COMPREHENSIVE BASIN MANAGEMENT PLAN

FOR THE ILLINOIS RIVER BASIN

IN OKLAHOMA

Prepared by

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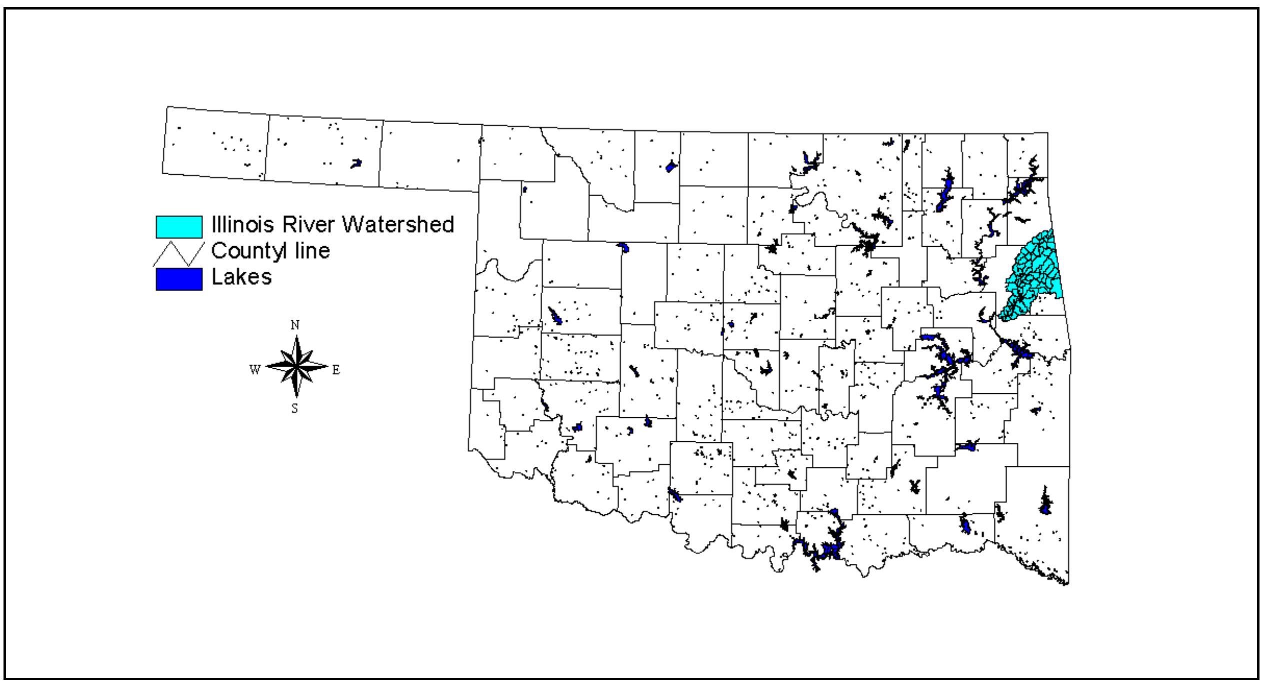
EXECUTIVE SUMMARY

The Illinois River Watershed (including Lake Tenkiller) in northeastern Oklahoma is one of the State's most valuable and controversial watersheds. Considerable effort has focused on studying the watershed to identify problems, causes, and potential solutions. These studies have concentrated primarily on water quality (both in the river and lake), land use, and the relationship between the two.

This report attempts to summarize the main historical research on water resources in the basin and then summarize what various government agencies have done or plan to do to remediate problems in the watershed. Many steps have already been taken to reduce pollution in the watershed; however, significant sources must still be addressed to protect the river and Lake Tenkiller.

The watershed extends from Northwestern Arkansas (Benton, Washington, and Crawford Counties) to Northeastern Oklahoma (Delaware, Adair, Cherokee, and Sequoyah Counties)(**Figure A**). Arkansas has developed their own plan to address water quality problems in the river and this report will outline a similar plan for Oklahoma. As such, this report will only address the Illinois River Watershed (including Lake Tenkiller) in Oklahoma.



Much of the initial investigation into the water quality of the basin was due to the perception by local citizens that water clarity had declined in the river, its tributaries, and in Lake Tenkiller (**Figure B**). Research was necessary to determine whether this

perception was valid or merely a manifestation of negative opinions concerning the blossoming poultry industry in the basin. Results indicated that there was cause for alarm; nutrient concentrations were high in the river and Lake Tenkiller and nutrient concentrations appeared to be increasing while clarity was decreasing. Data also revealed low dissolved oxygen and frequent algae blooms in the lake which indicated advancing eutrophication. Other studies revealed streambank erosion as a potential significant source of nutrients and sediment to the system. Overall, data indicated a decline in water quality which could translate into future loss of the river and Lake Tenkiller as a water supply, recreation, flood control, and biological resource.
Land use analysis correlated this decline in water quality to dramatic changes in land use in the basin. Agriculture increased substantially in the basin in the form of confined animal feeding operations (CAFOs), primarily poultry operations, and forest land continues to be cleared for pasture and hay production. Overall, these land use changes resulted in a net increase in the amount of nutrients entering the watershed (primarily through animal feed) without a concomitant increase in the amount being exported from the watershed. The resulting imbalance in the nutrient import/export cycle is manifested in the water quality of the basin.

However, agriculture cannot be cited as the sole source of water quality problems in the watershed. Other sources include point sources (pollution discharged by a large, stationary, identifiable sources such as wastewater treatment plants or factories) of pollution which currently include only municipal discharges, but in the past have included industrial discharges, and various nonpoint (pollution from multiple, diffuse, poorly identifiable sources such as agricultural or urban runoff), and combined sources (pollution from both point and nonpoint sources) of pollution. Additional nonpoint sources include recreation, the remains of Lake Frances, urban runoff, gravel mining, and streambank erosion. Combined sources (sources with essentially both point and nonpoint source pollution) include nurseries and urban runoff.

POLLUTION SOURCES

Point Sources

Although point source discharges in Oklahoma did not account for the majority of the nutrient loading to the river and Lake Tenkiller, the load was significant enough to warrant reduction. Significant upgrades have already been implemented on point sources in Oklahoma due to efforts of the Oklahoma Department of Environmental Quality, Cities of Tahlequah and Stillwell, U.S. Environmental Protection Agency (EPA), and the unfortunate closing of the Stillwell Cannery. Combination and elimination of discharges has resulted or soon will result in 2 of the 3 remaining discharges undergoing tertiary treatment. These discharges have phosphorus limits (< 1 mg P/l) written into their permits. The result of these upgrades is a significant decrease in the point source load to the river. However, diligence towards reducing loads to the river must be maintained during operation of the plant to reduce likelihood of accidental spills and storm-related overflows of lagoons (**Figure C**).

Nonpoint Sources

Recreation

The recreation industry has been a potentially significant source of pollution in the form of human waste and trash. Although the actual impact to water quality from the recreation industry is difficult to measure, it is not difficult to imagine the effects of over 400,000 river users and 1,500,000 lake users annually given the lack of restroom facilities and the visible trash left behind (**Figure D**). The recreation impact is likely more severe on the river than the lake due to the fact that an average 2,400 people per weekend float the river during peak months and until 1994 only one or two inadequately maintained toilet facilities were available.

Recent projects conducted primarily by the Oklahoma Scenic Rivers Commission in cooperation with the Oklahoma Conservation Commission (OCC), Cherokee County Conservation District, and US EPA have resulted a dramatic increase in the quality and quantity of facilities available to river users. These improvements include canoer-only access areas complete with toilet, picnicing, and camping facilities, properly maintained pit and portable toilet facilities dispersed along the river route (cleaned out twice daily during peak season), and the provision of trashbags and trash collection points along the river route. This change has resulted in the removal of over 3,000 gallons of raw sewage from the canoer access area alone that would likely have otherwise reached the river. In addition, an estimated 110 - 120 tons of litter which may have otherwise remained in the river are removed annually due to the trashbag program.

Lake Frances

The collapse of the Lake Frances Dam in 1991 resulted in an additional source of nonpoint source pollution to the Illinois River basin in Oklahoma. The collapse exposed several hundred thousand cubic meters of nutrient-enriched lake bed to potential erosion. The primary concern is loss of sediment during storm events (**Figure E**). Although several options have been discussed concerning the former lake, including reconstruction of the dam and dredging the sediments, the streambed appears to be stabilizing itself and the best option may be to leave the system alone. The former lake bed now exhibits many of the characteristics of a wetland and if left alone to develop, may serve as a valuable nutrient sink and sediment filter to reduce downstream loadings the river and Lake Tenkiller.

Animal Production Operations

Animal Production Operations provide the majority of agricultural income in the

watershed and indeed are the largest industry in the basin (**Figure F**). Unfortunately, the influx of feed necessary to grow animals in such operations has resulted in an imbalance of the nutrient transport in the watershed. More nutrients enter the watershed in feed than leave the watershed in animal products. The result is that these left over nutrients, in the form of animal waste, are left in the watershed and ultimately make their way to the river and lake.

A 1997 survey of confined animal operations in the watershed identified sites in the watershed, noted the number of houses present, and whether or not they were in production. Based on this survey and literature-supported estimates of nutrient production for various livestock, an estimated 13,256,000 lbs. of nitrogen and 4,284,800 lbs. of phosphorus are excreted annually by confined animals in the watershed. The survey also suggested that chickens produce 36% and 34%, turkeys produce 9% and 10%, dairy cattle produce 2% and 5%, hogs produce 9% and 10%, and beef cattle produce 44% and 41%, respectively of the nitrogen and phosphorus excreted in the watershed. These numbers suggest that although the poultry industry secrete a significant amount of nutrients, an even larger portion is secreted by beef cattle. This is important because beef cattle management is such that cattle often have direct access to streams. Thus, cattle may act as a point source and deposit the nutrients directly into the stream, while poultry waste accesses the stream mainly through overland flow. In addition, pasture management is not always optimal. Grazing land is scarce and pastures are often over grazed, resulting in poorer pasture with a lower capacity to process animal waste and prevent it from reaching the stream (**Figure G**).

Various solutions are available to reduce the impacts of this industry on water quality, ranging from reduction in animal numbers, installation of best management practices, and transport of wastes out of the basin. The installation of best management practices to reduce the transport of waste to the waterways is probably the best short-term approach. Mechanisms are in place to focus on this issue. The OCC will be devoting over 2 million dollars between 1999 and 2004 to implement best management practices to reduce nutrient and sediment loading to the river. Many of these practices will help producers reduce the amount of waste reducing the river. This program is a cost-share program with required monetary or labor buy-in from the producer. The program will focus on areas where the concentration of pollution sources is the greatest. The assessment of need is based on water quality data, land use surveys, and locally-driven decision-making. A locally-led watershed advisory group (WAG) will be established to determine what kinds of practices will be available for cost-share funding and how the program should be administrated at a local level.

Waste transport out of the basin is being investigated as a future long-term solution. Transport costs are an issue as well as making sure that the waste is not being transported to an area where it will cause water quality problems.

On-Site Waste Disposal

The majority of the human population in the watershed relies on septic systems to dispose of residential wastes. 1990 census estimates suggest over 27,000 septic systems are in place in the 3 main Oklahoma counties of the watershed. Previous work in small subwatersheds in the basin (Battle Branch) suggested only about 25% of the on-site waste disposal systems met state requirements. These inadequacies range from insufficient lateral lines, lack or insufficient septic tanks, direct disposal of grey water to streams, ditches or land surfaces, and improperly located tanks and lateral lines. Extrapolation to the whole watershed suggests the potential for 75% of rural households to have sub-standard systems. Although many well-maintained residences exist in the watershed, residences like those shown in **Figure H** are not uncommon.

Solutions to the problems include connections to waste water treatment facilities or upgrading/installation of proper on-site waste disposal systems. The most cost-effective

alternative is installation of or upgrading to proper on-site systems. This will require on-site investigation of current septic systems which will require additional personnel to those already in place with the Oklahoma Department of Environmental Quality (ODEQ) for that purpose. Cost of installation in the average residence varies between $1500 and $2500. Probably the most feasible means to facilitate these installations is as part of an overall cost-share program to protect water quality administered through conservation districts.

Gravel Mining

In-stream and near-stream gravel mining threatens water quality and the overall aquatic community through exposure of bed load and stream banks to erosion. Recent investigation into the impact of gravel mining on the Baron Fork River revealed that mining activities had significantly impacted the riparian community and changed the morphology of the channel to an unstable configuration (Rosgen D classification) which is unlikely to restabilize itself without major structural modifications (OCC 1999). The resulting changes in stream morphology led to a wider, shallower, less stable stream (**Figure I**).
Solutions to the problem range from restricting mining activities to training mine operators to regulating effluent water quality from mining operations. Training and regulations would require additional staff for Oklahoma Department of Mines and perhaps for Extension Service or Conservation Districts. The most feasible alternatives will probably involve more stringent limitations on the locations and extent of mining activities as well as training for mine operators to limit the impacts of their operations. Some site restoration operations may be necessary to repair damages already incurred.

Bank Erosion

Bank erosion along the Illinois River and its tributaries poses a substantial threat to the system. Eroding banks provide sediment, gravel, and nutrients which destroy valuable land, degrade water quality, destroy critical aquatic habitat, and eventually fill in Lake Tenkiller (**Figure J**). This bank erosion is often caused by elimination or poor maintenance of the riparian zone, bridge construction, upstream or downstream changes in channel morphology and/or various upstream land use changes. Estimates of the loading from bank material suggest that eroding banks contribute a significant amount of the total nutrient load in streams (OCC 1999).

The most appropriate solution to this problem is to establish and protect riparian areas. This may or may not require fencing and restricted and/or limited use of near-stream areas, but protection of these areas will allow native vegetation to establish which is often the only protective measure necessary. Roots of native vegetation hold soil in place and protect against and dissipate the force of high flow events.

However, in some extreme cases, active restabilization work is necessary to protect the bank. The OCC has successfully completed several of these projects across the state, one of which is located on the Illinois River at Echota Bend. For less that half of the cost of conventional methods, bank stabilization measures were constructed using natural materials that restructured the channel as closely as possible to its natural configuration, creating a system that was more equipped to withstand erosive pressure of high flows, but also protected landowners assets and provided better fish habitat.

Other Sources

A number of other nonpoint sources exist in the watershed which are not detailed in this report or plan. The reason for this omission is either due to insufficient ability to make estimates of the significance of these sources or known lack of significance considering the other nonpoint sources identified in this document. These other sources include but are not limited to wildlife, natural background loading due to geology and natural vegetation of the basin, illegal dumping (**Figure K**), and smaller livestock facilities such as people who keep a few head or horses or cattle.
Although all of these other sources currently seem to be insignificant, reduction in the impacts from other sources may magnify the effects of these sources. Thus, it may be necessary to revisit and better define the magnitude of these sources once steps have

been taken to reduce the impacts of known significant sources. In addition, education programs like those run by the OSRC and Cherokee County Conservation District are critical to reducing all types of nonpoint source pollution. Their goal is to provide citizens with an understanding of how pollutants reach the water, what types of effects they can have, and things people can do to reduce the impacts of pollution. Those education programs may be a significant tool towards reducing other minor sources.

Combined Sources

Urban Runoff

Urban runoff combines the effect of both point sources and nonpoint sources in that at times it contains pollution from point sources (in the form of overflows and system breaks) and overland flow. The urban areas in the Oklahoma portion of the watershed are small and thus likely produce only a small portion of the total pollutant load to the watershed (not counting discharged treated wastewater).

The most appropriate solution to the urban runoff solution is an education program targeted at providing urban dwellers with practices that reduce urban nonpoint source pollution. Coupled with this education program, stormwater permitting programs might be necessary to ensure the city planners and other appropriate entities incorporated nonpoint source pollution reduction into long-term goals.

The Cherokee County Conservation District and the Scenic Rivers Commission currently have education programs in place which provide citizens of the area with the knowledge to reduce Urban Nonpoint Source Pollution from their activities. The cities in the watershed are under the minimum size where stormwater permits are required. Should further research indicate urban stormwater runoff has a significant impact on the river, stormwater permits may be necessary in the future.

Nurseries

Two major nurseries are located along the Illinois River and one is located on the shores of Lake Tenkiller (**Figure L**). Irrigation tailwaters from the two largest nurseries have been shown to contribute significant quantities of nutrients to the basin. Oklahoma State Department of Agriculture estimates that one of the nurseries on the river contributed as much as 0.3% of the nitrate load and 0.19% of the yearly total phosphorus load to the river. The nursery on the shore of Lake Tenkiller was shown to contribute 1.95% of the total nitrate and 1.13% of the total phosphorus load to the lake. This loading was based on irrigation return flows and thus storm runoff from the nurseries was not even monitored. Stormwater runoff could have an even more significant impact.

The most workable solution to limit pollution from nurseries is to capture, treat, and recirculate irrigation and stormwater runoff from the site rather than allowing it to flow into the river or lake. This is being implemented at the lakeshore nursery. Tailwaters are captured and recirculated through the irrigation system to create a total retention system. A pond was constructed for irrigation and much of the stormwater runoff to filter into. This pond serves as a holding and treatment basin for the tailwater. Testing of the water has revealed that it does not contain toxic levels of fertilizer or other plant hazards such as fungus. This total retention system will result in a significant decrease in the nutrient load from nurseries to the watershed.

EFFECTIVENESS OF NONPOINT SOURCE NUTRIENT CONTROL PROGRAMS

Control of nonpoint source pollution on a complete watershed basis has been completed on only one watershed in the Illinois River basin. Oklahoma's first 319(h) demonstration project was implemented between 1990-1993 in the Battle Branch watershed. Approximately $100,000 worth of technical assistance, landowner contact, and BMP implementation over a 5970 acre watershed focused on practices aimed at reducing nutrient loading to Battle Branch Creek. This project "demonstrated" that BMPs could reduce nonpoint source pollution, but even more importantly, that the success of a nonpoint source pollution reduction program is based largely on the level of voluntary participation from the landowners. Approximately 84% of the landowners in the watershed participated in the project which was a significant factor behind its success.

Practices implemented included development and implementation of conservation plans, waste management plans, installation of septic tanks, dairy lagoons, poultry composters, waste storage structures, and improved management of pastures, forest land, hayland including soil testing and tree planing. Implementation of these practices resulted in significant reductions in the nitrogen and phosphorus concentrations at baseflow and during runoff events in Battle Branch Creek at a cost of approximately $16.75 per acre.

FUTURE PROGRAMS

One of the most critical future developments to protect the water resources of the basin will be the total maximum daily load (TMDL) currently being generated by the ODEQ. The TMDL will help appropriate an acceptable load between point and nonpoint sources. This acceptable load is one that will protect both the Illinois River and Lake Tenkiller for future use.

A critical part of the implementation of this TMDL is already underway in the form of a nonpoint source reduction program. Although the TMDL may require further point source reductions, the majority of load reduction necessary in Oklahoma will be through nonpoint source reductions.

The Oklahoma Conservation Commission has allocated significant funds toward a program to implement nonpoint source reductions in a cost-share program. Between 1999 and 2004, over 2 million dollars will go towards reducing nonpoint source pollution from various landuses in the basin. Many of these practices will focus on reducing the impact of animal waste on the basin; however, practices will also reduce streambank erosion, the impact of human waste, and the impact of various other human activities which affect water quality. Another critical component of the plan is the education component which will focus on educating the citizens and users of the watershed on the importance of water quality and practices which can be implemented to protect the aquatic resource.

This multi-million dollar effort will be directed through the activities of a watershed advisory group, made up of local decision makers and other concerned parties. They will offer assistance to land-owners on a cost-share basis to implement practices to protect water quality. The program will also monitor the affects of the program on the aquatic resources of the basin, in order to verify whether BMP installation improves water quality in the basin.

