiles.

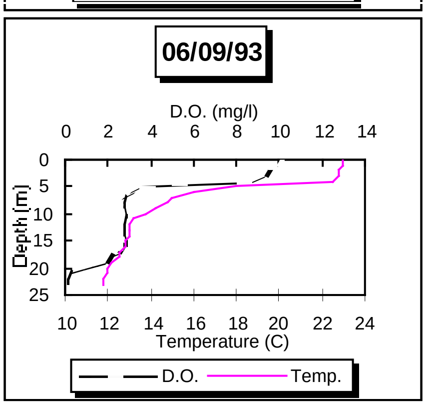
At the dam and Sawmill Point, bottom D.O. concentrations were less than 2 mg/l from June to October, 1993. The Highway 10 site remained well oxygenated throughout most of the year except for short periods during the summer (i.e. July 28 and August 25, 1993) when bottom D.O. concentrations approached 0 mg/l. Hypolimnetic D.O. depletion impacts the benthic macroinvertebrate and fish communities by limiting the areas of the lake which can be inhabited. On July 28, 1993, when D.O. depletion was at its worst, almost no D.O. was detected below 5 meters throughout the entire lake. During this period, approximately 44% of the lake volume could not be inhabited by fish and 72% of the lake bottom could not be inhabited by sensitive species of benthic macroinvertebrates.


03/10/93
D.O. (mg/l)
0 2 4 6 8 10 12 14
Depth (m)
0 5 10 15 20 25
2 4 6 8 10
Temperature (C)
D.O.
Temp.


04/13/93
D.O. (mg/l)
8 10 12 14
Depth (m)
0 5 10 15 20 25
6 8 10 12 14
Temperature (C)
D.O.
Temp.


05/12/93
D.O. (mg/l)
0 2 4 6 8 10 12 14
Depth (m)
0 5 10 15 20 25
10 12 14 16 18
Temperature (C)
D.O.
Temp.


05/26/93
D.O. (mg/l)
0 2 4 6 8 10 12 14
Depth (m)
0 5 10 15 20 25
10 12 14 16 18 20 22
Temperature (C)
D.O.
Temp.


06/09/93
D.O. (mg/l)
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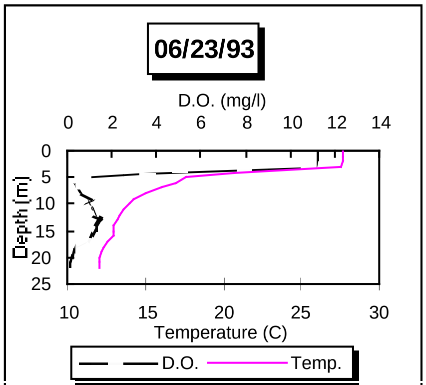
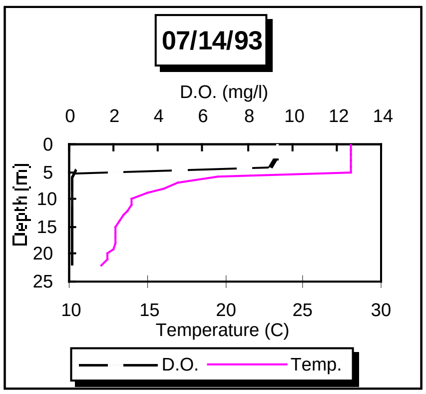
Depth (m)
0 5 10 15 20 25
10 12 14 16 18 20 22 24
Temperature (C)
D.O.
Temp.


06/23/93
D.O. (mg/l)
0 2 4 6 8 10 12 14
Depth (m)
0 5 10 15 20 25
10 15 20 25 30
Temperature (C)
D.O.
Temp.


07/14/93
D.O. (mg/l)
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Depth (m)
0 5 10 15 20 25
10 15 20 25 30
Temperature (C)
D.O.
Temp.

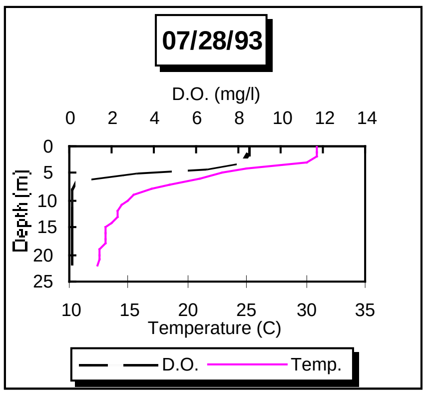
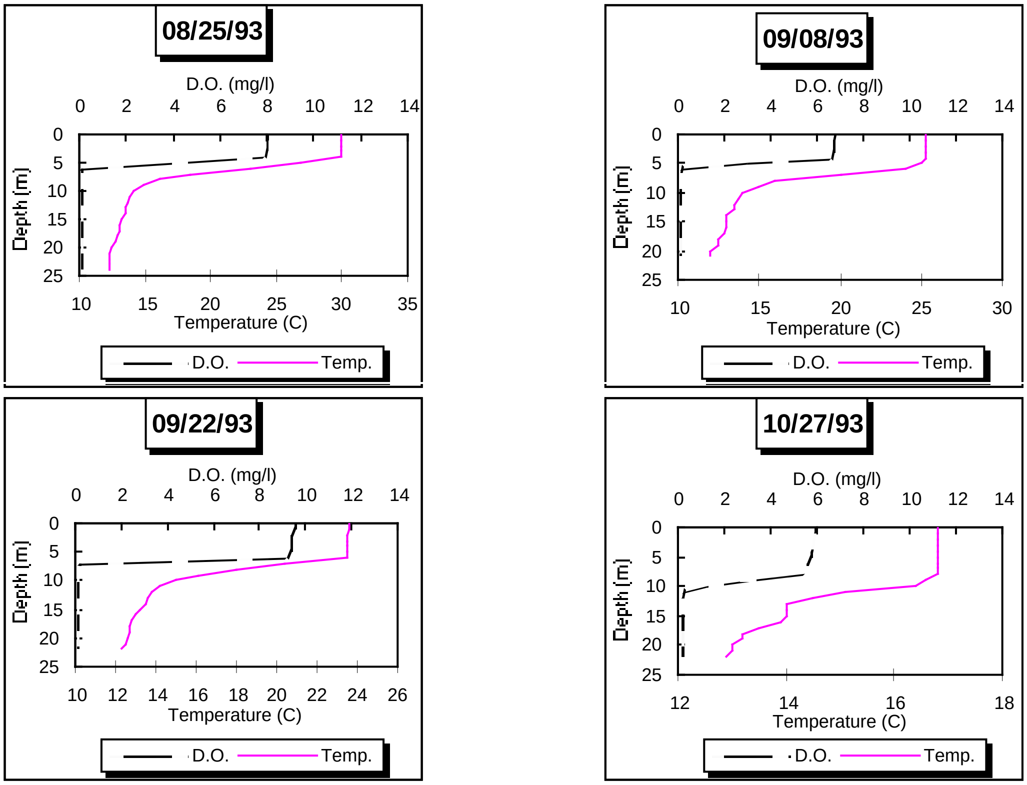
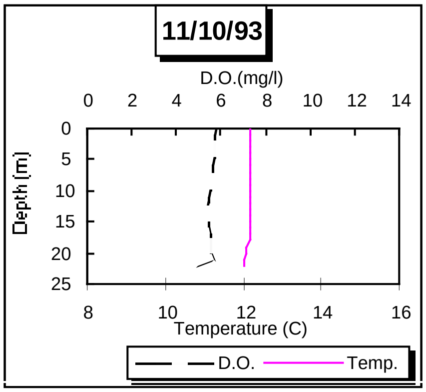

07/28/93
D.O. (mg/l)
0 2 4 6 8 10 12 14
Depth (m)
0 5 10 15 20 25
10 15 20 25 30 35
Temperature (C)
D.O.
Temp.

Figure 4. continued...




11/10/93
D.O.(mg/l)
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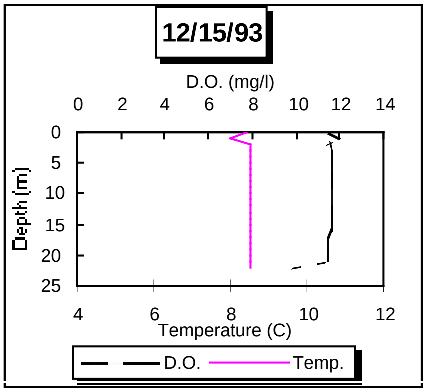
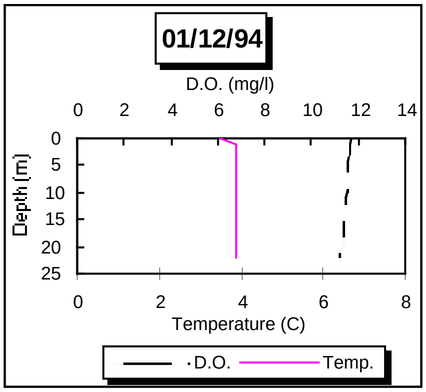
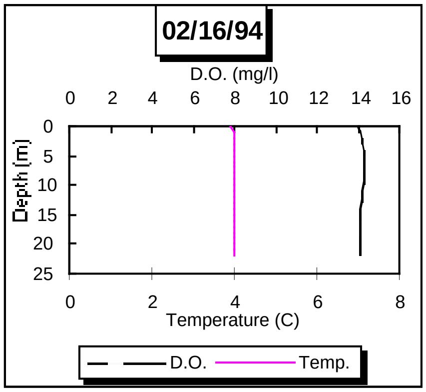
Depth (m)
0 5 10 15 20 25
8 10 12 14 16
Temperature (C)
D.O.
Temp.


12/15/93
D.O. (mg/l)
0 2 4 6 8 10 12 14
Depth (m)
0 5 10 15 20 25
4 6 8 10 12
Temperature (C)
D.O.
Temp.


01/12/94
D.O. (mg/l)
0 2 4 6 8 10 12 14
Depth (m)
0 5 10 15 20 25
0 2 4 6 8
Temperature (C)
D.O.
Temp.


02/16/94
D.O. (mg/l)
0 2 4 6 8 10 12 14 16
Depth (m)
0 5 10 15 20 25
0 2 4 6 8
Temperature (C)
D.O.
Temp.

Supersaturation was observed on numerous occassions. On June 18 and 27, July 14 and 28, and September 22, 1993, D.O. percent saturations of 118, 142, 139, 139, and 137, respectively, were observed at Highway 10. On May 26, June 23, and July 14 and 28, 1993, D.O. percent saturations of 145, 150, 125, and 126, respectively, were observed at Sawmill Point. On May 26, June 9 and 23, and July 14 and 28, 1993, D.O. percent saturations of 130, 119, 142, 119, and 114, respectively, were observed at the dam. Supersaturation provides a good indicator of algal blooms and potentially night-time D.O. depletion.

3. Chlorophyll *a* and Secchi Depth

Chlorophyll *a* concentrations are listed in **Appendix C**. During the study, mean chlorophyll *a* concentrations were 11.90 ug/l (maximum = 39.02) at the dam, 14.38 ug/l (maximum = 28.70) at Sawmill Point, and 14.44 ug/l (maximum = 43.18) at the Highway 10 bridge. During the study, chlorophyll *a* concentrations peaked during June 1993 at all three sampling sites. Chlorophyll *a* was also used as an indicator of trophic state. Trophic state will be discussed in Section I.10.J.

Surface chlorophyll *a* was also analyzed on a quarterly basis from 1987-92 as a part of the OCC's Small Lakes Sampling Program. During that study, surface chlorophyll *a* at the dam averaged 7.27 ug/l (maximum = 26.40). The statistical software WQStat was used to analyze the surface chlorophyll *a* data collected at the dam from 1987-94. Results of the Kruskal-Wallis test for seasonality indicated that the chlorophyll *a* concentrations do not express significant seasonality. However, the highest median concentration was observed during the winter. In addition, no significant trend was detected in the chlorophyll *a* data.

Secchi depth (**Table 15**), which is an indicator of water clarity, ranged from 54 to 96 inches at the dam and averaged 75 inches (CV=17%). The Secchi depth at Sawmill Point ranged from 25 to 89 inches and averaged 61 inches (CV=21%). Secchi depth ranged from 18 to 96 inches at the Highway 10 bridge and averaged 48 inches (CV=33%). As expected, water clarity increased considerably with distance from the inflows. In addition, Secchi depths varied less with distance from the inflows. Highest Secchi depths occured in November 1993 and January 1994.

Secchi depth and surface chlorophyll *a* concentrations were significantly correlated at the dam ($r = -0.50$, $\alpha = 0.05$, $n = 16$) indicating that surface chlorophyll *a* concentrations had a significant affect on the transparency of the water at the dam. Conversely, Secchi depth and surface chlorophyll *a* concentrations were not significantly correlated at Sawmill Point ($r = -0.12$, $\alpha = 0.05$, $n = 16$) or the Highway 10 bridge ($r = -0.05$, $\alpha = 0.05$, $n = 16$). Therefore, decreasing algal production should improve water clarity at the dam, but will not significantly improve water clarity at Sawmill Point and the Highway 10 bridge.

	Lake Eucha Sites		
Date	**Hwy 10**	**Sawmill Pt.**	**Dam**
03/10/93	42	60	78
04/13/93	60	68	90
05/12/93	18	25	83
05/26/93	36	52	60
06/09/93	40	53	60
06/23/93	42	60	64
07/14/93	42	54	58
07/28/93	48	66	78
08/11/93	40	54	65
08/25/93	38	72	72
09/08/93	48	89	90
09/22/93	48	60	84
10/27/93	49	52	54
11/10/93	54	62	96
12/15/93	54	68	84
01/12/94	96	67	72
02/16/94	60	67	84
Mean	**48**	**61**	**75**
Std. Dev.	**16**	**13**	**13**

Secchi depth and surface turbidity were not correlated at the dam (r = -0.31, α = 0.05, n = 16). In contrast, Secchi depth and surface turbidity were significantly correlated at Sawmill Point (r = -0.68, α = 0.05, n = 16) and the Highway 10 bridge (r = -0.61, α = 0.05, n = 17) indicating that surface turbidity has a significant impact on water clarity at in the middle and upper reaches of the lake. Decreasing turbidity should improve water clarity throughout the reservoir, especially in the middle and upper reaches (at Sawmill Point and the Highway 10 bridge).

4. Nitrogen and Phosphorus

As Table 16 indicates, mean total nitrogen (TN) concentrations (both surface and bottom) decrease with distance from the inflow. In contrast, mean surface total phosphorous (TP) concentrations did not vary significantly throughout the lake. However, mean bottom TP concentrations varied greatly between sites, with the highest mean bottom concentration occurring at Sawmill Point.

Throughout the lake, surface TN concentrations (**Appendix D**) were greatest during the winter and spring, and lowest during the summer and fall. Due to this seasonality, the TN:TP is also generally highest in the winter and early spring.

	Total Nitrogen		Total Phosphorous		TN:TP	
Site	_	sd	_	sd	_	sd
Hwy 10 - Top	1.46	0.78	0.03	0.01	76	121
Hwy 10 - Bottom	1.71	0.51	0.05	0.03	41	19
Sawmill Pt - Top	1.01	0.53	0.03	0.01	57	75
Sawmill Pt - Bottom	1.40	0.43	0.12	0.10	29	47
Dam - Top	1.00	0.58	0.02	0.01	49	39
Dam - Bottom	1.11	0.25	0.08	0.05	31	45

Accumulation of both TN and TP in the hypolimnion was observed at all sites during thermal stratification due to diffusion from sediment and suspended matter in the hypolimnion.

Runoff did not appear to directly affect nutrient concentrations at the dam. However, runoff had a considerable affect on TP concentrations at Sawmill Point and the Highway 10 bridge.

According to Wetzel (1983), a total nitrogen to total phosphorus ratio (TN:TP) of 7:1 or greater indicates phosphorus limitation. Because ninety-nine percent of the samples exhibited a TN:TP greater than 7:1, the lake was characterized as phosphorous limited. Because the lake is phosphorous limited, phosphorous was used as an indicator of trophic state (see I.10.J).

5. pH, Alkalinity, Hardness, TSS, Turbidity, TDS, Conductance, SO_4 and Cl

Means, standard deviations (sd), and coefficients of variation (CV) for pH, alkalinity, hardness, TSS, TDS, turbidity, conductance, sulfate (SO_4), and chloride (Cl) calculated from data collected between March 1993 and February 1994 are listed in **Table 17**. Detailed data are listed in **Appendix D**. All pH values measured in Lake Eucha complied with the Oklahoma Water Quality Standards (OWQS) numerical pH criteria (OWRB 1995). Alkalinities were low to moderate. All hardness measurements indicated that the water is moderately hard. Total suspended solids (TSS) in Lake Eucha are comparable to other lakes in Oklahoma and Kansas. The turbidity in 9 samples collected from Lake Eucha (6 from Highway 10 bridge and 3 from Sawmill Point) exceeded the OWQS numerical turbidity criteria of 10 NTU (OWRB 1995). Seven of the samples were bottom samples. The elevated turbidities in the two surface samples collected on May 12 and 26, 1993 at the Highway 10 bridge likely resulted from the runoff events which occurred on May 9-12 and May 17, 1993.

Parameter	Units	Hwy 10 Bridge Mean	sd	CV	Sawmill Point Mean	sd	CV
pH	S.U.	8.0	0.2	3%	8.0	0.3	4%
Alkalinity	mg/l	84	16.0	19%	86	23.0	27%
Hardness	mg/l	107	6.0	6%	102	7.0	7%
TSS	mg/l	13.8	13.70	99%	5.3	4.3	81%
TDS	mg/l	141	32.0	23%	118	19.0	16%
Turbidity	NTU	6.7	5.5	82%	4.3	4.0	93%
Conductance	uS/cm	216	24.0	11%	200	23.0	12%
Sulfate	mg/l	4.2	1.4	33%	3.4	1.2	35%
Chloride	mg/l	8.8	4.6	52%	7.7	4.0	52%

Total dissolved solids (TDS) concentrations were well below all recommended limits for drinking water supplies. TDS concentrations and conductivity were comparable to other water bodies in northeastern Oklahoma. Sulfate and chloride concentrations were well below all recommended limits for drinking water supplies.

6. <u>Metals</u>

Metals were analyzed on June 23 and December 15, 1993. Cadmium, chromium, lead, mercury, barium, and selenium were not detected in the lake water. However, calcium, magnesium, sodium, potassium, copper, iron, manganese, nickel, arsenic, and zinc were detected in lake water (**Table 18**). Copper, zinc, nickel, calcium, magnesium, sodium, iron, manganese, and potassium were not present at critical concentrations.

Concentrations of arsenic at Sawmill Point (10 ug/l) and the dam (15 and 93 ug/l) exceeded the OWQS water column criteria to protect human health for the consumption of fish flesh and water (0.175 ug/l) and the OWQS water column criteria to protect human health for the consumption of fish flesh (1.39 ug/l). In addition, the arsenic concentration at the dam (93 ug/l) approaches the OWQS raw water criteria of 100 ug/l (OWRB 1995). However, OWRB is in the process of modifying the arsenic criteria in Oklahoma. Proposed criterion changes include the elimination of the “fish flesh and water” criterion and changing the “fish flesh criterion from 1.399 to 205.0 ug/l. The arsenic concentrations in Lake Eucha would be compliant with these new criteria.

Hypolimnetic iron and manganese concentrations were noticeably greater than epilimnetic concentrations in June indicating that these metals are diffusing from the sediment.

Site	Date	Depth (ft)	Ca ug/l	Mg ug/l	Na ug/l	K ug/l	As ug/l	Ba ug/l	Cd ug/l	Cr ug/l	Cu ug/l	Fe ug/l	Pb ug/l	Mn ug/l	Ni ug/l	Zn ug/l	Se ug/l	Hg ug/l
Highway 10 Bridge	6/23/93	0.5	27	1.2	5.9		<1	<100	<1	<1	<1	40	<1	30	1	<10	<1	<0.1
Highway 10 Bridge	6/23/93	18	36	1.3	3.3		<1	<100	<1	<1	1	350	<1	640	2	<10	<1	<0.1
Highway 10 Bridge	12/15/93	0.5	39	1.3	2.9	1.4	< 10	< 100	< 10	<5	< 40	120	< 100	< 50	< 100	< 10	< 10	< 1
Highway 10 Bridge	12/15/93	18	35	1.2	2.8	1.2	< 10	< 100	< 10	<5	< 40	180	< 100	< 50	< 100	10	< 10	< 1
Sawmill Point	6/23/93	0.5	20	1.2	17.0		<1	<100	<1	<1	<1	10	<1	10	<1	<10	<1	<0.1
Sawmill Point	6/23/93	48	33	1.2	20.0	1.5	<1	<100	<1	<1	<1	130	<1	1400	<1	<10	<1	<0.1
Sawmill Point	12/15/93	0.5	34	1.2	2.9	1.6	***10***	< 100	< 10	<5	< 40	90	< 100	50	< 100	< 10	< 10	< 1
Sawmill Point	12/15/93	48	34	1.2	2.8	1.5	< 10	< 100	< 10	<5	< 40	210	< 100	< 50	< 100	< 10	< 10	< 1
Lake Eucha Dam	6/23/93	0.5	18	1.1	5.5		<1	<100	<1	<1	<1	<10	<1	10	<1	<10	<1	<0.1
Lake Eucha Dam	6/23/93	66	33	1.2	6.0	1.4	<1	<100	<1	<1	<1	10	<1	880	<1	<10	<1	<0.1
Lake Eucha Dam	12/15/93	0.5	33	1.2	3.0	1.5	***15***	< 100	< 10	<5	< 40	310	< 100	70	< 100	< 10	< 10	< 1
Lake Eucha Dam	12/15/93	66	33	1.1	2.7	1.4	***93***	< 100	< 10	< 5	< 40	50	< 100	60	< 100	17	< 10	< 1

E. Lake Sediment Quality

Sediment collected from the dam, Sawmill Point, and Highway 10 Bridge on September 2-3, 1993 was analyzed for nutrients and metals. Metal concentrations in Lake Eucha sediments are summarized in **Table 19. None of the detected quantities of metals exceeded the EPA Sediment Screening values (EPA 1995).**

Metal (ug/g)	Dam	Sawmill Point	Hwy 10 Bridge	Screening Values (ug/g)
As	5	8	7	85
Cd	1	1	1	9
Cr	10	20	20	145
Cu	10	12	16	390
Fe	26,000	16,000	17,000	N/A
Hg	0.54	0.04	0.04	1.3
K	140	1100	1300	N/A
Mg	640	1000	1400	N/A
Mn	1600	1100	2100	N/A
Na	40	60	60	N/A
NH3	12	28	31	N/A
Ni	10	20	20	50
NO2+NO3	12	21	63	N/A
Pb	10	30	50	110
Zn	40	50	85	270

F. Lake Biological Resources

1. Algae

The algal community is presented in **Appendix E**. Taxonomy was carried out to genera in the samples collected on April 13 and June 23, 1993 at the dam. Samples collected on October 27, 1993 and February 16, 1994 at the dam were only analyzed for diatoms.

Lake Eucha was dominated by green algae and diatoms in the spring (April 13, 1993) when green algae made up 70% of the biovolume and diatoms made up 27% of the biovolume. By summer (June 23, 1993), blue green algae dominated the algal community making up 81.5% of the biovolume. The dominant diatoms in the fall (October 27, 1993) were the pennate diatoms. The dominant diatoms in the winter (February 16, 1993) were the centric diatoms.

A study of numerous Oklahoma lakes found that whereas desmids and many pennate diatoms are found in oligotrophic waters because they generally cannot tolerate large nutrient concentrations, Cyanophyta, Euglenophyta, centric diatoms, and members of the Chlorococcales generally are associated with eutrophic waters (Kurklin 1990). If this is true in Lake Eucha, then Lake Eucha was eutrophic in the spring and summer, oligotrophic in the fall, and eutrophic again in the winter. This is consistent with the indications of the chlorophyll levels at the dam, except for the fact that the chlorophyll levels indicated that the lake was mesotrophic in the fall instead of oligotrophic.

2. Zooplankton

Zooplankton collections were made on April 13, June 23, and October 27, 1993. At least 6 species of zooplankton were identified in the lake (**Appendix F**). Copepods were consistently more abundant than cladocerans in the lake. Zooplankton were most abundant in the summer (June 23, 1993) and spring (April 13, 1993), and least abundant in the fall (October 27, 1993). Their abundance in the spring and summer and lower numbers in the fall correspond with high algal productivity in the spring and summer and lower algal productivity in the fall.

The size of zooplankton is closely related to fish community structure (Mills and Schiavone 1982). Most zooplankton collected in Lake Eucha were small (length < 0.80 mm) indicating that a predator:prey ratio of 0.2 or less may exist in the fish community (Mills et al. 1987). The dominance of small zooplankton may imply that insufficient numbers of predator fish are present to suppress the planktivorous fish (gizzard shad and sunfish) density (Mills and Schiavone 1982). In addition, the reduction in mean *Daphnia* length from 0.79 mm in June to 0.43 mm in October may result from predation impact of young fish indicating that the lake may contain a strong year-class of young fish (Mills et al. 1987). However, because of the small sample size, no firm conclusions can be made regarding the zooplankton community and its relationship to the fish community in Lake Eucha. If an imbalance does exist in Lake Eucha as indicated by the limited analysis of the zooplankton community, stocking and/or restrictive harvest of top predators (flathead catfish, saugeye, large-mouth bass, or hybrids) may provide an acceptable means to restoring the predator-prey balance. With the restoration of the predator-prey balance and the resulting larger zooplankton, it can be expected that clearer water will result from intense grazing of zooplankton on algae (Mills and Schiavone 1982) as filtering rates of zooplankton have been found to increase exponentially with increasing body length (Wetzel 1983).

The planktonic insect *Chaoborus* (Order Diptera) was found in high numbers in the sediment. *Chaoborus* (the phantom midge) larvae is capable of migrating vertically through the water column. During the day they migrate to the sediments to escape fish predation, and at night they migrate to the water surface to feed. Their abundance was highest in the transition zone (276.7 organisms/feet^2) and lowest in the riverine zone (20.8 organisms/feet^2). They were found in

97% of the sediment samples and had an average abundance of 139.17 organisms per square foot.

3. Benthic Macroinvertebrates

The benthic macroinvertebrate community was sampled on September 2-3, 1993. Thirty sediment samples were collected from Lake Eucha: ten from the riverine zone (Highway 10 bridge), ten from the transition zone (Sawmill Point), and ten from the lacustrine zone (dam). The benthic macroinvertebrate community was diverse throughout the lake, consisting of 3 Phyla, 5 Classes, 17 Families, and no less than 25 genera. Taxa and densities of the benthic organisms collected from the lake are summarized in **Appendix G**. The benthic macro-invertebrate community was dominated by tolerant tubificid oligochaetes. However, numerous sensitive species were also present.

The tubificid oligochaetes were the most abundant and prevalent benthic macroinvertebrates in Lake Eucha making up 73% of the organisms collected and being present in 87% of the samples. Oligochaetes are classified as tolerant according to Beck's Biotic Index (Terrell and Perfetti 1991) and Hilsenhoff's Family Biotic Index (Plafkin et al. 1989), and are able to withstand low dissolved oxygen levels. The tubificid oligochaetes were most abundant in the lacustrine zone. Four genera of tubificid worms (Family Tubificidae) were found in the lake (Limnodrilus, Branchiura, Aulodrilus, and Tubifex). Limnodrilus was the most abundant genus. Limnodrilus abundance was highest in the lacustrine zone and lowest in the riverine zone.

Another group of annelids, the leeches (Class Hirudinea), were present in 17 % of the samples. The leeches were found in the lacustrine and transition zones. The leeches are also considered a pollution tolerant class.

The chironomids (Class Insecta, Order Diptera) were also very abundant and prevalent in Lake Eucha. Chironomids were found in 85% of the samples and made up 27% of the organisms collected. Chironomids are considered tolerant according to Beck’s Biotic Index (Terrel and Perfetti 1991) and Hilsenhoff’s Family Biotic Index (Plafkin et al. 1989). Chironomids were most abundant in the riverine zone and least abundant in the lacustrine zone. Chironomids of the tribe Chironomini were the most abundant of this group and were found in 80% of the samples and had an average density of 12 organisms per square foot. Chironomids of the family tanypodinae were found in 37% of the samples and had an average density of 9 organisms per square foot. Another dipteran family, the ceratopogonidae, was also identified. Ceratopogonids were present in 17 % of the samples and were only found in the riverine zone. Ceratopogonids are considered tolerant by Beck’s Biotic Index and facultative by the Hilsenhoff FBI.

Mollusks are a relatively long lived and sensitive group. Their absence from lakes can indicate water quality problems. Clams and mussels (Pelecypoda) were very abundant throughout the lake, with a combined average abundance of over 6 organisms per square foot. The Pelecypod,

sphaerium, was present in over 50% of all samples. The Pelecypod psidium was present in 27% of all samples. Pelecypods were present throughout the lake; however, their abundance increased with distance from the dam. Snails (Gastropoda) were scarce throughout the lake, being present in only 3% of all samples. Snails were found only in the littoral zone near the dam.
Excluding the dipterans, many representatives of the class Insecta are considered sensitive and therefore a low concentration or absence of these groups can be indicative of water quality problems. Most of these sensitive representatives were absent from the deep waters of the transition and lacustrine zones of the lake where dissolved oxygen levels were very low. The mayflies (Order Ephemeroptera) were not abundant and had a combined average abundance of 1.13 organisms per square foot and were present mostly in the riverine zone and in the littoral zone of the lacustrine zone. Caddisflies (Order Trichoptera) had an average abundance of 0.13 organisms per square foot and were only present in the littoral zone of the lacustrine zone. Alderflies (Order Megaloptera) were only present in the riverine zone where they had an average abundance of 1.7 organisms per square foot. Riffle beetles (Order Coleoptera) were only present in the riverine zone were they had an average abundance of 0.3 organisms per square foot.