In conjunction with this program, several other programs are underway in the basin to reduce nutrient loading to the system. The Natural Resources Conservation Service will also focus funds towards cost-share assistance to reduce nonpoint source loading in the basin. The ODEQ continues to work with municipal dischargers and private citizens to reduce the impact of point sources and septic tanks to the system. The poultry industry is currently required by Oklahoma law to apply chicken litter on a soil phosphorus content ratio, rather than based on nitrogen needs or litter in need of disposal. This limitation should help focus phosphorus from chicken litter to areas of the watershed with lower soil phosphorus and prevent the continued phosphorus saturation of soils in the basin. Education efforts by the Scenic Rivers Commission, local Conservation Districts, and other state education programs continue to focus on protecting the basin's natural resources.

In addition to the efforts previously described, the Scenic Rivers Commission has adopted a management plan to focus on protecting water quality within their area of jurisdiction (Illinois River between the Arkansas/Oklahoma State line and the headwaters of Lake Tenkiller). This plan includes specific goals toward reducing the nutrient load to the river and Lake from all potential sources. The plan also focuses on overall improvement of the resource, both from the standpoint of safety and resource quality.

COST OF REMEDIATION

The overall cost of remediating the problems in the Oklahoma portion of the Illinois River Watershed will be quite high and may be unrealistic, given the economic resources available. Thus, remediation efforts must focus in the most cost-effective manner. Thus, most of the future efforts should probably focus on reducing the impact to the watershed from animal production operations. Much is already being done to reduce nutrient impacts to the watershed and substantial funds have already been allocated towards reducing point source and nonpoint source loading. Additional funds necessary to protect the water resources may be difficult to estimate prior to the completion of the TMDL and before the success of currently planned programs to reduce nonpoint source pollution can be assessed.

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INTRODUCTION

ILLINOIS RIVER COMPREHENSIVE BASIN MANAGEMENT PLAN

The purpose of this document is to develop a comprehensive management plan for the Illinois River Basin in Oklahoma to devise a systematic approach to addressing pollution problems in the basin. Historically, most discussion of river problems have focused on single areas and it is hoped that this document will push the state towards a holistic view of problems within the basin. The State of Arkansas has developed a similar document for the portion of the basin within their state which will be combined with Oklahoma's plan to create a complete basin management plan. This report will attempt to incorporate efforts of other state agencies in the Illinois River basin. The Oklahoma Scenic Rivers Commission has developed a management plan for the river corridor (OSRC 1998). Although the OSRC plan pertains only to the river corridor (generally the land within 1/4 mile on either side of the river, includes the Illinois River from the Oklahoma state line downstream to the confluence with the Baron Fork, and its two major tributaries, Flint Creek and Baron Fork Creek), many of the ideas are applicable basin wide and this report will correlate with the OSRC plan. This report could be considered as part of the overall statewide nonpoint source management plan and as such could serve as a template for future work in other priority watersheds (The statewide nonpoint source management plan is subject to public review. Therefore, should the review process indicate that this document is not appropriate for inclusion in the statewide plan, it will not be included). This document should also provide foundation for the implementation of the nonpoint source portion of the Total Maximum Daily Load (TMDL) for the basin established by the Oklahoma Department of Environmental Quality (ODEQ).

This document is organized into several sections, each of which deals with a different river issue. The first section introduces the Illinois River, characterizing its location and statistics. The second section summarizes studies previously conducted within the river basin. This section is intended to familiarize those who are not aware of river problems with basic water quality issues. The third section covers the major sources of pollution along with an estimation of their contribution to river problems. This section also discusses potential solutions and costs.

The fourth section outlines the process of best management practice (BMP) implementation in small watersheds by detailing the results of the first implementation project in the basin. In the fifth section, future programs, both needed and planned are discussed. The final section summarizes the estimated costs for the different approaches to water pollution control.

This document should present an understanding of the complex problems within the basin and estimates of the costs of remediating those problems. Although it is relatively simple to estimate the costs of clean-up programs in terms of construction or implementation, it is very difficult to estimate other impacts. The reader is encouraged to consider the socioeconomic impacts of such practices as reducing animal numbers or mandating waste control practices on the citizens of the river basin.

For each of the pollution sources discussed, potential solutions are provided. It should be stressed that 'no action' is a viable alternative in all cases. The effect of this approach should be considered for all sources and weighed against the costs. It is unlikely that all sources of pollution within the basin can be eliminated; therefore, difficult decisions are necessary. Both long-term and short-term consequences should be analyzed for each area and weighed against others.

OKLAHOMA'S GOAL FOR THE ILLINOIS RIVER

The Illinois River and its tributaries are viewed as outstanding water resources for the purpose of their recreation, wildlife propagation, and aesthetic values. It is further recognized that the Illinois River and its tributaries are the primary sources of water for Tenkiller Ferry Reservoir, another outstanding water resource, and as such are directly responsible for reservoir water quality.

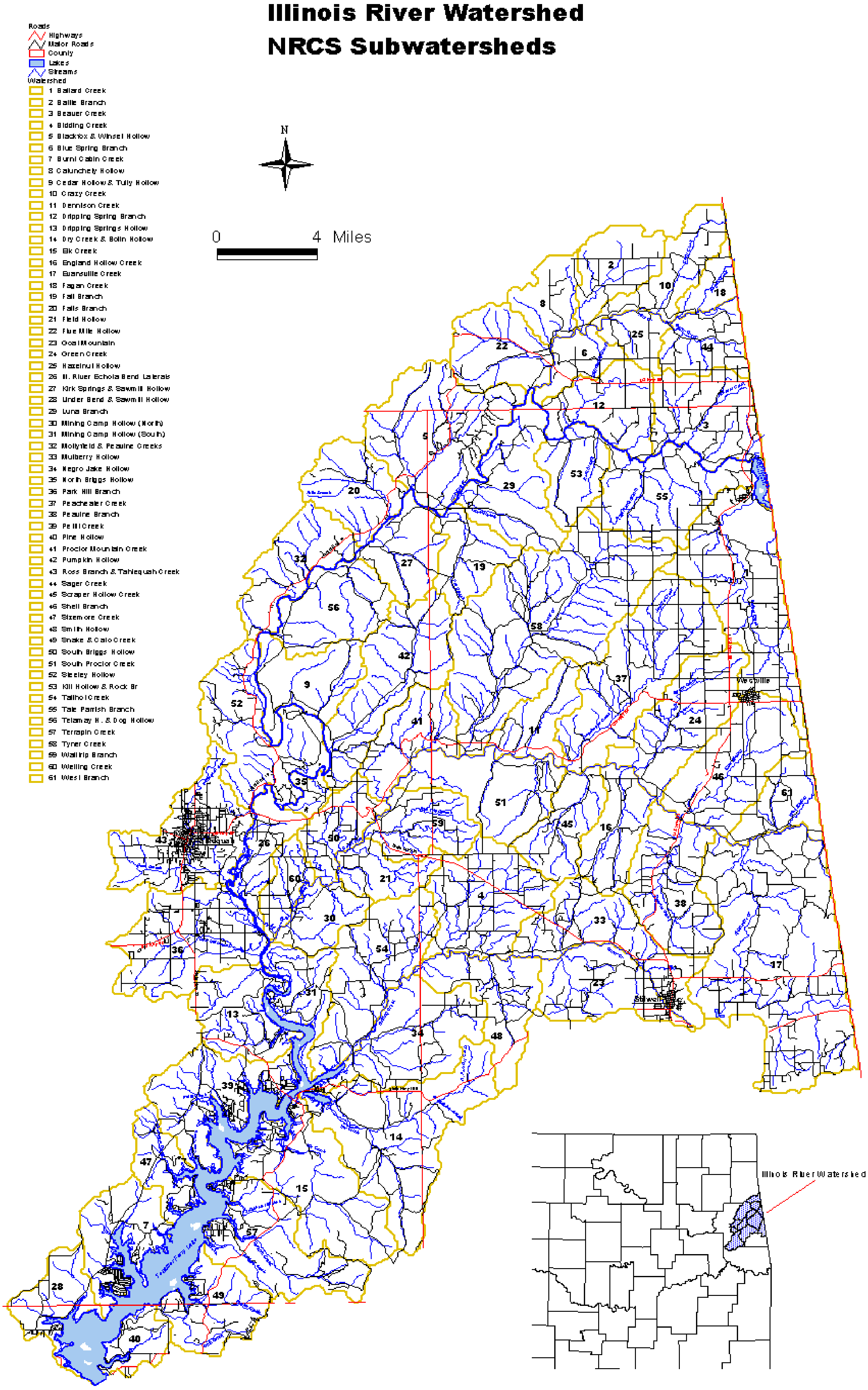
Oklahoma's goal is to maintain the quality of these water resources at the highest practical level by improving those practices which may contribute to water quality degradation. This will be accomplished through the identification and prioritization of problem areas followed by implementation of practices or procedures which will lessen the impact of individual sources to a practical minimum.

It is understood that the Illinois River and Tenkiller Ferry Reservoir have already experienced significant water quality deterioration as a result of both point and nonpoint sources of pollution and that specific contributors from both source categories must be addressed to prevent further degradation. Finally, it is recognized that significant improvements in river water quality must be accomplished if the river and reservoir are to remain classified as outstanding resource waters.

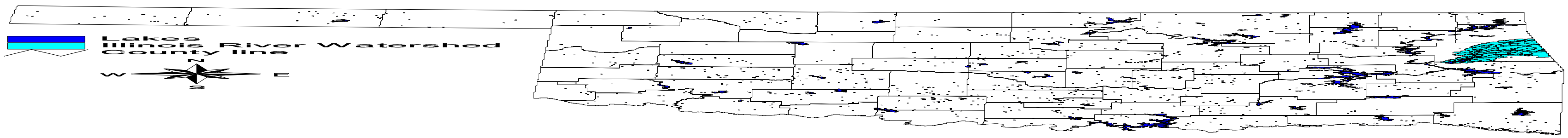
AREA DESCRIPTION

The Illinois River watershed straddles the Oklahoma/Arkansas border and of its 1,069,530 total acres, 576,030 (approximately 54% of the total basin area) are located in Oklahoma (USDA 1992). In Oklahoma, the watershed can be further sub-divided into 60 smaller watersheds ranging in size from 2382 to 31,046 acres with a mean size of 8825 (**Figure 1** & **Figure 2**). The basin is located in Delaware, Adair, Cherokee, and Sequoyah counties in northeastern Oklahoma.

Illinois River Watershed
NRCS Subwatersheds



Map by Oklahoma Conservation Commission
Water Quality Division GIS


Lakes
Illinois River Watershed
County line
N
W
E
S

The average flow of water in the river as it enters Oklahoma near Watts is 703 cfs which increases to 1095 cfs as the river reaches Tahlequah (USGS database, period of record 10/81 - 09/91), shortly after which it flows into Lake Tenkiller. The major tributaries of the Illinois River in Oklahoma are the Baron Fork River, Caney Creek, and Flint Creek.

The river is classified as a state scenic river from the Lake Frances Dam down to its confluence with the Baron Fork, a distance of approximately 70 miles. A 35 mile segment of the Baron Fork River and a 12 mile segment of Flint Creek are classified as scenic rivers upstream from their confluence with the Illinois River. The rest of the river basin in Oklahoma consists of Tenkiller Ferry Reservoir and a short segment downstream of the dam to its confluence with the Arkansas River.

The watershed lies with the Ozark Highlands and Arkansas Valley Ecoregions. The majority of the watershed in Oklahoma is in the Ozark Highland Ecoregion. This ecoregion is characterized by oak-hickory forests on well-drained soils of slopes, hills, and plains. Trees are of medium height (20 to 60 feet or 6 to 18 meters) with a relatively open canopy which allows a thick understory of slow-growing shrubs and trees. Areas of exposed rock are common. Blackjack oak, post oak, white oak, black hickory, and winged elm are the common overstory trees, and coralberry, huckleberry, and sassafras are representative of the understory. A taller forest community is found in protected ravines and on moist or north-facing slopes where soils are deeper and well drained. These forests are 60 to 90 feet (18 to 27 meters) high and consist of an overstory of sugar maples, white oaks, chinquapin oak, and hickory, with an understory of redbud, flowering dogwood, pawpaw, spice bush, sassafras and coral berry. Mosses, ferns, and liverworts are abundant on the moist forest floor. Bottomland hardwood forests of oak, sycamore, cottonwood, and elm exist along floodplains of larger streams. Elevations range from 1477 to 640 NGVD. Soils are derived mainly from chert and limestone.

The southern-most section of the watershed lies in the Arkansas Valley Ecoregion. This ecoregion forms the break between the Ozark Highlands and the Ouachita Mountains. Dry forests of short (50 feet or 15 meters tall) post oak, blackjack oak, and scattered hickories with significant cover of tallgrass prairie plants and little or no understory dominate rugged areas and extend into the plains. Shortleaf pine savannas occupy ridgetops of this ecoregion. Tallgrass prairie communities of bluestems, Indian grass, switchgrass, and other tall grasses dominate the broad valley, interspersed with wildflowers, dry upland forests, and bottomland hardwood forests along streams. These tall (100 feet or 30 meters) bottomland forests consist of oak, elm, and hackberry and usually have two or three levels of trees below the overstory. Grape, poison ivy, and greenbriar vines are common in the understory. Elevations range from 1000 to 460 NGVD.

Major soils within the basin are in the Captina, Clarksville, Enders, Jay, Linker, Mountainberg, Nella, Nixa, Noark, Razort, Steprock, and Waben series (USDA 1992). The majority of the higher reaches of the watershed are Clarksville-Nixa-Noark; deep, loamy cherty soils moderately to well drained, moderately to rapidly permeable. These soils are derived from cherty limestone. Soils in the vicinity of Lake Tenkiller are Enders-Linker-

Mountainberg-Nella; deep, loamy, gravelly or stony soils derived from acid sandstone, siltstone, and shale. These well drained soils range from very slowly permeable to moderately rapidly permeable.
The population of the basin in Oklahoma is approximately 50,000 - 60,000 based on 1995 estimates (OWRB 1996). The number of people below the poverty level in the four Oklahoma counties is higher than the state average (**Table 1**). The education attainment of the four Oklahoma counties was below the state average except in Cherokee County where Northeastern Oklahoma University is located (**Table 2**).

The dominant industry in the basin is agriculture, primarily poultry and livestock. **Table 3** displays rankings of Oklahoma counties in agriculture. Livestock is not the only agricultural

County/State	Persons	Families
Statewide-Oklahoma	13.4	10.3
Adair	27.6	22.1
Cherokee	22.2	18.3
Delaware	21.4	16.7
Sequoyah	20.1	16.3

activity in the basin. Although only a small percentage of the watershed is cropped,

	Percent > 12 years	Percent > 16 years
Oklahoma-Statewide	66.0	15.1
Adair	45.1	8.7
Cherokee	56.2	17.8
Delaware	52.8	7.3
Sequoyah	48.2	8.3

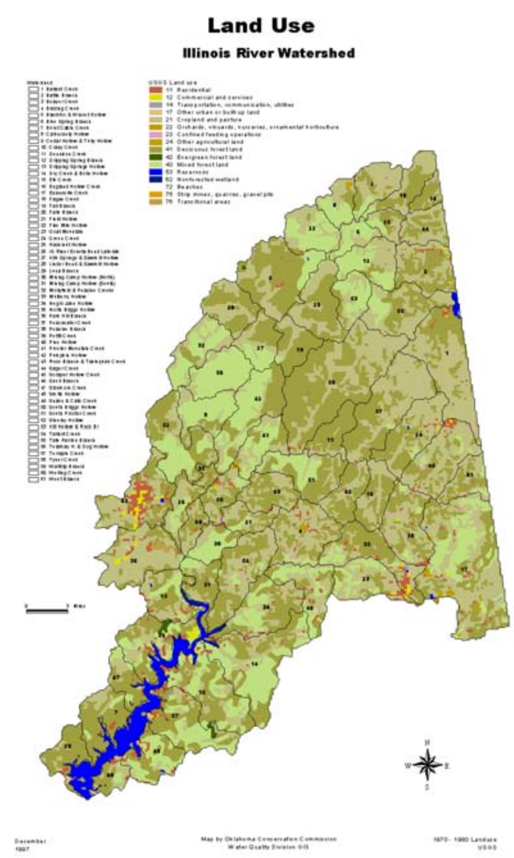
intensive crops such as vegetables, strawberries, fruit orchards, and nurseries are an important part of the economy in Cherokee and Adair Counties.

	County Ranking			
	Adair	Cherokee	Delaware	Sequoyah
Cash Receipts from Agricultural Products Sold	5	4		
Swine Production	2		1	
Number of Milk Cows in OK	2		4	

The watershed also has a significant recreation industry. Annual visitation to the river is about 400,000 with about 180,000 taking advantage of the floating opportunities (OSRC 1998). Lake Tenkiller also has one of the few and most noteworthy scuba diving opportunities in the state. Excellent fishing opportunities are also available on the Illinois River, Lake Tenkiller, Baron Fork Creek, and Flint Creek with over 68 game species available (OSRC 1998).

Land use in the Oklahoma portion of the watershed is illustrated in **Table 4** and **Figure 3**. Forest land (deciduous, evergreen, and mixed) makes up approximately 57 percent of the total watershed area. Agricultural land makes up approximately 38 percent of the total watershed area (A more specific view of some agricultural land is shown in a later section of this report. **Figure 12** displays locations of confined animal feeding operations in the watershed). Urban, transportation, and utilities areas make up approximately 3 percent of the watershed.

Land Use Category	Land Use Code	Area (m^2)	Area (mi^2)
Residential	11	46767802.33	18.06
Commercial and Services	12	8549757.01	3.30
Transportation, Commerce, Utilities	14	1015323.63	0.39
Other Urban or Built-up Land	17	5482459.55	2.12
Cropland & Pasture	21	813912103.00	314.25
Orchards, Nurseries, Ornamental Horticulture	22	5026276.57	1.94
Confined Feeding Operations	23	6594362.41	2.55
Other Ag. Land	24	1453287.53	0.56
Deciduous Forest	41	825790490.20	318.84
Evergreen Forest	42	4338258.94	1.68
Mixed Forest	43	413416922.80	159.62
Reservoirs	53	48709240.11	18.81
Nonforested Wetland	62	1872074.13	0.72
Beaches	72	149858.13	0.06
Strip mines, Quarries, Gravel Pits	75	86894.26	0.03
Transitional Areas	76	14801112.99	0.57


Land Use
Illinois River Watershed
N
W
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S
December
1997
Map by Oklahoma Conservation Commission
Water Quality Division GIS
1970 - 1980 Landuse
USGS

PROBLEMS AND CONCERNS

The Illinois River Basin has received as much attention as any other water resource in recent Oklahoma history. Most of this attention has focused on the perception that river quality has degraded over the past decade as a result of point and nonpoint source discharges.

Although some of the discussion of river degradation has been based upon public opinion, a considerable body of evidence indicates the river contains excessive levels of nutrients. In addition, studies in Lake Tenkiller indicate the upper portions of the lake have become eutrophic as evidenced by frequent and extensive algal blooms. Evidence to-date indicates that the source of the nutrients are both point and nonpoint source in nature with each contributing different proportions, dependent upon season and river flow volume.

Recent studies suggest a lesser known but perhaps even greater problem in the river and its tributaries is bank erosion. Bank erosion, primarily due to poor riparian management such as clearing native vegetation and overuse by livestock, is occurring at an alarming rate, contributing sediment and gravel to the streams and river. This causes shallowing and widening of the channels, resulting in loss of crucial habitat for benthic macroinvertebrate and fish populations. Although this degradation is most evident in the river and its tributaries, evidence will become increasingly apparent in the upper reaches of Lake Tenkiller as mud flats develop and turbidities increase.

Much of the understanding of problems in the basin has been generated through government projects and programs. While the data indicate that there are water quality problems, another important measure of the river's health is the public's opinion, especially in the eye of those who live in the river basin. Public opinion is particularly important when solutions for improving river quality are considered.

In order to develop an understanding of the public's opinion concerning the quality of water in the Illinois River, a series of public meetings were held in 1992. Each meeting focused on a different interest group in order to develop an understanding of that group's thoughts about the river. Each group was asked to identify and rank problems, identify and prioritize causes, and generate solutions for priority problems. The groups which met were decision makers (Indian tribes, municipalities, state government), nursery producers, recreational industry, and agricultural producers.

Taken together the groups agreed that the following pollution problems had occurred in the river:

Changes in fish populations
Wider and shallower river
Excessive growth of algae
Murky water

Stream bank erosion
Waste problems

The groups added that the following were problems and causes (listed in no particular order or relationship to one another):

Problems	Causes
recreation	nonpoint source pollution
poultry and agricultural waste	dumping of raw/treated sewage
open sewers	lack of education about wastes
loss of riparian areas	inadequate recreation facilities
sediment load from roads	development and growth
public apathy	waste dumping
confined animal operations	poor enforcement of trash laws
urban runoff	agricultural runoff
	solid waste
	tourism/recreation

Although some of these groups have specific interests in production activities within the basin, there was a noticeable lack of finger pointing. Each group recognized that the problems and causes were many and that contributions from all areas must be addressed. There was general agreement among the groups concerning pollution problems are their causes, although the prioritization of these factors varied.

Despite the extensive efforts to study and understand the condition of the river and the sources of pollution, no basin-wide plan to address pollution sources has been adopted. It has been recognized by all parties that any attempt to improve river quality must be based upon a comprehensive approach covering the entire basin. While this would seem to be an obvious approach to the problem, recent political history indicates that a diversity of opinion exists concerning pollution sources and their relative contribution to the problem.

WATER QUALITY STUDIES

Numerous projects have measured water quality of the Illinois River. These projects have not been coordinated to cover all areas of concern, nor have they been conducted in a consistent manner; however, despite these limitations, a substantial amount of information exists upon which to characterize river water quality. Many of these studies were reviewed and their findings condensed in a report titled "Evaluation and Assessment of Factors Affecting Water Quality of the Illinois River in Arkansas and Oklahoma" which was completed as a joint effort between Oklahoma State University and the University of Arkansas in 1991. Other important works which have been completed and are discussed in this document include a 1992 study which characterizes the natural, physical, and human resources of the basin (USDA et al.), a study of the quality of water from small streams which feed the river within Oklahoma (Oklahoma Conservation Commission, (OCC)), a report reviewing ten years of data collection on the river and major tributaries (Oklahoma Scenic Rivers Commission), and a Clean Lakes Phase I Diagnostic and Feasibility Study on Lake Tenkiller (Oklahoma Water Resources Board and Oklahoma State University). The following section will summarize the findings of these studies. The intent of this section is to familiarize the reader with some of the specific water quality issues which are important in the basin and is not intended to deal with all of the information which has been collected.

A. ARKANSAS/OKLAHOMA JOINT RIVER STUDY

The most thorough compilation of data from the Illinois River Basin is contained in the "Oklahoma State University (OSU) and University of Arkansas Cooperative Report on Evaluation and Assessment of Factors Affecting Water Quality of the Illinois River in Oklahoma and Arkansas".

The purpose of this report was to gather all information concerning water quality in the Illinois River Basin into a single document and to interpret the results. This is a lengthy document to which the reader is referred if additional or more detailed information is required. One of the major areas of focus was the identification of trends in the data over time and space which are discussed in the following sections.

1. Total Phosphorus

Spatial trends - statistically significant decrease in concentration from the Arkansas border to Tahlequah.

- statistically significant increase in concentration below Osage Creek.

Temporal trends - statistically significant increases at nine of seventeen sites.

Mean values were in excess of the recommended level of 0.05 mg/L at all sites with some being exceptionally high. The data summary for phosphorus is included in **Table 5**.

Station ID	Site #	n (months)	Total Phosphorus as P (mg/L)		
			Mean	Median	SD
USGS 07195000	1	134	1.082	0.755	0.927
SR 0.5	2	14	0.313	0.295	0.100
USGS 07195500	3	170	0.293	0.198	0.313
SR 1	4	64	0.265	0.233	0.151
SR 2	5	66	0.225	0.192	0.176
USGS 07195860	6	117	1.496	0.820	1.021
USGS 07196000	7	127	0.188	0.172	0.090
SR 3	8	66	0.211	0.184	0.098
SR 4	9	66	0.201	0.170	0.081
SR 4.5	10	14	0.200	0.187	0.090
SR 5	11	66	0.181	0.133	0.295
USGS 07196500	12	127	0.130	0.100	0.133
SR 6	13	62	0.845	0.387	0.936
SR 6.3	14	11	0.154	0.118	0.074
USGS 07197000	15	126	0.079	0.044	0.102

2. Nitrite/Nitrate

The data for summary is included in **Table 6**.

Spatial trends - statistically significant decrease in concentration from the Arkansas border to Tahlequah.

- increase in concentration below Osage Creek.

Temporal trends - statistically significant increases at most sites.

Mean values were high at all sites and exceeded recommended values of 1.0 mg/L.

Station ID	site #	n (months)	Total Nitrogen as N (mg/L)		
			Mean	Median	SD
USGS 07195000	1	108	4.081	4.000	1.262
SR 0.5	2	14	1.843	1.625	0.749
USGS 07195500	3	110	1.510	1.200	0.873
SR 1	4	64	1.819	1.800	0.966
SR 2	5	66	1.673	1.400	1.491
USGS 07195860	6	80	2.888	2.250	1.031
USGS 07196000	7	98	1.291	1.100	0.679
SR 3	8	66	1.480	1.475	0.778
SR 4	9	66	1.459	1.300	0.797
SR 4.5	10	14	1.357	0.417	0.647
SR 5	11	66	1.293	1.200	0.953
USGS 07196500	12	96	1.052	0.800	0.718
SR 6	13	62	2.245	1.600	1.619
SR 6.3	14	10	1.266	1.200	0.550
USGS 07197000	15	98	0.914	0.700	0.628

3. Nitrogen/Phosphorus Ratios

Nitrogen/phosphorus ratios are much lower from the river main stem and main tributaries than for the smaller tributaries. It can be seen by comparing the data from the two data sets that nitrogen values are relative similar, while phosphorus values are much higher at the main stem sites. This might indicate that point sources of phosphorus are playing a major role in maintaining high river values.

4. Nutrient Sources

Considerable attention was paid to the identification of nutrient sources, especially in regard to phosphorus loading. It was estimated that phosphorus loading from point versus nonpoint sources was approximately equal during low flow conditions but that nonpoint sources exceeded point sources during normal or high flows.

In terms of annual loading of phosphorus it was estimated that the loading at the upper end of Lake Tenkiller was 21% from point sources and 79% from nonpoint sources. Total point source loading of phosphorus was estimated to account for 12% of the Oklahoma total.

5. Effects on Lake Tenkiller

The primary conclusion that was drawn from the data was that phosphorus loading exceeds the levels, as predicted by Vollenweider's model, that would cause Lake Tenkiller to become eutrophic.

B. ILLINOIS RIVER COOPERATIVE RIVER BASIN RESOURCE BASE REPORT

The objectives of this report were to better define water quality problems of the Illinois River basin, to prioritize watersheds needing project action to improve water quality, and to develop separate water quality project plans on high priority watersheds in Arkansas and Oklahoma. This report covers a wide variety of subjects, including natural resources, human resources, problems, concern, ongoing activities, and recommendations. The main outputs of the report include three systems for designating priority watersheds developed by three different agencies; Arkansas Soil Conservation Service (SCS), Oklahoma SCS, and the Oklahoma Conservation Commission (OCC). These results are seen in **Table 7**, **Table 8**, and **Table 9**. The Arkansas SCS system was developed using potential nonpoint agriculture source data, land use, municipal water supply locations, benthic data, and chemical data. The Oklahoma SCS system was developed using potential nonpoint agriculture source data, land use, and watershed size. The OCC system was developed using potential agricultural nonpoint source data and water sampling data. The highest priority watersheds for both states are generally low order streams or headwater streams. Many of the highest priority subwatersheds in Oklahoma were tributaries of the Baron Fork Creek.

The report also included recommendations for improving environmental quality of the basin. Water quality plans were completed for Upper Osage, Little Osage, and Clear Creeks in Arkansas in 1992, and for Shell and Ballard Creeks in Oklahoma in 1991. These plans suggested voluntary adoption of conservation practices by producers with technical assistance provided by the SCS, cost share incentives provided by the ASCS, and a strong education and information program as the preferred methods to correct and prevent agricultural source nonpoint source pollution. Additional recommendations made in the report based on a review of studies summarized in the report included:

Rank	Watershed	County	Score	Map #
1	Clear Creek	Washington	3202	221
2	Upper Osage	Benton	3197	352
3	Little Osage	Benton	3186	375
4	Blair Creek	Washington	2684	420
5	Baron Fork of Ill. River	Washington	2400	820
6	Spring Creek	Benton	2281	380
7	Upper Moores Creek	Washington	2279	440
8	Ballard Creek	Washington	2163	081
9	Flint Creek	Benton	2134	610
10	Upper Illinois River	Washington	2094	140
11	Lower Osage Creek	Benton	2082	351
12	Ruby Creek	Washington	2037	120
13	Gum Springs Creek	Benton	NG	520
14	Fish Creek	Washington	NG	310
15	Little Flint Creek	Benton	NG	620
16	Wildcat Creek	Washington	NG	330
17	Galey Creek	Benton	NG	360
18	Hamstring Creek	Washington	NG	220
19	Wedington Creek	Washington	NG	720
20	Cincinnati Creek	Washington	NG	710
21	Lower Moores Creek	Washington	NG	430
22	Goose Creek	Washington	NG	130
23	Fly Creek	Washington	NG	840
24	Kinion Creek	Washington	NG	450
25	Brush Creek	Washington	NG	340
26	Muddy Fork of Ill. River	Washington	NG	410
27	Sager Creek	Benton	NG	630
28	Lick Branch	Benton	NG	371
29	Robinson Creek	Benton	NG	320
30	Gallatin Creek	Benton	NG	550
31	Evansville Creek	Washington	NG	830
32	Lake Wedington	Washington	NG	110
33	Puppy Creek	Benton	NG	392
34	Cross Creek	Benton	NG	391
35	Frances Creek	Benton	NG	510
36	Chambers Creek	Benton	NG	530
37	Pedro Creek	Benton	NG	540

NG: not given in report.

Rank	Watershed	County	Rank	Watershed	County
1	Tyner Creek	Adair	31	Pumpkin Hollow	Adair
2	Peacheater Creek	Adair	32	Mulberry Hollow	Cherokee
3	Ballard Creek	Adair	33	Dry Creek and Bolin Hollow	Adair, Cherokee Sequoyah
4	Green Creek	Adair	34	Cedar Hollow & Tully Hollow	Cherokee
5	Tahlequah & Kill H., Rock Branch	Adair	35	Field Hollow	Cherokee, Adair
6	Battle Branch Creek	Delaware	36	Dripping Springs	Adair, Delaware
7	Shell Creek	Adair	37	Smith Hollow	Adair
8	Evansville Creek	Adair	38	Goat Mountain	Adair
9	Mollyfield, Peavine Hollow	Cherokee	39	Walltrip Branch	Adair, Cherokee
10	Scraper Hollow	Adair	40	Tailholt Creek	Adair, Cherokee
11	Peavine Branch	Adair	41	Mining Camp Hollow North	Cherokee
12	England Hollow	Adair	42	Linder Bend & Saw Mill Hollow	Sequoyah
13	Tate Parrish	Adair	43	Luna Branch	Adair
14	Bidding Creek	Adair	44	Pettit Branch	Cherokee, Sequoyah
15	South Briggs	Cherokee	45	Pine Hollow	Sequoyah
16	West Branch	Adair	46	Park Hill Branch	Cherokee
17	Sager Creek	Delaware	47	South Proctor Branch	Adair
18	Hazelnut Hollow	Delaware	48	Snake & Cato Creek	Sequoyah
19	Blackfox, Winset Hollow	Adair, Cherokee Delaware	49	Elk Creek	Cherokee, Sequoyah
20	Bluespring Branch	Cherokee	50	Terrapin Creek	Sequoyah
21	Fagan Creek	Delaware	51	Mining Camp Hollow South	Cherokee
22	Crazy Creek	Delaware	52	Burnt Cabin Creek	Sequoyah
23	Negro Jake Hollow	Adair, Cherokee	53	Sizemore Creek	Cherokee, Sequoyah
24	Fall Branch	Adair	54	Proctor Mountain Creek	Adair, Cherokee
25	North Briggs Hollow	Cherokee	55	Ross Branch & Tahlequah Cr.	Cherokee
26	Calunchety Hollow	Delaware	56	Kirk Springs & Sawmill Hollow	Adair, Cherokee
27	Falls Branch	Cherokee	57	Dripping Springs Hollow	Cherokee
28	Steeley Hollow	Cherokee	58	Dennison Creek	Adair
29	Beaver Creek	Adair, Delaware	59	Welling Creek	Cherokee
30	Five Mile Hollow	Delaware	60	Telemay & Dog Hollow	Cherokee

Prioritization Based on Phosphorus			Prioritization Based on Nitrogen		
HU*	Name	Rank	HU*	Rank	Name
509	Tyner (L&U)		512	Peacheater	
330	Kill, Rock & Tahlequah		337	Ballard	
337	Ballard (L)		610	Fagan	
609	Sager		604	Battle Branch	
518	Shell		518	Shell	
604	Battle Branch		514	England	
514	England		315	Mollyfield	
325	Fall Branch (East)	1	606	Hazelnut	1
333	Tate Parrish		521	West	
610	Fagan		609	Sager	
521	West		515	Green	
504	Field		509	Tyner (L&U)	
321	Fall Branch		333	Tate Parrish	
310	Cedar & Tully		330	Kill, Rock, & Tahlequah	
513	Scraper		607	Crazy	
323	Black Fox & Winset	2	603	Calunchety	2
519	Peavine (E&W)		513	Scraper	
607	Crazy		519	Peavine (E & W)	
331	Dripping Springs Br.		404	Bidding	
315	Mollyfield		334	Beaver	
309	Pumpkin		331	Dripping Springs Br.	
603	Calunchety		520	Evansville (L&U)	
512	Peacheater		325	Fall Branch (E)	
606	Hazelnut	3	602	Five Mile	3
408	Goat		402	Negro Jake	
219	Bolin & Dry		408	Goat	
507	Walltrip Branch		227	Parkhill	
334	Beaver		409	Mulberry	
520	Evansville (L&U)		323	Black Fox & Winset	
227	Parkhill		312	Steeley	
403	Tailholt		326	Luna	
404	Bidding	4	507	Walltrip Branch	4

HU* Hydrologic Unit Number

Prioritization Based on Phosphorus			Prioritization Based on Nitrogen		
HU	Name	Rank	HU	Rank	Name
302	Ross & Town Branch		407	Smith	
515	Green		309	Pumpkin	
510	South Proctor (E&W)		510	South Proctor (E&W)	
204	Linder Bend		403	Tailholt	
401	Negro Jake		321	Fall Branch	
213	Terrapin		310	Cedar & Tully	
225	Mining Camp South		502	Mining Camp North	
215	Sizemore	5	302	Ross & Town Branch	5
218	Elk		216	Petit	
207	Burnt Cabin		212	Pine	
326	Luna		504	Field	
407	Smith		219	Bolin & Dry	
312	Steeley		605	Bluespring Branch	
602	Five Mile		506	South Briggs Hollow	
216	Petit		509	Proctor Mountain	
212	Pine	6	307	North Briggs Hollow	6
409	Mulberry		225	Mining Camp South	
502	Mining Camp North		215	Sizemore	
506	South Briggs Hollow		209	Cato & Snake	
605	Bluespring Branch		204	Linder Bend	
309	Kirk Spr./Sawmill		511	Dennison	
209	Cato & Snake		319	Kirk Spr./Sawmill	
307	North Briggs Hollow		218	Elk	
314	Dog & Telemay	7	213	Terrapin	7
	Missing Data			**Missing Data**	
226	Dripping Spr. Hollow		207	Burnt Cabin	
508	Proctor Mountain		314	Dog & Telemay	
511	Dennison		226	Dripping Spr. Hollow	
503	Welling Creek		503	Welling Creek	

1. Continued support of governor's animal waste task force in Arkansas as means to coordinate agency programs and projects and identify inadequacies, overlap, and/or conflict in animal waste regulations or guidelines.
2. A complete review of existing regulation, legislation, and agency policies concerning animal waste in Oklahoma to determine deficiencies.
3. Comprehensive study of groundwater quality coordinated with nonpoint source programs where possible and continued support of ongoing groundwater monitoring.

4. Continue to streamline and develop new practices to protect water quality.
5. Further develop and support technology to compost and market poultry litter as a soil improvement.
6. Continue to develop water quality farm plans, particularly in priority watersheds in response to local concerns and needs.
7. Develop an intensive educational program to educate the public, landowners, and operators about the extent of the nonpoint source pollution problem, the potential to their operation to contribute to the problem, and sources of available assistance.
8. Basin residents and government agencies need to be innovative in developing and implementing measures to protect, improve, or enhance water quality in the basin by:
   - evaluating existing programs, laws, and policies to determine potential contributions to water quality improvement and necessary modifications and expansions.
   - identification of need and development of new programs
   - establishing an effective monitoring program
   - Establishment of a governor's advisory group in Oklahoma to support water quality issues and provide a forum for economic growth while minimizing impacts on the environment.
9. Phosphorus discharge limits based on the cumulative phosphorus capacities in Lake Tenkiller and the Illinois River should be included in all point source discharge permits.

C. OKLAHOMA SCENIC RIVERS COMMISSION - RIVER TREND STUDY

The data from samples collected by the Oklahoma Scenic Rivers Commission was analyzed to determine existing and historic water quality conditions, as well as any trends which might be present. An excellent historic data base exists for several sites where monthly samples have been collected since December 1980. This report covers the analysis of approximately 120 samples collected between 12/80 and 10/92 from each of the following sites:

Camp Paddle Trails
Fiddlers Bend
Chewey Bridge
Round Hollow
Echota Bend
Illinois River below the Tahlequah Creek confluence
Flint Creek
Sager Creek

Other sites have been sampled less frequently due to changes in sample site location and other factors; therefore, less data exists from these sites, and that which exists may be temporally disrupted or may cover a limited duration. Despite these limitations, some of this data is very useful in interpreting stream conditions. This includes the following sites:

Peavine Hollow
No Head Hollow
Baron Fork
Hwy 59 bridge (Arkansas)
Hwy 16 bridge (Arkansas)
Illinois River above Osage Creek (Arkansas)
Illinois River above Flint Creek

1. Trend Analysis

Method I

Trend analysis is used to determine long-term changes in water quality. There are several methods available for accomplishing this; however, in this report the Seasonal Kendall Tau test was performed utilizing the WQSTAT software package developed by Woodward-Clyde and Colorado State University.

Taken as a whole, the data from the long-term sites show few trends and those trends which exist are of a low magnitude. This indicates that there has been little change in the quality of water at theses sites over the almost twelve year sampling period. It should be mentioned that there is a high degree of variance in the data, that is, values fluctuate widely from month to month. Some of this fluctuation is due to changes in river volume; therefore, if values could be looked at in terms of loading, the data would probably be more uniform. The wide degree of data variance probably masks some trends. Trends which were found to be statistically significant (95% confidence level) are listed in **Table 10**.

The best overall conclusion that can be drawn from this data is that chemical oxygen demand (COD) appears to be dropping at several sites, but that turbidity seems to be increasing. Given the amount of variance in the data, these analyses are largely unsatisfactory; therefore, long-term changes will be looked at in another fashion.