In a recent study, benthic macroinvertebrate metrics were used to assess the biotic integrity of fifteen small reservoirs in Oklahoma (including Lake Eucha). The seven metrics used to assess the biotic integrity of Lake Eucha are discussed below. The metric *percent of samples with long lived taxa present* indicated that 60 percent of Eucha's lake bottom had sufficient dissolved oxygen to support benthic macroinvertebrates over a long period of time (> 1 year). The average taxa richness per sample (family level) was 3.3 per square foot. Sixty-three percent of the samples contained sensitive taxa. Twenty-three percent of the samples contained only tubificids and/or chironomids indicating that 23% of the lake bottom will only support very tolerant organisms. Seventy-nine percent of the total organisms was composed of tubificids and *chironominii*. Only 9.1 percent of the total organisms were sensitive. Three percent of the samples contained no benthic macro-invertebrates. Overall, the benthic macroinvertebrate community is in fair condition.

4. Fisheries

a. Past and Present Activities and Suitability of the Lake

The principal purpose of Lake Eucha is to provide water for the City of Tulsa; however, its scenic beauty and reputation as an outstanding fishery attract a great deal of recreational use. Lake Eucha ranks as one of the finest largemouth bass fisheries in the state. It also offers good channel catfish and crappie fishing. The City of Tulsa maintains a fisheries staff that is responsible for monitoring and managing the fishery. Surveys are conducted on regular intervals. Collection methods include both spring and fall electrofishing and fall gillnetting. The bulk of the data used in the compilation of this report was collected by the Oklahoma Department of Wildlife Conservation (ODWC), during a May 1995 electrofishing survey.

Seventeen species (**Table 20**) were collected during the spring 1995 electrofishing survey, which was designed to sample all available habitats in proportion to their occurrence. Five species are considered moderately intolerant, nine are considered moderately tolerant, and three are considered tolerant (Jester, et al. 1992). A total of 2,352 individuals were collected. Of those, 3.5% are considered moderately intolerant, 90.8% are considered moderately tolerant, and 5.7% are considered tolerant. Fifty-three percent (53%) of the species collected were

Species	**Number**	**Tolerance**
Carp	37	Tolerant
Green sunfish	94	Tolerant
Golden shiner	3	Tolerant
Largemouth bass	269	Mod. Tolerant
Black crappie	5	Mod. Tolerant
Bluegill sunfish	808	Mod. Tolerant
Longear sunfish	99	Mod. Tolerant
Redear sunfish	78	Mod. Tolerant
Warmouth sunfish	28	Mod. Tolerant
Gizzard shad	772	Mod. Tolerant
Brook silverside	76	Mod. Tolerant
Channel catfish	1	Mod. Tolerant
Spotted bass	2	Mod. Intolerant
White sucker	3	Mod. Intolerant
Spotted sucker	70	Mod. Intolerant
Black redhorse	4	Mod. Intolerant
Golden redhorse	3	Mod. Intolerant

invertivores/ insectivores, 29% were omnivores, and 18% piscivores (Robinson and Buchanan 1992).

<u>Largemouth Bass (Micropterus salmoides)</u>
The spring 1995 electrofishing survey results for largemouth bass are encouraging as the catch per unit effort (CPUE) was 158.23, which ranks as one of the highest in the state. Both reproduction and recruitment appear to be good, as several strong year classes were evident. The structure of the population also appears to be sound. The survey yielded a proportional stock density (PSD) of 69. Growth rates and conditions also appear to be good, as the survey yielded a mean relative weight (WR) of 91.6. An index of condition was calculated on the largest fish sampled. Its score of 6.08 fell within the range of very plump as defined by Bennett (1986). Under current regulations, there is no length limit and the creel limit is 6. No regulation changes are anticipated in the near future. This appears to be a highly utilized fishery (Rainwater 1995).

<u>Spotted Bass (Micropterus punctulatus)</u>

Spotted bass were present in much lower densities than largemouth bass. The CPUE for the May 1995 survey was 1.18 with only two individuals being collected. The highest recent reported CPUE was 7.5, recorded in October 1994. The population structure appears to be poor, as the survey yielded a PSD of 29, with 83% of those sampled being less than 12 inches in length. Growth rates appear to be moderate, with the average WR of those collected being 83. An index of condition was calculated on the largest fish collected in the October 1994 sample. Its score of 4.47 was indicative of a fish in poor flesh, as defined by Bennett (1986). The spotted bass population appears to be suffering from a high degree of interspecific competition with largemouth bass. However, they may also be limited by habitat.

Crappie (Pomoxis nigromaculatus)

Crappie reproduction and recruitment appear to be moderate. Several year classes were present, but were poorly represented. Spring 1995 electrofishing yielded a CPUE of 2.94 (n=5), which is not significantly different from the fall 1994 survey, when CPUE was 3.0. Based on the small collection size, population structure appears to be sound, as the fall 1994 survey yielded a PSD of 100 and a relative stock density (RSD) of 82. Based on the small collection size, crappie growth rates and conditions appear to be good, as the fall 1994 survey produced an average WR of 87.25. There is currently no length limit and the statewide creel of 37 is in effect. Officials are considering imposing a 10 inch minimum length limit; however, they feel that fyke netting might first be necessary to more accurately assess that need.

White Bass (Morone chrysops)

White bass are a predominantly pelagic species (Robinson et al. 1992) and are rarely collected during electrofishing surveys (i.e. the 1995 survey), which are commonly geared toward near shore cover. Given their pelagic nature, white bass are more commonly collected in offshore gillnets. During 1994 fall gillnetting efforts, 203 white bass weighing an average of 0.79 pounds each were collected. This was down slightly from 1993, when 243 fish weighing an average of 1.03 pounds each was collected. Reproduction and recruitment are highly variable and largely dependant on flow. Population structure and growth is unknown, as there are currently no data regarding the lengths of the individuals collected. Presently, there are no length or creel limits and no regulation changes are expected in the near future. This is the lake's least utilized fishery.

Channel Catfish (Ictalras punctatus)

The numerous rock ledges and outcroppings present in the transitional region of the reservoir appear to be providing ample nesting cover, as both reproduction and recruitment are good. Fall 1994 gillnetting produced 116 fish that weighed an average of 2.73 pounds per fish. This is down somewhat from 1993, when 71 fish produced an average of 3.21 pounds per fish. The structure of the population appears to be sound, as the 1993 electrofishing survey yielded a PSD of 100 and a RSD of 40. Growth rates and conditions appear to be good as the survey yielded an average WR of 109. Currently, there is no length limit and the statewide creel of 15 is in effect. No regulation changes are anticipated in the near future. Channel catfish have not been stocked recently, as natural reproduction is felt to be sufficient to sustain a fishable population.

Gizzard Shad (Dorosoma cepedianum)
Gizzard shad is by far the most abundant species in this reservoir, both in terms of number and biomass. A 1986 cove rotenone sample produced 3,277 shad per acre that weighed a total of 262 pounds per acre. The next most abundant species in terms of number was bluegill sunfish at 1,230 bluegill per acre. The next most abundant, in terms of biomass, was the common carp at 28 pounds per acre. Results of the 1995 spring electrofishing survey yielded a CPUE of 454.12 (n=772). Fall gillnetting (1994) produced a total of 158 gizzard shad that averaged 0.32 pounds per fish. This is up slightly from the 1993 effort, which yielded a 0.30 pounds per fish average. The population structure appears to be sound (Rainwater 1995); however, its true status cannot be determined, as length frequency data was not available at the time of this report.

Threadfin Shad (Dorosoma petenese)
Threadfin shad were introduced in 1971. It was thought that their introduction would offer a broadened forage base, and that their smaller size might make it more suitable prey for small bass and crappie than the already abundant gizzard shad. Unfortunately, few representatives have been collected in recent surveys. It appears that an extended period of bitterly cold weather in the early 1980s played a major role in the population's demise (Rainwater 1995). Threadfin shad have been classified as a subtropical species that are relatively intolerant of temperature extremes. Large dieoffs have been documented when threadfin shad have been subjected to water temperatures of 5^{o}C or less for extended periods of time (Robinson and Buchanan 1992). The threadfin shad's intolerance of cold temperatures, coupled with Lake Eucha's latitudinal location, make it an unlikely candidate for restocking.

Bluegill Sunfish (Lepomis macrochirus)
Both reproduction and recruitment appear to be sound, as overall bluegill sunfish abundance is high. Results of the spring electrofishing survey (1995) yielded a CPUE of 475.3. This is up drastically from the fall 1993 survey, when electrofishing produced a CPUE of 34.15. The population structure however, appears to be poor to moderate at best, as spring electrofishing (1993) yielded a PSD of 31.7 and an RSD of only 1.0. Bluegill sunfish growth rates and conditions appear to be good, as results of the 1993 spring electrofishing survey produced an average WR of 99. Tulsa Fisheries officials feel that the population structure is considerably better than electrofishing data indicates. They point to creel survey data, which indicates that large numbers of quality and preferred size fish are routinely taken by anglers.

Longear Sunfish (Lepomis megalotis)
Longear sunfish reproduction and recruitment appear to be good, as abundance is high. The 1995 spring electrofishing survey yielded a CPUE of 58.24, which is up drastically from the fall 1993 survey, which produced a CPUE of 10.0. The structure of the population appears to be sound, as the survey yielded both a PSD and an RSD of 100. However, longear sunfish growth rates and conditions appear to be poor to moderate at best. Results of the 1993 spring electrofishing survey yielded an average WR of 76. This is not a heavily utilized fishery.

Rough Fish

Although "rough" fish (i.e. black and golden redhorse, northern hogsucker, white and spotted sucker, carp, gar) are not actively managed, they are heavily utilized by "giggers" (people attempting to take fish with a hand held spear). Only non-sportfish, with the exception of white bass can be gigged. Gigging is legal nearly statewide; however, Lake Eucha is unique in that the season is open year round. Thousands of pounds of rough fish alone are removed during the annual gigging tournament (Jenks 1995). This largescale removal of herbivores and insectivores likely has a significant impact on the distribution of energy within the fish community. The degree of this impact could be a subject deserving of further study.

b. Wholesomeness of Fish Tissue

In 1987, City of Tulsa officials collected specimens for fish flesh analysis for toxins. The analysis was performed by the Oklahoma State Department of Health. No residues of aldrin, chlordane, DDT, heptachlor, PCBs or toxaphene were detected in any fish species analyzed. Residues of mercury were found in several species, but at levels far below the OWQS Concern Level (OSDH 1987).

G. Sanitary Quality of the Lake and Tributaries

Appendix H presents bacteriological data and sampling sites for Lake Eucha between May and September of 1993. Semi-monthly samples were collected during this period and sent to the City of Tulsa's Mohawk Lab for analysis. The watershed area being sampled is widely used for agricultural activities which could contribute to the bacteriological impact on Lake Eucha.

Lake Eucha is designated as a primary body contact waterbody; therefore, the criterion for primary body contact recreation will be used to evaluate the results (**Table 21**). These serve as guidelines for the primary recreational season which covers May 1 to September 30th of each year. No criterion is set for streptococcus so the criterion for enterococcus will be used due to closely related speciation (City of Tulsa 1993). The data is presented in **Appendix H - Table I**. Any value that exceeds the OWQS bacterial criterion is shown in bold type.

Parameter	Units	Geometric Mean	Maximum
Fecal Coliform	col/100ml	200	400
E. Coli	col/100ml	126	235
Enterococcus	col/100ml	33	61

Appendix H - Table II compares the magnitude of the contaminants at each location for each parameter to the lowest count found at the Lake Eucha Dam site. The magnitude of the contaminants is expressed by how many times greater the bacterial count is compared to the lowest count at the dam. For example, Beaty Creek fecal coliform levels averaged 20.8 times greater than fecal coliform levels found at the dam (City of Tulsa 1993).

The OWQS bacterial criterion (**Table 21**) was never exceeded at the dam and only occasionally exceeded at the other lake sampling sites (Sawmill Point and Highway 10 Bridge). The tributary sampling sites however, exceeded the bacterial criterion more frequently. The criterion for fecal coliform and E. Coli. were exceeded only occasionally (9% and 13% of tributary samples respectively) in the streams while the criterion for Enterococcus and Fecal Strep. were exceeded in most of the stream samples (75% and 83% of samples tributary samples respectively).

The OWQS criterion for fecal coliform (400 col/100 ml) was never exceeded at the dam. The Sawmill Point and Highway 10 Bridge sampling sites both exceeded this criterion on May 12, 1993. None of the other lake samples exceeded the fecal coliform criterion. The Brush, Beaty, Spavinaw Creek (lower), and Spavinaw Creek (Highway 43 Bridge) sampling sites exceeded this criterion on June 9, 1993 and Spavinaw Creek (Highway 43 Bridge) exceeded the criterion on September 8, 1993. None of the other tributary samples exceeded the fecal coliform criterion.

The OWQS criterion for E. Coli. (235 col/100 ml) was never exceeded at any of the lake sampling sites. The Spavinaw Creek (lower) sampling site exceeded this criterion on May 12, 1993. The Brush, Beaty, Spavinaw Creek (lower), and Spavinaw Creek (Highway 43 Bridge) sampling sites exceeded this criterion on June 9, 1993. The Spavinaw Creek (lower) and Spavinaw Creek (Highway 43 Bridge) sampling sites exceeded this criterion on September 8, 1993. None of the other tributary samples exceeded the E. Coli. criterion.

The OWQS criterion for Enterococcus (61 col/100 ml) was never exceeded at the dam. The Sawmill Point and Highway 10 Bridge lake sampling sites exceeded this criterion on May 12, 1993 and the Highway 10 Bridge lake sampling site exceeded the criterion on June 9, August 25, and September 22, 1993. None of the other lake samples exceeded the criterion for Enterococcus. There were numerous instances in the tributary samples where the criterion for Enterococcus was exceeded. All tributary samples taken on May 12, June 9, August 25, September 8, and September 22, 1993 exceeded the criteria. The other instances where tributary samples exceed the criterion for Enterococcus can be seen in **Appendix H - Table I**.

No criterion is listed for Fecal Strep. in the OWQS so the criterion for enterococcus will be used due to closely related speciation (City of Tulsa 1993). The maximum concentration for fecal strep. (61 col/100 ml) was never exceeded at the dam. The Sawmill Point and Highway 10 Bridge lake sampling sites exceeded this criterion on May 12, 1993 and the Highway 10 Bridge lake sampling site exceeded the criterion on June 9, and September 22, 1993. None of the other lake samples exceeded the criterion for Fecal Strep.

There were numerous instances in the tributary samples where the criterion for Fecal Strep. was exceeded. All tributary samples taken on May 12, June 9, August 11, August 25, September 8, and September 22, 1993 exceeded the criteria. The other instances where tributary samples exceed the criterion for Fecal Strep. can be seen in **Appendix H - Table I**.

The data shows samples at locations most removed from the lake contained the highest levels of contaminants. There were many violations of the OWQS (OWRB 1995) in the upper ends of the watershed as can be seen in **Appendix H - Tables I** and **II**. This indicates that the sources for much of the bacteriological contaminants are located in the upper watershed. This is evident in the fact that peaks occurred when samples were taken shortly after runoff events. The high levels of bacteria in the upper watershed decrease as the water travels toward the lake due to dilution and natural die off.

H. Characteristics of Lake Tributaries

1. Base Flow - Chemical Characteristics

Base flow concentrations of parameters measured in the Lake Eucha tributaries are listed in **Appendix I**. **Table 22** lists means and ranges of the water quality parameters measured in the tributaries.

The dissolved oxygen criteria for cold water aquatic communities was never violated during the study period. Total dissolved solids (TDS) concentrations were well below all recommended limits for drinking water supplies and agricultural use. Conductivity, TDS, and TSS levels in the streams were comparable to those found in other waterbodies in northeast Oklahoma. Chloride and sulfate concentrations were also well below the recommended limits for drinking water and agricultural use. The pH of all stream samples were compliant with the OWQS. Alkalinity was low to moderate. The hardness of the stream water was classified as soft to moderately hard. The numerical criteria for turbidity (10 NTU) was never violated during the study.

As **Table 22** indicates, mean total nitrogen and total phosphorous concentrations in Spavinaw Creek and Beaty Creek were considerably higher than those found in Brush Creek, Dry Creek, and Rattlesnake Creek. Mean total nitrogen and total phosphorous concentrations in Spavinaw Creek decrease substantially between the Highway 43 bridge site and the lower site. On average, the TP concentration at the Highway 43 bridge site is three times greater than the TP concentration at the lower site.

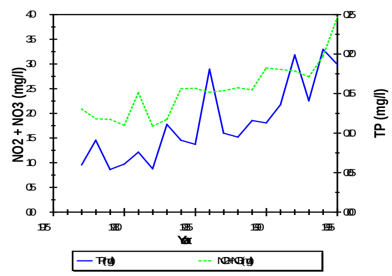
The *Gold Book* (EPA 1986) states: “To prevent the development of biological nuisances and to control accelerated or cultural eutrophication, total phosphates as phosphorous should not exceed 0.05 mg/l in any stream at the point where it enters any lake or reservoir”. Total phosphates as phosphorous concentrations exceeded 0.05 mg/l in 6.3% of the base flow samples collected from the lower Spavinaw Creek site, 11.8% of the samples from Beaty Creek, and 0% of the samples from Brush, Rattlesnake, and Dry Creeks.

Site		D.O. (mg/l)	Cond. (uS/cm)	pH (S.U.)	Alk. (mg/l)	Turb. (NTU)	Hard. (mg/l)	Cl (mg/l)	TDS (mg/l)	TSS (mg/l)	TN (mg/l)	SO_4 (mg/l)	TP (mg/l)
Spavinaw Cr. Hwy 43	Range	7.0 to 12.0	168 to 306	7.3 to 8.0	74 to 195	0.4 to 5.4	100 to 132	5.2 to 20.0	139 to 184	<1.0 to 15.0	2.20 to 4.47	<5.0 to 6.8	0.09 to 0.16
	Mean	9.6	249	7.6	111	1.6	122	10.6	162	3.0	2.99	4.7	0.12
Spavinaw Cr. Londagin Br.	Range	6.4 to 10.9	220 to 229	7.5 to 7.6	74 to 90	3.3 to 6.3	*	*	*	*	*	*	*
	Mean	8.7	225	7.6	82	4.8	110	9.0	133	<1.0	3.30	5.9	0.05
Spavinaw Cr. Lower	Range	6.5 to 11.2	102 to 284	7.2 to 8.0	11 to 195	0.3 to 8.9	95 to 128	4.2 to 20.0	124 to 179	<1.0 to 11.0	1.9 to 4.17	<5.0 to 6.4	0.03 to 0.11
	Mean	9.0	219	7.6	102	1.8	114	9.6	156	2.6	2.51	4.9	0.04
Beaty Creek	Range	5.5 to 11.7	155 to 273	7.1 to 8.2	72 to 118	0.3 to 9.2	98 to 132	4.2 to 17.0	124 to 163	<1.0 to 12.0	1.4 to2.26	<5.0 to 5.8	0.03 to 0.09
	Mean	8.9	220	7.6	100	1.8	117	7.8	145	2.1	2.08	3.8	0.05
Brush Creek	Range	7.0 to 10.8	122 to 240	7.1 to 8.1	62 to 112	0.3 to 4.3	86 to 119	1.0 to 16.0	107 to 149	<1.0 to 5.5	<0.50 to 1.54	<5.0 to 6.0	<0.01 to 0.10
	Mean	8.9	194	7.5	93	1.2	108	6.6	126	1.7	0.70	3.9	0.02
Dry Creek	Range	6.1 to 11.6	102 to 240	7.3 to 10.1	52 to 190	0.3 to 4.2	68 to 101	3.2 to 20.0	90 to 147	<1.0 to 9.0	<0.50 to 1.23	<5.0 to 6.7	<0.10 to 0.07
	Mean	9.1	197	7.8	87	1.1	89	9.9	124	1.9	0.52	4.1	0.02
Rattlesnake Creek	Range	6.5 to 10.8	140 to 240	7.4 to 8.3	48 to 104	0.5 to 3.7	73 to 100	2.1 to 20.0	82 to 136	<1.0 to 8.0	0.15 to 0.44	<5.0 to 5.7	<0.01 to 0.02
	Mean	8.2	194	7.7	87	1.4	87	7.1	111	2.1	0.25	4.3	0.01

*- *No range- only one sample taken*

The *Gold Book* (EPA 1986) also states: “A desired goal for the prevention of plant nuisances in streams or other flowing waters not discharging directly to lakes or impoundments is 0.10 mg/l total phosphorous”. Total phosphorous concentrations exceeded 0.10 mg/l in 88.2% of the base flow samples collected from Spavinaw Creek at the Highway 43 bridge. Phosphorous loading to Lake Eucha will be discussed in Section I.10.I.

A trend of increasing nutrient concentrations (total phosphorous and nitrate + nitrite) has been observed at the ADPC&E monitoring station on Spavinaw Creek (**Figure 5**). Average annual total phosphorous concentrations tripled between 1975 and 1995. Average annual nitrate + nitrite concentrations doubled between 1975 and 1995.



2. Runoff - Chemical Characteristics

Observed concentrations, means, and ranges of parameters measured in runoff samples collected from the lower Spavinaw Creek site, Beaty Creek, and Brush Creek are listed in **Appendix J**. Hardness indicated that all runoff samples were moderately hard. Chloride, sulfate, TDS concentrations in runoff were well below all recommended limits for drinking water supplies and agricultural use. Hardness, chloride, sulfate, and TDS levels in runoff were generally comparable to their levels found in baseflow. However, in the runoff sample from Brush Creek on February 22, 1994, a chloride concentration of 96 mg/l was observed. This high chloride concentration possibly resulted from runoff from roads to which salt had been applied.

Total suspended solids (TSS) levels in runoff were considerably higher than the levels observed in base flow samples. The difference was greatest in Beaty Creek where mean runoff TSS levels were nearly 27 times higher than mean base flow TSS levels. In Spavinaw Creek, runoff TSS levels were only 12 times higher than base flow TSS levels. The difference was least in Brush Creek where runoff TSS levels were only 8 times higher than base flow TSS levels.

Total nitrogen concentrations in the runoff samples were somewhat higher than levels observed in base flow samples. The greatest difference was observed in Brush Creek where mean TN levels in runoff were 2.3 times greater than mean base flow levels. In Beaty Creek and Spavinaw Creek, the TN levels in runoff were not significantly greater than the baseflow TN levels. However, mean TN concentrations in Spavinaw Creek and Beaty Creek were twice as high as TN concentrations in Brush Creek.

Total phosphorus concentrations were also higher in runoff than in base flow samples. The difference was greatest in Beaty Creek where mean runoff TP levels were nearly 6 times greater than mean base flow TP levels. In Brush Creek, runoff TP levels were only 3.5 times greater than base flow TP levels. The difference was least in Spavinaw Creek where runoff TP levels were only 2.25 times greater than base flow TP levels.

All of the runoff samples taken at the lower Spavinaw Creek and Beaty Creek sites exceeded the EPA suggested total phosphorous levels for streams discharging into a reservoir (0.05 mg/l), while only half of the runoff samples at Brush Creek violated the suggested EPA criteria for total phosphorus. The highest runoff total phosphorous levels were found in Beaty Creek. Total phosphorous levels in Beaty Creek were 3-4 times higher than the levels found in Spavinaw Creek and Brush Creek. Phosphorous loading to Lake Eucha will be discussed in Section I.10.I.

3. Toxics in Tributaries

Water quality samples were collected on February 22 and March 10, 1994 using autosamplers located on Spavinaw, Beaty, and Brush Creeks. The samples were tested for the following pesticides: BHC, heptachlor, heptachlor epoxide, endosulfan, dieldrin, endrin, chlordane, DDE, DDD, DDT, and PCB. No pesticides were detected in any of the samples.

I. Nutrient Loading

Estimated nutrient loading to the lake from each tributary

Based on USGS discharge data collected at Spavinaw Creek from 1962-84, it was estimated that approximately 35% of the total annual discharge results from base flow and 65% of the total annual discharge results from runoff. Assuming that these percentages applied to all the streams assessed during the period of study, estimates of runoff and baseflow volumes for each stream were made (**Table 23**).

Creek	Baseflow volume	Runoff Volume	Total volume
Spavinaw	53,556.17	99,461.47	153,017.64
Beaty	15,972.89	29,663.95	45,636.84
Brush	8,456.24	15,704.44	24,160.68
Dry	5,637.49	10,469.63	16,107.12
Rattlesnake	1,879.16	3,489.88	5,369.04
Unassessed Area	8,456.24	15,704.44	24,160.68

Estimated baseflow and runoff discharges were then multiplied by the mean total phosphorous concentrations measured during baseflow and runoff to calculate phosphorous loading from each stream (**Table 24**). Because runoff was not analyzed in Dry Creek and Rattlesnake Creek, the mean TP concentration from Brush Creek was used in the loading calculations due to the similarity of the baseflow TP concentrations and land use in these streams. In addition, the TP concentrations from Brush Creek were used to estimate loading from the unassessed area.

Based on the loading estimates (**Table 24**), it was calculated that the annual phosphorous load to

ESTIMATED ANNUAL PHOSPHOROUS LOAD (kg)

Creek	Baseflow	Runoff	Total
Spavinaw	2,644 (±1,322)	11,046 (±1,227)	13,690 (±2,549)
Beaty	986 (±319)	10,616 (±4,027)	11,602 (±4,346)
Brush	209 (±209)	1,357 (±775)	1,566 (±984)
Dry	139 (±139)	904 (±517)	1,043 (±656)
Rattlesnake	23 (±23)	301 (±172)	324 (±195)
Unassessed Area	209 (±209)	1,357 (±775)	1,566 (±984)
TOTAL	**4,210 (±2,221)**	**25,581 (±7,493)**	**29,791 (±9,714)**

Lake Eucha was approximately 29,791 kg (±9,714 kg). According to **Table 24**, Spavinaw Creek contributes approximately 46% of the total phosphorous load, Beaty Creek contributes roughly 39%, Brush Creek contributes around 5%, Dry Creek contributes nearly 4%, Rattlesnake contributes approximately 1%, and the unassessed area contributes roughly 5%. This compares to Spavinaw Creek contributing 57% of the total annual input of water, Beaty Creek contributing 17%, Brush Creek contributing 9%, Dry Creek contributing 6%, Rattlesnake Creek contributing 2%, and the unassessed area contributing 9%. Obviously, Beaty Creek is contributing greater amounts of phosphorous relative to its discharge. Because there are no point source dischargers in the Beaty Creek watershed, the elevated levels of phosphorous are assumed to originate from nonpoint sources.

The total nitrogen (TN) load to Lake Eucha (**Table 25**) was calculated using the method described above. According to **Table 24**, Spavinaw Creek contributes approximately 67% of the total nitrogen load, Beaty Creek contributes roughly 19%, Brush Creek contributes around 5%, Dry Creek contributes nearly 3%, Rattlesnake contributes approximately 1%, and the unassessed area contributes roughly 5%. This compares to Spavinaw Creek contributing 57% of the total annual input of water, Beaty Creek contributing 17%, Brush Creek contributing 9%, Dry Creek contributing 6%, Rattlesnake Creek contributing 2%, and the unassessed area contributing 9%. Obviously, Spavinaw Creek is contributing greater amounts of nitrogen relative to its discharge.

ESTIMATED ANNUAL NITROGEN LOAD (kg)

Creek	Baseflow	Runoff	Total
Spavinaw	165,882	382,935	548,817
Beaty	40,998	115,673	156,671
Brush	7,305	31,782	39,087
Dry	3,617	21,188	24,805
Rattlesnake	580	7,063	7,643
Unassessed Area	7,305	31,782	39,087
TOTAL	**225,687**	**590,423**	**816,110**

The following nutrient budget (**Table 26**) was calculated using the inflow loading estimates listed in **Table 24** (for phosphorous) and **Table 25** (for nitrogen). The outflow loading estimates were calculated using the mean nitrogen and phosphorous concentrations at the dam (surface samples) and the measured outflow. The surface samples at the dam should provide an accurate measure of the outflow nutrient concentrations as the lake only releases water from the spillway and flood gates. Obviously, large quantities of nitrogen and phosphorous are being assimilated in the lake. Of the inflowing nutrient loads, 78% of the phosphorous and 60% of the nitrogen was retained. The lake is clearly serving as a nutrient "sink".

Inflow	**kg/yr**
P Load	29,791
N Load	816,108
Outflow	
P Load	6,580
N Load	328,994

Only Spavinaw Creek receives permitted discharges from waste water treatment facilities. As mentioned in Section I.8, the cities of Gravette and Decatur, Arkansas release their effluents into tributaries of Spavinaw Creek. Both facilities monitor discharge; however, neither facility monitors total nitrogen or total phosphorus in their effluents, so no actual data on nitrogen and phosphorus loading can be obtained. Therefore, several methods were used to estimate the nutrient loading from these facilities.