Site	Trend	Parameter
Camp Paddle Trails	positive	turbidity
Fiddlers Bend	negative	COD
Fiddlers Bend	negative	phosphorus
Chewey Bridge	negative	COD
Chewey Bridge	positive	phosphorus
Chewey Bridge	positive	turbidity
Round Hollow	negative	COD
Echota Bend	negative	COD
Echota Bend	positive	turbidity
IR blw. Tahlequah Cr.	negative	COD
IR blw. Tahlequah Cr.	positive	turbidity

Method II

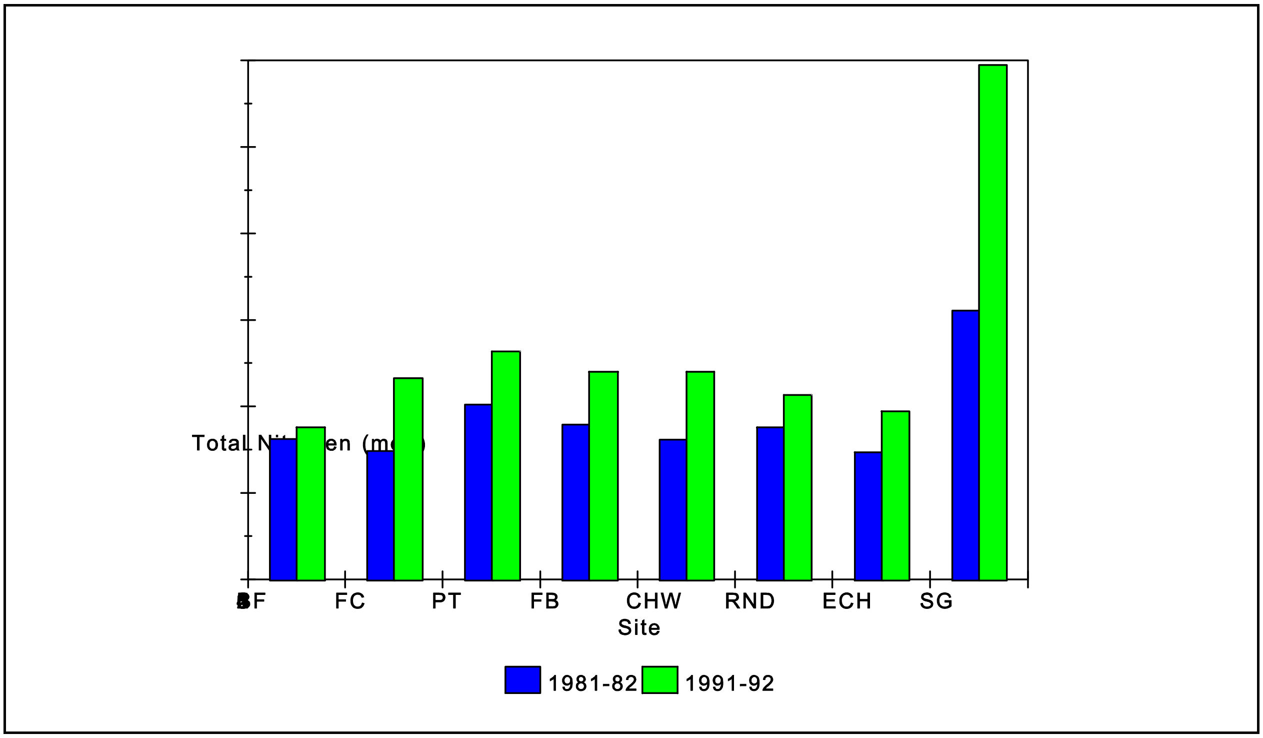
Another way that the time sequence data can be looked at is to compare average values during early years to that of later years. In this case data averages for the first two years have been compared to those of the last two years of sample collection as listed in **Table 11**.

Site	Date	COD	TN	TP	TSS	TURB.
Paddle Trails	80/81	10.6	2.02	0.253	17.6	11.1
	91/92	6.6	2.49	0.236	20.1	12.3
Fiddlers Bend	80/81	7.1	1.78	0.223	9.5	4.1
	91/92	3.7	2.22	0.170	6.4	3.9
Chewey Bridge	80/81	6.3	1.62	0.195	7.2	4.4
	91/92	4.5	1.98	0.170	4.3	5.0
Round Hollow	80/81	6.6	1.71	0.196	6.3	3.2
	91/92	4.0	2.02	0.166	5.2	3.1
Echota Bend	80/81	6.8	1.40	0.090	5.4	2.8
	91/92	4.1	1.93	0.115	5.9	2.8
IR blw. Tahlequah	80/81	8.7	2.45	0.475	11.9	4.7
	91/92	7.6	4.37	0.825	4.5	2.5
Baron Fork	80/81	4.6	1.59	0.152	2.2	1.2
	91/92	4.4	1.85	0.315	2.7	1.5
Flint Creek	80/81	4.5	1.54	0.041	3.1	2.7
	91/92	3.7	2.14	0.111	4.5	1.5
Sager Creek	80/81	6.9	3.13	1.008	2.4	1.1
	91/92	11.3	5.76	0.724	1.8	1.9

COD = Chemical Oxygen Demand (mg/L); TN = Total Nitrogen (mg/L); TP = Total Phosphorus (mg/L); TSS = Total Suspended Solids (mg/L); Turb. = Turbidity (NTU).

On the whole, averages from the two time periods are not very different, which corroborates that there has not been much of a trend over the years of the study. Again it should be mentioned that there was considerable variation within the two-year periods; therefore, mean values may be weighted by unusual events and differences in means may not be statistically significant.

Total nitrogen increased at all sites between the two periods. Although these increases were not generally of a large magnitude, the fact that they occurred at all sites leads to the conclusion that nitrogen loading has increased in the Illinois River (**Figure 4**).

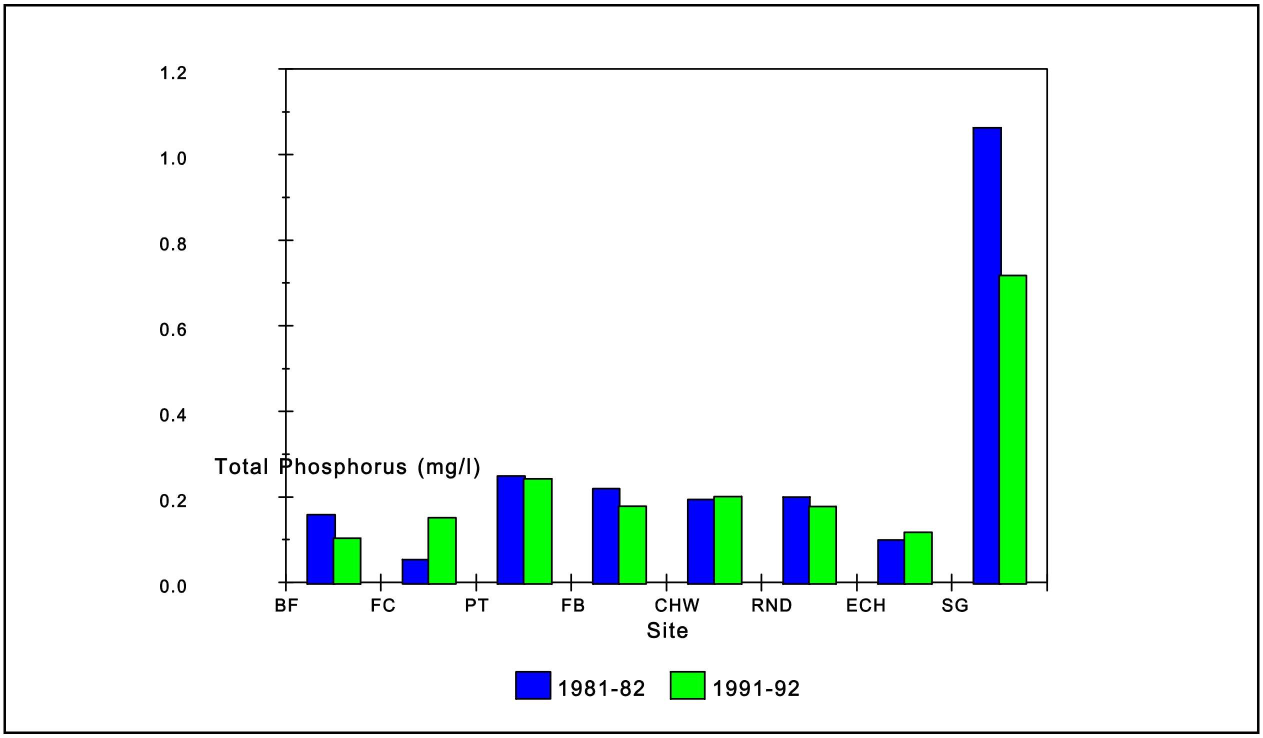


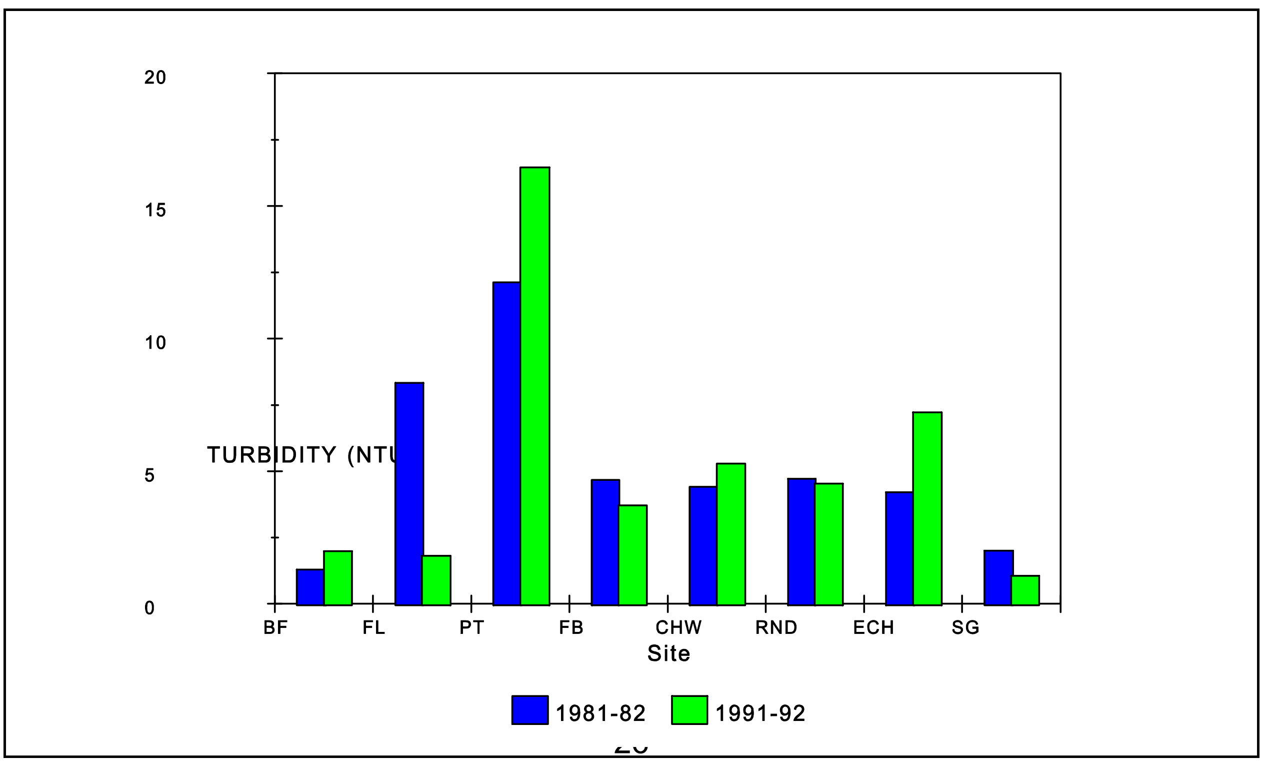
There was no consistent increase or decrease in TP values among the sites. The most important observation to make is these values are all very high.

Of all the data, the increases in Flint Creek and the Baron Fork are probably the most alarming (**Figure 5**). The values from the samples collected the first year at Flint Creek were uniformly low and often below the detection limit of 0.005 mg/L. These values began to rise during 1982 but the two-year average is still quite low compared to other sites. The 91-92 values from this site are much higher and indicate a real change in phosphorus concentrations over the study period. A similar situation occurred in the Baron Fork. Seventeen of the first twenty-four samples collected contained phosphorus concentrations below the detection limit. The 91-92 values are greatly increased indicating a definite change in water quality in this river.

The concentration of TSS has not changed much over the study period with a fairly uniform distribution of increases and decreases. The values are similar down the course of the river with the exception of Camp Paddle Trails which is much higher than other sites. This is probably due to the dislodging of sediments from Lake Frances.

There has been a great deal of discussion concerning the loss of clarity in the river. From the data above it cannot be concluded that any observable changes have occurred between 1980 and 1992 (**Figure 6**). Drinking water is allowed a turbidity of


Total Phosphorus (mg/l)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
BF
FC
PT
FB
CHW
RND
ECH
SG
Site
1981-82
1991-92


TURBIDITY (NTU
20
15
10
5
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BF
FL
PT
FB
CHW
RND
ECH
SG
Site
1981-82
1991-92

1.0 NTU; therefore, since most of the changes are around this level, it is doubtful that observable (human eye) changes have occurred.

With such a large percentage of county residences relying on private water supply, the potential adverse affects of ground water contamination are readily apparent.

D. WATER QUALITY IN SMALL STREAMS OF THE ILLINOIS RIVER BASIN

Sixty-two small streams in the Illinois River watershed were monitored during 1990-1992 to determine the extent of nonpoint source (NPS) pollution occurring from land uses in small watersheds and to rank the watersheds as part of the BMP implementation process.

Streams were monitored on a quarterly basis under baseflow conditions and twice per year during runoff events. The data from these collections are summarized in **Table 12**.

	TN (bf) (mg/L)	TP (bf) (mg/L)	TN/TP (bf) (%)	TN (re) (mg/L)	TP (re) (mg/L)	TN (re/bf) (%)	TP (re/bf) (%)
Minimum	0.18	0.001	8.51	0.24	0.004	0.41	0.31
Maximum	6.40	0.752	660	6.63	0.731	3.39	32.00
Mean	1.48	0.041	79	1.74	0.058	1.23	1.93*

TN = Total Nitrogen; TP = Total Phosphorus; bf = baseflow; re = runoff event
* = maximum value omitted (value = 2.41 with outlier)

It is generally agreed that nutrient loading in the Illinois River Basin is the major source of concern for both current conditions and long-term trends. Unfortunately, Oklahoma has no numerical standards for nitrogen or phosphorus. Guidelines exist in the literature but vary by author. Since the selection of a single guideline number would be somewhat subjective, it is probably best to discuss the data in terms of the range of opinion that exist in the literature.

Before the importance of nutrients at individual sites is discussed, it may be helpful to focus the discussion on the nutrient of greatest concern. The third column of data in the above table concerns the ratio of nitrogen to phosphorus found during baseflow conditions. This ratio is important in understanding the ability of the water to support algal growth and for management purposes as the addition of a limiting nutrient would accelerate algal growth. There is some range of opinion concerning the N:P ratio at which one or the other element becomes the factor responsible for limiting algal growth. The majority of research indicates that at N:P ratios of less than 10-16, nitrogen is the limiting nutrient, while phosphorus becomes limiting at higher ratios.

From column 3 it can be seen that the average N:P ratio is much greater than 16. In only 4 of 64 streams was the N:P ratio less than 16, and only one was less than 10. From these data it can be inferred that, as a basin-wide phenomenon, phosphorus availability is much more important in determining levels of algal growth than nitrogen; therefore, the discussion of nutrient levels will focus on phosphorus. It can also be inferred from this ratio and the high average nitrogen value that adequate nitrogen exists in these streams to support luxuriant algal growth. It should be noted that the factors concerning algal growth are much more complex than mere N:P ratios in that a number of micro-nutrient as well as physical factors are involved; however, N and P levels are often the controlling factors.

As previously mentioned, the maximum recommended level of phosphorus varies by author. In addition, the recommended level will also depend upon the nature of the receiving as well as downstream waters. It has been suggested that stream levels as high as 0.050 mg/L will cause no harm in the stream, although some authors put this value as low as 0.020 mg/L. The lower values are recommended when a downstream loading is a problem as occurs when a river is impounded. For the streams sampled in the Illinois River Basin it can be seen that, on average, baseflow phosphorus values approach the upper end of this range. Phosphorus values are distributed as follows:

Range (mg/L)	# of stream segments
<0.005 - <0.020	31
0.020 - <0.050	20
≥0.050	13

From these data it can be concluded that phosphorus is adequate to support rich algal growth in many streams of the Illinois River Basin, although it is inadequate in concentration relative to the amount of nitrogen present. This conclusion may seem somewhat contradictory as it suggests that phosphorus is both plentiful yet limiting. This type of contradictory evidence supports an assertion that algal productivity is closely tied to the abundance of some other nutrient. The identity of this nutrient is as yet unknown.

Historically, most attention has been placed on phosphorus limitation and as a result of this focus there is relatively little information suggesting maximum recommendations for nitrogen. A generally accepted upper limit for nitrogen for preventing the development of eutrophic conditions is 1.0 mg/L. The mean total nitrogen for all stream segments tested was 1.48 mg/L with the values being distributed as follows:

Range (mg/L)	# of stream segments
0.18 - 0.89	23
0.90 - 2.00	21
≥2.00	20

These data indicate that approximately two-thirds of the streams in the basin have nitrogen values which could result in eutrophic conditions. With twenty streams having values greater than 2.00 mg/L, it seems apparent that nitrogen levels are high enough to be a cause of concern for stream quality as well as downstream loading. These data also support the conclusion that nitrogen is not a limiting factor for algal growth.

It is also important to look at this data in terms of the relative concentration of nutrients under baseflow versus runoff conditions. As can be seen in the last two columns of **Table 12**, both nitrogen and phosphorus were elevated in runoff conditions. In some cases this was extreme while in others stream water appears to have been diluted. However, on average, nitrogen concentration increased approximately 23% while phosphorus increased 93%. Given the increased discharge during runoff events and the fact that the values gathered probably do not represent maximum event concentrations, it can be concluded that runoff of nutrients is an important contributor to stream and subsequently river water quality.

CONCLUSIONS

The primary conclusion that can be drawn from these data and comparing them to historical data is that water quality in the Illinois River was essentially similar between 91-92 and 81-92. There have been some changes, both positive and negative; however, for the most part these have been minor. The biggest changes that can be seen are in the degradation of water quality in Flint Creek and the Baron Fork.

A significant quantity of the nutrients in the river are coming from across the Arkansas border; however, significant contributions are occurring within Oklahoma. From the data it is obvious that sewage treatment plant discharges pose a major threat to river quality, although it should be mentioned that is difficult to assess the magnitude of this contribution relative to that from non-point sources based on these data. Contributions of nutrients within Oklahoma between Fiddlers Bend and Tahlequah must be almost entirely nonpoint source in nature.

A particular area of concern must be the contribution of nutrients and sediment from Lake Frances. Given the structural conditions which now exist, it is possible that almost all of the accumulated lake sediment will eventually be discharged into the river as it meanders across the lake bed unless corrective measures are taken.

Given the levels of nutrients in the river, it is not surprising that Lake Tenkiller is experiencing nutrient problems as demonstrated by accelerated eutrophication. The lake will continue to degrade at a rapid rate until these nutrient levels are significantly reduced.

One other area of concern is contamination of ground water from disposal of human and animal wastes. As will be illustrated in other sections of this document, rates of land disposal within the basin area very high. County residents rely on groundwater as their domestic supply as listed in **Table 13**.

E. ILLINOIS RIVER BASIN-- TREATMENT PRIORITIZATION FINAL REPORT

County	Housing Units	Units w/ Private Supply	Residents w/ Private Supply (%)
Adair	7124	3477	8989 (48.8)
Cherokee	16808	8891	14849 (52.9)
Delaware	15935	4589	9500 (28.8)
Total	39867	16957	33338

The OCC contracted with Oklahoma State University to use more sophisticated methods such as geographical information systems analysis to coordinate different types of data and prioritize subwatersheds in the Illinois River Basin (Sabbah et al. 1995). This report was an attempt to more closely coordinate land use and water quality information. The effort used the SIMPLE (Spatially Integrated Models for Phosphorus Loading and Erosion) modeling system developed by OSU to estimate watershed-level sediment and phosphorus loading to surface water bodies.

A section of the report dealt with identification and rank of potential phosphorus and sediment sources in the Peacheater Creek and Battle Branch Creek watersheds. Data layers were assembled including a digital elevation model, soil data, and current land use information assembled by the Oklahoma Cooperative Extension Service. Historical rainfall records (1950-1989) were used to run 40 one-year simulations. Long-term averages of runoff, sediment, and phosphorus loadings were estimated for each field and used to predict fields with high environmental risk potentials.

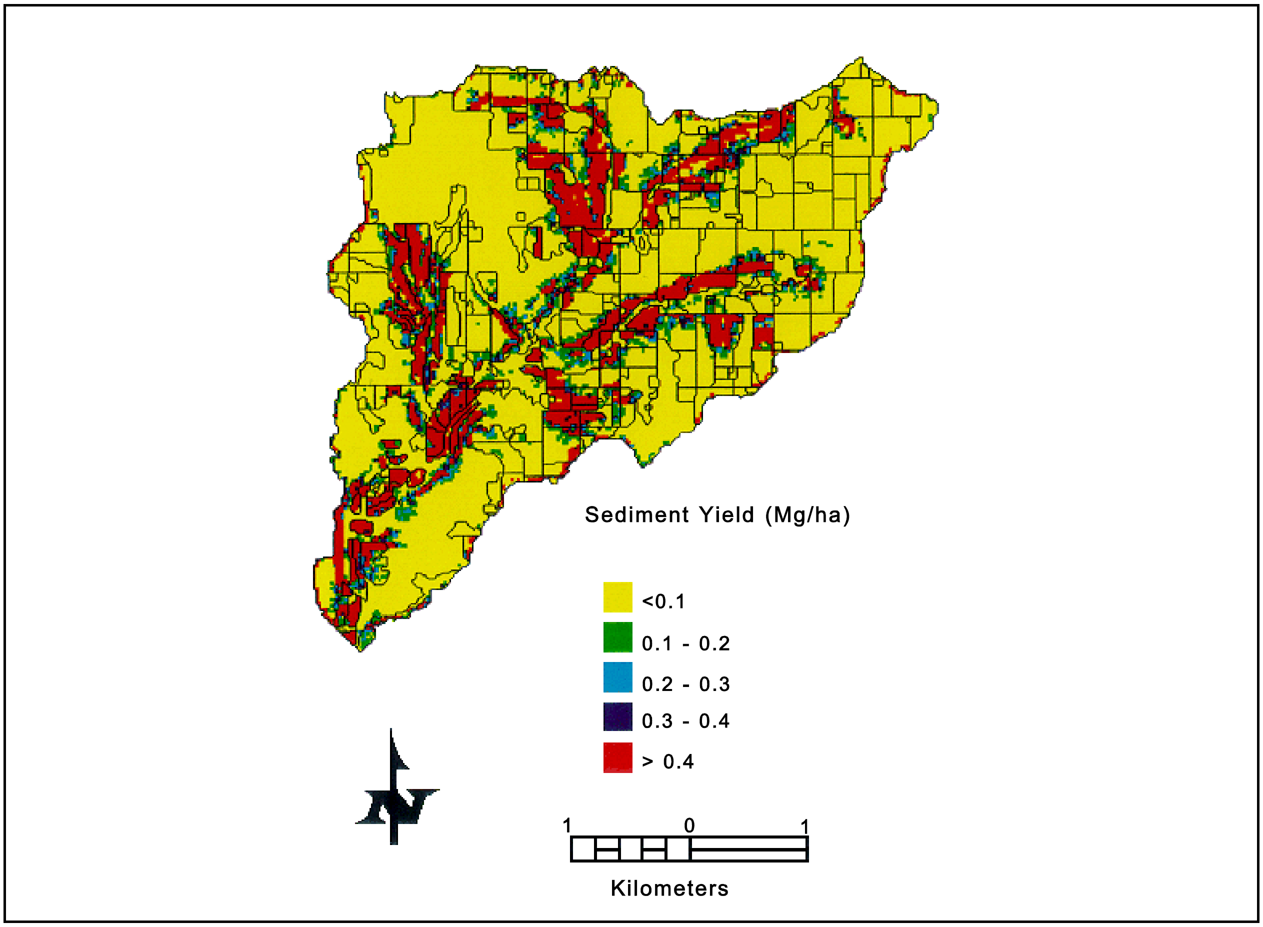
Average annual sediment loading from fields in the Battle Branch Watershed ranged from 0.00 - 0.88 Mg/ha (**Figure 7**). Predicted sediment loading was highest along the stream channel and from pasture, cropland, and hay meadows as opposed to woodlands.

Average annual total phosphorus loading to the stream ranged from 0 kg/ha - 9.34 kg/ha (**Figure 8**). Highest loadings came from fields with high soil test phosphorus levels and from cropped fields, pastures and hay meadows. Highest loadings were also seen in the headwaters of the watershed, as opposed to lower in the watershed, suggesting BMP implementation should focus on headwater areas, and then move downstream.

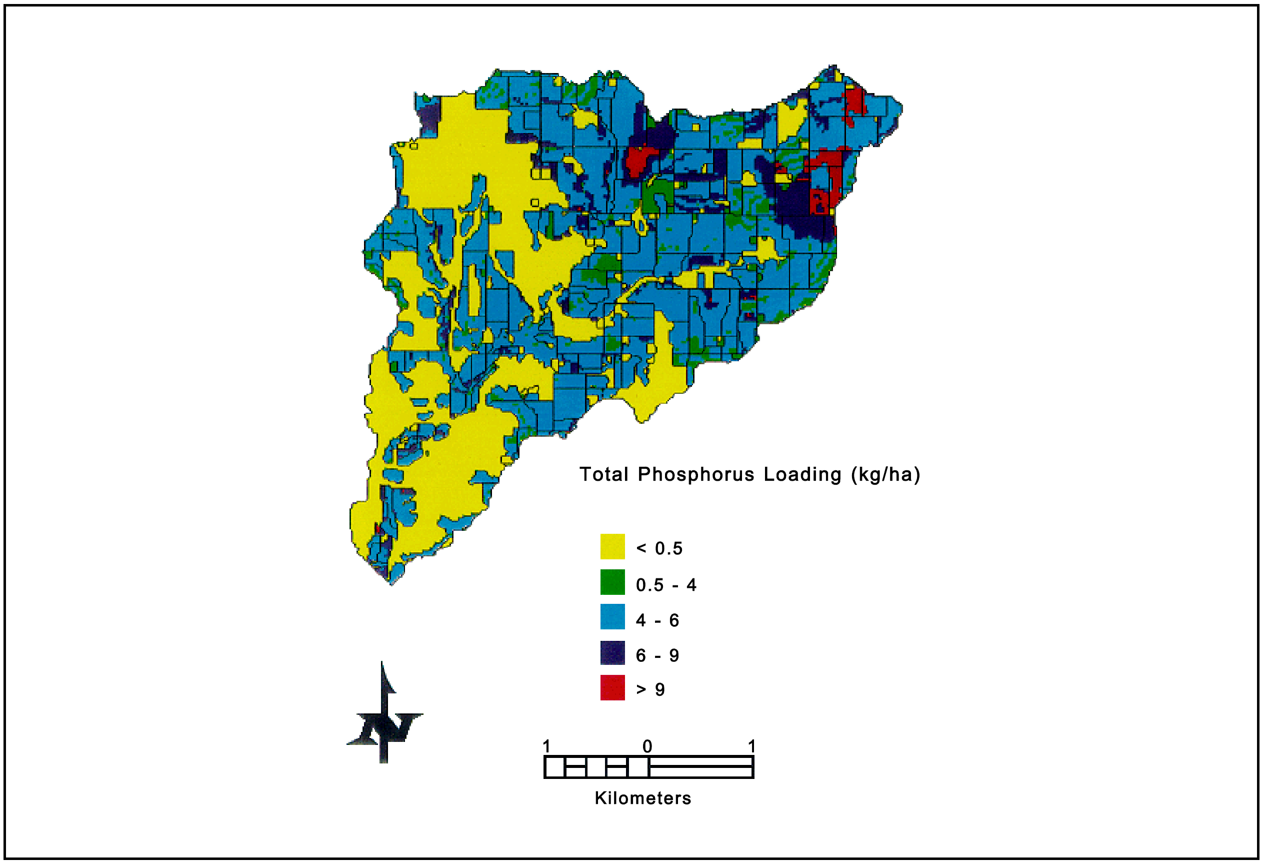
Average annual sediment loading from fields to Peacheater Creek ranged 0.00 - 0.96 kg/ha (**Figure 9**). Again, predicted sediment loading was highest along stream channels and from hay meadows and cropland.

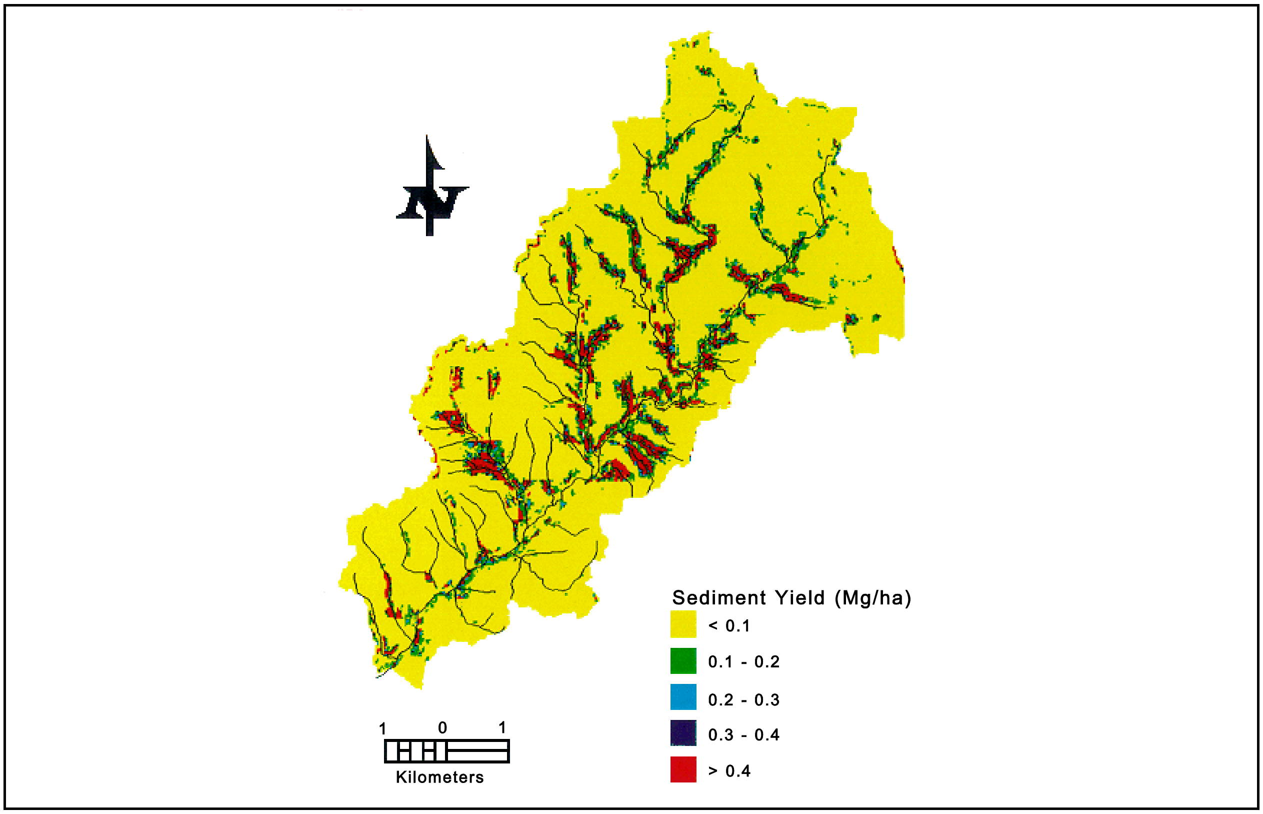
Average annual total phosphorus loading to the stream in Peacheater Creek ranged from 0.01 - 34.88 kg/ha (**Figure 10**). Highest loadings came from hay and pasture land and were associated with high soil phosphorus levels. These high soil P levels likely result from application of poultry litter and perhaps from pasturing cattle. Again, areas providing the highest phosphorus loading are concentrated in the headwaters. This suggests BMP implementation should focus in headwaters before downstream areas.

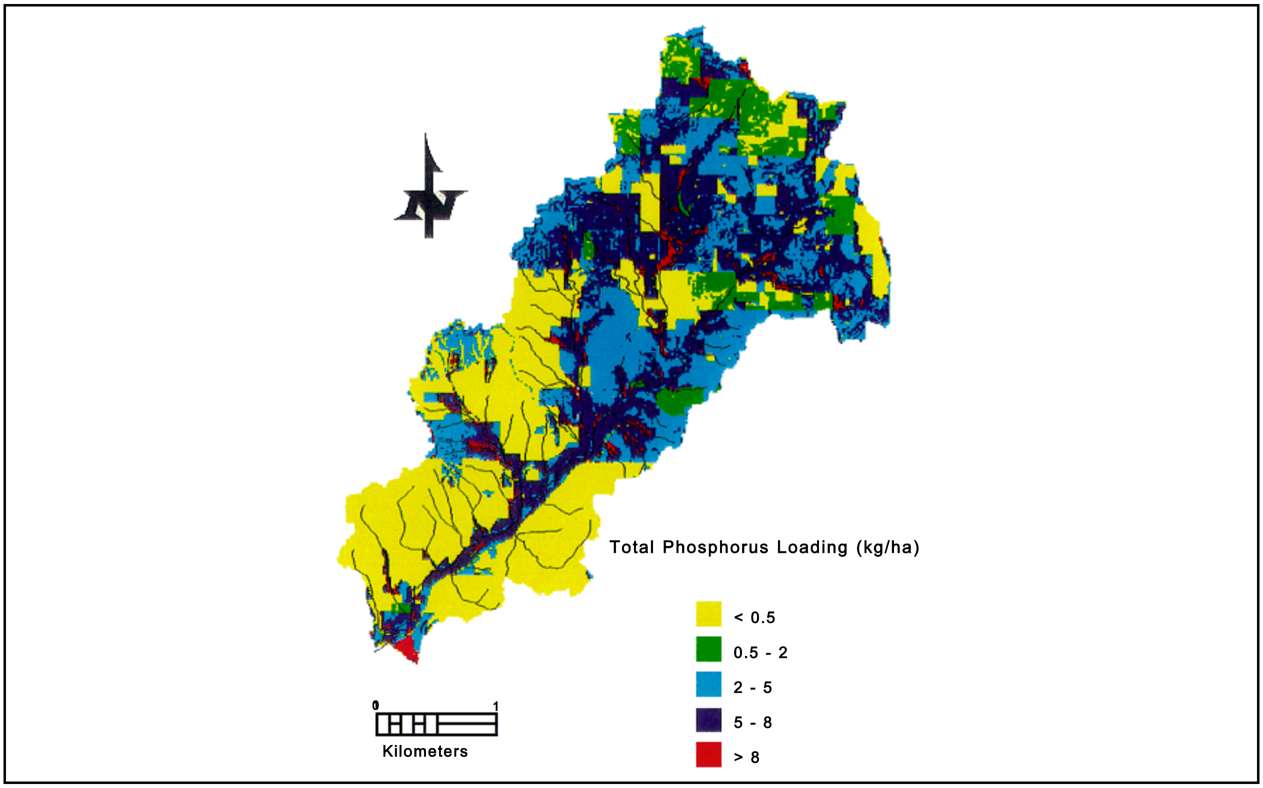
Two critical ideas are supported by this report. The first is that much of the soil erosion in these watersheds happens along stream courses, and is probably associated with stream bank erosion. The second is that much of the phosphorus comes from the headwaters of the watershed, thus remediation efforts should concentrate in this area.



Sediment Yield (Mg/ha)
<0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
> 0.4
1
0
1
Kilometers


Total Phosphorus Loading (kg/ha)
< 0.5
0.5 - 4
4 - 6
6 - 9
> 9
N
1
0
1
Kilometers


Sediment Yield (Mg/ha)
< 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
> 0.4
1 0 1
Kilometers


Total Phosphorus Loading (kg/ha)
< 0.5
0.5 - 2
2 - 5
5 - 8
> 8
0
1
Kilometers
N

F. CLEAN LAKES PHASE I DIAGNOSTIC AND FEASIBILITY STUDY OF LAKE TENKILLER

The OWRB contracted with Oklahoma State University Water Quality Research Laboratory (OSU WQRL) to conduct an EPA Phase I Clean Lakes Study on Lake Tenkiller to diagnose the problems and recommend solutions. OSU WQRL studied the lake intensively between April 1992 and October 1993. Samples were collected at eight stations in and below the lake (**Figure 11**). Water Quality in the Illinois River and its tributaries was also analyzed for purposes of the study.

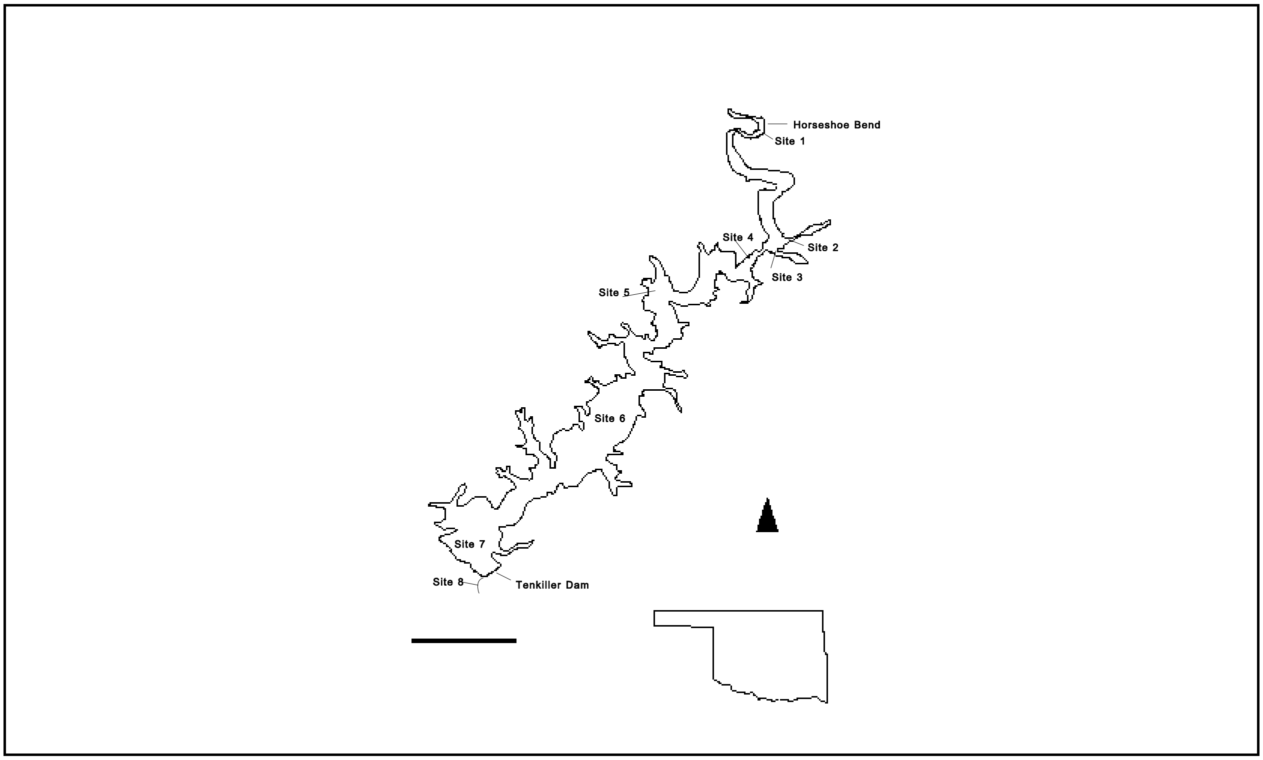
The study determined that water quality in Lake Tenkiller is currently showing signs of degradation. Symptoms included periodic algae blooms, excessive algal growth, and extensive hypolimnetic anoxia throughout stratified periods. The lake was classified as eutrophic based on nitrogen, phosphorus, and chlorophyll *a* concentrations (**Table 14**) which were excessive when compared to published criteria. These loads were predominantly derived from nonpoint sources during high flows and both point and nonpoint sources during low flows. These nutrient loads, especially the nonpoint fractions, have increased significantly since 1974 but have stabilized since 1985-86.