Estimated Nutrient Loading from Gravette Discharge

Three methods were used to estimate nutrient loading from Gravette (**Appendix K**). Method 1 utilized mean total phosphorous and total nitrogen concentrations associated with stabilization ponds from Gakstatter's publication in the Journal of the Water Pollution Control Federation (Gakstatter et al. 1978) and the measured discharges from March 1993 through February 1994 and from September 1995 through August 1996. Based on this method, an estimated total of 1,381 kg of phosphorous and 3,579 kg of nitrogen was discharged from Gravette during the study period (March 1993 through February 1994). An estimated total of 712 kg of phosphorous and 1,845 kg of nitrogen was discharged from Gravette from September 1995 through August 1996. This indicates the annual variability in the nutrient loading from this facility. Much of the variability in the observed discharge between the two periods likely resulted from climatic conditions. The 1993-94 period was relatively wet, especially when compared to the drought conditions of the 1995-96 period.

Method 2 utilized mean total phosphorous and total nitrogen concentrations associated with stabilization ponds from Gakstatter's publication in the Journal of the Water Pollution Control Federation (Gakstatter et al. 1978) and the design discharge of 0.56 mgd for the facility. Based on this method, an estimated total of 5,106 kg of phosphorous and 13,229 kg of nitrogen could be discharged from Gravette each year if it discharged according to its design flow. However, as noted in Section I.8., Gravette only discharged 27% of its design discharge in the 1993-94 period and 14% in the 1995-96 period. This method exhibits a worst case scenario and does not represent the current discharge.

Method 3 utilizes median total phosphorous and total nitrogen load per capita associated with stabilization ponds from Gakstatter's publication in the Journal of the Water Pollution Control Federation (Gakstatter et al. 1978) and the population of Gravette (1,412). Based on this method, an estimated total of 1,271 kg of phosphorous and 2,824 kg of nitrogen are discharged from Gravette each year.

Method 1 is considered most accurate, because monitored discharge data was used. Method 3 is considered the second most accurate, because the actual population was used. Method 2 is considered to be the least accurate method and representative of a worst case scenario. Therefore, it is estimated that the Gravette facility discharged an estimated total of 1,381 kg of phosphorous and 3,579 kg of nitrogen during the study period; however, it has the potential to discharge up to 5,106 kg of phosphorous and 13,229 kg of nitrogen if Gravette discharges at its design discharge.

If all the phosphorous and nitrogen discharged from Gravette during the study reached the lake, then Gravette would be responsible for only 5% of the total annual phosphorous load and 0.4% of the total annual nitrogen load to the lake. This equals 10% of the total annual phosphorous load from Spavinaw Creek to the lake and 0.6% of the total annual nitrogen load from Spavinaw Creek.

Estimated Nutrient Loading from Decatur Discharge

Four methods were used to estimate nutrient loading from Decatur (**Appendix K**). For Method 1, total nitrogen concentrations in the effluent were estimated from the measured ammonia and nitrate values. This estimate is conservative; however, it should provide a good estimate of the nutrient content in the effluent. Total phosphorous concentrations were estimated using the estimated total nitrogen concentration divided by 2.4. The TN:TP in effluent from activated sludge facilities was found to be 2.4 (Gakstatter et al. 1978). The measured discharge was used for the nutrient loading calculations. Based on this method, an estimated total of 8,153 kg of phosphorous and 19,567 kg of nitrogen was discharged from Decatur between March 1993 and February 1994. An estimated total of 15,923 kg of phosphorous and 38,214 kg of nitrogen was discharged from Decatur between October, 1995 and September, 1996. The mean total phosphorous concentration in the effluent, based on this method, was 6.7 mg/l during the study period (1993-94) and 10.2 mg/l during the 1995-96 period. This compares to the average total phosphorous concentration of 9.9 mg/l found in the Tyson Foods Waldron Plant effluent (OSU 1994).

For Method 2, total nitrogen concentrations in the effluent were estimated from the permitted amounts of ammonia and nitrate allowed in the effluent. This estimate provides a worst case scenario. The total phosphorous concentrations were estimated using the same method as used in Method 1. The design discharge was used for the nutrient loading calculations. Based on this method, an estimated total of 23,025 kg of phosphorous and 55,261 kg of nitrogen could be discharged from Decatur each year. Again, this provides a worst case scenario; however, Decatur could discharge these quantities of nutrients without violating their permit.

Method 3 utilized mean total phosphorous and total nitrogen concentrations associated with activated sludge facilities from Gakstatter's publication in the Journal of the Water Pollution Control Federation (Gakstatter et al. 1978) and the measured discharge. Based on this method, an estimated total of 8,313 kg of phosphorous and 19,316 kg of nitrogen was discharged from Decatur during the study (March 1993 through February 1994). An estimated total of 10,593 kg of phosphorous and 24,614 kg of nitrogen was discharged from Decatur between October 1995 and September 1996. Effluent from poultry processing plants is generally more nutrient rich than municipal wastewater effluents (from which the Gakstatter values were developed).

Method 4 utilized mean total phosphorous and total nitrogen concentrations associated with activated sludge facilities from Gakstatter's publication in the Journal of the Water Pollution Control Federation (Gakstatter et al. 1978) and the design discharge of 1.6 mgd for the facility.

Based on Method 4, an estimated total of 15,031 kg of phosphorous and 34,925 kg of nitrogen are discharged from Decatur each year. Coincidentally, these results are very similar to those found by Method 1 for the 1995-96 period.

Method 1 is considered the most accurate method, because of the use of actual monitoring data. Therefore, it is estimated that the Decatur facility discharged an estimated total of 8,153 kg of phosphorous and 19,567 kg of nitrogen during the study; however, it has the potential to discharge up to 23,025 kg of phosphorous and 55,261 kg of nitrogen if it discharges at its design discharge and at its permitted limits. If all the phosphorous and nitrogen discharged from Decatur during the study reached the lake, then Decatur would be responsible for 27% of the total phosphorous load and 2% of the total nitrogen load to the lake. This equals 60% of the phosphorous load from Spavinaw Creek to the lake and 4% of the nitrogen load from Spavinaw Creek.

Discussion of nutrient loading results

Based on the 1996 confined animal survey, an estimated total of 8,259,600 pounds of nitrogen and 2,585,540 pounds of phosphorous were excreted by confined animals (chickens, hogs, and turkeys) in 1996. This translates to 3,746,555 kg of nitrogen and 1,172,801 kg of phosphorous excreted annually. Although only a small portion of this reaches the lake, it is obvious that this could potentially provide a significant source of nutrients for the lake. This is especially apparent in Beaty Creek which contributes almost as much phosphorous to the lake as Spavinaw Creek despite its smaller watershed and discharge, and its lack of any point source dischargers.

In the Spavinaw Creek watershed, it is obvious that point source discharges have the potential to contribute a significant portion of the total phosphorous load. The Gravette discharge is not currently discharging substantial levels of phosphorous. In contrast, the Decatur discharge could account for over half of the phosphorous load from Spavinaw Creek. The Spavinaw Creek watershed also has a large amount of poultry production.

The data indicate that a large amount of phosphorous is being assimilated in the watershed. Only 2.5% of the phosphorous input into the watershed (from both point sources and confined animals) is currently reaching the lake. In theory, the only way phosphorous can leave the system is through export of manure, export of ag products, and export down stream. As discussed previously, some of the phosphorous becomes bound to soils. Some of the streams in the watershed are losing streams. Therefore, this nutrient rich water is recharging aquifers. While in the ground water, some of the phosphorous may become bound up. Some of the phosphorous is taken up by terrestrial plants. Aquatic communities also initially bind up some of the extra phosphorous. Some is also sedimented out in the streams and is only moved during large storm events. Eventually, however the watershed will become less and less efficient at assimilating phosphorous as it becomes “saturated” with phosphorous. When this occurs, water quality in the lake and tributaries will dimish rapidly. Therefore, it is imperative to begin work immediately in the watershed to decrease the amounts of nutrients reaching the stream, ground water, and eventually the lake.

J. Current Trophic State

Carlson's (1977) trophic state indices (TSI) were used to determine the lake's current trophic state. The following scale was used to assign trophic state:

Carlson TSI	Trophic State
0-39	Oligotrophic
40-49	Mesotrophic
50-59	Eutrophic
>60	Hypereutrophic

TSI values calculated from mean chlorophyll *a* concentrations, Secchi depths, and total phosphorous concentrations indicate that overall, Lake Eucha is eutrophic throughout (**Table 27**).

Site	**TSI-Chl. *a***	**TSI-Secchi**	**TSI-TP**
Highway 10 Bridge	53	58	52
Sawmill Point	55	54	50
Dam	52	51	49

As would be expected, TSI values varied greatly throughout the year due to events such as algal blooms and runoff events. However, with the exception of the dam, no distinct trends were observed in the trophic states. The trophic state at the dam was mesotrophic (borderline eutrophic) from late August through December and eutrophic for most of the rest of the year. This observation is consistent with other findings of the study.

K. Conclusion

Lake Eucha and its tributaries are currently supporting their designated beneficial uses of public and private water supply, cool water aquatic community, agriculture, primary recreation and aesthetics. However, eutrophication threatens these uses and would impact the Cities of Tulsa and Jay, Oklahoma which depend on the lake to supply their populations (approximately 370,000 people) with drinking water and recreation.

The eutrophication has been caused by elevated nutrient loads, primarily from Beaty Creek and Spavinaw Creek, to Lake Eucha. Together Beaty Creek and Spavinaw Creek supply 85% of the phosphorous entering the lake. Because Lake Eucha is phosphorous limited, the increased nutrient loads have resulted in eutrophication of the lake.

Land use in the watershed is primarily forest and pasture. However, there are two permitted point source dischargers in the Spavinaw Creek watershed. The permitted discharge from Decatur appears to be supplying substantial nutrient loads to Spavinaw Creek. In addition, large numbers of poultry are produced in the Spavinaw Creek watershed each year which also have the potential to provide substantial nutrient loads to Spavinaw Creek. No point source dischargers are located in the Beaty Creek watershed; therefore, the source of the elevated levels of nutrients appears to be from nonpoint sources. The large numbers of poultry produced in the Beaty Creek watershed are the only obvious source of the excessive nutrients.

Other than eutrophication, the lake and its tributaries are generally in good shape. In fact, Lake Eucha ranks as one of the finest largemouth bass fisheries in the state. In addition, fish flesh analysis has revealed that the fish are free of notable levels of toxins.

The pH, alkalinity, hardness, TSS, turbidity, TDS, conductance, SO_4 and Cl in both the lake and streams were comparable to the levels found in the area. Metals were not present in lake sediment, lake water, or water collected from the tributaries at concentrations exceeding the OWQS or EPA criteria. Pesticides were also absent from water samples. In addition, lake samples were generally free of excessive levels of health threatening bacteria; although, excessive levels of bacteria were found in the tributaries. The elevated levels of bacteria in the tributaries are another indication of the impact of animal waste on water quality.

The algal assemblage in Lake Eucha was typical of eutrophic lakes. Most zooplankton collected in Lake Eucha were small indicating that a predator:prey ratio of 0.2 or less may exist in the fish community and insufficient numbers of predator fish are present to suppress the planktivorous fish density. If this is the case, stocking and/or restrictive harvest of top predators may be desired to provide an acceptable means to restoring the predator-prey balance in the fish community. The benthic macroinvertebrate community was dominated by tolerant tubificid oligochaetes. However, numerous sensitive species were also present. Overall, the benthic macroinvertebrate community was in fair condition.

Because the lake has been designated a sensitive public and private water supply (SWS), new point source discharges or increased loading from existing point sources without approval from the Oklahoma Water Resources Board are prohibited. In addition, BMP's for control of Non-Point Source pollution should be implemented in watersheds of water bodies designated SWS. This could be enforced in the Lake Eucha watershed to protect the uses of the lake for future generations.

II. LAKE EUCHA FEASIBILITY STUDY

II.1 Identification and Discussion of Pollution Control and Lake Restoration Alternatives Considered and Selected

A. Identification and Justification of Each Selected Alternative

Source control of phosphorous loadings (from both point and nonpoint sources) to the headwaters of Lake Eucha was recommended for the following reasons:

1) represents a long term solution,
2) is protective of the scenic Spavinaw Creek and Lake Eucha, and
3) in-lake treatments would be cost-prohibitive and are only symptomatic correctives.

1. Expected Water Quality Improvement From Source Control of Phosphorous Loadings

Reductions in phosphorous loadings have been shown to control and in some cases reverse the eutrophication process. Expected water quality improvements include, but are not limited to:

1) increased water clarity,
2) decreased frequency of algal blooms and thus reduced risk of fish kills from dissolved oxygen depletions
3) increased recreational use, and
4) decreased likelihood of the development of taste and odor problems.

2. Technical Feasibility of Source Control of Phosphorous Loadings

In order to determine the necessary (and feasible) phosphorous reductions, the Oklahoma Conservation Commission (OCC) has entered into an agreement with the Tulsa Metropolitan Utility Authority. The Tulsa Metropolitan Utility Authority will compensate the OCC to:

1) develop and run a reservoir model to determine how algae in Lake Eucha respond to varying levels of phosphorous,
2) develop and run, concurrently, an overland flow and instream model under different management scenarios to identify the level and type of management necessary to achieve the desired phosphorous level for the lake, and
3) design a watershed management plan to attain the desired level of phosphorous reduciton in the most efficient manner.

3. Estimated Cost of Source Control of Phosphorous Loadings

Few published estimates of costs of phosphorous removal are available. Seip (1994) cites that phosphorous removal costs approximately $6.50-$6.65 per kg. However, this probably reflects the costs of point source phosphorous removal only and does not include nonpoint source control which will also be required.

4. <u>Detailed Description - Exact Activities (How and Where Implemented), Engineering Specifications with Drawings, Anticipated Pollution Control Effectiveness</u>

Control of phosphorous from NPS, as well as point sources, will require site-specific recommendations; therefore, exact activities and drawings are not variable. However, the watershed management plan should describe the management needed to preserve the lake.

Once the watershed management plan has been developed, implementation will be initiated. Funding through EQIP and §319 of the Clean Water Act should be pursued for implementation of BMPs. An example of a §319 project would be a manure marketing program, such as the FY 1997 §319(h) project being implemented in the Illinois River, Little River, Poteau River, and Neosho River basins. This could help reduce phosphorous loadings through the removal of poultry manure from the Lake Eucha watershed. This could be subsidized, to some extent, by lake users.

Several measures can be taken to ensure that BMPs are implemented. The OWQS, which state that best management practices for control of non-point source discharges should be implemented in watersheds of waterbodies designated SWS, should be enforced. The OWQS could also be modified to make the SWS designation more protective by requiring development of conservation plans in sub-watersheds where discharges from non-point sources are identified as causing, or significantly contributing to degradation of SWS waterbodies. Legislation, such as a "Bad Actor Law", could also be pursued to encourage BMP implementation. BMP implementation should be aggressively tracked using a GIS system.

The OWQS, which also state that SWS are "prohibited from having any new point source discharge(s)", should be enforced to prevent increased nutrient loading from point sources. Funding from lake users, along with federal and state funding, could be used to help subsidize upgrading the existing waste treatment facilities.

B. <u>Identification and Justification of Each Alternative Considered</u>

Three broad categories considered were (with examples):

<u>Source Control</u>

1. Site Treatment (e.g., BMPs) - Management of the watershed to protect Spavinaw Creek and Lake Eucha will require implementation of BMPs.

2. NPDES phosphorous limits - Limits on phosphorous in effluent discharged from wastewater treatment plants may be necessary.

<u>In-Lake Treatment</u>

1. Dredging - Sedimentation is not a problem in Lake Eucha and thus dredging would not only be cost-prohibitive, but ineffective as well.

2. Nutrient Precipitation / Inactivation (e.g., alum application) - Nutrient precipitation/ inactivation would be cost prohibitive, because of the large allochthonous phosphorous loads would likely render the technique ineffective after a few years or require continual application.

Problem Treatment

1. Physical (e.g., biological) - The use of algacides (e.g., copper sulfate) were not recommended, because continual application of an algalcide would be required and might accumulate toxicity in the higher organisms and/or sediments.

2. Hypolimnetic Aeration - The cost of hypolimnetic aeration prohibits its application in Lake Eucha. In addition, like all in-lake treatments, hypolimnetic aeration only treats symptoms, not the cause of the problem.

1. Expected Water Quality Improvement

Expected water quality improvements include those discussed in Section II.1.A(1). The overall goal is to slow or reverse the eutrophication process in the lake. This will prolong the life of the reservoir and should allow the lake to fully support its beneficial uses.

2. Technical Feasibility

Most of the alternatives are cost-prohibitive for installation, operation, and maintenance. Some, such as in-lake chemical treatment would be ineffective, because the short residence time of the reservoir would force frequent treatments.

3. Estimated Cost

Most of the alternatives would be cost-prohibitive and require extensive personnel and management for operation and maintenance.

4. Detailed Description - Exact Activities (How and Where Implemented), Engineering Specifications with Drawings, Anticipated Pollution Control Effectiveness

The exact details of the considered alternatives (excluding those recommended) were not evaluated in depth, because the disadvantages nullify the possible benefits of their implementation. Should the proposed recommendations not effectively meet the water quality goals, the alternatives may be considered in addition to the source control.

II.2 Expected Benefits of Project

Benefits of water quality restoration should allow the lake to fully support all its beneficial uses (public and private water supply, cool water aquatic community, agriculture, primary recreation, aesthetics, and sensitive public and private water supply) for years to come.

II.3 Description of Phase II Monitoring Program

Because a basin-wide watershed management approach is proposed by this study, a detailed proposal for Phase II funding was not prepared. However, a monitoring schedule was suggested for evaluating the effectiveness of the point source (e.g., NPDES limits) and nonpoint source (e.g., BMPs) controls. The monitoring schedule is given below.

Monthly/biweekly in-lake data should be collected, at a minimum, at the sampling sites of the 1993-93 OCC study. Epilimnetic and hypolimnetic samples should be collected for water quality analyses. Profiles of temperature, dissolved oxygen, conductivity, and pH should be collected during each sampling trip. Tributary sites should be included, provided funding is available. Total and soluble reactive phosphorous; nitrite, nitrate, ammonia, and organic nitrogen; pH; temperature; dissolved oxygen; alkalinity; hardness; chlorophyll a; Secchi depth; suspended solids; and any other specific measurements deemed necessary should be analyzed.

II.4 Proposed Milestone Work Schedule

Since a Phase II application is not submitted here, a typical milestone schedule, budget, and payment schedule was not developed. However, it is the hope of the author that a restoration project is initiated in the near future to prevent further degradation of the reservoir.

II.5 Sources on Non-Federal Funds

The non-federal match, as required by the Clean Lakes Program is not applicable, because a Phase II was not proposed. However, non-federal agencies which could provide funds include the Oklahoma Conservation Commission, Tulsa Metropolitan Utility Authority, Oklahoma Water Resources Board, Oklahoma Department of Environmental Quality, Arkansas Soil and Water Conservation Commission, and Arkansas Department of Pollution Control and Ecology.

II.6 Relationship of Proposed Project to Local, State, Regional, and/or Federal Programs Related to the Project

No Phase II project was proposed. However, the OCC, in an agreement with the Tulsa Metropolitan Utility Authority, will model the system and develop a watershed management plan. Section 319 grants will be pursued to implement the watershed management plan.

II.7 Summary of Public Participation Activities

On July 17, 1993, the initial public meeting prior to the start of the study was conducted by the Oklahoma Conservation Commission and the Delaware County Conservation District. This presentation summarized the goals and methodology of the Phase I Clean Lakes study. On November 5, 1996, the results of the Clean Lakes Project were presented to the Tulsa Metropolitan Utility Authority. Upon final approval of the report by EPA, a public meeting will be held to present the results of the study.

II.8 Operation and Maintenance Plan and Time Frame for the State to Follow

Since no formal Phase II project was proposed, no O&M plan and time frame were developed.

II.9 Copies of all Permits or Pending Permits Necessary to Satisfy the Requirements of Section 404 of the Act

The recommendations set forth did not necessitate any section 404 permits.

III. PROJECT ENVIRONMENTAL EVALUATION

III.1 Displacement of People

The remediation recommendations put forth here should not displace people, but will impact lifestyles and cost of living expenses of many people. For example, changes in agricultural practices will impact the poultry industry while implementing point source criteria could and likely will cost the discharge contributors more.

III.2 Defacement of Residences and Residential Areas, Available and Applied Mitigative Actions

The proposed remediation should not deface existing residences or residential areas. The recommendations put forth include working with state agencies to implement buffer zones along the riparian areas along the tributaries to Lake Eucha. Each buffer zone needs to be customized to existing conditions on a site-specific basis; therefore, mitigative actions are unforeseen.

III.3 Changes in Land Use Patterns

The remediation proposed in this report will require a change in land use practices, especially for the agricultural industry. Implementation of BMPs will require extensive involvement by the conservation agencies (e.g., Natural Resources Conservation Service, Oklahoma and Arkansas Departments of Agriculture, Oklahoma Conservation Commission, Arkansas Soil and Water Conservation Commission, Oklahoma Department of Environmental Quality, Arkansas Department of Pollution Control and Ecology, Oklahoma Water Resources Board).

III.4 Impact on Prime Agricultural Land

The change in agricultural practices will affect a significant portion of land. However, the remediation does not include a reduction in production from the land, thus adverse affects are not anticipated. However, operation costs may increase due to restrictions on land application of wastes and/or new costs of transport and disposal of such wastes.

III.5 Impact on Park Land, Public Land, and Scenic Value Lands

The changes recommended here should not impact these land categories, but enhance them.

III.6 Impacts on Lands or Structures of Historic, Architectural, Archeological, or Cultural Value

While the State Historical Society was not contacted, it was assumed that the project will not impact any such structures as listed above. However, if construction activities are necessary for the implementation of BMPs or upgrading wastewater treatment plants, an assessment will be performed at the site prior to approval of the construction activities to determine its historical significance.

III.7 Long Term Energy Impacts

The recommendations should not lead to a significant increase in energy demands.

III.8 Short and Long Term Ambient Air Quality and Noise Level Impacts

The recommendations should not result in significant, adverse changes in the short or long term ambient air quality or noise level. In fact, implementation of BMPs may actually improve the air quality associated with poultry operations and the land application of animal wastes.

III.9 Short and Long Term Impacts of In-Lake Chemical Treatment

No in-lake treatment was recommended; therefore, adverse effects are not implied.

III.10 Flood Plain Impacts

The project does not include construction of devices in the floodplain that would impact current flood control capacities.

III.11 Impacts From Dredging Activities

No dredging activities were recommended.

III.12 Wetland, Fish and Wildlife, Endangered Species Impacts

The recommended management targeted land use changes and reduction of phosphorous loads. Impacts on wetlands from this management should be neglible. However, installation of sedimentation ponds for nutrient retention could effect current wetlands or form new ones.

These implications will be on a site specific basis. Appropriate agencies will be contacted and appropriate actions will be taken to protect existing wetlands should this occur.

III.13 Feasible Alternatives to Project

The proposed management is believed to be the optimum alternative based on cost-effectiveness, environmental impacts, commitment of resources, public interest, and costs. Other treatments, such as in-lake treatment, would be cost-prohibitive and could require large quantities of chemicals. Furthermore, such treatments would be only short term, symptomatic approaches.

III.14 Other Measures and Impacts Not Previously Discussed

None.

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APPENDIX A

MAP SHOWING LOCATIONS OF BENTHIC MACROINVERTEBRATE COLLECTIONS


LAKE EUCHA
A
B
C
SCALE OF MILES
A = Lacustrine Zone
B = Transition Zone
C = Riverine Zone

APPENDIX B

LAKE EUCHA TEMPERATURE AND DISSOLVED OXYGEN PROFILES

Sample Date: March 10, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	10.7	10.9
Hwy 10	1.00	10.7	10.8
Hwy 10	2.00	10.7	10.8
Hwy 10	3.00	10.6	10.8
Hwy 10	4.00	9.1	11.6
Hwy 10	5.00	8.8	11.6
Hwy 10	6.00	8.7	11.5

Sample Date: April 13, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	13.3	10.6
Hwy 10	1.00	13	10.9
Hwy 10	2.00	12.8	10.4
Hwy 10	3.00	11.1	10.2
Hwy 10	4.00	10	9
Hwy 10	5.00	9.9	8.8
Hwy 10	6.00	9.8	8.8

Sample Date: May 12, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	13	9
Hwy 10	1.00	13	8.6
Hwy 10	2.00	13	8.6
Hwy 10	3.00	13	8.6
Hwy 10	4.00	12.8	8.5
Hwy 10	5.00	12.8	8.5
Hwy 10	6.00	12.8	8.5
Hwy 10	6.50	12.8	8.5

Sample Date-. May 26, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	18	10.2
Hwy 10	1.00	18	10
Hwy 10	2.00	18	9.8
Hwy 10	3.00	17	7.6
Hwy 10	4.00	16.5	5.8
Hwy 10	5.00	16	5.4
Hwy 10	6.00	16	4.6
Hwy 10	6.50	16	4.5

Sample Date: June 8, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	22	10.3
Hwy 10	1.00	22	10.3
Hwy 10	2.00	21.5	9.9
Hwy 10	3.00	18.5	7.4
Hwy 10	4.00	18	7.7
Hwy 10	5.00	16.8	6.9
Hwy 10	6.00	16.8	6.8
Hwy 10	6.50	16.8	6.7

Sample Date: June 27, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	25.2	11.7
Hwy 10	1.00	25.1	11.9
Hwy 10	2.00	24	11.4
Hwy 10	3.00	22	9.9
Hwy 10	4.00	20.8	8
Hwy 10	5.00	19.8	7.4
Hwy 10	6.00	17.6	0.6

Sample Date: July 14, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	27.5	11
Hwy 10	1.00	27.5	10.8
Hwy 10	2.00	27	8.6
Hwy 10	3.00	25	4.7

Sample Date: July 28, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	30	10.5
Hwy 10	1.00	30	10.6
Hwy 10	2.00	30	10.2
Hwy 10	3.00	28	5.1

Hwy 10	4.00	23	6
Hwy 10	5.00	22.2	3.7
Hwy 10	6.00	22	2.8

Hwy 10	4.00	26	4.8
Hwy 10	5.00	23	0.3
Hwy 10	6.00	21	0.2

Sample Date: August 25, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	29	7
Hwy 10	1.00	29	7
Hwy 10	2.00	29	6.8
Hwy 10	3.00	28.3	3.25
Hwy 10	4.00	26	2.2
Hwy 10	5.00	24	0.2
Hwy 10	6.00	23.5	0.2

Sample Date: September 8, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	26.3	8.6
Hwy 10	1.00	26.3	8.6
Hwy 10	2.00	26.3	8.45
Hwy 10	3.00	26	5.7
Hwy 10	4.00	25.5	4.7
Hwy 10	5.00	24.5	5.7
Hwy 10	6.00	24	4.5

Sample Date: September 22, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	23.4	11.7
Hwy 10	1.00	23.5	11.6
Hwy 10	2.00	22.5	9.8
Hwy 10	3.00	22.1	7.9
Hwy 10	4.00	21.2	7.4
Hwy 10	5.00	20.8	6.8
Hwy 10	5.50	20.8	6.6

Sample Date: October 27, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	15.8	10.8
Hwy 10	1.00	15.8	10.8
Hwy 10	2.00	15.8	10.8
Hwy 10	3.00	15.8	10.8
Hwy 10	4.00	15.8	10.8
Hwy 10	5.00	15.8	10.8
Hwy 10	5.50	15.8	10.8

Sample Date: November 10, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10		
Hwy 10	1.00	11.0	11.3
Hwy 10	2.00	11.0	11.3
Hwy 10	3.00	11.0	11.4
Hwy 10	4.00	11.0	11.5
Hwy 10	5.00	11.0	11.6
Hwy 10	5.50	11.0	12.0

Sample Date: December 15, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	8.0	11.6
Hwy 10	1.00	8.0	11.6
Hwy 10	2.00	8.0	11.6
Hwy 10	3.00	8.0	11.6
Hwy 10	4.00	8.0	11.6
Hwy 10	5.00	8.0	11.6
Hwy 10	5.50	8.0	11.6

Sample Date: January 12, 1994

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	4.5	11.4
Hwy 10	1.00	4.5	11.4
Hwy 10	2.00	4.5	11.4
Hwy 10	3.00	4.0	11.5
Hwy 10	4.00	3.8	12.0
Hwy 10	5.00	3.5	12.0
Hwy 10	6.00	3.7	12.0

Sample Date: February 16, 1994

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Hwy 10	0.10	5.0	14.0
Hwy 10	1.00	6.1	14.1
Hwy 10	2.00	6.0	14.4
Hwy 10	3.00	6.0	14.4
Hwy 10	4.00	6.0	14.4
Hwy 10	5.00	5.5	14.4
Hwy 10	6.00	5.5	14.4

Sample Date: March 10, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	8.1	12.8
Sawmill Pt.	1.00	8.1	12.7
Sawmill Pt.	2.00	8.1	12.7
Sawmill Pt.	3.00	8.1	12.7
Sawmill Pt.	4.00	8.1	12.6
Sawmill Pt.	5.00	8.0	12.6
Sawmill Pt.	6.00	8.1	12.6
Sawmill Pt.	7.00	8.1	12.6
Sawmill Pt.	8.00	8.0	12.5
Sawmill Pt.	9.00	8.0	12.5
Sawmill Pt.	10.00	8.0	12.5
Sawmill Pt.	11.00	7.9	12.5
Sawmill Pt.	12.00	7.9	12.4
Sawmill Pt.	13.00	7.9	12.4
Sawmill Pt.	14.00	7.9	12.3
Sawmill Pt.	15.00	7.5	12.1
Sawmill Pt.	15.50	7.4	11.7