The study estimated the total nutrient loading to the lake, and partitioned that estimate by source. These estimates are seen in **Table 15**. These estimates represent loading to the lake from both Oklahoma and Arkansas. Distribution of the loading suggests the majority of the nutrient load is from nonpoint sources, although point sources contribute significant amounts. Analysis of the loading estimates also suggests the majority of loading is associated with highflow events. These conclusions are critical to the development of pollution reduction plans in the basin.

The excessive nutrient loads have increased algal growth and thus compromised water clarity throughout the lake and its tributaries. Nutrient limitation analysis indicated that the lake was phosphorus limited in the lower end (near the dam), variably limited (both phosphorus, nitrogen, and light) in the midreaches, and probably light limited in the headwaters. Based on these results, it was concluded that source control of phosphorus loading was the optimum management alternative. Accumulation of toxics in the lake water and sediments and resident fish did not appear to be a problem.

The study listed three alternative phosphorus control options and recommended initiation of a phosphorus control strategy in the basin. Those three options included:

1. No action.
2. Maintain current condition of the lake by preventing further increases in nutrient loads.
3. Reverse the accelerated eutrophication with more stringent phosphorus control measures.


Horseshoe Bend
Site 1
Site 4
Site 2
Site 3
Site 5
Site 6
Site 7
Site 8
Tenkiller Dam

PARAMETER	STATION	MEAN	MEDIAN	S	n
o-PHOSPHATE (mg/l)	1	0.11	0.09	0.05	16
	2	0.05	0.04	0.03	18
	3	0.04	0.03	0.03	18
	4	0.04	0.03	0.03	18
	5	0.03	0.02	0.03	18
	6	0.02	0.01	0.02	18
	7	0.02	0.01	0.02	18
TOTAL PHOSPHORUS (mg/l)	1	0.14	0.12	0.07	16
	2	0.08	0.08	0.03	18
	3	0.08	0.08	0.04	18
	4	0.08	0.07	0.04	18
	5	0.05	0.05	0.03	18
	6	0.04	0.02	0.04	18
	7	0.03	0.02	0.04	18
NITRATE (mg/l)	1	1.27	1.18	0.56	16
	2	0.53	0.46	0.44	17
	3	0.49	0.36	0.45	18
	4	0.46	0.34	0.42	18
	5	0.38	0.21	0.38	18
	6	0.44	0.30	0.40	18
	7	0.47	0.30	0.36	18
TOTAL NITROGEN (mg/l)	1	2.25	2.18	1.00	16
	2	1.45	1.16	0.75	17
	3	1.40	1.23	0.77	17
	4	1.34	1.17	0.66	17
	5	1.06	0.79	0.60	17
	6	0.97	0.74	0.59	17
	7	1.01	0.74	0.64	17

S = Standard Deviation; n = sample size

Source	Estimated Average Load at Horseshoe Bend kg/yr (%)		Estimated Low Flow Contribution at Horseshoe Bend kg/yr (%)		Estimated Medium Flow Contribution at Horseshoe Bend kg/yr (%)		Estimated High Flow Contribution at Horseshoe Bend kg/yr (%)	
	N	P	N	P	N	P	N	P
Background	550000 (23.9)	25000 (11.0)	35200 (22.8)	1600 (9.7)	208450 (23.9)	5225 (10.9)	306350 (24.0)	18175 (11.2)
Point Source	61605 (2.7)	12547 (5.5)	35793 (23.2)	7290 (44.1)	19406 (2.2)	3952 (8.2)	6407 (0.5)	1305 (0.8)
Nonpoint Source	1688980 (73.4)	190078 (83.5)	83345 (54.0)	7628 (46.2)	643869 (73.9)	38968 (80.9)	961795 (75.5)	143482 (88.0)
Total	**2300585**	**227625**	154338 (6.71)	16518 (7.26)	871725 (37.89)	48145 (21.15)	1274552 (55.40)	162962 (71.59)

The above three options are not discrete options but represent a continuum of management. After considering the feasibility and effectiveness of control measures, the report recommended a 30 - 40% reduction in headwater phosphorus loads be implemented as a short-term goal and a 70 - 80 % reduction as a long-term goal. Since both of these goals still indicated a significant risk of hypolimnetic anoxia, it was further recommended that re-aeration devices be installed in the tailrace to protect the downstream trout fishery.

The report recommended the following programs be initiated to attempt to reduce phosphorus contamination within the basin:

1. Voluntary switch to non-phosphate detergents by all lakeside residents and the cities of Tahlequah and Watts, OK and Rogers and Springdale, AK.
2. Implementation of best management practices upstream from Lake Tenkiller to minimize contributions of phosphorus in surface water runoff from agricultural fertilizer and waste and poultry litter applications.
3. Continue to work with point source dischargers, to the extent possible within the watershed, to minimize discharges of nutrients, including phosphorus
4. Establish a citizens monitoring group for basic water quality analysis and evaluation thus affording a more robust assessment of management effectiveness.

G. DETERMINING THE NUTRIENT STATUS OF THE UPPER ILLINOIS RIVER BASIN USING A LOTIC ECOSYSTEM TROPHIC STATE INDEX

The Clean Lakes Study determined that Lake Tenkiller was phosphorus limited at the lower end, variably limited by nitrogen, phosphorus, and light availability in the mid-reaches, and light limited at the upper end. However, it was unknown whether the Illinois River was limited by the same factors. One goal of this study was to determine which nutrients most often limit primary productivity in tributaries to the Illinois River.

The watersheds of three tributaries to the Illinois River were chosen based on availability of historical water quality data, similar land use, and similar size. These were Peacheater Creek, Tyner Creek, and Battle Creek. Although Battle Creek watershed was smaller than Peacheater and Tyner Creek watersheds, all had predominantly pasture and range land use (63 to 68 percent), and substantial forest cover (32 to 36 percent). The main difference in land uses among the three watersheds was the degree of anthropogenic activity.

The study used *in situ* nutrient limitation assays to estimate limiting nutrients in the three creeks. Six nutrient enrichment treatments were tested: 1. Nitrate - 5 ppm, 2. Phosphate - 5 ppm, 3.Nitrate and phosphate - 5 ppm, 4. Micronutrients - from Weber et al. (1989) at 200 times concentration, 5. Total nutrients, consisting of treatments 3 and 4, combined, and 6. Control- deionized water. Periphytometers were colonized in a run 0.3 m deep above a riffle for 14 days. Growth surfaces were protected from grazers with an aluminum screen. Assays were conducted in April and October 1995.

Results of the nutrient limitation assays are seen in **Table 16** and **Table 17**. Sample replicates numbers less than six indicate loss of samples. High flow events occurred in Battle Creek during both sampling periods, resulting in loss of replicates due to scouring. Comparisons of the treatment means was done using the Waller-Duncan K-ratio t test ($\alpha = 0.20$). Results of t tests suggested that Battle Creek was phosphorus limited in the spring 1995 but limited by something other than nutrients during the fall, possibly light availability. Peacheater Creek appeared to be co-limited by nitrogen and phosphorus during both spring and fall sampling. Tyner Creek appeared to be limited by some factor other than nutrients during the spring and co-limited during the fall.

Conclusions of the report focus on the variable status of growth limiting factors in tributaries of the Illinois River. Clearly the creeks are impacted by nutrients, but also appear to be impacted by another factor, possibly light availability which would be affected by turbidity. The variability of growth limiting factors in these streams suggest they are primarily impacted by nonpoint source pollution. Nonpoint sources vary temporally as well as they do in substance and nature of pollution. A stream impacted by point sources would be expected to have a more consistent growth limiting factor between seasons. The findings of this report support conclusions of previous studies

Site	Treatment	Replicate Number	Mean Chl. *a* (µg/cm^{-2})	Standard Deviation (µg/cm^{-2})	Coefficient of Variation (%)
Battle Creek	N	5	1.16	0.64	60
	P	1	1.61	--	--
	N and P	5	1.67	0.60	36
	Micro-nutrients	5	0.48	0.76	160
	Total Nutrients	2	1.98	0.39	19
	Control	6	1.05	0.30	28
Peacheater Creek	N	6	1.05	0.42	40
	P	6	1.38	0.44	32
	N and P	6	1.61	0.72	45
	Micro-nutrients	6	0.35	0.10	28
	Total Nutrients	6	1.66	0.69	20
	Control	6	0.51	0.23	46
Tyner Creek	N	6	0.31	0.17	57
	P	6	0.20	0.08	42
	N and P	5	0.28	0.11	40
	Micro-nutrients	6	0.20	0.15	77
	Total Nutrients	6	0.33	0.10	29
	Control	6	0.21	0.14	65

that nutrients and sediment are problematic in the Illinois River Basin.

Site	Treatment	Replicate Number	Mean Chl. *a* ($\mu g/cm^{-2}$)	Standard Deviation ($\mu g/cm^{-2}$)	Coefficient of Variation (%)
Battle Creek	N	4	0.33	0.05	17
	P	2	0.24	0.26	109
	N and P	4	0.63	0.36	56
	Micro-nutrients	2	0.21	0.09	42
	Total Nutrients	4	0.57	0.14	25
	Control	4	0.28	0.17	62
Peacheater Creek	N	6	0.55	0.18	33
	P	6	0.35	0.06	16
	N and P	6	0.55	0.55	49
	Micro-nutrients	6	0.23	0.23	24
	Total Nutrients	6	0.69	0.69	50
	Control	6	0.28	0.04	11
Tyner Creek	N	6	1.09	0.43	40
	P	6	1.06	0.20	19
	N and P	5	1.01	0.24	24
	Micro-nutrients	5	0.45	0.21	46
	Total Nutrients	6	0.98	0.40	41
	Control	6	0.55	0.19	35

H. ANALYSIS OF BANK EROSION ON THE ILLINOIS RIVER IN NORTHEAST OKLAHOMA

One source of increased turbidity in the Illinois River, its tributaries, and Lake Tenkiller and increased bedload in the Illinois River and its tributaries is believed to be streambank erosion. However, the magnitude of the contribution of streambank erosion had not been investigated until OSU and the OCC completed a survey of bank erosion on the Illinois River in 1996-1997. This project involved completion of several milestones:

1. Initial bank characterization, selection of banks for detailed study, and detailed characterization of selected banks were performed and reported in the Bank and Reach Characterization Report.
2. Long-term bank erosion was measured from aerial photographs and reported in the Aerial Photograph Erosion Analysis Report.
3. Short-term bank erosion was measured in the field at selected sites along the length of the river.

1. Initial Bank Characterization

In July 1996 193 bank segments along the length of the Illinois River from below Lake Frances dam to Horseshoe Bend on the upper portion of Lake Tenkiller were characterized. Data was generally collected only on eroding banks, however, several stable banks were characterized to provide a comparison. An effort was made to measure only significantly eroding banks, based on the area of bank erosion, generally exceeding 1000 ft^2. Data collected included length, height, angle, river position, location, material, vegetation type and percent cover, root depth and density, maximum water depth, bankfull depth, and percent flow in the near bank region under bankfull flow conditions. Banks were then grouped according to physical and vegetative conditions and hydrologic influence. At least one bank from each group (36 sites) was selected for detailed characterization. Selected sites were characterized with Rosgen Level III stream reach condition evaluation (Rosgen 1996). Twenty-three of the 36 sites were characterized as C4c-channels, 11 as C4, and 2 as F4. C4c and C4 channels are gravel dominated, slightly entrenched, gentle gradient, riffle/pool channels with high width/depth ratios. These channels, characterized by depositional features, are very susceptible to shifts in stability caused by flow changes and sediment delivery from the watershed. F4 channels have similar characteristics but are entrenched. Channel bars are common, and bank erosion rates may be high due to mass-wasting of the steep banks (Rosgen 1996).

2. Aerial Photograph Erosion Analysis

USDA-SCS 1:7920 scale aerial photographs taken in 1958, 1979, and 1991 were analyzed with a method modified from Brice (1982) to estimate long-term bank erosion. A complete set of aerial photographs for the Upper Illinois River was not available for

1958, thus measurements for the period between 1958 and 1979 were made on a smaller area than measurements for the period between 1979 and 1991. Analysis yielded information on the 193 initially characterized sites in addition to 28 other significant erosional / depositional areas (generally greater than 0.5 acres lost by erosion or gained by deposition). Measurements included maximum lateral erosion, lateral erosion and/or deposition, land surface area, and length. For the period between 1958 and 1979, maximum lateral erosion averaged 67 ft, lateral erosion averaged 37 ft or 1.7 ft/yr, and lateral deposition averaged 47 ft or 2.2 ft/yr. A total of 64 acres of land was eroded, and 78 acres was deposited. The length of eroding areas averaged 1014 ft, and the length of depositional areas averaged 999 ft. For the period from 1979 to 1991, maximum lateral erosion averaged 74 ft, lateral erosion averaged 41 ft or 3.6 ft/yr, and lateral deposition averaged 5 ft or 0.4 ft/yr. A total of 195 acres of land surface area was eroded and 13 acres was deposited. The length of eroding areas averaged 1131 ft. and the length of depositional areas averaged 665 ft.

The river width, measured at each 0.5 river mile from bank tracings indicates that the river is widening. Average river width for 1979 and 1991 was 175 ft and 206 ft, respectively. Dividing the river into three 21 mile sections indicates that the river width increases in the downstream direction. River width in the first 21 mile section averaged 147 ft in 1958, 158 ft in 1979, and 185 ft in 1991. For miles 21 to 42, average width increased from 169 ft in 1979 to 195 ft in 1991. Average width on the lower third of the river increased from 199 ft in 1979 to 239 ft in 1991. Overall, the Illinois River became an average of 18% wider between 1979 and 1991.

The impact of riparian vegetation was measured using long-term erosion data. Relationships tested included maximum lateral erosion rate for forested, grassed, and mixed sites, maximum lateral erosion rate for forested, grassed, and mixed sites given the site eroded between 1958 and 1991, and percent of grassed, forested, and mixed bank length that eroded or received deposition. Between 1979 and 1991, mean erosion was greater on grassed and mixed land than on forested land but not statistically significantly. From 1958 to 1979, mean values were significantly different between forested, grassed, and mixed sites. Although mean values were generally lowest on forested areas, data indicated that major erosion could occur on forested as well as grassed and mixed sites and minor erosion could occur on grassed and mixed vegetation sites as well as forested sites.

The lengths of erosional and depositional areas were compared to vegetation data to determine the percent of forested, grassed, and mixed vegetation area length that eroded or received deposition. In both time periods, grassed areas had the greatest percent length of erosion and deposition and forested areas had the least. Over the two comparison periods, grassed areas were almost twice as likely to experience detectable erosion than mixed vegetation areas and 3.5 times more than forested areas.

3. Field Measurement of Bank Erosion

Short-term streambank erosion was measured with bank pins and cross-section surveys from September 1996 to July 1997. Erosion was measured after major flow events (exceeded 9000 cfs at the Tahlequah gage station) in September 1996, twice in November 1996, and in February 1997. Erosion was measured for 33 and 29 sites (out of 36 sites) after the second and fourth major flow events, respectively. After the first and third events, only 11 and 18 sites were measured. Pins could not always be relocated after events, and thus no data could be reported at those sites. In addition, several pins were lost due to excessive bank erosion (greater than 4 ft or erosion which removed 4 ft pins from bank). When possible, distance measurements from bank surveys were used to measure erosion in these cases.

Cumulative erosion after the four major flow events averaged 4.5 ft and ranged from -0.03 to 26.5 ft. Erosion was also measured once after two at or near bankfull events that occurred in spring and summer 1997. Erosion from these two events from averaged 0.40 ft and ranged from 0.00 to 2.35 ft. This study was conducted during a wet year when streamflow volume and frequency of significant flow events exceeded normal conditions. The average flow was 1123 cfs from August 1, 1996 to July 31, 1997, representing a 20% increase from normal conditions and a 3.0 year return period. Flow events also occurred with greater or equal to a 2 year return period during the course of this sampling. Data from the surveys indicated that several sites experienced aggradation, ranging from moderate to major. Other sites experienced degradation, although to a lesser degree than the aggrading sites experienced aggradation.

The impact of riparian vegetation was evaluated on short-term erosion data. Cumulative erosion for 27 sites after four major flow events was compared to riparian vegetation data. Differences in bank erosion between forested, grassed, and mixed sites suggested mean erosion from grassed and mixed sites exceeded that of forested sites. However, large variability among the vegetation types caused none of the differences to be statistically significant. Substantial erosion occurred on some forested sites while little erosion occurred on some grassed sites.

Conclusion

One of the major sources of sediment in the Illinois River basin is likely streambank erosion. Much of the watershed is grassland or forested (92%). Although clearing of forested areas for pasture is increasing, this area still represents only a small portion of the watershed. Estimated inputs of sediment from bank erosion (3.5 million tons of material between 1979 and 1991) indicate this to be a significant, perhaps the major source, contributing to bedload in the river and sedimentation of Lake Tenkiller.

Long-term erosion analysis indicated that natural riparian forested vegetation was important in reducing and preventing bank erosion on the Illinois River. Grassed banks were 3.5 times more likely to erode than forested banks and almost twice as likely at mixed vegetation banks.

In addition, the river is changing to a wider, shallower, perhaps braided river. Data show that in addition to extensive bank erosion, the river has widened from an average of 175 ft in 1979 to 206 ft in 1991. The width to depth ratio in many reaches of the river is approaching or exceeding 40 (the Rosgen criteria for a braided channel). The sinuosity in many reaches is approaching or less than 1.2 (the Rosgen criteria for a braided channel). Many channel reaches show signs of aggradation. This behavior can follow a cycle of high sediment input (either from upland or bank erosion), increased in-channel deposition, and increased bank erosion.

DESCRIPTION OF POLLUTION SOURCES

A number of potential sources of pollution exist in the Oklahoma portion of the Illinois River watershed. These sources have been identified by water quality studies, land use surveys, and local citizens as potential sources. These sources can be categorized as follows:

A. Point Sources:

Stilwell A.D.A. (WWTF)
Tahlequah WWTF
Westville WWTF

B. Nonpoint Sources:

Recreation
Lake Frances
Agriculture
Animal Production Operations
Urban Runoff
Mining
Streambank Erosion
Other

C. Combined Sources:

Nurseries
Urban Runoff

A. POINT SOURCES

A great deal of focus has been placed on the effects of sewage treatment plant (STP) discharge into the river. This section will attempt to summarize the relative contribution of those facilities to river water quality problems.

The majority of residents in Adair, Cherokee, and Delaware counties do not rely on public sewage systems for the disposal of domestic wastes. Figures concerning the use of public and private sewage disposal for these three counties are contained in **Table 18** (U.S. Census Bureau Structural, Plumbing, and Equipment Characteristics: 1990).

County	Population	Housing Units	% public sewer	# public sewer
Adair	18,421	7124	29.1	2073
Delaware	34,049	16808	19.8	3328
Cherokee	28,070	15935	37.8	10610
Total	80,540	39867		16011

Based upon the combination of 1990 county population figures and data from the SCS Agricultural Waste Management Field Handbook the yearly disposal of wastes from residences on public sewage systems can be calculated (**Table 18**).
The Shell Branch of the Baron Fork is listed on the 1998 Oklahoma 303(d) list as

County	Waste (dry tons)	Nitrogen (lbs.)	Phosphorus (lbs.)
Adair	482	58258	5826
Cherokee	498	60396	6040
Delaware	1154	139793	13979
Total	2134	258477	25845

impaired by organic enrichment and dissolved oxygen problems from sources including nonpoint sources, agriculture, and waste disposal. The town of Westville discharges to Shell Branch and has thus been identified as potentially partially responsible for the water quality problems. A TMDL is slated for this stream in 1998-1999 by the ODEQ.

1. POTENTIAL SOLUTIONS

There are a number of approaches for addressing the effects of waste water treatment plant (WWTF) discharges on river quality. These include but are not limited to:

1. Upgrade all facilities
2. Establish a moratorium on new hook-ups
3. Move the points of discharge to different basins
4. Do nothing

<u>Discussion of Potential Solutions</u>

1. Upgrading wastewater treatment plants to operate under best attainable technologies or best practicable technologies is one solution for improving river

quality. Given current technology, it is technically feasible for most discharges to produce water near purity. Although this level of treatment for all parameters is not warranted, reduction of nutrient discharges to the lowest achievable level should be considered. For facilities with retention lagoons, upgrading may be as simple as increasing the size of the lagoon so that discharge is not necessary. Upgrading waste water treatment plants is a very expensive alternative.

2. One alternative for preventing further increases in discharges from WWTFs is to restrict loadings to the treatment plants. This can be accomplished by restricting or eliminating new wastewater hookups. This would be an unpopular option for a number of reasons as it would affect most economic sectors.

3. Moving plant discharges out of the Illinois River Basin would eliminate discharges altogether but would likely be a very expensive process. In addition to technical considerations, cost of transport, and the physical availability of alternative discharge locations, citizens in potential discharge areas might object to this practice.

4. The option of taking no action should be considered in weighing the costs of river improvement. It may be that available financial resources would be better directed towards other sources. The TMDL process should help determine the direction of the most cost-effective nutrient reduction strategy. Although this option might be popular with municipalities, it will be difficult to convince landowners to take action if municipalities do not.

2. RESPONSIBLE ENTITIES

Oklahoma Department of Environmental Quality
Local Municipalities
Indian Tribes
Private Industry

The Oklahoma Department of Environmental Quality has jurisdiction over point source dischargers and the NPDES permitting process. ODEQ is also responsible for the development of wasteload allocations for other point source dischargers. ODEQ cooperates with local municipalities and Indian tribes in the construction and operation of WWTFs.

3. STATE GOALS

1) Municipal Wastewater Improvements

Two point sources were recently eliminated by combining flows with the city of Tahlequah. Wastewater Treatment facilities at the Cherokee Nation and

Sequoyah High School facilities no longer discharge to the river, but is now subject to tertiary treatment at the City of Tahlequah facility. In addition, the cannery at Stilwell is no longer in operation, thus eliminating a third discharge to the river. The city of Stillwell will soon be upgrading to tertiary treatment to comply with an upcoming 1 mg/l phosphorus limit in their discharge permit, similar to that of the city of Tahlequah.

2) Water Quality Modeling

The water quality modeling currently planned by ODEQ in the Illinois River Basin is to set a total maximum daily load (TMDL) for causes of water quality problems in the Illinois River as identified on the State's 303(d) List. These include organic enrichment/dissolved oxygen, flow alteration, metals, nutrients, and siltation. TMDL's will be estimated for pollutants which affect these parameters. These TMDL's will be completed in 1998-1999. As previously mentioned, TMDLs will be completed for Shell Branch of the Baron Fork in 1998-1999.

4. COSTS

The City of Tahlequah upgraded its WWTF to tertiary treatment or nutrient removal capability and began operation in late 1990-91. This upgrade cost approximately 1.5 million dollars, but significantly reduced total P concentrations in the effluent.

The cost of upgrading the Stilwell WWTF to advanced treatment capabilities would be approximately 1.2 million dollars.

The cost of upgrading the Westville WWTF to advanced treatment capabilities would be approximately 2.6 million dollars.

These upgrades are generally funded by loans provided by and payable to the Oklahoma Water Resources Board Revolving Fund Program. Upgrades are generally financed by rate hikes, municipal bonds, etc.

B. NONPOINT SOURCES

1. RECREATION

Recreation provides a considerable economic stimulus in the Illinois River Basin. It is largely because of the potential effects on recreation that water quality problems in the Illinois River has received so much attention. Although most of the attention has been focused on the effects of point and nonpoint sources on recreation, the effects of recreational activities themselves must be considered.

It is estimated that over 400,000 persons visit the river each year for recreation uses and many of those visitors enjoy the river through canoe trips. During peak periods approximately 2,400 canoes are rented per weekend. Unfortunately the physical amenities are not in place to provide this many visitors with adequate waste disposal. Until 1995, only two of the seventeen river access points were equipped with toilet facilities. There were no convenient toilet or trash collection facilities for canoers.

With this many canoers and a lack of toilet and trash facilities, the disposal of trash and human waste is an obvious problem. A trip down the river clearly reveals the trash problem as evidenced by aluminum cans, paper, and other goods lying along the banks. The disposal of sewage is less evident; however, the ultimate fate of this material is obvious.

a. POTENTIAL SOLUTIONS

1. Restrict number of river visitors
2. Restrict river access
3. Restrict river activities
4. Improve facilities
5. Education

Discussion of Potential Solutions

1. Reducing the number of river visitors would have a direct effect on improving water quality and the aesthetic qualities of the river and its corridor as less trash and human waste would be disposed of in and along the river. This would likely be an unpopular alternative to canoe operators and concessionaires.

2. This approach is directly tied to one discussed above as reducing access should reduce the number of visitors. One benefit of this approach is that trash and

waste collection facilities could be concentrated at remaining access points. In addition to the negative economic consequences, this approach might cause physical degradation of access areas due to the increased intensity of use.

3. A restriction on river activities could reduce the amount of trash and physical damage to the environment. Examples of activities which might be restricted include: use of disposable materials, alcohol consumption, and overnight camping. The economic effects of these restrictions are difficult to predict and it can be argued that each would have positive as well as negative effects.

4. Improving the number and quality of trash and waste collection facilities should cause a significant decrease in the amount of material illicitly disposed. Increasing the availability of facilities does not guarantee their use; therefore, this alternative would not appear to be the best way to ensure a reduction in recreation associated waste. On the other hand, the absence of facilities guarantees the adoption of other practices. This would appear be a popular alternative with the only downfall being the cost of construction and maintenance.

5. Educating the public concerning proper river use and the consequences of improper river management offers a promising avenue for establishing direct contact with those who might be most affected by river degradation. Although education might not have a significant effect on adults, the effects on younger people, who make up a large percentage of river visitors, might result in long-term changes in attitudes towards the environment.

b. RESPONSIBLE ENTITIES

Oklahoma Scenic Rivers Commission
Recreation Concessions

The Oklahoma Scenic Rivers Commission (OSRC) is responsible for the operation and maintenance of the recreational corridor along the river. As such, OSRC has the authority to implement rules and regulations concerning waste practices along the river. OSRC is also responsible for the construction and maintenance of river access and waste disposal facilities.

c. STATE GOALS

One of the goals of OSRC is to improve the number and quality of toilet facilities at river access points. OSRC has recently completed a project that bought land and developed a "canoer only" access area on the river (OSRC 1998). This area provides restroom, picnic, and trash disposal facilities which are accessible only from the river. The long term goal was the establishment of a minimum of 10 complete facilities. Funds have been provided to establish 10 - 12 restroom facilities easily accessible from the river. In addition, a contract has been signed to lease and maintain (twice daily clean out during peak season) portable facilities which goes into effect in 1999.

As part of the aforementioned project, OSRC purchased and placed informational signs at all access areas including one commercial canoe landing. These signs were placed where river users can see them from the water and identify the site and list various conveniences available to users. In addition, OSRC placed a sign at the entrance to the Illinois River on Highway 10 which promotes the OSRC's and Cherokee County Conservation District's Educational Illinois Jones Program. This program is directed at educating children in the watershed about the problems and potential solutions to problems in the Illinois River Watershed.

Funds from the OSRC project have also been used to purchase and continue a trash bag program, originally instituted under an FY 1991 319(h) Illinois River Program. Bags have been provided to each commercial floatation device operation and other businesses for distribution to river users. Commercial floatation device operators estimate that 60-80% of the bags distributed are used for litter. OSRC estimates average return of 5 lbs. of litter per bag, resulting in approximately 118 tons of litter being collected and removed as part of this program.

OSRC is considering the option of limiting canoer numbers through a voluntary program with canoe operators. Other considerations for the future include banning the consumption of alcoholic beverages on the river.

d. COSTS

Purchase of land and construction of pit toilets and facilities at the canoer-only access point cost approximately $40,000. It is estimated that the installation of pit toilets at the ten facilities would cost $100,000. Improved toilet facilities would cost approximately $600,000. Trash disposal from river access points costs $40,000 to $50,000 yearly not considering labor. Future plans call for the use of portable toilet facilities at access points where permanent facilities are impractical. These would cost approximately $50,000 with annual operating costs of $10,000 to $20,000. It is estimated that stream bank stabilization in critical areas under the jurisdiction of OSRC would cost $200,000. The current operating budget for the Oklahoma Scenic Rivers Commission (OSRC) is $337,000.
Although the long range goal of the OSRC is to install permanent facilities and purchase more land for access areas, the current contract to provide clean portable facilities should be sufficient to meet the needs of river users for the

foreseeable future. Almost as important as the provision of the facilities are the education programs which emphasize to users why it is important for them to make the effort to use the facilities provided. Both the OSRC and the Cherokee County Conservation District have education programs which focus on that aspect and others pertaining to protecting the water resources of the basin.

2. LAKE FRANCES

Lake Frances lies on the border of Oklahoma and Arkansas and serves as the upstream boundary for the Scenic River designation. The main portion of the dam collapsed in 1991 and essentially no lake remains, although there is still some retardation of river flow.

A the time of the dam collapse the lake had experienced a high degree of siltation with sediment levels being over 15 feet at the dam. All of the lake bed (approximately 560 acres) is now exposed with several hundred thousand cubic meters of nutrient-enriched sediment being subject to removal by river flow. Water quality data taken during 1992 and 1993 from sites above and below the lake show that river turbidity increases below the lake, although not significantly. The major concern appears to be loss of sediment during storm events. At present the river channel skirts the south shore of the former lake; however, given the soft nature of the sediments and the tendency for rivers to meander, the potential for much of the lake sediment to be dislodged into the river is high. It is difficult to imagine that water quality in the river can be much improved until this situation is addressed as a high potential exists for release of sediment to the river.

a. POTENTIAL SOLUTIONS

1. Restore impoundment

2. Remove sediment material

3. Stabilize streambed

4. Wetland development

<u>Discussion of Potential Solutions</u>

1. Restoration (reconstruction) of the lake dam so that it serves as an impoundment would help to ensure that accumulated material stays in place. This would be a relatively expensive alternative; however, creation of a lake would provide long term benefits for the river by acting as a sediment and nutrient trap. This would appear to be a popular solution for area residents and municipalities. However, creation of a lake with nutrient rich sediment would also likely result in a eutrophic impoundment. Thus, Lake Frances would likely have water quality

problems that would affect the river downstream in both positive and negative ways. Although creation of a sediment trap seems like a positive impact for the river, the reimpoundment would likely result in significant entrenchment and widening of the river downstream along with increased sediment loads from this process. Reimpounding Lake Frances would likely result in increased water quality problems downstream, rather than fewer.

2. The removal of the accumulated material would ensure that it is never washed into the river system. Since there is such a large volume of material, this would be a considerable undertaking, although the dry condition of the lake bed makes this type of dredging easier and less expensive. This option does not necessarily involve removal of all sediment as that which is some distance from the river edge may be safe from erosion. It is likely that option 1 would include some sediment removal.

3. Stabilization of the streambed to lessen the potential for erosion is a relatively inexpensive option. It has not been determined whether this option could provide for adequate protection from erosion; however, this approach would appear to have significant potential. This would involve revegetation of the lake bottom with erosion resistant plant species combined with river bank stabilization using Rosgen method techniques. Since 1991, the river has begun to stabilize itself through this section and as long as major disturbances do not occur upstream or downstream, this could be a very effective method of preventing Lake Frances sediment from polluting the river.

4. The lake bed now exhibits many characteristics of a wetland. These properties could be augmented with the establishment of wetland vegetation and control of water levels. Water traveling through such a system would be stripped of much of the nutrient and sediment load. However, structures to control water levels must be developed with care so as not to effect the natural tendencies of the river upstream or downstream.

b. RESPONSIBLE ENTITIES

It is difficult to determine which entities are responsible for the Lake Frances at this point. The following entities would potentially be involved in any clean-up effort:

Oklahoma Scenic Rivers Commission
Oklahoma Conservation Commission
City of Siloam Springs
Oklahoma Water Resources Board
Oklahoma Department of Environmental Quality
Adair County Conservation District

State of Arkansas

c. STATE GOALS

The goal of the state is to repair or remediate the situation in what remains of Lake Frances so that lake sediments are removed or stabilized to the point where they do not contribute to water quality problems in the Illinois River. The Oklahoma Conservation Commission (OCC) has initiated an investigation into potential solutions working with USEPA. Wetland development could be funded through the EPA wetland program.

d. COSTS

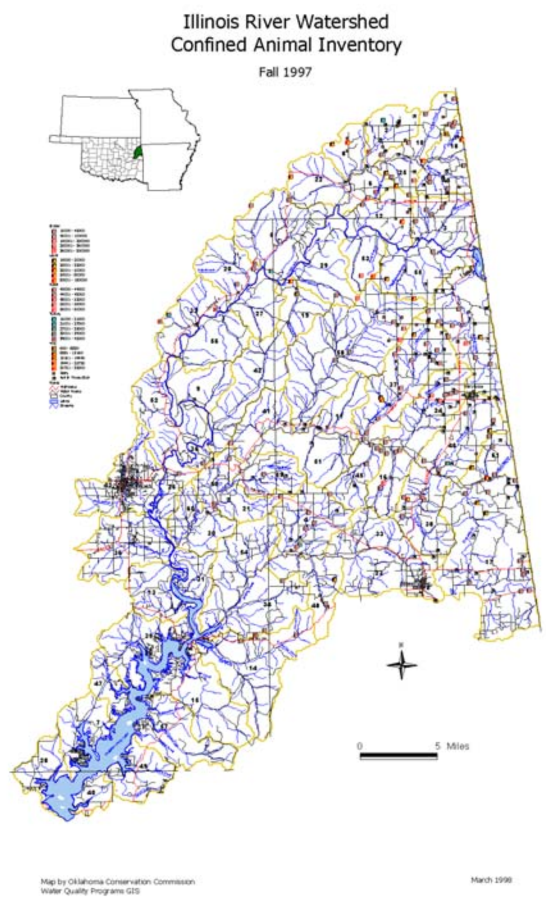
No firm costs estimate is available as this will be dependent upon the restoration/remediation plan chosen. It is estimated that costs could vary between $300,000 and $1,000,000. However, the developing native vegetation could provide sufficient stabilization such that no funding will be required, rather just a provision to allow the vegetation to establish, rather than actions to clear it. This currently appears to be the case, however, certain reaches may require augmentation in the future, should the vegetation be insufficient. Possibly the most appropriate measures to take would be to allow the vegetation to establish itself for 4 or 5 more years while other problems in the watershed are focused on, and then reevaluate the site to determine whether augmentation of the stabilization process is necessary.

3. ANIMAL PRODUCTION OPERATIONS

Agricultural activities are very important in the basin with the majority of income being produced through cattle, hogs, and poultry operations. The Oklahoma Conservation Commission (OCC) conducted a survey of animal production operations in 1997 to update 1989 Natural Resources Conservation Service (NRCS) numbers. Estimates were based on site visits and usually a discussion with the grower. This method allowed differentiation between active and inactive sites 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 easily find them. Using these signs, previously mapped houses were verified and those which didn't appear on any of the NRCS or USGS maps were mapped. **Figure 12** shows the location of confined animal feeding operations (CAFOs) in the Oklahoma portion of the Illinois River Watershed.

Table 20 lists the growers in the Oklahoma portion of the Illinois River Basin by location, the number and type of animals produced, and the company they are produced for. Listed are all sites surveyed in the 1997 assessment. Also listed are sites that were active in the NRCS 1985 survey which are no longer active (no longer in production (NIP) and not standing (NS)).

Table 21, **Table 22**, **Table 23**, **Table 24**, and **Table 25** list the subwatersheds of the Illinois River from the Lake Tenkiller dam to the Oklahoma border. 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 the Illinois River are delineated and referred to as Illinois Laterals. They are designated either North or South depending on their position relative to the Illinois River, and are located along the Illinois River 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 indicated 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. The column labeled animals refers to the actual number of chickens, turkeys, dairy cattle, hogs, etc. for a particular watershed or subwatershed.


Illinois River Watershed
Confined Animal Inventory
Fall 1997
0
5 Miles
Map by Oklahoma Conservation Commission
Water Quality Programs GIS
March 1998

Site ID#	Type	Houses #	Sizes	# Animals	Company	Location
102P	Broiler	2	400	40,000	Tyson	Tyner Creek
103P	Broiler	2	400	40,000	Tyson	Tyner Creek
108P	Broiler	2	400	40,000	Tyson	Peacheater Creek
109P	Broiler	2	400	40,000	Hudson	Green Creek
10P	Broiler	3	400	60,000		
111P	Broiler	3	400	60,000	Hudson	Peacheater Creek
113P	Broiler	2	400	40,000	Tyson	Peacheater Creek
115P	Broiler	3	400	60,000	Tyson	Peacheater Creek
120P	Broiler	3	400	60,000	Hudson	Ballard Creek
124P	Broiler	4	400	80,000		Ballard Creek
125P	Broiler	2	300	30,000	Hudson	Ballard Creek
127P	Broiler	3	400	60,000	Hudson	Ballard Creek
128P	Broiler	3	400	60,000	Hudson	Ballard Creek
134P	Broiler	1	400	20,000	Simmon’s	Peacheater Creek
135P	Broiler	2	400	40,000	Simmon’s	Peacheater Creek
136P	Broiler	1	300	15,000	Simmon’s	Scraper Hollow Creek
137P	Broiler	2	400	40,000	Simmon’s	Scraper Hollow Creek
138P	Broiler	2	400	40,000	Hudson	Scraper Hollow Creek
139P	Broiler	1	400	20,000	Hudson	England Hollow Creek
141P	Broiler	2	400	40,000	Simmon’s	Peavine Branch
144P	Broiler	2	400	40,000	Simmon’s	Shell Branch
145P	Broiler	4	400	80,000		Peavine Branch
146P	Broiler	2	400	40,000	Simmon’s	Peavine Branch
147P	Broiler	2	400	40,000	Hudson	Peavine Branch
14P	Broiler	1	400	20,000	Peterson	
150P	Broiler	2	400	40,000	Cal-Maine	Scraper Hollow Creek
153P	Broiler	3	400	60,000	Hudson	Bidding Creek
156P	Broiler	1	400	20,000	Tyson	Green Creek
157P	Broiler	3	400	55,000	Tyson	Green Creek
159P	Broiler	2	400	40,000	Hudson	Green Creek
15P	Broiler	4	400	80,000	Peterson	Fagan Creek
160P	Broiler	18	400	360,000	Hudson	Green Creek
163P	Broiler	15	400	300,000	Hudson	Green Creek
16P	Broiler	2	400	40,000	Simmon’s	Fagan Creek
171P	Broiler	2	400	40,000	Simmon’s	Shell Branch
174P	Broiler	1	400	20,000	Simmon’s	Shell Branch
17P	Broiler	2	400	40,000	Simmon’s	Crazy Creek
185P	Broiler	2	300	45,000	Tyson	West Branch
188P	Broiler	3	400	20,000	Simmon’s	West Branch
189P	Broiler	1	400	40,000	Simmon’s	West Branch