Sample Date: April 13, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	11.3	10.4
Sawmill Pt.	1.00	11..3	10.4
Sawmill Pt.	2.00	11.3	10.3
Sawmill Pt.	3.00	11.0	10.3
Sawmill Pt.	4.00	10.9	10.2
Sawmill Pt.	5.00	10.8	10.2
Sawmill Pt.	6.00	10.8	10.2
Sawmill Pt.	7.00	10.8	10.2
Sawmill Pt.	8.00	10.6	10.1
Sawmill Pt.	9.00	10.2	10
Sawmill Pt.	10.00	9.6	9.6
Sawmill Pt.	11.00	9.6	9.6
Sawmill Pt.	12.00	9.4	9.6
Sawmill Pt.	13.00	9.4	9.6
Sawmill Pt.	14.00	9.3	9.6
Sawmill Pt.	15.00	9.2	9.2
Sawmill Pt.	16.00	9.1	9.2
Sawmill Pt.	16.50	9.1	8.6

Sample Date: May 12, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	14.8	9.2
Sawmill Pt.	1.00	15	9.1
Sawmill Pt.	2.00	15	9
Sawmill Pt.	3.00	14.8	9
Sawmill Pt.	4.00	14.8	8.9
Sawmill Pt.	5.00	14.8	8.8
Sawmill Pt.	6.00	14.8	8.7
Sawmill Pt.	7.00	14.6	8.5
Sawmill Pt.	8.00	14.0	7.6
Sawmill Pt.	9.00	13.8	7.2
Sawmill Pt.	10.00	12.5	6
Sawmill Pt.	11.00	12.0	5.5
Sawmill Pt.	12.00	12.0	5
Sawmill Pt.	13.00	12.0	5
Sawmill Pt.	14.00	12.0	4.9
Sawmill Pt.	15.00	11.8	4.9

Sample Date: May 26, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	20.0	13.2
Sawmill Pt.	1.00	20.0	13.1
Sawmill Pt.	2.00	19.0	11.9
Sawmill Pt.	3.00	18.5	10.4
Sawmill Pt.	4.00	17.5	8.5
Sawmill Pt.	5.00	16.0	6
Sawmill Pt.	6.00	15.5	5.7
Sawmill Pt.	7.00	15.0	5.3
Sawmill Pt.	8.00	14.8	5.1
Sawmill Pt.	9.00	14.2	4.8
Sawmill Pt.	10.00	14.0	4.2
Sawmill Pt.	11.00	13.2	2.8
Sawmill Pt.	12.00	13.0	2.6
Sawmill Pt.	13.00	13.0	2.6
Sawmill Pt.	14.00	13.0	2.6
Sawmill Pt.	15.00	13.0	2.6

Sawmill Pt.	15.50	11.8	4.8

Sawmill Pt.	15.50	13.0	2.4

Sample Date: June 9, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	22.0	8.8
Sawmill Pt.	1.00	22.0	9.7
Sawmill Pt.	2.00	21.8	9.7
Sawmill Pt.	3.00	21.5	9.6
Sawmill Pt.	4.00	21.2	8.9
Sawmill Pt.	5.00	20.0	5.6
Sawmill Pt.	6.00	17.5	3.5
Sawmill Pt.	7.00	16.0	3.2
Sawmill Pt.	8.00	15.0	2.8
Sawmill Pt.	9.00	14.8	2.4
Sawmill Pt.	10.00	14.0	2.3
Sawmill Pt.	11.00	13.5	0.8
Sawmill Pt.	12.00	13.0	0.3
Sawmill Pt.	13.00	13.0	0.1
Sawmill Pt.	14.00	13.0	0.1
Sawmill Pt.	15.00	13.0	0.1
Sawmill Pt.	15.50	13.0	0.1

Sample Date: June 23, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	26.6	12.1
Sawmill Pt.	1.00	26.6	12.2
Sawmill Pt.	2.00	25.9	10.6
Sawmill Pt.	3.00	23.6	6.7
Sawmill Pt.	4.00	21.0	4.8
Sawmill Pt.	5.00	19.0	2.3
Sawmill Pt.	6.00	18.1	1.2
Sawmill Pt.	7.00	16.4	0.24
Sawmill Pt.	8.00	15.0	0.2
Sawmill Pt.	9.00	14.3	0.1
Sawmill Pt.	10.00	13.9	0.1
Sawmill Pt.	11.00	13.7	0.1
Sawmill Pt.	12.00	13.3	0.1
Sawmill Pt.	13.00	13.1	0.1
Sawmill Pt.	14.00	13.0	0.1
Sawmill Pt.	15.00	13.0	0.1
Sawmill Pt.	15.50	13.0	0.1

Sample Date: July 14,1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	28.0	9.8
Sawmill Pt.	1.00	28.0	9.8
Sawmill Pt.	2.00	27.5	9.2
Sawmill Pt.	3.00	26.0	5.8
Sawmill Pt.	4.00	24.0	3.6
Sawmill Pt.	5.00	22.0	0.2
Sawmill Pt.	6.00	19.0	0.1
Sawmill Pt.	7.00	17.0	0.1

Sample Date: July 28,1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	29.0	9.7
Sawmill Pt.	1.00	29.0	9.7
Sawmill Pt.	2.00	29.0	9.7
Sawmill Pt.	3.00	29.0	9.7
Sawmill Pt.	4.00	26.0	8.2
Sawmill Pt.	5.00	23.0	1
Sawmill Pt.	6.00	20.0	0.3
Sawmill Pt.	7.00	17.0	0.2

Sawmill Pt.	8.00	15.0	0.1
Sawmill Pt.	9.00	14.8	0.1
Sawmill Pt.	10.00	14.0	0.1
Sawmill Pt.	11.00	13.8	0.1
Sawmill Pt.	12.00	13.5	0.1
Sawmill Pt.	13.00	13.2	0.1
Sawmill Pt.	14.00	13.0	0.1
Sawmill Pt.	15.00	13.0	0.1
Sawmill Pt.	16.00	13.0	0.1

Sawmill Pt.	8.00	16.0	0.2
Sawmill Pt.	9.00	15.0	0.2
Sawmill Pt.	10.00	14.0	0.2
Sawmill Pt.	11.00	14.0	0.2
Sawmill Pt.	12.00	13.5	0.2
Sawmill Pt.	13.00	13.0	0.1
Sawmill Pt.	14.00	13.0	0.1
Sawmill Pt.	15.00	13.0	0.1

Sample Date: August 25, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	29.1	8.4
Sawmill Pt.	1.00	29.1	8.4
Sawmill Pt.	2.00	29.1	8.4
Sawmill Pt.	3.00	29.1	8.4
Sawmill Pt.	4.00	28.0	5.2
Sawmill Pt.	5.00	26.3	2.3
Sawmill Pt.	6.00	21.0	0.2
Sawmill Pt.	7.00	18.7	0.18
Sawmill Pt.	8.00	16.7	0.15
Sawmill Pt.	9.00	15.0	0.15
Sawmill Pt.	10.00	14.3	0.1
Sawmill Pt.	11.00	14.0	0.1
Sawmill Pt.	12.00	13.8	0.1
Sawmill Pt.	13.00	13.8	0.1
Sawmill Pt.	14.00	13.8	0.1
Sawmill Pt.	15.00	13.8	0.1

Sample Date: September 8, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	26.0	7.7
Sawmill Pt.	1.00	26.0	7.7
Sawmill Pt.	2.00	26.0	7.6
Sawmill Pt.	3.00	26.0	7.6
Sawmill Pt.	4.00	26.0	7.4
Sawmill Pt.	5.00	25.5	4.6
Sawmill Pt.	6.00	21.5	0.25
Sawmill Pt.	7.00	18.2	0.2
Sawmill Pt.	8.00	16.0	0.15
Sawmill Pt.	9.00	15.0	0.1
Sawmill Pt.	10.00	14.0	0.1
Sawmill Pt.	11.00	14.0	0.1
Sawmill Pt.	12.00	13.5	0.1
Sawmill Pt.	13.00	13.0	0.1
Sawmill Pt.	14.00	13.0	0.1
Sawmill Pt.	15.00	13.0	0.1

Sample Date: September 22, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)

Sample Date: October 27, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)

Sawmill Pt.	0.10	22.3	8.9
Sawmill Pt.	1.00	22.3	8.8
Sawmill Pt.	2.00	22.1	8.6
Sawmill Pt.	3.00	21.8	6.1
Sawmill Pt.	4.00	21.3	5.6
Sawmill Pt.	5.00	21.0	4.9
Sawmill Pt.	6.00	19.8	2.9
Sawmill Pt.	7.00	19.1	3.1
Sawmill Pt.	8.00	17.5	0.2
Sawmill Pt.	9.00	16.5	0.1
Sawmill Pt.	10.00	16.0	0.1
Sawmill Pt.	11.00	14.8	0.1
Sawmill Pt.	12.00	13.9	0.1
Sawmill Pt.	13.00	13.8	0.1
Sawmill Pt.	14.00	13.8	0.1
Sawmill Pt.	15.00	13.7	0.1

Sawmill Pt.	0.10	16.8	6.8
Sawmill Pt.	1.00	16.8	6.8
Sawmill Pt.	2.00	16.8	6.8
Sawmill Pt.	3.00	16.8	6.8
Sawmill Pt.	4.00	16.8	6.6
Sawmill Pt.	5.00	16.8	6.8
Sawmill Pt.	6.00	16.8	6.8
Sawmill Pt.	7.00	16.8	6.7
Sawmill Pt.	8.00	16.8	6.7
Sawmill Pt.	9.00	16.8	6.4
Sawmill Pt.	10.00	16.8	6.1
Sawmill Pt.	11.00	16.0	1.0
Sawmill Pt.	12.00	14.8	0.3
Sawmill Pt.	13.00	14.1	0.2
Sawmill Pt.	14.00	14.1	0.2
Sawmill Pt.	15.00	14.1	0.2
Sawmill Pt.	16.00	14.0	0.2

Sample Date: November 10, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	12.0	8.1
Sawmill Pt.	1.00	12.0	8.0
Sawmill Pt.	2.00	12.0	8.0
Sawmill Pt.	3.00	12.0	8.0
Sawmill Pt.	4.00	12.0	8.0
Sawmill Pt.	5.00	12.0	8.0
Sawmill Pt.	6.00	12.0	8.0
Sawmill Pt.	7.00	12.0	8.0
Sawmill Pt.	8.00	12.0	8.0
Sawmill Pt.	9.00	12.0	7.8
Sawmill Pt.	10.00	12.0	7.7
Sawmill Pt.	11.00	11.8	7.8
Sawmill Pt.	12.00	11.5	8.0
Sawmill Pt.	13.00	11.5	8.2
Sawmill Pt.	14.00	11.5	8.2
Sawmill Pt.	15.00	11.5	8.1
Sawmill Pt.	16.00	14.0	2.0

Sample Date: December 15, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	8.2	12.2
Sawmill Pt.	1.00	8.2	12.0
Sawmill Pt.	2.00	8.2	11.8
Sawmill Pt.	3.00	8.2	11.9
Sawmill Pt.	4.00	8.2	11.8
Sawmill Pt.	5.00	8.2	11.8
Sawmill Pt.	6.00	8.2	11.8
Sawmill Pt.	7.00	8.2	11.8
Sawmill Pt.	8.00	8.2	11.8
Sawmill Pt.	9.00	8.2	11.8
Sawmill Pt.	10.00	8.2	11.8
Sawmill Pt.	11.00	8.2	11.8
Sawmill Pt.	12.00	8.2	11.8
Sawmill Pt.	13.00	8.2	11.8
Sawmill Pt.	14.00	8.2	11.8
Sawmill Pt.	15.00	8.2	11.8
Sawmill Pt.	16.00	8.2	11.8

Sample Date: January 12, 1994

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	3.2	12.1
Sawmill Pt.	1.00	3.2	12.1
Sawmill Pt.	2.00	3.2	12.1
Sawmill Pt.	3.00	3.2	12.1
Sawmill Pt.	4.00	3.2	12.1
Sawmill Pt.	5.00	3.2	12.1
Sawmill Pt.	6.00	3.2	12.1
Sawmill Pt.	7.00	3.2	12.1
Sawmill Pt.	8.00	3.2	12.1
Sawmill Pt.	9.00	3.2	12.1
Sawmill Pt.	10.00	3.2	12.1
Sawmill Pt.	11.00	3.2	12.1
Sawmill Pt.	12.00	3.2	12.0
Sawmill Pt.	13.00	3.0	11.9
Sawmill Pt.	14.00	3.0	11.9
Sawmill Pt.	15.00	3.0	11.0

Sample Date: Febuary 16, 1994

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Sawmill Pt.	0.10	4.0	14.2
Sawmill Pt.	1.00	4.0	14.2
Sawmill Pt.	2.00	4.0	14.2
Sawmill Pt.	3.00	4.0	14.2
Sawmill Pt.	4.00	4.0	14.2
Sawmill Pt.	5.00	4.0	14.2
Sawmill Pt.	6.00	4.0	14.2
Sawmill Pt.	7.00	4.0	14.2
Sawmill Pt.	8.00	4.0	14.2
Sawmill Pt.	9.00	4.0	14.1
Sawmill Pt.	10.00	4.0	14.1
Sawmill Pt.	11.00	4.0	14.0
Sawmill Pt.	12.00	4.0	13.9
Sawmill Pt.	13.00	4.0	13.9
Sawmill Pt.	14.00	4.0	13.9
Sawmill Pt.	15.00	4.0	13.9

Sawmill Pt.	16.00	4.0	13.8

Sample Date: March 10, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	6.7	13.1
Dam	1.00	6.7	13.1
Dam	2.00	6.6	13.1
Dam	3.00	6.6	03
Dam	4.00	6.5	13
Dam	5.00	6.4	12.9
Dam	6.00	6.4	12.8
Dam	7.00	6.4	12.7
Dam	8.00	6.3	12.7
Dam	9.00	6.2	12.6
Dam	10.00	6.2	12.5
Dam	11.00	6.0	12.3
Dam	12.00	5.9	12.2
Dam	13.00	5.9	12.0
Dam	14.00	5.8	12
Dam	15.00	5.8	11.9
Dam	16.00	5.8	11.9
Dam	17.00	5.8	11.9
Dam	18.00	5.8	11.9
Dam	19.00	5.8	11.9
Dam	20.00	5.8	11.9
Dam	21.00	5.8	11.9
Dam	22.00	5.8	11.9
Dam	22.50	5.8	11.8

Sample Date: April 13, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	12.0	10.4
Dam	1.00	12.0	10.4
Dam	2.00	12.0	10.4
Dam	3.00	12.0	10.4
Dam	4.00	12.0	10.4
Dam	5.00	12.0	10.4
Dam	6.00	12.0	10.4
Dam	7.00	12.0	10.4
Dam	8.00	12.0	10.4
Dam	9.00	11.8	10.4
Dam	10.00	11.8	10.4
Dam	11.00	11.8	10.4
Dam	12.00	11.6	10.2
Dam	13.00	11.0	10.1
Dam	14.00	10.6	10.1
Dam	15.00	10.0	9.9
Dam	16.00	9.6	99
Dam	17.00	9.3	9.8
Dam	18.00	9.2	9.7
Dam	19.00	9.0	9.5
Dam	20.00	8.8	9.2
Dam	21.00	8.8	9.2
Dam	22.00	8.7	9.2
Dam	22.50	8.3	8.6

Sample Date: May 12, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	16.0	8.9
Dam	1.00	16.0	8.8
Dam	2.00	16.0	8.5
Dam	3.00	15.5	8.8
Dam	4.00	15.5	8.7
Dam	5.00		8.3
Dam	6.00	15.0	8.1
Dam	7.00	15.0	8.1
Dam	8.00	14.0	7.2
Dam	9.00	13.5	6.9
Dam	10.00	13.0	6.4
Dam	11.00	12.5	6.3
Dam	12.00	12.0	6.8
Dam	13.00	12.0	6.9
Dam	14.00	11.8	7.1
Dam	15.00	11.5	6.7
Dam	16.00	11.5	6.3
Dam	17.00	11.3	6.1
Dam	18.00	11.2	5.8
Dam	19.00	11.0	5.8
Dam	20.00	11.0	5.7
Dam	21.00	11.0	5.5
Dam	22.00	10.8	4.3

Sample Date: May 26, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	21.0	11.6
Dam	1.00	21.0	11.6
Dam	2.00	21.0	11.5
Dam	3.00	21.0	11.
Dam	4.00	21.0	1.4
Dam	5.00	17.5	7.6
Dam	6.00	16.8	6.9
Dam	7.00	16.0	5.9
Dam	8.00	15.0	5.2
Dam	9.00	14.5	4.8
Dam	10.00	14.0	4.6
Dam	11.00	13.5	4.4
Dam	12.00	13.0	4.4
Dam	13.00	13.0	4.4
Dam	14.00	13.0	4.4
Dam	15.00	12.8	4.6
Dam	16.00	12.5	4.5
Dam	17.00	12.5	4.3
Dam	18.00	12.5	4.2
Dam	19.00	12.5	4.0
Dam	20.00	12.0	3.8
Dam	21.00	12.0	3
Dam	22.00	12.0	2.2
Dam	23.00	11.5	2.2

Sample Date: June 9, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	23.0	10.2
Dam	1.00	23.0	10
Dam	2.00	22.8	9.7
Dam	3.00	22.8	9.4
Dam	4.00	22.5	8.7
Dam	5.00	18.0	3.6
Dam	6.00	16.0	3.2
Dam	7.00	15.0	2.8
Dam	8.00	14.8	2.7
Dam	9.00	14.2	2.7
Dam	10.00	13.8	2.8
Dam	11.00	13.2	2.8
Dam	12.00	13.0	2.7
Dam	13.00	13.0	2.7
Dam	14.00	13.0	2.7
Dam	15.00	12.8	2.8
Dam	16.00	12.8	2.8
Dam	17.00	12.5	2.5
Dam	18.00	12.5	2.3
Dam	19.00	12.2	2
Dam	20.00	12.0	0.9
Dam	21.00	12.0	0.3
Dam	22.00	11.8	0.1
Dam	23.00	11.8	0.1

Sample Date: June 23, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	27.7	11.2
Dam	1.00	27.7	11.2
Dam	2.00	27.7	11.2
Dam	3.00	27.6	11.1
Dam	4.00	20.7	3.4
Dam	5.00	17.6	0.5
Dam	6.00	17.0	0.4
Dam	7.00	16.0	0.4
Dam	8.00	15.0	0.6
Dam	9.00	14.2	1.2
Dam	10.00	14.0	0.9
Dam	11.00	13.6	1.1
Dam	12.00	13.4	1.3
Dam	13.00	13.2	1.5
Dam	14.00	13.0	1.3
Dam	15.00	13.0	1.3
Dam	16.00	13.0	1.1
Dam	17.00	12.6	0.9
Dam	18.00	12.3	0.4
Dam	19.00	12.2	0.3
Dam	20.00	12.1	0.2
Dam	21.00	12.0	0.1
Dam	22.00	12.0	0.1

Sample Date: July 14, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	28.0	9.3
Dam	1.00	28.0	9.3
Dam	2.00	28.0	9.3
Dam	3.00	28.0	9.3
Dam	4.00	28.0	9
Dam	5.00	28.0	0.3
Dam	6.00	19.5	0.1
Dam	7.00	17.0	0.1
Dam	8.00	16.0	0.1
Dam	9.00	15.0	0.1
Dam	10.00	14.0	0.1
Dam	11.00	14.0	0.1
Dam	12.00	13.8	0.1
Dam	13.00	13.5	0.1
Dam	14.00	13.2	0.1
Dam	15.00	13.0	0.1
Dam	16.00	13.0	0.1
Dam	17.00	13.0	0.1
Dam	18.00	13.0	0.1
Dam	19.00	12.8	0.1
Dam	20.00	12.5	0.1
Dam	21.00	12.5	0.1
Dam	22.00	12.0	0.1

Sample Date: July 28, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	31.0	8.5
Dam	1.00	31.0	8.5
Dam	2.00	31.0	8.5
Dam	3.00	30.0	8.2
Dam	4.00	25.0	6.6
Dam	5.00	23.0	3.2
Dam	6.00	21.0	1
Dam	7.00	18.5	0.3
Dam	8.00	17.0	0.1
Dam	9.00	15.5	0.1
Dam	10.00	15.0	0.1
Dam	11.00	14.5	0.1
Dam	12.00	14.0	0.1
Dam	13.00	14.0	0.1
Dam	14.00	13.5	0.1
Dam	15.00	13.0	0.1
Dam	16.00	13.0	0.1
Dam	17.00	13.0	0.1
Dam	18.00	13.0	0.1
Dam	19.00	12.5	0.1
Dam	20.00	12.5	0.1
Dam	21.00	12.5	0.1
Dam	22.00	12.3	0.1

Sample Date: August 25, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	29.9	8
Dam	1.00	29.9	8
Dam	2.00	29.9	8
Dam	3.00	29.9	8
Dam	4.00	29.9	7.9
Dam	5.00	26.9	4
Dam	6.00	23.1	0.1
Dam	7.00	18.5	0.1
Dam	8.00	16.1	0.05
Dam	9.00	14.9	0.05
Dam	10.00	14.1	0.05
Dam	11.00	13.9	0.05
Dam	12.00	13.7	0.05
Dam	13.00	13.5	0.05
Dam	14.00	13.5	0.05
Dam	15.00	13.2	0.05
Dam	16.00	13.0	0.05
Dam	17.00	13.0	0.05
Dam	18.00	12.9	0.05
Dam	19.00	12.8	0.05
Dam	20.00	12.5	0.05
Dam	21.00	12.3	0.05
Dam	22.00	12.3	0.05
Dam	23.00	12.3	0.05
Dam	24.00	12.3	0.05

Sample Date: September 8, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	25.3	6.8
Dam	1.00	25.3	6.7
Dam	2.00	25.3	6.7
Dam	3.00	25.3	6.7
Dam	4.00	25.3	6.6
Dam	5.00	25.0	3
Dam	6.00	24.0	0.2
Dam	7.00	20.0	0.1
Dam	8.00	16.0	0.1
Dam	9.00	15.0	0.1
Dam	10.00	14.0	0.1
Dam	11.00	13.7	0.1
Dam	12.00	13.5	0.1
Dam	13.00	13.5	0.1
Dam	14.00	13.0	0.1
Dam	15.00	13.0	0.1
Dam	16.00	13.0	0.1
Dam	17.00	12.8	0.1
Dam	18.00	12.5	0.1
Dam	19.00	12.5	0.1
Dam	20.00	12.0	0.1
Dam	21.00	12.0	0.1

Sample Date: September 23, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	23.6	9.5
Dam	1.00	23.6	9.5
Dam	2.00	23.5	9.4
Dam	3.00	23.5	9.4
Dam	4.00	23.5	9.4
Dam	5.00	23.5	9.4
Dam	6.00	23.5	9.2
Dam	7.00	20.4	0.2
Dam	8.00	18.0	0.2
Dam	9.00	6.1	0.1
Dam	10.00	15.0	0.1
Dam	11.00	14.2	0.1
Dam	12.00	13.8	0.1
Dam	13.00	13.6	0.1
Dam	14.00	13.5	0.1
Dam	15.00	13.2	0.1
Dam	16.00	13.0	0.1
Dam	17.00	12.8	0.1
Dam	18.00	12.7	0.1
Dam	19.00	12.7	0.1
Dam	20.00	12.6	0.1
Dam	21.00	12.5	0.1
Dam	22.00	12.3	0.1

Sample Date: October 27, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	16.8	5.9
Dam	1.00	16.8	5.9
Dam	2.00	16.8	5.8
Dam	3.00	16.8	5.7
Dam	4.00	16.8	5.7
Dam	5.00	16.8	5.6
Dam	6.00	16.8	5.6
Dam	7.00	16.8	5.5
Dam	8.00	16.8	3.2
Dam	9.00	16.6	1.3
Dam	10.00	16.4	0.3
Dam	11.00	15.1	0.2
Dam	12.00	14.5	0.2
Dam	13.00	14.0	0.2
Dam	14.00	14.0	0.2
Dam	15.00	14.0	0.2
Dam	16.00	13.9	0.2
Dam	17.00	13.5	0.2
Dam	18.00	13.2	0.2
Dam	19.00	13.2	0.2
Dam	20.00	13.0	0.2
Dam	21.00	13.0	0.2
Dam	22.00	12.9	0.2

Sample Date: November 10, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	12.2	5.8
Dam	1.00	12.2	5.7
Dam	2.00	12.2	5.7
Dam	3.00	12.2	5.7
Dam	4.00	12.2	5.7
Dam	5.00	12.2	5.7
Dam	6.00	12.2	5.6
Dam	7.00	12.2	5.6
Dam	8.00	12.2	5.6
Dam	9.00	12.2	5.5
Dam	10.00	12.2	5.5
Dam	11.00	12.2	5.4
Dam	12.00	12.2	5.4
Dam	13.00	12.2	5.4
Dam	14.00	12.2	5.4
Dam	15.00	12.2	5.4
Dam	16.00	12.2	5.4
Dam	17.00	12.2	5.5
Dam	18.00	12.2	5.5
Dam	19.00	12.1	5.5
Dam	20.00	12.1	5.5
Dam	21.00	12.0	5.7
Dam	22.00	12.0	5.0

Sample Date: December 15, 1993

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	8.4	11.6
Dam	1.00	8.0	12.0
Dam	2.00	8.5	11.5
Dam	3.00	8.5	11.6
Dam	4.00	8.5	11.6
Dam	5.00	8.5	11.6
Dam	6.00	8.5	11.6
Dam	7.00	8.5	11.6
Dam	8.00	8.5	11.6
Dam	9.00	8.5	11.6
Dam	10.00	8.5	11.6
Dam	11.00	8.5	11.6
Dam	12.00	8.5	11.6
Dam	13.00	8.5	11.6
Dam	14.00	8.5	11.6
Dam	15.00	8.5	11.6
Dam	16.00	8.5	11.6
Dam	17.00	8.5	1.4
Dam	18.00	8.5	1.4
Dam	19.00	8.5	1.4
Dam	20.00	8.5	11.4
Dam	21.00	8.5	11.4
Dam	22.00	8.5	9.9

Sample Date: January 12, 1994

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	3.5	11.7
Dam	1.00	3.9	11.6
Dam	2.00	3.9	11.6
Dam	3.00	3.9	11.6
Dam	4.00	3.9	11.5
Dam	5.00	3.9	11.5
Dam	6.00	3.9	11.5
Dam	7.00	3.9	11.5
Dam	8.00	3.9	11.5
Dam	9.00	3.9	11.5
Dam	10.00	3.9	11.5
Dam	11.00	3.9	11.4
Dam	12.00	3.9	11.4
Dam	13.00	3.9	11.4
Dam	14.00	3.9	11.3
Dam	15.00	3.9	11.3
Dam	16.00	3.9	11.3
Dam	17.00	3.9	11.3
Dam	18.00	3.9	11.3
Dam	19.00	3.9	11.3
Dam	20.00	3.9	11.3
Dam	21.00	3.9	11.2
Dam	22.00	3.9	11.2

Sample Date: February 16, 1994

Site	Depth (m)	Temp. (°C)	D.O. (mg/l)
Dam	0.10	3.9	13.9
Dam	1.00	4.0	14.0
Dam	2.00	4.0	14.1
Dam	3.00	4.0	14.1
Dam	4.00	4.0	14.2
Dam	5.00	4.0	14.2
Dam	6.00	4.0	14.2
Dam	7.00	4.0	14.2
Dam	8.00	4.0	14.2
Dam	9.00	4.0	14.2
Dam	10.00	4.0	14.2
Dam	11.00	4.0	14.1
Dam	12.00	4.0	14.1
Dam	13.00	4.0	14.1
Dam	14.00	4.0	14.0
Dam	15.00	4.0	14.0
Dam	16.00	4.0	14.0
Dam	17.00	4.0	14.0
Dam	18.00	4.0	14.0
Dam	19.00	4.0	14.0
Dam	20.00	4.0	14.0
Dam	21.00	4.0	14.0
Dam	22.00	4.0	14.0

APPENDIX C

LAKE EUCHA CHLOROPHYLL DATA

Surface Chlorophyll Concentrations (ug/l) in Lake

Date	Highway 10	Sawmill Pt.	Dam
4/13/93	10.35	11.49	6.78
5/12/93	1.02	12.78	12.14
5/26/93	19.81	28.70	16.21
6/9/93	43.18	24.79	39.02
6/23/93	12.27	10.95	13.46
7/14/93	28.86	18.63	15.71
7/28/93	18.82	15.19	7.78
8/11/93	19.66	13.11	9.29
8/25/93	3.28	9.13	6.92
9/8/93	3.36	3.02	2.69
9/22/93	14.26	18.95	6.11
10/27/9	3.85	6.64	7.14
11/10/9	22.76	9.44	3.18
12/15/9	1.35	8.22	3.55
1/12/94	10.55	21.79	21.87
2/16/94	17.70	17.30	18.50
Mean	14.44	14.38	11.90
Low	1.02	3.02	2.35
High	43.18	28.70	39.02

Surface Chlorophyll Concentrations (ug/l) in Lake Eucha

Date	Dam
7/1/87	5.90
10/1/87	4.70
1/1/88	3.90
4/1/88	2.00
7/1/88	3.80
10/1/88	5.60
1/1/89	26.40
4/1/89	3.60
7/1/89	4.20
10/1/89	5.40
1/1/90	12.80
4/1/90	7.80
7/1/90	3.40
10/1/90	11.20
2/1/91	4.30
5/1/91	21.60
8/28/91	5.80
11/25/91	11.10
3/10/92	4.50
5/29/92	0.80
8/12/92	3.80
Mean	**7.27**
Low	**0.80**
High	**26.40**

APPENDIX D

LAKE EUCHA WATER QUALITY DATA

Lake Eucha Water Quality Data

Site	Date	Cond. (uS/cm)	pH (S.U.)	Alk. (mg/l	Turb. (NTU)	Hard. (mg/l	Cl (mg/l	TDS (mg/l	TSS (mg/l	NO2+NO3 (mg/l)	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l	TN:TP
Hwy 10 (top)	3/10/93	203	7.9	81	9.4	92	6.5	142	<1.0	2.30	0.40	2.70	5.9	0.02	0.02	135
Hwy 10 (bottom)	3/10/93	187	7.8													
Hwy 10 (top)	4/13/93	230	8.1	80	3.3			141	25.0	1.70	0.60	2.30		0.04	0.02	58
Hwy 10 (bottom)	4/13/93	210	8.1	74	6.7			147	25.0	1.80	0.60	2.40		0.05	0.01	48
Hwy 10 (top)	5/12/93	200	7.8	66	14.0		4.6	138	3.0	1.90	0.30	2.20	4.9	0.07	0.06	31
Hwy 10 (bottom)	5/12/93	200	7.7	70	12.0											
Hwy 10 (top)	5/26/93	215	8.0	66	14.0				8.0	1.60	<0.20	1.60		0.02	0.01	80
Hwy 10 (bottom)	5/26/93	240	7.8	70	12.0				11.0	1.40	<0.20	1.40		0.02	<0.01	70
Hwy 10 (top)	6/9/93	200	8.2	78	4.4		5.2	111	3.0	0.85	0.30	1.15	4.4	0.04	<0.01	29
Hwy 10 (bottom)	6/9/93	240	7.7	88	26.0		6.0	169	39.0	2.00	0.20	2.20	4.7	0.09	0.06	24
Hwy 10 (top)	6/23/93	182	8.3	74	2.5				3.0	0.71	0.40	1.11		0.02	0.01	56
Hwy 10 (bottom)	6/23/93	240	7.7	96	6.5				41.0	0.82	0.30	1.12		0.02	0.03	56
Hwy 10 (top)	7/14/93	170	8.0	38	3.2		5.6	230	49.0	0.47	0.50	0.97	4.2	0.03	<0.01	32
Hwy 10 (bottom)	7/14/93	240	7.5	98	12.0					0.66	0.40	1.06		0.03	<0.01	35
Hwy 10 (top)	7/28/93	165	8.3	58	2.7				2.0	0.20	0.40	0.60		0.02	<0.01	30
Hwy 10 (bottom)	7/28/93	240	7.8	108	9.7				19.0	0.09	1.10	1.19		0.04	0.02	30
Hwy 10 (top)	8/11/93						5.3	106	3.0	<0.05	0.50	0.50	4.2	0.03	<0.01	17
Hwy 10 (bottom)	8/11/93						6.7	170	10.0	<0.05	1.70	1.70		0.11	<0.01	15
Hwy 10 (top)	8/25/93	180	7.9	80	4.1			102	3.0							
Hwy 10 (bottom)	8/25/93	230	7.5	98	1.4			134	23.0							
Hwy 10 (top)	9/8/93	180	8.3	78	2.5		5.7	114	6.0	<0.05	0.40	0.40	4.1	0.04	<0.01	10
Hwy 10 (bottom)	9/8/93	210	7.8	100	7.4		7.2	166	36.0	1.00	0.50	1.50	4.8	0.08	<0.01	19
Hwy 10 (top)	9/22/93	200	8.1	85	2.5			112	6.0	0.71	0.40	1.11		0.03	<0.01	37
Hwy 10 (bottom)	9/22/93	220	7.7	98	8.5					1.80	0.20	2.00		0.05	0.01	40
Hwy 10 (top)	10/27/93	220	8.1	102	2.6	108	10.0	123	7.5	0.87	0.35	1.22	<5.00	0.03	0.01	41
Hwy 10 (bottom)	10/27/93	230	8.0	92	2.0	110	10.0	145	12.0	0.85	0.34	1.19	<5.00	0.03	0.01	40
Hwy 10 (top)	11/10/93					104	10.6		4.5	0.70	0.36	1.06	<5.00	0.05	<0.01	21
Hwy 10 (bottom)	11/10/93	230	8.0	98	3.0	110	10.6		5.0	1.30	0.34	1.64	<5.00	0.05	<0.01	33
Hwy 10 (top)	12/15/93	240	7.8	94	3.1	110	19.0		6.0	2.15	0.28	2.43	5.8	0.04	0.00	61
Hwy 10 (bottom)	12/15/93	260	7.9	86	3.4	106	21.0		9.0	2.15	0.26	2.41	<5.00	0.05	0.00	48
Hwy 10 (top)	1/12/94	220	8.1	100	1.4	112	8.2		4.0	2.20	0.30	2.50	6.0	<0.01	<0.01	500
Hwy 10 (bottom)	1/12/94	230	8.1	92	6.7	110	8.0		24.0	2.00	0.40	2.40	6.2	0.03	<0.01	80
Hwy 10 (top)	2/16/94	230	8.2													
Hwy 10 (bottom)	2/16/94	240	8.1													

Lake Eucha Water Quality Data

Site	Date	Cond. (uS/cm)	pH (S.U.))	Alk. (mg/l	Turb. (NTU)	Hard. (mg/l	Cl (mg/l	TDS (mg/l	TSS (mg/l	NO2+NO3 (mg/l)	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l	TN:TP
Sawmill Pt. (top)	3/10/93	187	8.1	73		90	5.8	118	<1.0	1.70	0.20	1.90	6.1	0.03	<0.01	63
Sawmill Pt. (bottom)	3/10/93	186	8.0													
Sawmill Pt. (top)	4/13/93	200	8.2	72	3.1			124	5.0	1.40	0.50	1.90		0.02	<0.01	95
Sawmill Pt. (bottom)	4/13/93	200	8.2	72	4.1											
Sawmill Pt. (top)	5/12/93	200	7.9	66	9.3		4.8	120	3.0	1.20	0.20	1.40	4.7	0.06	0.03	23
Sawmill Pt. (bottom)	5/12/93	220	7.8	82	2.4											
Sawmill Pt. (top)	5/26/93	200	7.9	66	9.3				3.0	0.92	<0.20	0.92		0.01	<0.01	92
Sawmill Pt. (bottom)	5/26/93	220	7.8	82	2.4				3.0	0.94	0.30	1.24		0.03	0.03	41
Sawmill Pt. (top)	6/9/93	180	8.3	70	2.4		4.7	98	<1.0	0.68	0.30	0.98	4.3	0.03	<0.01	33
Sawmill Pt. (bottom)	6/9/93	220	7.6	81	2.6		5.3	127	2.0	1.00	0.20	1.20	5.0	0.04	0.02	30
Sawmill Pt. (top)	6/23/93	146	8.8	56	1.5					0.45	0.50	0.95		0.02	<0.01	48
Sawmill Pt. (bottom)	6/23/93	230	7.6	92	1.1				4.0	0.53	0.30	0.83		0.07	0.08	12
Sawmill Pt. (top)	7/14/93	180	8.3	60	2.0		5.3	102	8.0	0.45	0.40	0.85	4.3	0.03	<0.01	28
Sawmill Pt. (bottom)	7/14/93	210	7.6	96	2.2					<0.05	0.80	0.80		0.12	0.08	7
Sawmill Pt. (top)	7/28/93	150	8.3	52	1.4				1.0	0.20	0.60	0.80		0.02	<0.01	40
Sawmill Pt. (bottom)	7/28/93	210	7.6	100	1.5				1.0	<0.05	1.00	1.00		0.11	0.08	9
Sawmill Pt. (top)	8/11/93						5.2	104	2.0	<0.05	0.60	0.60	4.4	0.02	<0.01	30
Sawmill Pt. (bottom)	8/11/93						4.6	142	5.0	<0.05	1.60	1.60	3.3	0.20	0.09	8
Sawmill Pt. (top)	8/25/93	160	8.3	58	1.5			86	<1.0	<0.05	0.30	0.30		0.01	<0.01	30
Sawmill Pt. (bottom)	8/25/93	220	7.5	104	6.5			142	11.0	<0.05	1.20	1.20		0.13	0.07	9
Sawmill Pt. (top)	9/8/93	160	8.3	168	1.4		5.5	96	8.0	<0.05	0.30	0.30	4.2	0.03	<0.01	10
Sawmill Pt. (bottom)	9/8/93	200	7.7	104	12.0		4.6	146	8.0	<0.05	1.40	1.40	1.9	0.17	0.10	8
Sawmill Pt. (top)	9/22/93	195	8.0	78	2.5			108	3.0	0.08	0.30	0.38		0.03	<0.01	13
Sawmill Pt. (bottom)	9/22/93	215	7.6	110	17.0			142	2.0	<0.05	1.40	1.40		0.19	0.14	7
Sawmill Pt. (top)	10/27/93	200	7.8	92	2.0	98	10.0	109	5.0	0.31	0.34	0.65	<5.00	0.04	<0.01	16
Sawmill Pt. (bottom)	10/27/93	240	7.6	112	12.0	112	7.5	130	11.8	<2.50	1.88	1.88	<5.00	0.39	0.37	5
Sawmill Pt. (top)	11/10/93	220	8.0	96	1.7	100	9.6		4.0	0.70	0.39	1.09	<5.00	0.04	<0.01	27
Sawmill Pt. (bottom)	11/10/93	220	8.0	96	5.8	105	10.6		17.0	1.70	0.60	2.30	<5.00	0.10	<0.01	23
Sawmill Pt. (top)	12/15/93	220	7.9	94	2.4	100	16.0		5.5	1.16	0.44	1.60	<5.00	0.04	0.00	40
Sawmill Pt. (bottom)	12/15/93	220	7.9	86	3.2	100	18.0		6.5	1.18	0.40	1.58	<5.00	0.04	0.00	40
Sawmill Pt. (top)	1/12/94	190	8.4	90	2.1	107	7.4		11.5	1.20	0.40	1.61	<5.00	<0.01	<0.01	322
Sawmill Pt. (bottom)	1/12/94	200	8.3	88	3.7	110	6.7		12.0	1.30	0.50	1.81	<5.00	0.01	<0.01	181
Sawmill Pt. (top)	2/16/94	200	8.4													
Sawmill Pt. (bottom)	2/16/94	210	8.3													

Lake Eucha Water Quality Parameters

Site	Date	Cond. (uS/cm)	pH (S.U.)	Alk. (mg/l	Turb. (NTU)	Hard. (mg/l	Cl (mg/l	TDS (mg/l	TSS (mg/l	NO2+NO3 (mg/l)	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l	TN:TP
Dam (top)	3/10/93	184	8.1			87	5.4	134	<1.0	1.60	0.30	1.90	5.8	0.03	0.01	63
Dam (bottom)	3/10/93	187	7.9													
Dam (top)	4/13/93	210	8.2	72	2.1			121	10.0	1.40	0.40	1.80		0.02	<0.01	90
Dam (bottom)	4/13/93	200	8.1	74	4.0											
Dam (top)	5/12/93	200	7.9	76	1.8		5.4	111	<1.0	1.10	0.20	1.30	5.1	0.02	<0.01	65
Dam (bottom)	5/12/93	220	7.8	76	2.5											
Dam (top)	5/26/93	175	8.3	76	1.8				7.0	0.81	0.30	1.11		0.03	<0.01	37
Dam (bottom)	5/26/93	215	7.9	76	2.5				<1.0	0.88	<0.2	0.88		<0.01	0.02	176
Dam (top)	6/9/93	160	8.4	60	2.0		4.7	89	8.0	0.55	0.40	0.95	4.5	0.03	<0.01	32
Dam (bottom)	6/9/93	220	7.6				5.9	127	<1.0	1.10	0.40	1.50	5.2	0.05	0.02	30
Dam (top)	6/23/93	137	8.8	55	1.5				<1.0	0.31	0.40	0.71		0.02	<0.01	36
Dam (bottom)	6/23/93	214	7.6	90	1.4				11.0	0.98	0.30	1.28		0.15	0.04	9
Dam (top)	7/14/93	160	8.5	52	2.2		5.1	108	13.0	0.32	0.30	0.62	4.3	0.02	<0.01	31
Dam (bottom)	7/14/93	215	7.7	92	0.7					0.85	0.40	1.25		0.05	0.04	25
Dam (top)	7/28/93	150	8.4	59	1.1				<1.0	0.19	0.30	0.49		0.04	<0.01	12
Dam (bottom)	7/28/93	205	7.7	92	1.0				2.0	0.58	0.50	1.08		0.05	0.04	22
Dam (top)	8/11/93						4.8	91	1.0	0.07	1.70	1.77	4.3	0.02	0.01	88
Dam (bottom)	8/11/93						4.8	138	2.0	0.35	0.60	0.95	4.7	0.06	0.05	16
Dam (top)	8/25/93	160	8.3	66	1.4			82	<1.0	<0.05	0.30	0.30		0.01	<0.01	30
Dam (bottom)	8/25/93	220	7.7	98	1.5			132	8.0	<0.05	0.70	0.70		0.09	0.06	8
Dam (top)	9/8/93	160	8.1	66	1.3		5.2	108	2.0	<0.05	0.30	0.30	4.3	0.03	0.01	10
Dam (bottom)	9/8/93	195	7.7	1000	1.6		4.8	134	5.0	0.06	0.90	0.96	4.3	0.10	0.07	10
Dam (top)	9/22/93	180	7.8	79	1.8			108	2.0	<0.05	0.30	0.30		0.01	<0.01	30
Dam (bottom)	9/22/93	225	7.5	101	2.5			118	5.0	<0.05	1.00	1.00		0.10	0.06	10
Dam (top)	10/27/93	200	7.7	90	1.5	95	9.0	108	<1.0	<0.25	0.37	0.37	<5.0	0.04	<0.01	9
Dam (bottom)	10/27/93	220	7.5	102	9.0	110	9.0	121	9.5	<0.25	0.99	0.99	<5.0	0.21	0.14	5
Dam (top)	11/10/93	220	7.8	90	1.2	100	10.6		2.0	0.60	0.57	1.17	<5.0	0.03	0.02	39
Dam (bottom)	11/10/93		7.9	96	2.0	104	9.6		3.0	0.50	0.50	1.00	<5.0	0.06	0.02	17
Dam (top)	12/15/93	230	7.9	90	1.9	100	16.0		2.7	0.86	0.52	1.38	<5.0	0.03		46
Dam (bottom)	12/15/93	240	7.9	94	2.3	100	16.0		3.7	0.92	0.45	1.37	<5.0	0.05		27
Dam (top)	1/12/94	200	8.3	90	2.0	104	7.2		10.5	1.00	0.60	1.61	<5.0	0.01	<0.01	161
Dam (bottom)	1/12/94	200	8.3	94	2.4	110	7.7		10.5	1.10	0.40	1.51	<5.0	0.03	<0.01	50
Dam (top)	2/16/94	210	8.6													
Dam (bottom)	2/16/94	220	8.5													

APPENDIX E

LAKE EUCHA ALGAL DATA

Lake Eucha Dam Algal Sample Analysis

Date: April 13, 1993

Taxa	Division	GALD (um)	Conc. Unit/ml	Rel. % Conc.	Biov. (uM^3/U)	Rel. % Biov.
Asterionella sp.	Diatom	103.40	52.10	0.30	1,169.20	2.20
Cyclotella sp.	Diatom	8.80	1,632.10	7.90	187.20	10.90
Melosira sp.	Diatom	76.10	191.00	0.90	1,132.10	7.70
Navicula sp.	Diatom	19.80	17.40	0.10	446.90	0.30
Stephanodiscus sp.	Diatom	27.50	17.40	0.10	5,550.70	3.40
Synedra sp.	Diatom	253.00	34.70	0.20	1,942.90	2.40
Ankistrodesmus sp.	Chloro	42.60	69.40	0.30	108.10	0.30
Chlamydomonas sp.	Chloro	6.60	34.70	0.20	150.40	0.20
Crucigenia sp.	Chloro	11.00	17.40	0.10	225.50	0.10
Non-motile chlorococcales	Chloro	4.40	17.40	0.10	44.60	TR
Lagerhemia sp.	Chloro	16.50	17.40	0.10	17.40	TR
Rhodomonas sp.	Crypto	9.90	295.20	1.40	45.90	0.50
Non-motile blue-greens	Cyano	1.10	9,896.50	48.10	0.70	0.20
Gymnodiniam sp.	Dinofl	12.10	34.70	0.20	329.40	0.40
Misc. chlorophyte	Chloro	16.50	833.40	4.10	2,349.40	69.60
Misc. micros, 1 flagellum	Misc.	2.20	3,611.40	17.60	5.60	0.70
Misc. micros, 2 flagella	Misc.	3.30	3,785.00	18.40	8.40	1.10

Lake Eucha Dam Algal Sample Analysis

Date: July 23, 1993

Taxa	Division	GALD (um)	Conc. Unit/ml	Rel. % Conc.	Biov. (uM^3/U)	Rel. % Biov.
Cyclotella sp.	Diatom	6.60	599.00	0.60	79.00	2.90
Nitzschia sp.	Diatom	80.30	78.10	0.10	186.40	0.90
Coelastrum sp.	Chloro	11.00	26.00	TR	178.20	0.30
Cosmarium sp.	Chloro	11.00	26.00	TR	267.50	0.40
Crucigenia sp.	Chloro	15.40	26.00	TR	601.40	0.90
Dictyosphaerium sp.	Chloro	22.00	26.00	TR	133.70	0.20
Golenkinia sp.	Chloro	36.70	364.60	0.40	44.60	1.00
Kirchneeriella sp.	Chloro	13.80	156.30	0.20	87.40	0.80
Micractinium sp.	Chloro	55.00	52.10	0.10	178.20	0.60
Pediastrum sp.	Chloro	15.40	26.00	TR	1,115.10	1.80
Scenedesmus sp.	Chloro	4.40	468.80	0.50	18.80	0.50
Selenastrum sp.	Chloro	5.50	1,432.40	1.60	21.30	1.80
Tetraedron sp.	Chloro	10.70	208.30	0.20	107.20	1.30
Colonial chlorophyta	Chloro	22.00	26.00	TR	601.40	0.90
Non-motile chlorococccales	Chloro	4.40	182.30	0.20	44.60	0.50
Cryptomonas sp.	Chloro	11.00	52.10	0.10	112.70	0.40
Unknown Fil. blue-greens	Cyano	26.00	56,253.80	61.00	23.70	80.40
Non-motile blue greens	Cyano	1.10	25,001.70	27.10	0.70	1.10

Gymnosporidium	Dinofl.	10.30	78.10	0.10	201.20	0.90
Misc. micros, 1 flagella	Misc.	2.20	4,479.50	4.90	5.60	1.50
Misc. micros, 2 flagella	Misc.	2.20	2,630.40	2.90	5.60	0.90

Lake Eucha Dam Algal Sample

Date: October 27, 1993

Taxa	Division	GALD (um)	Conc. Unit/ml	Rel. % Conc.	Biov. (uM^3/U)	Rel. % Biov.
Melosira sp.	Diatom		2200			
Other Centrales	Diatom		900			
Pennales	Diatom		16200			

Lake Eucha Dam Algal Sample

Date: February 16,1994

Taxa	Division	GALD (um)	Conc. Unit/ml	Rel. % Conc.	Biov. (uM^3/U)	Rel. % Biov.
Melosira sp.	Diatom		39400			
Other Centrales	Diatom		9500			
Pennales	Diatom		15500			

APPENDIX F

LAKE EUCHA ZOOPLANKTON DATA

ZOOPLANKTON ABUNDANCE (Organisms per liter) in Lake Eucha
All samples take from Eucha Dam sampling site.

Zooplankton	4/13/93	6/23/93	10/27/93
Copepoda			
Cyclopoids	2.9	11	6.3
Calanoids	0.2	0.2	3.6
nauplii	25.6	44	6.7
Cladocera			
Chydorus	0.1	0	0
Daphnia	0.2	3	0.5
Bosmina	0.1	0	0
Rotifers	common	common	0

ZOOPLANKTON LENGTH (mm) in Lake Eucha
All samples taken from Eucha Dam sampling site.

	6/23/93		10/27/93	
Zooplankton	Mean	sd	Mean	sd
Copepoda				
Calanoids	0.5	0.07	0.67	0.3
Cyclopoids	0.59	0.07	0.55	0.21
Cladocera				
Daphnia	0.79	0.53	0.43	0.06

APPENDIX G

LAKE EUCHA
BENTHIC MACROINVERTEBRATE DATA

Benthic Macroinvertebrates Collected in Lake Eucha

Phyllum	Class	Order	Family	Subfam/Tribe/Genus	Tolerance
ANNELIDA	Oligochaeta		Tubificidae	Limnodrilus	T
				Tubifex	T
				Branchiura	T
				Aulodrilus	T
			Naididae	Dero	T
	Hirudinea		Glossiphoniidae	Helobdella	T
				H. Stagnalis	T
MULLUSCA	Pelecypoda		Sphaeriidae	Sphaerium	I
				Pisidium	I
			Corbiculidae	Corbicula	I
			Unionidae		I
	Gastropoda		Planorbidae		I
ARTHROPODA	Insecta	Ephemoropter	Caenidae	Caenis	I
			Leptophlebiidae	Choroterpes	I
			Ephemeridae	Hexagenia	I
		Megaloptera	Sialidae	Sialis	I
		Trichoptera	Leptoceridae	Decitus	I
			Polycentropodidae		I
		Diptera	Ceratopogonidae		T
			Chironomidae	Tanypodinae	T
				Chironomini	T
				Pseudochironomini	T
				Orthocladiinae	T
		Coleoptera	Elmidae	Dubiraphia	I
		Hemiptera	Corimidae		

Lake Eucha Benthic Macroinvertebrates

Subfam/Tribe	Lacustrine Zone (Dam)										Transition Zone (Sawmill Pt.)										Riverine Zone (Hwy 10 Bridge)									
Genus	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***	***17***	***18***	***19***	***20***	***21***	***22***	***23***	***24***	***25***	***26***	***27***	***28***	***29***	***30***
Limnodrilus				15	7	14	211	580	395	214	7						5	12	35	43			8	25	15	5	1		19	4
Tubifex						1					2		1		15	3	11	33	17	37				1		4			1	1
Branchiura											4			1						1				2		1	1		3	
Aulodrilus		1																				2						1		
Dero		1																												
Helobdella	5																													
H. Stagnalis					2	4	2									1		1												
Sphaerium											6	3				11	8	3	8	4	6	31	4	11	10	1		10	27	5
Pisidium		1																			1			2	1	4		3	7	3
Corbicula	13																							1						
Unionidae	1																													
Planorbidae	2																													
Caenis	10																													
Choroterpes	5																													
Hexagenia																					12	3					2	2		
Sialis																					4	3	4					4		2
Decitus	3																													
Polycentropodidae	1																													
Ceratopogonidae																						1			1		1	1	2	
Tanypodinae	7																				36	42	12	25	37	18	18	41	17	31
Chironomini	20	6		1	4	4	20	10	5		1			1		18	24	3	29	25	8	34		21	13	11	53	19	10	20
Pseudochironomin	11	1																												
Orthocladiinae																					3	3								
Chaoborus	20		35	69	182	250	190	310	120	24	307	51	8	21	480	445	310	555	285	305	10	78	12	10	16	13	4	29	15	21
Dubiraphia																								2	1					
Corimidae																											1			
Totals	98	10	35	85	195	273	423	900	520	238	327	54	9	23	495	478	358	607	374	415	80	197	40	100	94	57	81	110	101	87

APPENDIX H

LAKE EUCHA
BACTERIOLOGICAL DATA

Table I. Lake Eucha Bacteria Samples
(All values in colonies/100 ml)

		May		June		July		August		September	
Method	**Location**	12th	26th	9th	23rd	14th	28th	11th	25th	8th	22nd
Fecal	Dam	91	8	2	1	<1	10		<1	5	1
	Sawmill Pt	400	<1	6	1	<1	<1		<1	3	<1
	Hwy 10 Bridge	600	19	47	9	4	<1		<1	3	5
	Brush Creek	290	38	964	45	64	20	155			30
	Rattlesnake Creek	191	8	23	17	10					40
	Beaty Creek	280	72	845	50	24	36	20	58	220	80
	Spav. Cr. At Hwy 43 Br.	390	58	2200	30	72	56	42	46	400	120
	Spav. Cr. Lower	191	27	3600	10	21	23	28	33	370	30
	Dry Creek		20	35	60	35	2	79	8	38	20
Strep.	Dam	60	16	24	7	45	4		3	5	11
	Sawmill Pt	570	<1	38	7	21	4		10	1	19
	Hwy 10 Bridge	570	17	74	35	36	12		49	12	77
	Brush Creek	260	36	818	155	149	490	730			460
	Rattlesnake Creek	430	40	144	82	58					109
	Beaty Creek	320	23	8000	191	112	82	121	230	710	230
	Spav. Cr. At Hwy 43 Br.	390	76	7600	118	130	157	168	285	1180	565
	Spav. Cr. Lower	300	44	13350	40	116	76	102	102	820	270
	Dry Creek		25	122	48	68	38	380	147	500	90
E. Coli	Dam	60	17	2	1	1	12		<1	5	<1
	Sawmill Pt	36	2	12	<1	1	<1		<1	3	<1
	Hwy 10 Bridge	<1	26	25	8	1	<1		<1	3	3
	Brush Creek	200	48	640	65	23	26				60
	Rattlesnake Creek	177	10	35	15	6					20
	Beaty Creek	200	72	680	80	23	36		50	190	20
	Spav. Cr. At Hwy 43 Br.	164	44	1155	64	44	50		35	360	110
	Spav. Cr. Lower	330	82	2100	10	25	24		25	340	60
	Dry Creek		22	48	28	23	<1		16	23	30
Entero.	Dam	30	10	40	<1	43	7		4	6	13
	Sawmill Pt	610	<1	24	4	11	7		4	5	27
	Hwy 10 Bridge	610	6	6	35	17	11		69	15	142
	Brush Creek	530	31	560	109	100	580	520			460
	Rattlesnake Creek	280	32	90	50	12					154
	Beaty Creek	490	17	6150	118	76	110	76	270	790	154
	Spav. Cr. At Hwy 43 Br.	480	86	6700	118	54	340	102	230	1430	420
	Spav. Cr. Lower	470	31	11100	10	33	88	42	78	730	200
	Dry Creek		27	125	20	46	40	92	114	420	64

Table II - Relative Bacterial Magnitude

Location	Fecal	E. Coli	Strep.	Entero.
Dam	1.00	1.00	1.00	1.00
Sawmill Pt.	0.80	1.00	1.10	1.10
Hwy 10 Bridge	2.30	1.00	4.30	4.70
Dry Creek	5.50	6.00	8.70	7.00
Rattlesnake Creek	6.00	6.00	9.70	12.50
Spavinaw Cr. Lower	16.00	24.30	20.70	15.20
Brush Creek	20.30	24.00	31.60	31.30
Beatty Creek	20.80	25.30	23.30	22.70
Spavinaw Cr. at Hwy 43 Br.	29.80	31.70	33.40	34.60

APPENDIX I

LAKE EUCHA
STREAM DATA - BASEFLOW

Stream Water Quality Data - Spavinaw Cr
43

Date	Temp. (^{0}C)	D.O. (mg/l	Cond. (uS/cm)	pH (S.U.)	Alk. (mg/l	Turb. (NTU)	Hard. (mg/l	Cl (mg/l)	TDS (mg/l	TSS (mg/l)	NO2+NO3 (mg/l)	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l
3/10/93	12.5	11.9	235	7.8	92	3.7	100	7.9	147	<1.0	3.50	<0.20	3.50	5.9	0.11	0.11
4/13/93									150	2.0	3.30	<0.20	3.30		0.12	0.11
5/12/93	13.5	9.2	168	7.5	74	4.0		5.2	143	<1.0	2.80	<0.20	2.80	5.5	0.09	0.09
5/26/93	14.2	8.9	202	7.4	98	0.7				<1.0	2.80	<0.20	2.80		0.11	0.11
6/9/93	17.1	9.4	195	7.4	195	5.4		6.2	139	11.0	2.50	<0.20	2.50	5.3	0.12	0.10
6/23/93	17.5	8.7	228	7.7	108	1.4				<1.0	2.50	<0.20	2.50		0.10	0.11
7/14/93	18.8	11.4	270	7.8	112	0.8		8.0	182	7.0	2.60	<0.20	2.60	4.9	0.11	0.10
7/28/93	20.0	7.9	280	7.6	130	1.2				1.0	2.60	<0.20	2.60		0.09	0.09
8/11/93								9.0	163	<1.0	2.50	<0.20	2.50	5.2	0.11	0.10
8/25/93	21.0	9.3	306	7.6	122	0.6			176	<1.0	2.20	<0.20	2.20		0.12	0.10
9/8/93	19.8	7.0	300	7.3	112	0.9		10.0	184	1.0	2.40	<0.20	2.40	5.3	0.13	0.12
9/22/93	18.5	8.3	276	7.8	93	1.9			172	15.0	3.30	<0.20	3.30		0.16	0.13
10/27/9	16.2	9.0	285	7.6	114	0.5	132	12.0	166	<2.0	2.99	0.05	3.04	<5.0	0.14	0.12
11/10/9							130	14.9		<1.0	2.90	0.11	3.01	<5.0	0.12	0.12
12/15/9	9.2	11.3	270	7.8	100	0.6	120	20.0		1.0	3.44	0.25	3.69	5.5	0.12	0.00
1/12/94	9.5	10.3	290	7.8	102	0.4	132	11.2		6.0	3.50	0.08	3.58	6.8	0.12	0.12
2/16/94	5.8	12.0	185	8.0	100	0.5	120	12.5		2.0	4.40	0.07	4.47	<5.0	0.16	0.04

Stream Water Quality Data - Spavinaw Cr at Londagin Bridge

Date	Temp. (^{0}C)	D.O. (mg/l	Cond. (uS/cm)	pH (S.U.)	Alk. (mg/l	Turb. (NTU)	Hard. (mg/l	Cl (mg/l)	TDS (mg/l	TSS (mg/l)	NO2+NO3 (mg/l)	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l
3/10/93	12.1	10.9	229	7.5	90	3.3	110	9.0	133	<1.0	3.30	<0.20	3.30	5.9	0.05	0.05
5/12/93	13.5	6.4	220	7.6	74	6.3										

Stream Water Quality Data - Spavinaw Cr Lower

Date	Temp. (^{0}C)	D.O. (mg/l	Cond. (uS/cm)	pH (S.U.)	Alk. (mg/l	Turb. (NTU)	Hard. (mg/l	Cl (mg/l)	TDS (mg/l	TSS (mg/l)	NO2+NO3 (mg/l)	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l
3/10/93	7.6	10.6	210	7.6	11	4.3	95	6.8	152	<1.0	2.70	<0.20	2.70	5.8	0.03	0.03
4/13/93									131	5.0	2.60	<0.20	2.60		0.03	0.03
5/12/93	13.5	8.8	148	7.2	72	3.9		4.2	124	1.0	2.10	<0.20	2.10	4.4	0.06	0.05
5/26/93	14.5	8.2	154	7.3	90	1.2				2.0	2.20	<0.20	2.20		0.03	0.03
6/9/93	16.7	8.8	195	7.5	195	8.9		6.3	149	11.0	2.30	0.20	2.50	5.4	0.11	0.08
6/23/93	18.2	8.2	102	7.5						2.0	1.90	<0.20	1.90		0.03	0.03
7/14/93	20.5	9.5	260	7.7	108	0.7		6.8	178	9.0	2.00	<0.20	2.00	5.0	0.05	0.03
7/28/93	21.8	7.3	270	7.5	114	0.9				1.0	2.20	<0.20	2.20		0.04	0.03
8/11/93								7.5	179	<1.0	2.10	<0.20	2.10	5.1	0.04	0.03
8/25/93	23.0	8.4	284	7.2	120	0.6			170	1.0	1.90	<0.20	1.90		0.03	0.02
9/8/93	22.0	6.5	282	7.6	110	0.8		8.9	168	1.0	2.00	<0.20	2.00	5.3	0.04	0.03
9/22/93	20.0	7.5	264	7.7	102	2.0			158	2.0	2.60	<0.20	2.60		0.04	0.04
10/27/9	15.2	8.9	250	7.7	110	0.4	128	12.0	155	<2.0	2.77	<0.01	2.77	6.3	0.04	0.03
11/10/9	13.0	10.2	220	7.8	106	0.3	123	12.8		<1.0	2.50	0.10	2.60	<5.0	0.09	0.02
12/15/9	9.2	11.0	240	7.8	92	0.8	110	20.0		2.5	2.80	0.17	2.97	5.5	0.04	
1/12/94	9.0	10.3	240	7.7	98	0.4	118	9.2		3.5	3.20	0.11	3.31	6.5	0.03	0.03
2/16/94	5.8	11.2	168	8.0	94	0.4	112	11.0		0.1	4.10	0.07	4.17	<5.0	0.03	0.03

Stream Water Quality Data - Beaty
Cr

Date	Temp. (^{0}C)	D.O. (mg/l	Cond. (uS/cm)	pH (S.U.)	Alk. (mg/l	Turb. (NTU)	Hard. (mg/l	Cl (mg/l)	TDS (mg/l	TSS (mg/l)	NO2+NO3 (mg/l)	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l
3/9/93	12.0	10.8	213	7.6	87	3.1	98	6.0	128	<1.0	2.50	<0.20	2.50	5.1	0.03	0.03
4/12/93	12.5	11.7	165	7.5	84	2.5			136	12.0	2.30	0.20	2.50		0.03	0.03
5/12/93	13.5	9.1	155	7.1	72	9.2		4.2	124	1.0	1.80	0.30	2.10	4.4	0.07	0.06
5/26/93	14.8	8.1	181	7.5	90	0.7				2.0	1.90	<0.20	1.90		0.04	0.04
6/9/93	17.2	8.1	185	7.4	88	6.5		5.3	132	<1.0	1.80	<0.20	1.80	4.1	0.09	0.08
6/23/93	18.4	7.7	205	7.6	94	1.5				<1.0	1.60	<0.20	1.60		0.05	0.05
7/14/93	21.0	8.8	240	8.0	107	0.8		5.6	162	4.0	1.70	<0.20	1.70	4.2	0.06	0.05
7/28/93	22.0	5.5	250	7.4	114	0.9				1.0	1.80	<0.20	1.80		0.05	0.05
8/11/93	22.2	8.4	250	7.5	112	0.6		5.6	163	<1.0	1.60	<0.20	1.60	4.2	0.05	0.04
8/25/93	23.0	7.6	273	7.2	118	0.5			160	<1.0	1.50	<0.20	1.50		0.05	0.05
9/8/93	22.0	6.0	269	7.7	118	0.7		6.0	162	6.0	1.40	<0.20	1.40	4.2	0.05	0.04
9/22/93	19.0	7.8	251	7.6	100	1.0			138	2.0	2.00	<0.20	2.00		0.05	0.05
10/27/9	14.0	9.0	260	7.7	118	0.3	132	9.5	147	<2.0	2.00	0.16	2.16	<5.0	0.04	0.04
11/10/9	11.0	10.2	200	7.8	110	0.3	122	11.7		<1.0	2.30	0.08	2.38	<5.0	0.05	0.03
12/15/9	8.0	11.1	240	7.8	90	2.1	106	17.0		1.0	2.37	0.35	2.72	<5.0	0.06	0.00
1/12/94	7.5	10.5	240	7.6	100	0.3	130	6.7		1.5	2.40	0.09	2.49	5.8	0.03	0.03
2/16/94	4.2	11.7	158	8.2	98	0.3	116	8.0		2.0	3.20	0.06	3.26	<5.0	0.03	0.03

Stream Water Quality Data - Brush Cr

Date	Temp. (^{0}C)	D.O. (mg/l	Cond. (uS/cm)	pH (S.U.)	Alk. (mg/l	Turb. (NTU)	Hard. (mg/l	Cl (mg/l)	TDS (mg/l	TSS (mg/l)	NO2+NO3 (mg/l)	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l
3/9/93	11.5	10.3	178	7.4	75	3.0	86	4.9	113	<1.0	0.71	<0.20	0.71	5.6	<0.01	<0.01
4/12/93	12.0	10.7	170	7.3	73	2.5			120	<1.0	0.55	<0.20	0.55		0.01	<0.01
5/12/93	13.0	9.1	122	7.5	62	4.3		3.3	107	<1.0	0.69	<0.20	0.69	4.6	0.03	<0.01
5/26/93	14.3	7.5	168	7.1	90	0.7				1.0	0.52	<0.20	0.52		0.01	0.01
6/9/93	15.5	7.4	170	7.4	92	1.5		5.0	122	<1.0	0.52	<0.20	0.52	4.6	<0.01	0.01
6/23/93	17.3	7.2	178	7.5	94	1.3				2.0	0.50	<0.20	0.50		0.02	0.01
7/14/93	18.2	8.4	220	7.6	98	0.8		4.4	140	5.0	0.57	<0.20	0.57	4.2	0.02	0.01
7/28/93	19.5	7.3	220	7.3	104	0.5				1.0	0.55	<0.20	0.55		<0.01	<0.01
8/11/93	20.5	7.9	220	7.4	109	0.8		5.6	149	<1.0	0.49	<0.20	0.49	4.4	<0.01	0.02
9/22/93	19.0	7.0	234	7.6	95	0.8			124	3.0	0.85	<0.20	0.85		<0.01	<0.01
10/27/9	14.2	7.8	235	7.6	104	0.3	118	1.0	134	<2.0	0.47	0.39	0.86	<5.0	0.03	<0.01
11/10/9	11.0	8.6	185	7.7	112	0.3	119	10.6		<1.0	1.00	0.05	1.05	<5.0	0.10	<0.01
12/15/9	9.3	10.5	240	7.8	100	0.5	106	16.0		<1.0	0.86	<0.01	0.86	<5.0	<0.01	0.00
1/12/94	8.0	9.9	230	7.6	98	0.3	112	7.2		5.5	<0.50	0.04	<0.50	6.0	<0.01	<0.01
2/16/94	5.2	10.8	140	8.1	96	0.3	108	8.0		3.0	1.50	0.04	1.54	<5.0	0.01	0.01

Stream Water Quality Data - Dry Cr

Date	Temp. (^{0}C)	D.O. (mg/l	Cond. (uS/cm)	pH (S.U.)	Alk. (mg/l	Turb. (NTU)	Hard. (mg/l	Cl (mg/l)	TDS (mg/l	TSS (mg/l)	NO2+NO3 (mg/l)	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l
3/10/93	7.4	11.3	146	10.1	60	3.4	68	4.9	98	<1.0	0.50	<0.20	0.50	5.1	0.01	<0.01
4/13/93									128	4.0	0.44	<0.20	0.44		0.03	<0.01
5/12/93	13.5	9.8	102	7.3	52	4.2		3.2	90	<1.0	0.39	<0.20	0.39	4.0	0.02	0.01
5/26/93	14.0	8.5	240	7.3	68	0.7				1.0	0.37	<0.20	0.37		<0.01	0.01
6/9/93	15.0	9.1	190	7.6	190	0.8		6.7	108	<1.0	0.34	<0.20	0.34	4.0	<0.01	<0.01
6/23/93	16.1	8.5	180	7.6	82	1.0				1.0	0.39	<0.20	0.39		<0.01	0.01
7/14/93	17.5	8.3	200	7.7	88	1.1		8.6	142	9.0	0.37	<0.20	0.37	4.1	<0.01	<0.01
7/28/93	19.0	7.4	220	7.7	90	0.5				1.0	0.43	<0.20	0.43		<0.01	<0.01
8/11/93								8.8	147	<1.0	0.44	<0.20	0.44	4.3	<0.01	0.01
8/25/93	21.0	6.1	240	7.5	98	1.1			142	2.0	0.45	<0.20	0.45			<0.01
9/8/93	19.0	6.4	220	7.6	92	0.6		11.0	144	1.0	0.50	<0.20	0.50	4.8	0.02	0.01
9/22/93	17.9	8.1	205	7.7	82	0.8			112	3.0	0.55	<0.20	0.55		<0.01	<0.01
10/27/9	14.2	8.8	225	7.7	86	0.9	101	12.0	125	2.6	0.34	0.28	0.62	<5.0	0.06	<0.01
11/10/9	13.2	9.8	175	7.8	92	0.6	101	16.0		1.0	0.70	0.05	0.75	<5.0	0.07	<0.01
12/15/9	11.8	11.6	210	7.6	74	0.5	88	20.0		2.5	0.53	0.21	0.74	5.1	<0.01	
1/12/94	9.0	11.4	200	7.7	72	0.3	90	9.2		2.0	<0.50	0.10	<0.50	6.7	<0.01	<0.01
2/16/94	9.0	11.5	205	8.3	80	0.3	84	9.0		<1.0	1.20	0.03	1.23	<5.0	0.02	0.02

Stream Water Quality Data - Rattlesnake

Date	Temp. (^{0}C)	D.O. (mg/l	Cond. (uS/cm)	pH (S.U.)	Alk. (mg/l	Turb. (NTU)	Hard. (mg/l	Cl (mg/l)	TDS (mg/l	TSS (mg/l)	NO2+NO3 (mg/l)	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l
3/10/93	11.5	9.5	152	8.3	104	3.0	73	3.5	114	<1.0	0.29	<0.20	0.29	5.7	0.02	<0.01
4/13/93									104	8.0	0.22	<0.20	0.22		0.02	<0.01
5/12/93	12.2	9.5	140	7.6	48	3.7		2.1	82	<1.0	0.29	<0.20	0.29	4.8	0.01	0.01
5/26/93	14.0	7.7	195	7.4	76	0.9				5.0	0.21	<0.20	0.21		<0.01	<0.01
6/9/93	15.0	7.7	220	7.5	90	0.8		5.1	104	<1.0	0.19	<0.20	0.19	4.4	0.02	<0.01
6/23/93	16.1	6.5	195	7.7	94	0.6				2.0	0.15	<0.20	0.15		<0.01	0.01
7/14/93	17.5	7.0	200	7.8	94	0.7		4.6	136	1.0	0.21	<0.20	0.21	4.2	<0.01	<0.01
9/22/93	18.2	7.0	210	7.6	96	1.0			128	<1.0	0.29	<0.20	0.29		0.01	0.01
12/15/93	11.1	10.8	240	7.9	94	0.5	100	20.0		<1.0	0.35	0.09	0.44	<5.0	<0.01	

APPENDIX J

LAKE EUCHA
STREAM DATA - RUNOFF

Lake Eucha Tributary Runoff Samples - Spavinaw Cr

Date	Hard. (mg/l	Cl (mg/l	TDS (mg/l	TSS (mg/l)	NH3 (mg/l)	NO2 (mg/l	NO3 (mg/l	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l
15-Nov-93	97	7.0	139	71.0			3.20	0.90	4.10	< 5.0	0.09	0.09
22-Feb-94	108	10.5		37.0		<0.01	3.10	0.38	3.48	< 5.0	0.07	0.03
10-Mar-94	102	7.0	136	17.6	< 0.10	<0.01	2.30	0.32	2.62	5.7	0.09	0.06
28-Mar-94	102	7.4	158	2.6	< 0.10	<0.01	2.10	0.19	2.29	7.5	0.10	0.04
Mean	102	8.0	144	32.1	< 0.10	<0.01	2.68	0.45	3.12	4.5	0.09	0.06
Min.	97	7.0	136	2.6	< 0.10	<0.01	2.10	0.19	2.29	< 5.0	0.07	0.03
Max.	108	10.5	158	71.0	< 0.10	<0.01	3.20	0.90	4.10	7.5	0.10	0.09

Lake Eucha Tributary Runoff Samples -
Beaty Cr

Date	Hard. (mg/l	Cl (mg/l	TDS (mg/l	TSS (mg/l)	NH3 (mg/l)	NO2 (mg/l	NO3 (mg/l	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l
15-Nov-93	92	6.4	137	46.0			2.30	0.77	3.07	< 5.0	0.26	0.15
14-Sep-93	57	3.1	176	131.0		<0.01	1.50	0.80	2.30	2.8	0.42	0.34
22-Feb-94	88	8.0		41.0		<0.01	2.70	2.12	4.83	< 5.0	0.31	0.17
10-Mar-94	86	6.0	126	8.0	< 0.10	<0.01	2.10	0.35	2.45	< 5.0	0.16	0.10
Mean	81	5.9	146	56.5	< 0.10	<0.01	2.15	1.01	3.16	< 5.0	0.29	0.19
Min.	57	3.1	126	8.0	< 0.10	<0.01	1.50	0.35	2.30	< 5.0	0.16	0.10
Max.	92	8.0	176	131.0	< 0.10	<0.01	2.70	2.12	4.83	< 5.0	0.42	0.34

Lake Eucha Tributary Runoff Samples -
Brush Cr

Date	Hard. (mg/l	Cl (mg/l	TDS (mg/l	TSS (mg/l)	NH3 (mg/l)	NO2 (mg/l	NO3 (mg/l	TKN (mg/l	TN (mg/l	SO4 (mg/l	TP (mg/l	PO4 (mg/l
22-Feb-94	96	96.0		24.0		<0.01	1.80	0.11	1.91	<5.0	0.03	0.04
14-Sep-93	81	4.5	142	27.0		<0.01	0.87	0.30	1.17	4.1	0.08	0.05
10-Mar-94	88	6.0	119	2.8	<0.01	<0.01	2.10	0.25	2.35	6.0	0.03	0.01
28-Mar-94	90	6.9	144	2.0	<0.01	<0.01	0.90	0.23	1.13	5.5	0.12	<0.01
Mean	89	28.4	135	14.0	<0.01	<0.01	1.42	0.22	1.64	4.5	0.07	0.03
Min.	81	4.5	119	2.0	<0.01	<0.01	0.87	0.11	1.13	<5.0	0.03	<0.01
Max.	96	96.0	144	27.0	<0.01	<0.01	2.10	0.30	2.35	6.0	0.12	0.05

APPENDIX K

NUTRIENT LOADING FROM
POINT SOURCES

GRAVETTE NUTRIENT LOAD

METHOD 1 - Using measured discharge x nutrient values from Gakstatter et al. 1978.

Month	Discharge (gallons)	Discharge (liters)
Mar-93	0	0
Apr-93	12498090	47305270.65
May-93	12163408	46038499.28
Jun-93	0	0
Jul-93	0	0
Aug-93	0	0
Sep-93	0	0
Oct-93	10234061	38735920.89
Nov-93	10574790	40025580.15
Dec-93	9828643	37201413.76
Jan-94	0	0
Feb-94	0	0
TOTAL	**55298992**	**209306684.7**

Nutrient levels in stabilization ponds effluent (Gakstatter et al. 1978)

	Median	std error	Mean	std error
TP (mg/L)	5.2	0.45	6.6	0.81
TN (mg/L)	11.5	0.84	17.1	3.59

Nutrient Loads from Gravette based on Median values

	kg/yr	plus or minus	Min	Max
TP	1088.395	94.18801	994.206	1182.583
TN	2407.027	175.8176	2231.20	2582.844

Nutrient Loads from Gravette based on Mean values

	kg/yr	plus or minus	Min	Max
TP	1381.424	169.5384	1211.88	1550.963
TN	3579.144	751.411	2827.73	4330.555

METHOD 2 - Using design discharge x nutrient values from Gakstatter et al. 1978

Mean daily Q (gallons)	560000
Annual Q (gallons)	204400000
Annual Q (Liters)	773654000

Nutrient Loads from Gravette based on Median values

	kg/yr	plus or minus	Min	Max
TP	4023.001	348.1443	3674.85	4371.145
TN	8897.021	649.8694	8247.15	9546.89

Nutrient Loads from Gravette based on Mean values

	kg/yr	plus or minus	Min	Max
TP	5106.116	626.6597	4479.45	5732.776
TN	13229.48	2777.418	10452.0	16006.9

METHOD 3 - Using population x annual nutrient load per capita from Gakstatter et. al. 1978

Population	1412	
Median TP Load (kg/yr)	1270.8	
TP Load Range	1129.6	1412
Median TN Load (kg/yr)	2824	
TN Load Range	2456.88	3191.12

Nutrient loads from stabilization ponds (Gakstatter et al.

	Median	std. error
TP load (kg/cap.yr)	0.9	0.1
TN load (kg/cap.yr)	2	0.26

GRAVETTE NUTRIENT LOAD

METHOD 1 - Using measured discharge x nutrient values from Gakstatter et al. 1978.

Month	Discharge (gallons)	Discharge (liters)
Sep-95	0	0
Oct-95	0	0
Nov-95	9985830	37796366.55
Dec-95	0	0
Jan-96	0	0
Feb-96	0	0
Mar-96	0	0
Apr-96	9285420	35145314.7
May-96	9236295	34959376.58
Jun-96	0	0
Jul-96	0	0
Aug-96	0	0
TOTAL	**28507545**	**107901057.8**

Nutrient levels in stabilization ponds effluent (Gakstatter et al. 1978)

	Median	std error	Mean	std error
TP (mg/L)	5.2	0.45	6.6	0.81
TN (mg/L)	11.5	0.84	17.1	3.59

Nutrient Loads from Gravette based on Median values

	kg/yr	plus or minus	Min	Max
TP	561.0855	48.55548	512.53	609.641
TN	1240.862	90.63689	1150.225	1331.499

Nutrient Loads from Gravette based on Mean values

	kg/yr	plus or minus	Min	Max
TP	712.147	87.39986	624.7471	799.5468
TN	1845.108	387.3648	1457.743	2232.473

METHOD 2 - Using design discharge x nutrient values from Gakstatter et al. 1978

Mean daily Q (gallons)	560000
Annual Q (gallons)	204400000
Annual Q (Liters)	773654000

Nutrient Loads from Gravette based on Median values

	kg/yr	plus or minus	Min	Max
TP	4023.001	348.1443	3674.857	4371.145
TN	8897.021	649.8694	8247.152	9546.89

Nutrient Loads from Gravette based on Mean values

	kg/yr	plus or minus	Min	Max
TP	5106.116	626.6597	4479.457	5732.776
TN	13229.48	2777.418	10452.07	16006.9

METHOD 3 - Using population x annual nutrient load per capita from Gakstatter et. al. 1978

Population 1412

Median TP Load (kg/yr)	1270.8	
TP Load Range	1129.6	1412
Median TN Load (kg/yr)	2824	
TN Load Range	2456.88	3191.12

Nutrient loads from stabilization ponds (Gakstatter et al. 1978)

	Median	std. error
TP load (kg/cap.yr)	0.9	0.1
TN load (kg/cap.yr)	2	0.26

DECATUR NUTRIENT LOAD

METHOD 1 - TN load estimated using measured Q x est. TN values (NH4+NO3)
TP load estimated using est. TN / 2.4 (the TN:TP in Gakstatter et al. 1978 for activated sludge facilities)

	Discharge (gallons)	Discharge (liters)	NH4 (mg/L)	NO3 (mg/L)	Estimated TN (mg/L)	Est. TN Load (kg)	Est. TP Load (kg)	
Mar-93	24000000	90840000	4.7	3.8	8.5	772.14	321.73	
Apr-93	24000000	90840000	28.2	2.1	30.3	2752.45	1146.86	
May-93	24800000	93868000	20.9	6.6	27.5	2581.37	1075.57	
Jun-93	27000000	102195000	14	2.9	16.9	1727.10	719.62	
Jul-93	34100000	129068500	5.5	2.3	7.8	1006.73	419.47	
Aug-93	24800000	93868000	6.6	2.8	9.4	882.36	367.65	
Sep-93	28500000	107872500	7.7	3	10.7	1154.24	480.93	
Oct-93	27900000	105601500	7.8	3.5	11.3	1193.30	497.21	
Nov-93	30000000	113550000	7.8	10	17.8	2021.19	842.16	
Dec-93	27900000	105601500	11.6	9.8	21.4	2259.87	941.61	
Jan-94	24800000	93868000	8.7	9	17.7	1661.46	692.28	
Feb-94	25200000	95382000	10.2	6.1	16.3	1554.73	647.80	
TOTAL	**323000000**	**1222555000**				**19566.94**	**8152.89**	6.67

METHOD 2 - TN load estimated using design Q x permitted TN values (NH4+NO3)
TP load estimated using est. TN / 2.4 (the TN:TP in Gakstatter et al. 1978 for activated sludge facilities)

Design Daily Q (gallons)	1600000
Annual Q (gallons)	584000000
Annual Q (liters)	2210440000
Permitted TN load	55261
Est. TP load (kg/yr)	23025.4167

Permitted NO3 conc (mg/L)	10
Permitted NH4 conc (mg/L)	15
Est. TN conc. permitted (mg/L)	**25**

METHOD 3 - Using actual Q x nutrient levels from activated sludge facilities (Gakstatter et al. 1978)

Total Q (L) 122255500

Nutrient levels in activated sludge plant effluent (Gakstatter et al. 1978)

	Median	std error	Mean	std error
TP (mg/L)	5.8	0.29	6.8	0.51
TN (mg/L)	13.6	0.62	15.8	1.16

Nutrient Loads from Decatur based on Median values

	kg/yr	plus or minus	Min	Max
TP	7090.819	354.541	6736.278	7445.36
TN	16626.75	757.9841	15868.76	17384.73

Nutrient Loads from Decatur based on Mean values

	kg/yr	plus or minus	Min	Max
TP	8313.374	623.5031	7689.871	8936.877
TN	19316.37	1418.164	17898.21	20734.53

METHOD 4 - Using design Q x nutrient levels from activated sludge facilities (Gakstatter et al. 1978)

Total Q (L) 221044000

Nutrient levels in activated sludge plant effluent (Gakstatter et al. 1978)

	Median	std error	Mean	std error
TP (mg/L)	5.8	0.29	6.8	0.51
TN (mg/L)	13.6	0.62	15.8	1.16

Nutrient Loads from Decatur based on Median values

	kg/yr	plus or minus	Min	Max
TP	12820.55	641.0276	12179.52	13461.58
TN	30061.98	1370.473	28691.51	31432.46

Nutrient Loads from Decatur based on Mean values

	kg/yr	plus or minus	Min	Max
TP	15030.99	1127.324	13903.67	16158.32
TN	34924.95	2564.11	32360.84	37489.06

*Note: Pop. could not be used to estimate load, because a poultry processing plant is the major contributor to the plant.

DECATUR NUTRIENT LOAD

METHOD 1 - TN load estimated using measured Q x est. TN values (NH4+NO3)
TP load estimated using est. TN / 2.4 (the TN:TP in Gakstatter et al. 1978 for activated sludge facilities)

	Discharge (gallons)	Discharge (liters)	NH4 (mg/L)	NO3 (mg/L)	Estimated TN (mg/L)	Est. TN Load (kg)	Est. TP Load (kg)	
Oct-95	24800000	93868000	6.3	1.6	7.9	741.5572	308.9822	
Nov-95	24000000	90840000	6	6.2	12.2	1108.248	461.77	
Dec-95	27900000	105601500	9.3	5.9	15.2	1605.1428	668.8095	
Jan-96	34100000	129068500	12.5	5	17.5	2258.69875	941.1245	
Feb-96	31900000	120741500	12.9	3.9	16.8	2028.4572	845.1905	
Mar-96	34100000	129068500	10	8.1	18.1	2336.13985	973.3916	
Apr-96	36000000	136260000	19.6	3.9	23.5	3202.11	1334.213	
May-96	34100000	129068500	25	13.4	38.4	4956.2304	2065.096	
Jun-96	36000000	136260000	34.7	8.6	43.3	5900.058	2458.358	
Jul-96	37200000	140802000	19	14.6	33.6	4730.9472	1971.228	
Aug-96	46500000	176002500	10.3	10	20.3	3572.85075	1488.688	
Sep-96	45000000	170325000	22	11.9	33.9	5774.0175	2405.841	
TOTAL	**411600000**	**1557906000**				**38214.45765**	**15922.69**	10.22057

METHOD 2 - TN load estimated using design Q x permitted TN values (NH4+NO3)
TP load estimated using est. TN / 2.4 (the TN:TP in Gakstatter et al. 1978 for activated sludge facilities)

Design Daily Q (gallons)	1600000
Annual Q (gallons)	584000000
Annual Q (liters)	2210440000
Permitted TN load (kg/yr)	55261
Est. TP load (kg/yr)	23025.4167

Permitted NO3 conc (mg/L)	10
Permitted NH4 conc (mg/L)	15
Est. TN conc. permitted (mg/L)	**25**

METHOD 3 - Using actual Q x nutrient levels from activated sludge facilities (Gakstatter et al. 1978)

Total Q (L) 1557906000

Nutrient levels in activated sludge plant effluent (Gakstatter et al. 1978)

	Median	std error	Mean	std error
TP (mg/L)	5.8	0.29	6.8	0.51
TN (mg/L)	13.6	0.62	15.8	1.16

Nutrient Loads from Decatur based on Median values

	kg/yr	plus or minus	Min	Max
TP	9035.855	451.7927	8584.062	9487.648
TN	21187.52	965.9017	20221.62	22153.42

Nutrient Loads from Decatur based on Mean values

	kg/yr	plus or minus	Min	Max
TP	10593.76	794.5321	9799.229	11388.29
TN	24614.91	1807.171	22807.74	26422.09

METHOD 4 - Using design Q x nutrient levels from activated sludge facilities (Gakstatter et al. 1978)

Total Q (L) 2210440000

Nutrient levels in activated sludge plant effluent (Gakstatter et al. 1978)

	Median	std error	Mean	std error
TP (mg/L)	5.8	0.29	6.8	0.51
TN (mg/L)	13.6	0.62	15.8	1.16

Nutrient Loads from Decatur based on Median values

	kg/yr	plus or minus	Min	Max
TP	12820.55	641.0276	12179.52	13461.58
TN	30061.98	1370.473	28691.51	31432.46

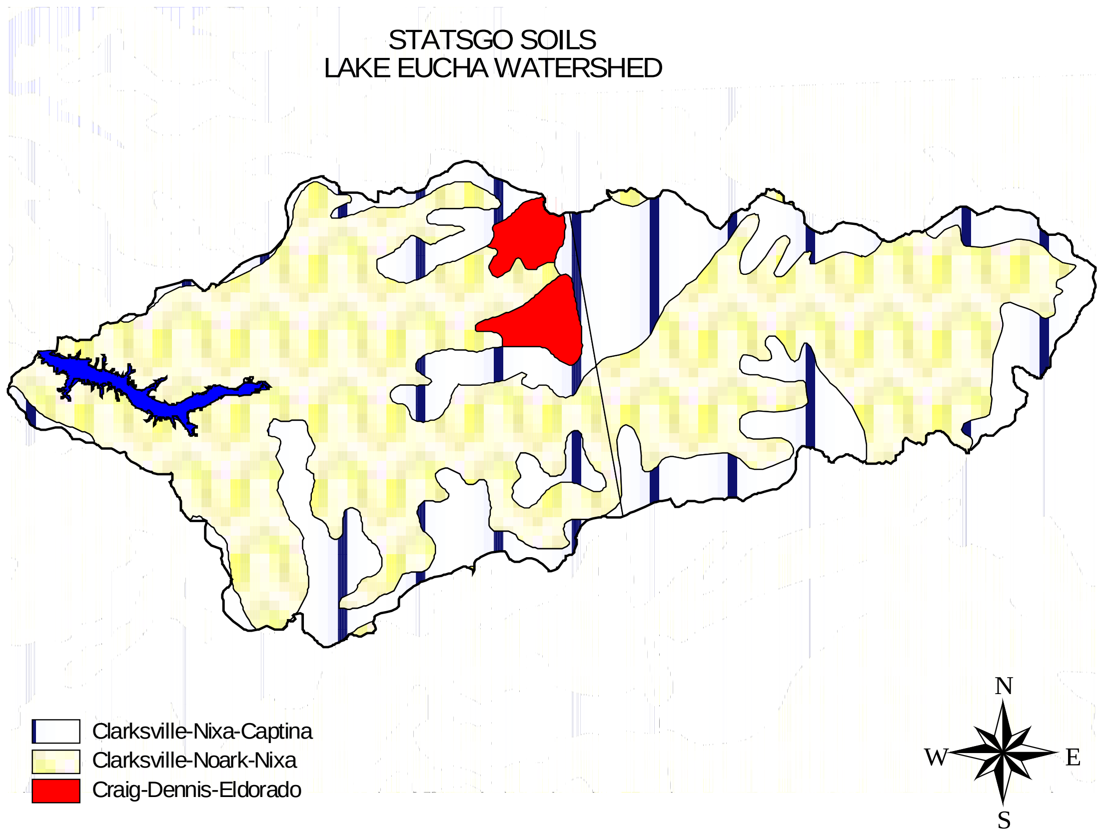
Nutrient Loads from Decatur based on Mean values

	kg/yr	plus or minus	Min	Max
TP	15030.99	1127.324	13903.67	16158.32
TN	34924.95	2564.11	32360.84	37489.06

*Note: Pop. could not be used to estimate load, because a poultry processing plant is the major contributor to the plant.

APPENDIX L

SOILS IN THE LAKE EUCHA
WATERSHED


STATSGO SOILS
LAKE EUCHA WATERSHED
Clarksville-Nixa-Captina
Clarksville-Noark-Nixa
Craig-Dennis-Eldorado
N
W
E
S

Soil	Slope (%)	Percent of Total
Clarksville Very Cherty Silt Loam	20-50	27
Clarksville Very Cherty Silt Loam	8-20	3
Noark Very Cherty Silt Loam	20-40	20
Noark Very Cherty Silt Loam	8-20	8
Nixa Very Cherty Silt Loam	8-12	11
Nixa Very Cherty Silt Loam	3-8	9
Captina Silt Loam	3-8	2
Tonti Cherty Silt Loam	3-8	2
Arkana Very Cherty Silt Loam	20-40	3
Moko Very Stony Silt Loam	20-40	3
Razort Silt Loam	0-3	2
Elsah Very Gravelly Silt Loam	0-3	2
Peridge Silt Loam	3-8	2
Secesh Silt Loam	0-3	1
Britwater Gravelly Silt Loam	3-8	1
Nella Very Stony Loam	20-40	1
Enders Very Stony Loam	20-40	1
Gepp Very Cherty Silt Loam	20-40	1
Waben Cherty Silt Loam	3-8	1

Soil	Slope (%)	Percent of Total
Clarksville Very Cherty Silt Loam	1-8	14
Clarksville Stony Silt Loam	5-20	4
Clarksville Cherty Silt Loam	12-60	2
Nixa Cherty Silt Loam	1-3	5
Nixa Very Cherty Silt Loam	3-8	7
Nixa Very Cherty Silt Loam	8-20	3
Captina Silt Loam	1-3	12
Captina Silt Loam	3-8	1
Jay Silt Loam	1-3	10
Jay Silt Loam	3-8	1
Tonti Cherty Silt Loam	1-3	8
Tonti Cherty Silt Loam	3-8	1
Peridge Silt Loam	3-8	7
Britwater Silt Loam	1-3	6
Taloka Silt Loam	0-1	5
Taloka Silt Loam	1-3	1
Noark Very Cherty Silt Loam	1-8	4
Noark Very Cherty Silt Loam	8-20	1
Razort Gravelly Loam	0-1	3
Johnsburg Silt Loam	0-2	3
Newtonia Silt Loam	1-3	2

Soil	Slope (%)	Percent of Total
Craig Silt Loam	1-3	13
Craig Silt Loam	3-5	3
Dennis Silt Loam	1-3	15
Eldorado Gravelly Silt Loam	1-12	7
Eldorado Silt Loam	1-3	2
Eldorado Silt Loam	3-5	2
Eldorado Silt Loam	3-12	2
Britwater Silt Loam	1-3	8
Jay Silt Loam	1-3	7
Clarksville Gravelly Silt Loam	1-8	6
Bates Loam	1-3	5
Taloka Silt Loam	0-1	5
Mayes Silty Clay Loam	0-1	4
Okemah Silt Loam	0-1	4
Newtonia Silt Loam	1-3	3
Riverton Loam	1-3	3
Verdigris Silt Loam	0-1	3
Apperson Silty Clay Loam	1-3	2
Razort Gravelly Loam	0-1	2
Collinsville Fine Sandy Loam	2-5	2
Woodson Silt Loam	0-1	2

Soil	**Slope (%)**	**Percent of Total**
Waben Cherty Silt Loam	1-3	36
Waben Cherty Silt Loam	3-8	19
Midco Cherty Loam	0-1	18
Razort Gravelly Loam	0-1	10
Johnsburg Silt Loam	0-1	5
Healing Silt Loam	0-1	4
Clarksville Stony Silt Loam	8-50	3
Hector Stony Fine Silt Loam	8-30	3
Osage Clay	0-1	2

Confined Animal Inventory:
Lake Eucha Watershed
August, 1996

This is a brief report containing an inventory of confined poultry and hogs in the watershed of Lake Eucha. A large amount of related material, such as lake and stream water quality, estimates of annual nutrient loadings to the lake, watershed land uses, soils and geology, and much more not discussed here, are contained within the Phase I Clean Lakes Diagnostic and Feasibility of Lake Eucha which will be published in September of 1996. It will be forwarded to the City of Tulsa at the time of publication.

Three separate methods were considered for this inventory. The first and most inexpensive involves mapping of animal houses from 8 inch to the mile Natural Resource Conservation Service aerial photos. While the houses are easily visible on these photos, it is impossible to distinguish active from inactive ones. Also, none of the photos are up to date. The ones covering Oklahoma were shot in 1991 and the ones covering Arkansas were shot in the early 1980’s. This method was rejected early on in the course of the project.

The second method considered was a flyover of the watershed with a global positioning system unit getting locational information along with the number and size of the houses. This method was rejected because it offered no way to distinguish active from inactive houses and would have resulted in a large overestimation of animal production in the watershed.

The method chosen was direct mapping based on a site visit and usually a discussion with the grower. This method allows differentiation of active from empty houses and additionally allows recording of the name of the producer and the company they grow for. Using existing aerial Photos and USGS 7.5” topographic maps as a starting point, all roads were driven. Houses are all marked at the driveway or entrance from the nearest public road by easily visible signs so that the company feed and animal transporting truck drivers can find them. Using these signs, we verified previously mapped houses, and mapped those which didn’t appear on any of the NRCS or USGS maps.

Table 1 lists all the growers in the watershed by name, location, number and type of animals produced, and the company they are produced for.

Table 2 lists the subwatersheds of Spavinaw Creek from Lake Eucha dam to the headwaters. The GIS number column refers to the identification number of each subwatershed on the map. Areas not draining to major tributaries or draining directly to Spavinaw creek are delineated and referred to as Spavinaw laterals. They are designated either North or South depending on their position relative to Spavinaw Creek, and are located along Spavinaw Creek by the occurrence of major tributaries which form their East - West boundaries. The size column lists the size of each mapping unit in square miles. Sites indicates the number of animal producers. One site can have any number of houses. Houses refers to the actual number of buildings used to raise animals in. The column labeled animals refers to the actual number of chickens, turkeys or hogs for a particular watershed or subwatershed.

Sites not standing are sites which appear on USGS 1:24000 topographic maps but are no longer there. Sites not in production are houses which are standing and could be used for production but were empty at the time of the site visit. Potential houses in production, potential animals, and potential animal density all refer to the total number of animals that would exist if all empty houses were put into production along with those already producing. For ease of calculation, all empty houses are assumed to be chicken houses.

Table 3 lists the estimated nutrients (Nitrogen and Phosphorous) excreted by all of the confined animals in each watershed or subwatershed. Estimates are derived from numbers provided by Doug Hamilton of OSU Cooperative Extension in Stillwater. A synopsis of these numbers follows.

Broilers/20,000 birds

- 5 flocks / year at 50 days / flock
- Average weight of bird = 2 pounds
- Nitrogen production = 1.10 lbs. /1000 lbs. live weight / day
- Phosphorous production = 0.34 lbs. / 1000 lbs. live weight / day
- Nitrogen excreted by 20,000 bird house / year =11,000 lbs.
- Phosphorous excreted by 20,000 bird house / year = 3,400 lbs.

Turkeys / 20,000 birds

- Occupied 300 days / year
- average weight = 11.75 lbs.
- Nitrogen production = 0.74 lbs. / 1000 lbs. live weight / day
- Phosphorous production = 0.28 lbs. / 1000 lbs. live weight / day
- Nitrogen excreted / 20,000 bird operation / year = 53,000 lbs.
- Phosphorous excreted / 20,000 bird operation / year = 20,000 lbs.

Hogs / 600 sow unit

- Nitrogen excreted / 600 sow unit / year =23,000 lbs.
- Phosphorous excreted / 600 sow unit / year = 7600 lbs.

An estimated total of 8,259,600 lbs. of Nitrogen and 2,585,540 lbs. of Phosphorous will be excreted by confined animals in the watershed this year. Of this total, 33% of each nutrient will be produced in Oklahoma with the remainder coming from Benton County, Arkansas. In Oklahoma, chickens produce 82.8% and 81.8% of the total Nitrogen and Phosphorous respectively with the remainder being produced by hogs. While the majority of the nutrients and poultry are produced in Arkansas, 70% of the hogs produced in the watershed are grown in Oklahoma accounting for the rather large percentage of the Oklahoma total which is derived from hogs. There are no turkeys grown in the Oklahoma portion of the Eucha watershed. In Arkansas, chickens produce 91.5% and 90.3% of the total Nitrogen and Phosphorous respectively, with the remainder being split fairly evenly between hogs and turkeys.

A large number of the houses not in production will never be used because of outdated equipment and facilities. Nonetheless, many of them are currently being used for production but did not have birds in them at the time of the visit due to a variety of reasons. If all of the empty houses were put into production of chickens, the total number of chickens in the watershed would increase from 13,302,000 to 25,095,700 with 76.1% of the increase occurring in Arkansas and the remainder in Oklahoma.

If all houses capable of production were being used, it is estimated that a total of 10,184,600 lbs. of Nitrogen and 3,180,540 lbs. of Phosphorous would be produced in the entire watershed per year. Arkansas would produce 68.6% of both nutrients under this scenario.

It is very important to note that this is an estimate of the total amount of nutrients excreted by confined animals in the watershed and that under normal conditions, only a small fraction of the total would ever reach the water. Only in an extreme worst case scenario would all of these nutrients end up in Spavinaw Creek. Typically, about 40% of the total Nitrogen in poultry litter is lost to the atmosphere during storage, so that unless the grower took the litter straight from the house to the field throughout the entire year the amount of Nitrogen introduced to the environment would be quite a bit less than the amount excreted. Likewise, a large portion of the remaining Nitrogen is lost to the atmosphere after application, and living plants take up much of the rest leaving only a fraction of the original to become a potential water pollutant. Phosphorous, although not volatile in any naturally occurring form, often binds tightly to soil particles. Only a fraction of the original will be available in a water soluble form that is likely to wash into surface water. One troublesome thing about Phosphorous is that it occurs in poultry waste in greater amounts than plants need in relation to the Nitrogen present. This means that it tends to accumulate on and near the soil surface and will eventually become a water pollutant wherever poultry waste is used as a fertilizer year after year.

Other factors that influence the amount of nutrients reaching water include the timing of application in relationship to rainfall and plant growth cycles. Litter applied right before a heavy rain or in the winter when grass isn't growing is far more likely to reach water than is litter applied when grass is actively growing and rainfall is absent or slow. Also, the amount of nutrients produced is a function of the number of flocks raised per year. Our calculations assume that growers are running their houses at maximum capacity, but this is often not the case. Many growers will only raise three or four flocks a year rather than five which is the maximum possible. Finally, in almost all cases, hog and laying hen waste is put into a lagoon or detention pond where much of the Nitrogen is lost to the atmosphere, and a majority of the Phosphorous settles out of the liquid phase. The lagoon will eventually be pumped out and the Phosphorous in the sludge will be land applied, but by that time an unknown amount will be in a non-soluble form not available to plants and algae.

Even though most of the nutrients excreted may not reach the lake, it is apparent that a significant portion of them do. This is demonstrated by the steady increase in total Nitrogen and Phosphorous concentrations seen at the monitoring site at the Arkansas Department of Pollution Control and Ecology at Arkansas Hwy. 43 over the last twenty years. It's also manifested in the lake as steadily increasing chlorophyll values. The decrease in water quality matches an increase in poultry production that can be estimated by comparing the number of animal houses on the USGS 7.5" topo maps that were mapped in the early 70's to those that appear on the photorevisions of the early 80's and those that appear on our map of 1996. It is easy to see that water quality has decreased as the confined animal industry has increased.

Chickens, pigs, turkeys, and humans all excrete Nitrogen and Phosphorus at different ratios and concentrations. That means that while one person equals 23 broilers in terms of the pounds of waste excreted, they equal 11 broilers in terms of Nitrogen excreted, and only 3.7 broilers in terms of

Phosphorous excreted. Of course poultry aren't present in any given house all year. A normal flock of broilers takes 50 days to mature, and five flocks per year are normally grown, so those numbers should all be multiplied by the inverse of the fraction of the year they are actually present which is 365/250 or 1.46. This changes the above numbers to 33.6, 16.1, and 5.4 respectively. Similar calculations can be performed for other animals. The total number of confined animals in the watershed is equal to 1,275,000 humans in terms of Nitrogen excreted, and 3,778,000 humans in terms of Phosphorous excreted. Averaging these two numbers and dividing by the number of square miles in the watershed, we arrive at a human density equivalent of 7,121 humans per square mile or 11 humans per acre. This is in addition to the humans that actually live there.

Looking at the data in this way allows one to better understand the need to properly manage animal waste to prevent eutrophication and health hazards. The thought of this many people in the watershed without any waste treatment system would be startling to say the least, and the populace would want something done about the situation immediately. Many of the animal growers are on animal waste management plans, and most of those on a plan adhere to it to a greater or lesser degree. This is demonstrated by the fact that Lake Eucha is still in fairly good shape. There is still much room for improvement however. People disagree on just what constitutes an adequate plan, who must have an animal waste plan, and what level of compliance to the plan should be expected, and whether or not there should be enforcement or not. If the present day water quality of Lake Eucha is to be preserved or improved, it's imperative to begin work in the watershed to decrease the amount of nutrients reaching the stream and groundwater immediately.

Table 1. Lake Eucha Watershed CAFO List

SITE ID#	HOUSES	SIZES	TYPE	ANIMALS #	OWNER	COMPANY	LOCATION
A100	3	3\400	Broiler	60,000		Tyson	Beaty Cr.
A101	4	4\300	Broiler	45,000	Jimmy's Turner	Peterson	Beaty Cr.
A111	3	3\400	Broiler	60,000	Benson	Tyson	Beaty Cr.
A112	2	2\300	Broiler	30,000	Rowena Meeks	Peterson	Beaty Cr.
A113	4	4\400	Broiler	80,000	Roberts	Simmons	Beaty Cr.
A120	2	2\400	Broiler	40,000	James Crawley	Simmons	Beaty Cr.
A122	4	3\400, 1\300	Broiler	60,000	Bill Pace	Simmons	Beaty Cr.
A123	2	2\300	Broiler	30,000	Jo Austin	Peterson	Beaty Cr.
A124	3	3\400	Broiler	60,000	Carltons	Hudson	Beaty Cr.
A84	3	3\400	Broiler	60,000	Eaton	Simmons	Beaty Cr.
A85	2	2\400	Broiler	40,000	Menna Yodder	Tyson	Beaty Cr.
A89	1	1\400	Broiler	20,000	Mitch Florer	Tyson	Beaty Cr.
A90	6	6\400	Broiler	120,000	Bell Farm	Simmons	Beaty Cr.
A91	7	7\400	Broiler	140,000	Archie Sperry	Peterson	Beaty Cr.
O114	10	10\400	Broiler	200,000		Tyson	Beaty Cr.
O116	2	2\400	Broiler	40,000		Hudson	Beaty Cr.
O117	2	2\400	Layers	40,000		Peterson	Beaty Cr.
O118	4	4\400	Layers	32,000		Hudson	Beaty Cr.
O119	2	2\400	Layers	40,000		Hudson	Beaty Cr.
O121	1	1\400	Layer	20,000	James Black	Simmons	Beaty Cr.
O122	2	2\300	Broiler	30,000	Wayne Armstrong	Simmons	Beaty Cr.
O29	4	3\300, 1\400	Broiler	45,000	Roger Isaac	Simmons	Beaty Cr.
O30	2	2\400	Broiler	40,000		Hudson	Beaty Cr.
O32	2	2\400	Broiler	20,000	Don Reed	Simmons	Beaty Cr.
O56	2	2\300	Broiler	30,000	Dave Chamberlin	Peterson	Beaty Cr.
O59	2	2\400	Broiler	40,000	J. Harris	Peterson	Beaty Cr.
O63	3	3\400	Broiler	60,000	Rhonda Palm	Peterson	Beaty Cr.
O64	2	1\400, 1\300	Broiler	20,000		Tyson	Beaty Cr.
O65	3	3\400	Broiler	60,000	Georgia Allen	Peterson	Beaty Cr.
O66	1	1\400	Broiler	20,000		Simmons	Beaty Cr.
O67	3	3\400	Broiler	60,000	Randy Allen	Peterson	Beaty Cr.
O68	3	3\300	Broiler	45,000	Ray Allen	Peterson	Beaty Cr.
O70	2	2\400	Broiler	40,000		Peterson	Beaty Cr.
O71	2	2\300	Broiler	30,000	Dave Chamberlin	Peterson	Beaty Cr.
O73	4	4\300	Broiler	60,000	Don Albert	Hudson	Beaty Cr.
O74	3	3\400	Broiler	60,000	Shelia Hartley	Hudson	Beaty Cr.
O75	4	4\300	Broiler	60,000	Wesley Beaty	Peterson	Beaty Cr.
O76	10	10\400	Broiler	200,000		Tyson	Beaty Cr.
O77	5		Hogs	15,000		Tyson	Beaty Cr.
O46	2		Layers	16,000	Bishop	Simmons	Brush Cr.
O47	10	10\400	Broiler	200,000		Tyson	Brush Cr.
O49	1	1\400	Broiler	20,000	Carol Ritter	Peterson	Brush Cr.
O51	10	10\400	Broiler	200,000		Tyson	Brush Cr.
O55	4	4\400	Broiler	80,000	Rhonda Williams	Peterson	Brush Cr.
O58	2	2\400	Broiler	40,000		Peterson	Brush Cr.
O60	2	2\400	Broiler	40,000	Tom Denny	Simmons	Brush Cr.
A22	4	4\400	Broiler	80,000	Thoron Wilmont	Peterson	Cherokee Cr.
A24	5	4\300,1\400	Broiler	80,000	Floyd Norris	Peterson	Cherokee Cr.
A27	2	2\400	Broiler	40,000	Brad Wofford	George's	Cherokee Cr.
A37	4	4\400	Broiler	80,000	Cherokee Farms	Cobb-Vantress	Cherokee Cr.

A585	2	2\400	Broiler	40,000	Merrell Amos	Peterson	Cherokee Cr.
A8	3	3\400	Broiler	60,000	Dale Becker	Peterson	Cherokee Cr.
O10	3	3\400	Broiler	60,000	Dale Guthrie	George's	Cherokee Cr.
O106	1	1\400	Broiler	20,000		Hudson	Cherokee Cr.
O3	2	2\400	Broiler	40,000	Wilks Harper	Peterson	Cherokee Cr.
O4	2	2\400	Broiler	40,000	John Jones	Peterson	Cherokee Cr.
O6	3	3\400	Broiler	60,000	Mark Becker	Peterson	Cherokee Cr.
O7	2	2\400	Broiler	40,000	Dennis Chamberlin	Peterson	Cherokee Cr.
O8	5	5\400	Broiler	100,000	Montey Jones	Hudson	Cherokee Cr.
O82	2	2\300	Broiler	30,000	Gary Smith	Peterson	Cherokee Cr.
O85	2	2\400	Broiler	40,000	Ron Allen	Peterson	Cherokee Cr.
O86	4	4\400	Broiler	80,000	Larry Ahrens	Peterson	Cherokee Cr.
O91	2	2\400	Broiler	40,000	Jerold Amos	Peterson	Cherokee Cr.
O94	2	2\400	Broiler	40,000	Mickey Capps	Peterson	Cherokee Cr.
O95	3	3\400	Broiler	60,000	David Koehn	Simmons	Cherokee Cr.
O16	16		Hogs	4,800		Tyson	Cherokee Cr.
O5	3		Hogs	1,500		Tyson	Cherokee Cr.
O128	3	3\400	Broiler	60,000	Joy Thompson	Peterson	Cloud Cr.
O129	1	1\400	Layer	20,000	Don Bishop	Peterson	Cloud Cr.
O37	2	2\300	Broiler	30,000	Lowell Wood	Tyson	Cloud Cr.
O79	4	4\400	Broiler	80,000	Leonard Partain	George's	Cloud Cr.
A11	2	1\400,1\300	Broiler	35,000	Billie McChristian	Tyson	Coon Cr.
A13	2	2\400	Broiler	40,000	Kate Unruh	Peterson	Coon Cr.
A213	3	3\400	Broiler	60,000	Leon Keohn	Peterson	Coon Cr.
A220	3	3\400	Broiler	60,000	Fred Rossenbrugh	Peterson	Coon Cr.
A233	4	4\400	Broiler	80,000		Peterson	Coon Cr.
A245	4	4\400	Broiler	80,000	Rene Singleton	Peterson	Coon Cr.
A246	4	4\400	Broiler	80,000	Mel Redmond	Peterson	Coon Cr.
A38	3	3\400	Broiler	60,000			Coon Cr.
A39	3	3\400	Broiler	60,000			Coon Cr.
A41	3	3\400	Broiler	60,000	Gary Stanfield	Peterson	Coon Cr.
A43	2	2\400	Broiler	40,000	Pat Hallford	Peterson	Coon Cr.
A44	2	2\400	Broiler	40,000	Bob Bowman	Peterson	Coon Cr.
A45	2	2\400	Broiler	40,000	Sharon Mitchell	Tyson	Coon Cr.
A47	3	3\400	Broiler	60,000	K. Pike	Simmons	Coon Cr.
A51	2	2\300	Broiler	30,000	Lester Amos	Peterson	Coon Cr.
A56	2	2\400	Broiler	40,000	McChesney	Cobb-Vantress	Coon Cr.
A57	2	2\400	Broiler	40,000	McChesney	Cobb-Vantress	Coon Cr.
A65	4	4\400	Broiler	80,000	Doug Holly	Peterson	Coon Cr.
A68	3	3\400	Broiler	60,000	Freda Wilmoth	Simmons	Coon Cr.
A69	4	4\400	Broiler	80,000	Charles Wilmoth	Simmons	Coon Cr.
A70	2	2\400	Broiler	40,000	Lisa McGarrah	Peterson	Coon Cr.
A73	3	3\400	Broiler	60,000	Audrey Lakey	Peterson	Coon Cr.
A62	1	1\400	Hog	300	Tammy Meek	Peterson	Coon Cr.
A78	2		Hogs	600		Tyson	Coon Cr.
A190	14	14\400	Broiler	280,000		Peterson	Decatur Br.
A194	3	3\400	Broiler	60,000		Peterson	Decatur Br.
A195	4	4\400	Broiler	80,000	D. Frye	Peterson	Decatur Br.
A196	6	6\400	Broiler	120,000		Peterson	Decatur Br.
A197	2	2\400	Broiler	40,000	M. Crowder	Peterson	Decatur Br.
A229	1	1\400	Broiler	20,000	Tom Mills	Peterson	Decatur Br.
A234	2	2\400	Broiler	40,000	Ken Goodwin	Peterson	Decatur Br.

A235	4	4\400	Broiler	80,000	Terry Redman	Peterson	Decatur Br.
A236	3	3\300	Broiler	45,000	Jim Howell	Peterson	Decatur Br.
A239	2	1\300, 1\400	Broiler	35,000	Leroy Browers	Peterson	Decatur Br.
A240	3	2\300, 1\400	Broiler	50,000	Pat Austin	Peterson	Decatur Br.
A243	1	1\300	Broiler	15,000	C. Greenlawn	Peterson	Decatur Br.
A244	2	2\400	Broiler	40,000	Pat Jones	Peterson	Decatur Br.
A247	4	4\400	Broiler	80,000	Gunter	Peterson	Decatur Br.
A249	2	2\400	Broiler	40,000	Don Wilkerson	Peterson	Decatur Br.
A98	3	3\400	Broiler	60,000	Bill Meeks	Peterson	Decatur Br.
A99	5	5\400	Broiler	100,000	Dianie Ewin	Peterson	Decatur Br.
O36	4	4\00	Broiler	80,000	Jim Pigeon	Peterson	Dry Cr.
O78	4	4\400	Broiler	80,000	Farrell Mefford	Peterson	Dry Cr.
O120	4	4\400	Layers	32,000		Cobb-Vantress	Hog Eye Cr.
O125	10	10\400	Broiler	200,000	Robert Brown	Tyson	Hog Eye Cr.
O126	4	4\400	Broiler	80,000	Sharron Glenn	Simmons	Hog Eye Cr.
O42	4	4\400	Broiler	80,000	Barney Barns	Peterson	Rattlesnake Cr.
A178	2	2\400	Broiler	40,000	Wanda Thompson	Peterson	South Prong
A181	2	2\400	Broiler	40,000	Gibbons	Peterson	South Prong
A371	2	2\300	Broiler	30,000	Kenneth Bufford	George's	South Prong
A372	4	4\300	Broiler	60,000	Robert Smith	Peterson	South Prong
A373	3	3\400	Broiler	60,000	Lance Webb	Peterson	South Prong
A377	2	2\400	Broiler	40,000	Pat Croman	Peterson	South Prong
A378	3	3\400	Turkey	60,000	Greg Pruitt	Cargill	South Prong
A456	10	10\400	Broiler	200,000	Robert Smith	Peterson	South Prong
A457	1	1\400	Broiler	20,000	Tim Henderson	Peterson	South Prong
A458	4	4\400	Broiler	80,000	Russ Henderson	Peterson	South Prong
A459	2	2\400	Broiler	40,000	Scott Bunch	Peterson	South Prong
A514	2	2\400	Broiler	40,000		Peterson	South Prong
A515	3	3\300	Broiler	45,000	Tim Mathews	Peterson	South Prong
A517	2	2\300	Broiler	30,000	Jim Davis	Peterson	South Prong
O111	2	2\400	Broiler	40,000	Dona Woods	Peterson	Spavinaw north laterals btwn Beaty Cr. and Un-n
O112	4	4\400	Broiler	80,000	Paul Woods	Peterson	Spavinaw north laterals btwn Beaty Cr. and Un-n
O113	3	3\400	Broiler	60,000	Fred Spence	Peterson	Spavinaw north laterals btwn Beaty Cr. and Un-n
A81	2	2\400	Broiler	40,000	Dan Peadrey	Peterson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
A82	4	4\400	Broiler	80,000	Coats	Peterson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
A83	2	2\400	Broiler	40,000	Janice Bunch	Tyson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
A86	2	2\400	Broiler	40,000	Wendell Hicks	Tyson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
A87	1	1\400	Broiler	20,000	Ann Florer	Tyson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
A88	2	2\400	Broiler	40,000	Dennis Florer	Tyson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
O127	4	4\400	Broiler	80,000	Dan Ransom	Peterson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
O23	3	3\400	Broiler	60,000	Chester Walker	Hudson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
O24	2	2\400	Broiler	40,000	Wayne Florer	Tyson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
O25	4	4\400	Broiler	80,000	Russell Peterson	Peterson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
O34	20		Hogs	6,000		Tyson	Spavinaw north laterals btwn Hog Eye Cr. and Sp
A107	4	4\400	Broiler	80,000	Delbert Buffer	Peterson	Spavinaw north laterals btwn Spring Branch and
A108	1	1\400	Broiler	20,000	P.J. Hust	Simmons	Spavinaw north laterals btwn Spring Branch and
A109	2	2\400	Broiler	40,000	Hust	Simmons	Spavinaw north laterals btwn Spring Branch and
A270	3	3\400	Broiler	60,000	Nelson Roberts	Peterson	Spavinaw north laterals btwn Spring Branch and
A273	3	3\400	Broiler	60,000	Lambert	Peterson	Spavinaw north laterals btwn Spring Branch and
A286	4	4\400	Broiler	80,000	Ronnie Austin	Hudson	Spavinaw north laterals btwn Un-named trib. at
A287	3	3\400	Broiler	60,000		Tyson	Spavinaw north laterals btwn Un-named trib. at
A297	3	3\400	Broiler	60,000		Tyson	Spavinaw north laterals btwn Un-named trib. at
A298	3	3\400	Broiler	60,000	Rebecca Boiling	Peterson	Spavinaw north laterals btwn Un-named trib. at

A301	4	4\400	Broiler	80,000	Jerry Yingst	Hudson	Spavinaw north laterals btwn Un-named trib. at
A315	6	6\300	Broiler	90,000	Pat Boling	Peterson	Spavinaw north laterals btwn Un-named trib. at
A316	2	2\300	Broiler	30,000	Geneva Hamilton	Tyson	Spavinaw north laterals btwn Un-named trib. at
A317	2	2\400	Broiler	40,000	Robert Sooter	Peterson	Spavinaw north laterals btwn Un-named trib. at
A318	2	2\400	Broiler	40,000	Bryon Hinderson	Peterson	Spavinaw north laterals btwn Un-named trib. at
A320	3	3\600	Turkey	120,000	Keith Roberts	Cargil	Spavinaw north laterals btwn Un-named trib. at
A322	3	3\400	Broiler	60,000	Brenda Plazzo	George's	Spavinaw north laterals btwn Un-named trib. at
A329	3	3\400	Broiler	60,000	Paul Galyear	Peterson	Spavinaw north laterals btwn Un-named trib. at
A77	2	2\400	Broiler	40,000	George Norris	Peterson	Spavinaw south laterals btwn Cherokee Cr. & C
A79	4	4\400	Broiler	80,000	Big Mac	Tyson	Spavinaw south laterals btwn Cherokee Cr. and C
A80	4	4\400	Broiler	80,000			Spavinaw south laterals btwn Cherokee Cr. & C
O13	1	1\400	Broiler	20,000	Don Copeland	Peterson	Spavinaw south laterals btwn Cherokee Cr. & C
O15	4	4\400	Broiler	80,000	H.J. Ron Trager	George's	Spavinaw south laterals btwn Cherokee Cr. & C
O20	2	2\400	Broiler	40,000	Glenn Hurt	Hudson	Spavinaw south laterals btwn Cherokee Cr. & C
O22	2	2\400	Broiler	40,000	Tom Morgan	Simmons	Spavinaw south laterals btwn Cherokee Cr. & C
A35	1	1\400	Turkey	20,000	Carl Jones	Cargill	Spavinaw south laterals btwn Cherokee Cr. & C
O102	3	3\400	Broiler	60,000		Peterson	Spavinaw south laterals btwn Cloud Cr. and Cher
O107	2	2\400	Broiler	40,000	Greg Brockman	Peterson	Spavinaw south laterals btwn Cloud Cr. and Cher
O109	1	1\400	Layer	20,000	Koehn	Simmons	Spavinaw south laterals btwn Cloud Cr. and Cher
O96	2	2\400	Broiler	40,000	Wesley Koehn	Simmons	Spavinaw south laterals btwn Cloud Cr. and Cher
O98	2	2\400	Broiler	40,000	Wendell Harper	Peterson	Spavinaw south laterals btwn Cloud Cr. and Cher
A48	4	4\400	Turkey	80,000	Dennis Owens	Cargill	Spavinaw south laterals btwn Coon Cr. & Decat
A198	1	1\300	Broiler	15,000	M. Wilkins	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A199	2	2\300	Broiler	30,000	R. Hopkins	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A200	2	2\400	Broiler	40,000	John Burr	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A202	3	3\400	Broiler	60,000	Lyle Austin	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A203	2	2\400	Broiler	40,000	Suzanne Austin	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A204	2	2\400	Broiler	40,000	C. Herrigton	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A205	2	2\400	Broiler	40,000	C. Tharp	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A206	2	2\400	Broiler	40,000	L. Thompson	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A207	4	4\400	Broiler	80,000	Charles Austin	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A208	4	4\400	Broiler	80,000	Jim Tormey	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A257	3	3\400	Broiler	60,000	Ruben Barnes	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A92	2	2\400	Broiler	40,000	Janes	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A95	5	5\400	Broiler	100,000	C.G. Knox	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A97	3	3\400	Broiler	60,000	Mary Yates	Peterson	Spavinaw south laterals btwn Decatur Br. and Wo
A93	10		Hogs	3,000		Tyson	Spavinaw south laterals btwn Decatur Br. and Wo
A96	5		Hogs	1,500		Tyson	Spavinaw south laterals btwn Decatur Br. and Wo
A368	4	2\400, 2\300	Broiler	70,000	K. Alsup	Peterson	Spavinaw south laterals btwn South Prong & he
A369	3	3\400	Broiler	60,000	R. Alsup	Peterson	Spavinaw south laterals btwn South Prong & he
A375	4	4\400	Broiler	80,000	Duane Blessing	Peterson	Spavinaw south laterals btwn South Prong & he
A379	2	2\400	Broiler	40,000	Orlene Webb	Peterson	Spavinaw south laterals btwn South Prong & he
A380	2	2\400	Broiler	40,000	John Webb	Peterson	Spavinaw south laterals btwn South Prong & he
A381	2	2\400	Turkey	40,000	Tim Swank	Cargill	Spavinaw south laterals btwn South Prong & he
A409	9	9\400	Broiler	180,000		Tyson	Spavinaw south laterals btwn South Prong & he
A262	3	3\400	Broiler	60,000		Hudson	Spavinaw south laterals btwn Wolf Cr. and South
A265	1	1\400	Broiler	20,000	S. Hatfield	Peterson	Spavinaw south laterals btwn Wolf Cr. and South
A104	4	4\400	Broiler	80,000		Tyson	Spring Branch
A105	2	2\400	Broiler	40,000	Kay Russo	Peterson	Spring Branch
A268	4	4\400	Broiler	80,000	Chris Buffer	Peterson	Spring Branch
A269	3	3\400	Broiler	60,000	Vernon Buffer	Peterson	Spring Branch
A252	2	2\400	Broiler	40,000	Jim Pruitt	Peterson	Un-named trib. at Gravette

A283	1	1\400	Broiler	20,000	G. Frusum	Hudson	Un-named trib. at Nebo
A284	6	6\300	Broiler	90,000		Hudson	Un-named trib. at Nebo
A285	3	3\400	Broiler	60,000	Danny Boiling	Peterson	Un-named trib. at Nebo
A179	2	2\400	Broiler	40,000	W. Hibbard	Tyson	Wolf Cr.
A182	2	2\400	Broiler	40,000	Tim Hochsteller	Peterson	Wolf Cr.
A183	23	23\400	Broiler	460,000	Peterson	Peterson	Wolf Cr.
A185	5	5\400	Broiler	100,000	Royce Johnson	Peterson	Wolf Cr.
A186	6	6\400	Broiler	120,000	D. Rogers	Peterson	Wolf Cr.
A187	2	2\400	Broiler	40,000	J. Phillips	Simmons	Wolf Cr.
A188	2	2\300	Broiler	30,000	John Smith	Peterson	Wolf Cr.
A189	1	1\400	Broiler	20,000	W. Hanson	Peterson	Wolf Cr.
A191	29		Hatchery	232,000		Peterson	Wolf Cr.
A192	13	13\400	Broiler	260,000		Peterson	Wolf Cr.
A201	3	3\400	Broiler	60,000	Val Smith	Peterson	Wolf Cr.
A263	2	2\400	Broiler	40,000	Glenn Whitman	Peterson	Wolf Cr.
A264	2	2\400	Broiler	40,000	Monte Staha	Peterson	Wolf Cr.
O123							Beaty Cr.
O52							Beaty Cr.
O62							Beaty Cr.
A9							Cherokee Cr.
O101							Cherokee Cr.
O12							Cherokee Cr.
O17							Cherokee Cr.
A10							Coon Cr.
A12							Coon Cr.
A42							Coon Cr.
A180							South Prong
A374							South Prong
A516							South Prong
O110							Spavinaw north laterals btwn Beaty Cr. &Un-n
O26							Spavinaw north laterals btwn Hog Eye Cr. & Sp
A255							Spavinaw north laterals btwn Spring Branch &
A272							Spavinaw north laterals btwn Spring Branch &
A295							Spavinaw north laterals btwn Un-named trib. at
A114							Spring Branch
A102							Beaty Cr.
A103							Beaty Cr.
A125							Beaty Cr.
A126							Beaty Cr.
A128							Beaty Cr.
O115							Beaty Cr.
O28							Beaty Cr.
O31							Beaty Cr.
O33							Beaty Cr.
O53							Beaty Cr.
O57							Beaty Cr.
O61							Beaty Cr.
O69							Beaty Cr.
O72							Beaty Cr.
O43							Brush Cr.
O44							Brush Cr.
O45							Brush Cr.
O54							Brush Cr.

O84							Brush Cr.
A21							Cherokee Cr.
A23		3\NS,1\NIP					Cherokee Cr.
A580							Cherokee Cr.
A583							Cherokee Cr.
O104							Cherokee Cr.
O105							Cherokee Cr.
O11							Cherokee Cr.
O18							Cherokee Cr.
O81							Cherokee Cr.
O83							Cherokee Cr.
O87							Cherokee Cr.
O88							Cherokee Cr.
O89							Cherokee Cr.
O9							Cherokee Cr.
O90							Cherokee Cr.
O93							Cherokee Cr.
O100							Cloud Cr.
O130							Cloud Cr.
O38							Cloud Cr.
O39							Cloud Cr.
O40							Cloud Cr.
O41							Cloud Cr.
O80							Cloud Cr.
O99							Cloud Cr.
A221							Coon Cr.
A248							Coon Cr.
A36							Coon Cr.
A40							Coon Cr.
A46							Coon Cr.
A53							Coon Cr.
A54							Coon Cr.
A55							Coon Cr.
A567							Coon Cr.
A58							Coon Cr.
A60			Hog	10			Coon Cr.
A61							Coon Cr.
A63							Coon Cr.
A64							Coon Cr.
A66							Coon Cr.
A67							Coon Cr.
A71							Coon Cr.
A72							Coon Cr.
A193							Decatur Br.
A227							Decatur Br.
A228							Decatur Br.
A237							Decatur Br.
A238							Decatur Br.
A241							Decatur Br.
A242							Decatur Br.
A250							Decatur Br.
A49							Decatur Br.
A50							Decatur Br.

A52							Decatur Br.
A561							Decatur Br.
A562							Decatur Br.
A563							Decatur Br.
A564							Decatur Br.
A568							Decatur Br.
A582							Decatur Br.
A59							Decatur Br.
O124							Hog Eye Cr.
O27							Hog Eye Cr.
A259							South Prong
A281							South Prong
A414							South Prong
A415							South Prong
A416							South Prong
A460							South Prong
A518							South Prong
A552							South Prong
A553							South Prong
A554							South Prong
A556							South Prong
A578							Spavinaw north laterals btwn Hog Eye Cr. & Sp
A579							Spavinaw north laterals btwn Hog Eye Cr. & Sp
A110							Spavinaw north laterals btwn Spring Branch
A251							Spavinaw north laterals btwn Spring Branch
A254							Spavinaw north laterals btwn Spring Branch
A256							Spavinaw north laterals btwn Spring Branch
A267							Spavinaw north laterals btwn Spring Branch
A271							Spavinaw north laterals btwn Spring Branch
A535							Spavinaw north laterals btwn Spring Branch
A540							Spavinaw north laterals btwn Spring Branch
A541							Spavinaw north laterals btwn Spring Branch
A288							Spavinaw north laterals btwn Un-named trib. at
A289							Spavinaw north laterals btwn Un-named trib. at
A290							Spavinaw north laterals btwn Un-named trib. at
A291							Spavinaw north laterals btwn Un-named trib. at
A302							Spavinaw north laterals btwn Un-named trib. at
A319							Spavinaw north laterals btwn Un-named trib. at
A321							Spavinaw north laterals btwn Un-named trib. at
A323							Spavinaw north laterals btwn Un-named trib. at
A324							Spavinaw north laterals btwn Un-named trib. at
A330							Spavinaw north laterals btwn Un-named trib. at
A335							Spavinaw north laterals btwn Un-named trib. at
A336							Spavinaw north laterals btwn Un-named trib. at
A354							Spavinaw north laterals btwn Un-named trib. at
A528							Spavinaw north laterals btwn Un-named trib. at
A76							Spavinaw south laterals btwn Cherokee Cr. & C
O19							Spavinaw south laterals btwn Cherokee Cr. & C
O21							Spavinaw south laterals btwn Cherokee Cr. & C
O92							Spavinaw south laterals btwn Cherokee Cr. & C
O103							Spavinaw south laterals btwn Cloud Cr. & Cher
O108							Spavinaw south laterals btwn Cloud Cr. & Cher
O97							Spavinaw south laterals btwn Cloud Cr. & Cher

A209							Spavinaw south laterals btwn Decatur Br. & Wo
A266							Spavinaw south laterals btwn Decatur Br. & Wo
A565							Spavinaw south laterals btwn Decatur Br. & Wo
A566							Spavinaw south laterals btwn Decatur Br. & Wo
A569							Spavinaw south laterals btwn Decatur Br. & Wo
A570							Spavinaw south laterals btwn Decatur Br. & Wo
A573							Spavinaw south laterals btwn Decatur Br. & Wo
A574							Spavinaw south laterals btwn Decatur Br. & Wo
A575							Spavinaw south laterals btwn Decatur Br. & Wo
A576							Spavinaw south laterals btwn Decatur Br. & Wo
A577							Spavinaw south laterals btwn Decatur Br. & Wo
A94							Spavinaw south laterals btwn Decatur Br. & Wo
A282							Spavinaw south laterals btwn South Prong & he
A355							Spavinaw south laterals btwn South Prong & he
A356							Spavinaw south laterals btwn South Prong & he
A362							Spavinaw south laterals btwn South Prong & he
A363							Spavinaw south laterals btwn South Prong & he
A364							Spavinaw south laterals btwn South Prong & he
A365							Spavinaw south laterals btwn South Prong & he
A366							Spavinaw south laterals btwn South Prong & he
A367							Spavinaw south laterals btwn South Prong& he
A376							Spavinaw south laterals btwn South Prong & he
A382							Spavinaw south laterals btwn South Prong & he
A383							Spavinaw south laterals btwn South Prong & he
A384							Spavinaw south laterals btwn South Prong & he
A385							Spavinaw south laterals btwn South Prong & he
A386							Spavinaw south laterals btwn South Prong & he
A410							Spavinaw south laterals btwn South Prong & he
A519							Spavinaw south laterals btwn South Prong & he
A526							Spavinaw south laterals btwn South Prong & he
A534							Spavinaw south laterals btwn South Prong &
A260							Spavinaw south laterals btwn Wolf Cr. & South
A261							Spavinaw south laterals btwn Wolf Cr. & South
A106							Spring Branch
A274							Spring Branch
A275							Spring Branch
A542							Spring Branch
A571							Spring Branch
A572							Spring Branch
A253							Un-named trib. at Gravette
A292							Un-named trib. at Nebo
A536							Un-named trib. at Nebo
A537							Un-named trib. at Nebo
A538							Un-named trib. at Nebo
A177							Wolf Cr.
A184							Wolf Cr.
A258							Wolf Cr.
A557							Wolf Cr.
A558							Wolf Cr.
A559							Wolf Cr.
A560	175						Wolf Cr.

TABLE 2: Lake Eucha Confined Animal Inventory Summary of Results

			Chicken				Hog				Turkey								
SUBWATERSHED	**GIS Label**	**Size (sq. mile)**	**Sites**	**Houses**	**Animals**	**Animal Density (per sq. mile)**	**Sites**	**Houses**	**Animals**	**Animal Density (per sq. mile)**	**Sites**	**Houses**	**Animals**	**Animal Density (per sq. mile)**	**Sites Not Standing**	**Sites Not In Production**	**Potential Houses In Production***	**Potential Animals ****	**Potential Animal Density (per sq. mile)**
Beaty Cr.	3	59.4	39	126	2,152,000	36,240	0				0				3	14	173	3,086,080	51,970
Brush Cr.	2	34.4	7	31	596,000	17,338	0				0				0	5	48	929,600	27,042
Cherokee Cr.	34	19.4	19	53	1,030,000	53,073	2	19	6,300	325	0				4	16	108	2,103,820	108,404
Cloud Cr.	32	24.9	4	10	190,000	7,619	0				0				0	8	37	723,760	29,025
Coon Cr.	29	15.4	22	62	1,225,000	79,740	2	3	900	59	0				3	18	124	2,426,860	157,974
Decatur Br.	24	11.2	17	61	1,185,000	105,382	0				0				0	18	121	2,385,960	212,184
Dry Cr.	31	28.7	2	8	160,000	5,576	0				0				0	0	8	160,000	5,576
Eucha and Spavinaw north laterals btwn Brush Cr and Beaty Cr.	22	1.2	0				0				0				0	0			
Eucha and Spavinaw south laterals btwn Dry Cr. and Cloud Cr.	27	2.9	0				0				0				0	0			
Eucha Laterals btwn Rattlesnake Cr. and Brush Cr.	19	2.2	0				0				0				0	0			
Eucha north laterals btwn Dam and Rattlesnake Cr.	17	5.3	0				0				0				0	0			
Eucha south laterals btwn Dam and Dry Cr.	21	11.7	0				0				0				0	0			
Hog Eye Cr.	18	6.9	3	18	312,000	45,446	0				0				0	2	25	445,440	64,882
Rattlesnake Cr.	11	9.0	1	4	80,000	8,905	0				0				0	0	4	80,000	8,905
South Prong	13	17.6	14	42	785,000	44,663	0				0				3	11	79	1,518,920	86,421
Spavinaw north laterals btwn Beaty Cr. and Hog Eye Cr.	26	5.2	3	9	180,000	34,880	0				0				1	0	9	180,000	34,880
Spavinaw north laterals btwn Hog Eye Cr. and Spring Branch	14	9.8	10	26	520,000	52,869	1	20	6,000	610	0				1	2	34	659,440	67,046
Spavinaw north laterals btwn Spring Branch and Un-named trib. at Gravette	5	7.2	5	13	260,000	36,135	0				0				2	9	43	860,480	119,591
Spavinaw north laterals btwn Un-named trib. at Nebo and head waters	6	13.1	12	38	780,000	59,749	0				0				1	14	85	1,714,080	131,301
Spavinaw north laterals btwn Un-named trib. at Gravette and Un-named trib. at Nebo	9	1.0	0				0				0				0	0			
Spavinaw south laterals btwn Cherokee Cr. and Coon Cr.	30	8.4	7	19	380,000	45,031	0				1	1	20,000	2,370	0	4	33	666,880	79,026
Spavinaw south laterals btwn Cloud Cr. and Cherokee Cr.	33	9.5	5	10	200,000	20,954	0				0				0	3	20	400,160	41,924
Spavinaw south laterals btwn Coon Cr. and Decatur Br.	23	1.1	0				0				1	4	80,000	74,652	0	0	1	80,000	74,652
Spavinaw south laterals btwn Decatur Br. and Wolf Cr.	15	8.2	14	37	725,000	88,607	2	15	4,500	550	0				0	12	79	1,530,140	187,009
Spavinaw south laterals btwn South Prong and head waters	10	16.2	7	26	510,000	31,509	0				0				0	19	89	1,777,680	109,829
Spavinaw south laterals btwn Wolf Cr. and South Prong	12	1.7	2	4	80,000	46,590	0				0				0	2	11	213,440	124,303
Spring Branch	4	6.3	4	13	260,000	41,427	0				0				1	6	33	660,320	105,211
Un-named trib. at Gravette	8	2.2	1	2	40,000	18,437	0				0				0	1	5	106,720	49,189
Un-named trib. at Nebo	7	2.7	3	10	170,000	63,593	0				0				0	4	23	436,880	163,426

Wolf Cr.	16	12.3	13	92	1,482,000	120,906	0				0				0	7	115	1,949,040	159,008
Total Spavinaw	-	354.8	214	714	13,302,000	37,492	7	57	17,700	50	2	5	100,000	282	19	175	1307	25,095,700	70,733
Total Oklahoma (Delaware County)	-	211.1	71	225	4,115,000	19,496	3	39	12,300	58	0	0	0	0	8	42	368	6,929,540	32,831
Total Arkansas (Benton County)	-	143.7	143	489	9,187,000	63,920	4	18	5,400	38	2	5	100,000	696	11	133	939	18,166,160	126,393

*** Potential Houses In Production is calculated based on the average of 3.336 houses per active site in the Spavinaw watershed.**

**** Sites not inproduction are assumed to be chicken CAFO's with the potential of 20,000 chickens per house.**

TABLE 3: Lake Eucha Watershed Confined Animal Estimated Nutrient Production

			Chicken				Hog				Turkey				Total (Houses In Production)				Total (Full Production)			
			Pounds per year *		Pounds per sq mile per year		Pounds per year **		Pounds per sq mile per year		Pounds per year ***		Pounds per sq mile per year		Pounds per year		Pounds per sq mile per year		Pounds per year ****		Pounds per sq mile per year	
SUBWATERSHED	GIS Label	Size (sq. mile)	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus
Beaty Cr.	3	59.4	1,183,600	365,840	19,932	6,161	0	0	0	0	0	0	0	0	1,183,600	365,840	19,932	6,161	1,337,600	413,440	22,525	6,962
Brush Cr.	2	34.4	327,800	101,320	9,536	2,947	0	0	0	0	0	0	0	0	327,800	101,320	9,536	2,947	382,800	118,320	11,136	3,442
Cherokee Cr.	34	19.4	566,500	175,100	29,190	9,022	241,500	79,800	12,444	4,112	0	0	0	0	808,000	254,900	41,634	13,134	984,000	309,300	50,703	15,937
Cloud Cr.	32	24.9	104,500	32,300	4,191	1,295	0	0	0	0	0	0	0	0	104,500	32,300	4,191	1,295	192,500	59,500	7,720	2,386
Coon Cr.	29	15.4	673,750	208,250	43,857	13,556	34,500	11,400	2,246	742	0	0	0	0	708,250	219,650	46,103	14,298	906,250	280,850	58,991	18,282
Decatur Br.	24	11.2	651,750	201,450	57,960	17,915	0	0	0	0	0	0	0	0	651,750	201,450	57,960	17,915	849,750	262,650	75,568	23,357
Dry Cr.	31	28.7	88,000	27,200	3,067	948	0	0	0	0	0	0	0	0	88,000	27,200	3,067	948	88,000	27,200	3,067	948
Eucha and Spavinaw north laterals btwn Brush Cr and Beaty Cr.	22	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucha and Spavinaw south laterals btwn Dry Cr. and Cloud Cr.	27	2.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucha Laterals btwn Rattlesnake Cr. and Brush Cr.	19	2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucha north laterals btwn Dam and Rattlesnake Cr.	17	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucha south laterals btwn Dam and Dry Cr.	21	11.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hog Eye Cr.	18	6.9	171,600	53,040	24,995	7,726	0	0	0	0	0	0	0	0	171,600	53,040	24,995	7,726	193,600	59,840	28,200	8,716
Rattlesnake Cr.	11	9.0	44,000	13,600	4,898	1,514	0	0	0	0	0	0	0	0	44,000	13,600	4,898	1,514	44,000	13,600	4,898	1,514
South Prong	13	17.6	431,750	133,450	24,565	7,593	0	0	0	0	0	0	0	0	431,750	133,450	24,565	7,593	552,750	170,850	31,449	9,721
Spavinaw north laterals btwn Beaty Cr. and Hog Eye Cr.	26	5.2	99,000	30,600	19,184	5,930	0	0	0	0	0	0	0	0	99,000	30,600	19,184	5,930	99,000	30,600	19,184	5,930
Spavinaw north laterals btwn Hog Eye Cr. and Spring Branch	14	9.8	286,000	88,400	29,078	8,988	230,000	76,000	23,384	7,727	0	0	0	0	516,000	164,400	52,462	16,715	538,000	171,200	54,699	17,406
Spavinaw north laterals btwn Spring Branch and Un-named trib. at Gravette	5	7.2	143,000	44,200	19,874	6,143	0	0	0	0	0	0	0	0	143,000	44,200	19,874	6,143	242,000	74,800	33,634	10,396
Spavinaw north laterals btwn Un-named trib. at Nebo and head waters	6	13.1	429,000	132,600	32,862	10,157	0	0	0	0	0	0	0	0	429,000	132,600	32,862	10,157	583,000	180,200	44,659	13,804
Spavinaw north laterals btwn Un-named trib. at Gravette and Un-named trib. at Nebo	9	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spavinaw south laterals btwn Cherokee Cr. and Coon Cr.	30	8.4	209,000	64,600	24,767	7,655	0	0	0	0	53,000	20,000	6,281	2,370	262,000	84,600	31,047	10,025	306,000	98,200	36,261	11,637
Spavinaw south laterals btwn Cloud Cr. and Cherokee Cr.	33	9.5	110,000	34,000	11,524	3,562	0	0	0	0	0	0	0	0	110,000	34,000	11,524	3,562	143,000	44,200	14,982	4,631
Spavinaw south laterals btwn Coon Cr. and Decatur Br.	23	1.1	0	0	0	0	0	0	0	0	212,000	80,000	197,827	74,652	212,000	80,000	197,827	74,652	212,000	80,000	197,827	74,652
Spavinaw south laterals btwn Decatur Br. and Wolf Cr.	15	8.2	398,750	123,250	48,734	15,063	172,500	57,000	21,082	6,966	0	0	0	0	571,250	180,250	69,816	22,030	703,250	221,050	85,949	27,016
Spavinaw south laterals btwn South Prong and head waters	10	16.2	280,500	86,700	17,330	5,356	0	0	0	0	0	0	0	0	280,500	86,700	17,330	5,356	489,500	151,300	30,242	9,348
Spavinaw south laterals btwn Wolf Cr. and South Prong	12	1.7	44,000	13,600	25,625	7,920	0	0	0	0	0	0	0	0	44,000	13,600	25,625	7,920	66,000	20,400	38,437	11,881
Spring Branch	4	6.3	143,000	44,200	22,785	7,043	0	0	0	0	0	0	0	0	143,000	44,200	22,785	7,043	209,000	64,600	33,301	10,293
Un-named trib. at Gravette	8	2.2	22,000	6,800	10,140	3,134	0	0	0	0	0	0	0	0	22,000	6,800	10,140	3,134	33,000	10,200	15,210	4,701
Un-named trib. at Nebo	7	2.7	93,500	28,900	34,976	10,811	0	0	0	0	0	0	0	0	93,500	28,900	34,976	10,811	137,500	42,500	51,435	15,898
Wolf Cr.	16	12.3	815,100	251,940	66,498	20,554	0	0	0	0	0	0	0	0	815,100	251,940	66,498	20,554	892,100	275,740	72,780	22,496
Total Spavinaw	-	354.8	7,316,100	2,261,340	585,568	180,994	678,500	224,200	59,156	19,547	265,000	100,000	204,108	77,022	8,259,600	2,585,540	848,832	277,563	10,184,600	3,180,540	1,022,857	331,352
Total Oklahoma (Delaware County)	-	211.1	2,263,250	699,550	10,723	3,314	471,500	155,800	2,234	738	0	0	0	0	2,734,750	855,350	12,957	4,052	3,196,750	998,150	15,146	4,729

Total Arkansas (Benton County)	**-**	**143.7**	**5,052,850**	**1,561,790**	**35,156**	**10,866**	**207,000**	**68,400**	**1,440**	**476**	**265,000**	**100,000**	**1,844**	**696**	**5,524,850**	**1,730,190**	**38,440**	**12,038**	**6,987,850**	**2,182,390**	**48,619**	**15,184**

*** Esimated based on one 20,000 bird (chicken) house produces 11,000 lbs. nitrogen per and 3,400 lbs. phosphorus per year**

**** Esimated based on one 20,000 bird (turkey) house produces 53,000 lbs. nitrogen per and 20,000 lbs. phosphorus per year**

***** Esimated based on one 600 sow unit produces 23,000 lbs. nitrogen per and 7,600 lbs. phosphorus per year**

****** Esimated based the assumption that all houses not in production (Table 2) could be occupied by chickens during production.**