Site ID#	Type	Houses #	Sizes	# Animals	Company	Location
192P	Broiler	2	400	20,000	Cal-Maine	Shell Branch
196P	Broiler	1	300	40,000	Hudson	Shell Branch
1P	Broiler	2	400	60,000	George’s	Crazy Creek
206P	Broiler	3	400	40,000	Simmon’s	South Briggs Hollow
207P	Broiler	2	400	60,000	Hudson	Proctor Mountain Creek
219P	Broiler	3	300	45,000	Hudson	Walltrip Branch
222P	Broiler	3	400	60,000	Hudson	Field Hollow
223P	Broiler	3	400	40,000	Hudson	Bidding Creek
224P	Broiler	2	400	60,000	Simmon’s	Negro Jake Creek
226P	Broiler	2	400	40,000	Simmon’s	Dry Creek & Bolin Hollow
227P	Broiler	1	400	20,000	Simmon’s	Dry Creek & Bolin Hollow
228P	Broiler	1	300	15,000	Hudson	Negro Jake Hollow
22P	Broiler	2	400	40,000	Hudson	Sager Creek
231P	Broiler	2	400	40,000	Simmon’s	Bidding Creek
232P	Broiler	3	400	60,000	Simmon’s	Bidding Creek
236P	Broiler	3	400	60,000	Simmon’s	Bidding Creek
23P	Broiler	5	400	100,000	Hudson	Sager Creek
241P	Broiler	3	400	60,000	Hudson	
242P	Broiler	2	400	40,000	Hudson	
249P	Broiler	2	400	40,000	Hudson	Ill. R. Echota Bend Laterals
24P	Broiler	2	400	40,000	Hudson	Sager Creek
250P	Broiler	2	400	40,000	Hudson	North Briggs Hollow
252P	Broiler	2	400	40,000	Hudson	
253P	Broiler	3	400	60,000	Hudson	
254P	Broiler	2	400	40,000	Hudson	
259P	Broiler	4	400	80,000	Peterson	
260P	Broiler	2	400	40,000	Peterson	
262P	Broiler	2	400	40,000	Simmon’s	Falls Branch
263P	Broiler	2	300	40,000	Simmon’s	Falls Branch
265P	Broiler	1	400	20,000	Simmon’s	Evansville Creek
273P	Broiler	2	400	40,000	Simmon’s	Ballard Creek
274P	Broiler	1	400	20,000	Simmon’s	Ballard Creek
277P	Broiler	30	300	600,000	Hudson	Ballard Creek
280P	Broiler	3	400	60,000	Hudson	England Hollow Creek
281P	Broiler	1	400	20,000	Hudson	England Hollow Creek
282P	Broiler	2	400	40,000	Simmon’s	England Hollow Creek
283P	Broiler	1	400	20,000	Hudson	Peacheater Creek
288P	Broiler	2	400	40,000	Hudson	Evansville Creek
289P	Broiler	3	400	60,000	Simmon’s	Evansville Creek
291P	Broiler	2	400	40,000	Simmon’s	Evansville Creek
292P	Broiler	2	400	40,000	Cargill	Evansville Creek

Site ID#	Type	Houses #	Sizes	# Animals	Company	Location
303P	Broiler	2	400	40,000	Simmon’s	Smith Hollow
306P	Broiler	6	400	100,000	Simmon’s	
308P	Broiler	3	400	60,000	Simmon’s	Evansville Creek
309P	Broiler	1	400	20,000	Simmon’s	Evansville Creek
30P	Broiler	2	400	40,000		Sager Creek
310P	Broiler	2	400	40,000	Simmon’s	
311P	Broiler	2	400	40,000	Simmon’s	
312P	Broiler	5	400	100,000	Simmon’s	
32P	Broiler	2	400	40,000	Peterson	Beaver Creek
34P	Broiler	1	400	20,000	Simmon’s	Beaver Creek
35P	Broiler	2	400	40,000	Simmon’s	Beaver Creek
36P	Broiler	2	400	40,000	Tyson	
42P	Broiler	2	400	40,000	Tyson	Battle Branch
47P	Broiler	2	400	40,000	Simmon’s	Crazy Creek
49P	Broiler	2	400	40,000	Cobb-Vantress	Tate Parrish Branch
51P	Broiler	8	400	160,000	George’s	Blue Spring Branch
52P	Broiler	2	400	40,000	Simmon’s	Dripping Spring Branch
54P	Broiler	2	400	40,000	Hudson	Hazelnut Hollow
56P	Broiler	8	400	160,000	George’s	Hazelnut Hollow
59P	Broiler	4	400	80,000	Simmon’s	Dripping Spring Branch
5P	Broiler	2	400	40,000	George’s	
62P	Broiler	2	400	40,000	Simmon’s	Beaver Creek
64P	Broiler	2	400	40,000	Simmon’s	Dripping Spring Branch
66P	Broiler	4	400	80,000	Simmon’s	Blackfox & Winset Hollow
67P	Broiler	4	400	80,000	Cobb-Vantress	
68P	Broiler	2	400	40,000	Peterson	
69P	Broiler	2	400	40,000	Peterson	Blackfox & Winset Hollow
6P	Broiler	3	400	60,000	Hudson	
75P	Broiler	1	400	20,000	Simmon’s	
76P	Broiler	40	400	800,000	Hudson	
77P	Broiler	18	400	360,000	Hudson	
7P	Broiler	2	400	40,000	George’s	Luna Branch
82P	Broiler	5	400	100,000	Hudson	Luna Branch
84P	Broiler	10	400	200,000	Hudson	Tahlequah, Kill Hollow, Rock Br
91P	Broiler	38	400	760,000	Hudson	
92P	Broiler	2	400	40,000	Simmon’s	Tyner Creek
92P	Broiler	2	300	30,000	Simmon’s	Tyner Creek
93P	Broiler	4	400	80,000	Simmon’s	Tyner Creek
95P	Broiler	4	400	80,000	Tyson	Peacheater Creek
99P	Broiler	3	400	60,000	Simmon’s	
9P	Broiler	2	400	40,000	Peterson	Peacheater Creek

Site ID#	Type	Houses #	Sizes	# Animals	Company	Location
109P	Dairy			50		
118D	Dairy			90		Peacheater Creek
126D	Dairy			60		Ballard Creek
129D	Dairy			60		Peacheater Creek
140D	Dairy			60		England Hollow Creek
142P	Dairy			80		
148P	Dairy			60		
176D	Dairy			35		Shell Branch
178D	Dairy			60		Shell Branch
179D	Dairy			60		
194D	Dairy			60		Shell Branch
214D	Dairy			40		Dennison Creek
229D	Dairy			50		Negro Jake Hollow
22P	Dairy			80	Hudson	
230D	Dairy			50		Bidding Creek
237D	Dairy			40		Bidding Creek
240D	Dairy			40		Park Hill Branch
255D	Dairy			50		
258D	Dairy			60		Falls Branch
266D	Dairy			60		Ballard Creek
271D	Dairy			60		Ballard Creek
272D	Dairy			60		Ballard Creek
278D	Dairy			60		Ballard Creek
285D	Dairy			70		Dripping Springs Branch
28D	Dairy			60		Sager Creek
2D	Dairy			60		Crazy Creek
304D	Dairy			45		Smith Hollow
305D	Dairy			60		Smith Hollow
38D	Dairy			40		Calunchety Hollow
39D	Dairy			30		Calunchety Hollow
3D	Dairy			60		
44D	Dairy			80		Battle Branch
46D	Dairy			60		Battle Branch
48D	Dairy			100		Battle Branch
61P	Dairy			60		Dripping Spring Branch
73D	Dairy			60		Fall Branch
74D	Dairy			50		Fall Branch
80D	Dairy			40		Tate Parrish Branch
81D	Dairy			50		Tyner Creek
85D	Dairy			50		Tyner Creek

Site ID#	Type	Houses #	Sizes	# Animals	Company	Location
86D	Dairy			65		Tyner Creek
87D	Dairy			40		Peacheater Creek
8D	Dairy			40		Crazy Creek
94D	Dairy			100		Tyner Creek
96D	Dairy			100		Peacheater Creek
97D	Dairy			40		Peacheater Creek
98D	Dairy			50		Peacheater Creek
998D	Dairy			50		Battle Branch
276P	Feed Mill				Hudson	Ballard Creek
131P	Hen	1	400	25,000	Simmon's	Peacheater Creek
132P	Hen	2	400	40,000	Simmon's	Peacheater Creek
142P	Hen	2	400	40,000	Hudson	Peavine Branch
177P	Hen	2	400	30,000		West Branch
180P	Hen	1	400	15,000	Simmon's	Evansville Creek
181P	Hen	2	400	30,000	Simmon's	Evansville Creek
191P	Hen	2	400	40,000	Cal-Maine	West Branch
193P	Hen	1	400	15,000	Cal-Maine	Shell Branch
20P	Hen	4	400	60,000	Tyson	Fagan Creek
21P	Hen	4	400	60,000	Tyson	Crazy Creek
270P	Hen	1	400	15,000	Simmon's	Ballard Creek
301P	Hen	1	400	15,000	Hudson	Smith Hollow
306P	Hen	2	400	30,000	Simmon's	
37P	Hen	2	400	30,000	Peterson	Calunchety Hollow
40P	Hen	12	400	180,000	Hudson	Calunchety Hollow
53P	Hen	2	400	30,000	Simmon's	Blue Spring Branch
55P	Hen	1	400	10,000	Peterson	Hazelnut Hollow
60P	Hen	4	400	80,000	Hudson	Dripping Spring Branch
65P	Hen	2	400	40,000	Tyson	Five Mile Hollow
71P	Hen	2	400	40,000	Cal-Maine	Fall Branch
72P	Hen	1	400	20,000	Cal-Maine	Fall Branch
79P	Hen	4	400	32,000	Cal-Maine	Tate Parrish Branch
88D	Hen	4	400	50,000	Cobb-Vantress	Tate Parrish Branch
90P	Hen	2	400	25,000	Cobb-Vantress	Peacheater Creek
18H	Hog			600	Tyson	Fagan Creek
78H	Hog	12	400	3,200	Tyson	Tahlequah, Kill Hollow, Rock Br
148P	Pullet	3	400	60,000	Cal-Maine	Five Mile Hollow
149P	Pullet	2	400	40,000	Cal-Maine	Dripping Spring Branch
173T	Turkey	3	400	30,000	Cargill	Shell Branch
225T	Turkey	3	400	45,000	Cargill	Negro Jake Hollow
235T	Turkey	2	300	30,000	Cargill	Bidding Creek

Site ID#	Type	Houses #	Sizes	# Animals	Company	Location
238T	Turkey	3	400	45,000	Cargill	South Briggs Hollow
329T	Turkey	3	400	45,000	Cargill	South Briggs Hollow
243T	Turkey	2	400	30,000	Cargill	
244T	Turkey	3	400	45,000	Cargill	Mollyfield & Peavine Creeks
245T	Turkey	3	400	45,000	Cargill	Mollyfield & Peavine Creeks
246T	Turkey	2	400	30,000	Cargill	Mollyfield & Peavine Creeks
261T	Turkey	3	400	45,000	Cargill	Falls Branch
319T	Turkey	1	400	15,000	Cargill	Battle Branch
70T	Turkey	2	400	30,000	Cargill	Blackfox & Winset Hollow
100P	NIP					
101P	NIP					
104P	NIP					
105P	NIP					Peacheater Creek
106P	NIP					Peacheater Creek
107P	NIP					Peacheater Creek
110P	NIP					Green Creek
112P	NIP					Peacheater Creek
114P	NIP					Peacheater Creek
116P	NIP					Peacheater Creek
117P	NIP					Ballard Creek
119P	NIP					Ballard Creek
11P	NIP					Battle Branch
121P	NIP					Tate Parrish Branch
122P	NIP					Ballard Creek
123P	NIP					Ballard Creek
12P	NIP					Battle Branch
130P	NIP					Peacheater Creek
133P	NIP					Peacheater Creek
13P	NIP					Battle Branch
143P	NIP					Peavine Branch
151P	NIP					Scraper Hollow Creek
155P	NIP					Bidding Creek
158P	NIP					Green Creek
161P	NIP					Green Creek
162P	NIP					Green Creek
164P	NIP					Green Creek
165P	NIP					Green Creek
166P	NIP					Green Creek
168P	NIP					Green Creek
169P	NIP					Shell Branch

Site ID#	Type	Houses #	Sizes	# Animals	Company	Location
170P	NIP					Shell Branch
172P	NIP					Shell Branch
175P	NIP					Shell Branch
182P	NIP					Evansville Creek
183P	NIP					Evansville Creek
184P	NIP					Evansville Creek
186P	NIP					West Branch
187P	NIP					West Branch
190P	NIP					West Branch
195P	NIP					Shell Branch
199P	NIP					Ballard Creek
19P	NIP					Fagan Creek
200P	NIP					Ballard Creek
201P	NIP					Shell Branch
202P	NIP					Ballard Creek
203P	NIP					Shell Branch
204P	NIP					Shell Branch
205P	NIP					Shell Branch
208P	NIP					South Briggs Hollow
209P	NIP					Proctor Mountain Creek
210P	NIP					Tyner Creek
211P	NIP					Tyner Creek
212P	NIP					Dennison Creek
213P	NIP					Dennison Creek
215P	NIP					Bidding Creek
216P	NIP					South Proctor Creek
217P	NIP					Walltrip Branch
218P	NIP					Walltrip Branch
220P	NIP					Walltrip Branch
221P	NIP					Field Hollow
233P	NIP					Bidding Creek
234P	NIP					Bidding Creek
247P	NIP					Cedar and Tully Hollows
251P	NIP					South Briggs Hollow
256P	NIP					Mollyfield & Peavine Creeks
257P	NIP					
25P	NIP					Sager Creek
264P	NIP					Shell Branch
268P	NIP					Ballard Creek
26P	NIP					Sager Creek

Site ID#	Type	Houses #	Sizes	# Animals	Company	Location
175P	NIP					Ballard Creek
279P	NIP					Ballard Creek
27P	NIP					Sager Creek
284P	NIP					Beaver Creek
286P	NIP					Peavine Branch
287P	NIP					Mulberry Hollow
290P	NIP					Evansville Creek
293P	NIP					Evansville Creek
294P	NIP					Evansville Creek
295P	NIP					Evansville Creek
296P	NIP					Evansville Creek
299P	NIP					Mulberry Hollow
29P	NIP					Sager Creek
302P	NIP					Smith Hollow
307P	NIP					Evansville Creek
313P	NIP					Goat Mountain
317P	NIP					Battle Branch
31P	NIP					Beaver Creek
321P	NIP					Green Creek
33P	NIP					Beaver Creek
38D	NIP					
41P	NIP					Battle Branch
43P	NIP					Crazy Creek
45P	NIP					Battle Branch
4P	NIP					
50P	NIP					Crazy Creek
57P	NIP					Hazelnut Hollow
58P	NIP					Blue Spring Branch
63P	NIP					Dripping Spring Branch
83P	NIP					Tyner Creek
89P	NIP					Tate Parrish Branch
999P	NIP					Battle Branch
152P	NS					Scraper Hollow Creek
154P	NS					Bidding Creek
167P	NS					Green Creek
197P	NS					Shell Branch
198P	NS					Ballard Creek
248P	NS					
267P	NS					Ballard Creek
269P	NS					Ballard Creek

Site ID#	Type	Houses #	Sizes	# Animals	Company	Location
297P	NS					Mulberry Hollow
298P	NS					Peavine Branch
300P	NS					Mulberry Hollow
318P	NS					
314N	Nursery				Greenleaf Nursery	Petit Creek
315N	Nursery				Park Hill Nursery	Park Hill Branch
316N	Nursery				Midwestern Nursery	Steeley Hollow

Sites not standing are sites that appear on the USGS 1:24000 topographic maps but no longer exist. Sites not in production are houses that are standing and capable of production but were empty at the time of the site visit. Potential houses in production, potential animals, and potential animal density 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, rather than turkey houses.

			Broiler				Layer			
Subwatershed	**GIS label**	**Size (mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (per mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (per mi^2**
Ballard Creek	1	25.19	8	48	950000	37719.18	1	1	15000	595.57
Battle Branch	2	9.33	1	2	40000	4286.92	0	0	0	0.00
Beaver Creek	3	14.51	4	7	140000	9649.50	0	0	0	0.00
Bidding Creek	4	17.46	5	13	260000	14893.59	0	0	0	0.00
Blackfox & Winset Hollow	5	22.92	1	2	40000	1744.97	0	0	0	0.00
Blue Spring Branch	6	5.28	1	8	160000	30284.76	1	2	30000	5678.39
Burnt Cabin Creek	7	12.32	0	0	0	0.00	0	0	0	0.00
Calunchety Hollow	8	6.95	0	0	0	0.00	1	12	180000	25907.94
Cedar Hollow & Tully Hollow	9	11.12	0	0	0	0.00	0	0	0	0.00
Crazy Creek	10	9.41	3	7	140000	14883.58	1	4	60000	6378.68
Dennison Creek	11	7.89	0	0	0	0.00	0	0	0	0.00
Dripping Spring Branch	12	11.35	3	8	160000	14093.79	1	4	80000	7046.89
Dripping Springs Hollow	13	11.76	0	0	0	0.00	0	0	0	0.00
Dry Creek & Bolin Hollow	14	27.48	2	3	60000	2183.63	0	0	0	0.00
Elk Creek	15	21.67	0	0	0	0.00	0	0	0	0.00
England Hollow Creek	16	9.46	4	7	140000	14805.01	0	0	0	0.00
Evansville Creek	17	48.52	8	16	320000	6594.64	2	3	45000	927.37
Fagan Creek	18	3.72	2	6	120000	32246.93	1	4	60000	16123.46
Fall Branch	19	8.62	0	0	0	0.00	2	3	60000	6962.59
Falls Branch	20	10.93	2	4	80000	7319.25	0	0	0	0.00
Field Hollow	21	6.64	1	3	60000	9036.18	0	0	0	0.00
Five Mile Hollow	22	11.23	0	0	0	0.00	1	2	40000	3563.03
Goat Mountain	23	12.6	0	0	0	0.00	0	0	0	0.00
Green Creek	24	15.6	6	41	815000	52232.73	0	0	0	0.00
Hazelnut Hollow	25	4.52	2	10	200000	44204.52	1	1	10000	2210.23
Illinois River Echota Bend	26	6.92	1	2	40000	5780.77	0	0	0	0.00
Kirk Springs & Sawmill Hollow	27	9.13	0	0	0	0.00	0	0	0	0.00
Linder Bend & Sawmill Hollow	28	8.46	0	0	0	0.00	0	0	0	0.00
Luna Branch	29	14.83	2	41	820000	55287.75	0	0	0	0.00
Mining Camp Hollow (North)	30	6.91	0	0	0	0.00	0	0	0	0.00
Mining Camp Hollow (South)	31	7.87	0	0	0	0.00	0	0	0	0.00
Mollyfield & Peavine Creeks	32	12.03	0	0	0	0.00	0	0	0	0.00
Mulberry Hollow	33	15.96	0	0	0	0.00	0	0	0	0.00
Negro Jake Hollow	34	16.98	2	4	75000	4417.58	0	0	0	0.00
North Briggs Hollow	35	2.11	1	2	40000	18920.30	0	0	0	0.00
Park Hill Branch	36	19.14	0	0	0	0.00	0	0	0	0.00
Peacheater Creek	37	25.34	11	27	570000	22496.43	3	5	90000	3552.07
Peavine Branch	38	16.14	4	10	200000	12390.12	1	2	40000	2478.02
Pettit Creek	39	15.51	0	0	0	0.00	0	0	0	0.00
Pine Hollow	40	5.12	0	0	0	0.00	0	0	0	0.00
Proctor Mountain Creek	41	10.03	1	3	60000	5980.55	0	0	0	0.00
Pumpkin Hollow	42	18.66	0	0	0	0.00	0	0	0	0.00
Ross Branch & Tahlequah Cr	43	18.35	0	0	0	0.00	0	0	0	0.00
Sager Creek	44	8.24	4	11	220000	26711.18	0	0	0	0.00
Scraper Hollow Creek	45	9.33	4	7	135000	14468.73	0	0	0	0.00
Shell Branch	46	17.58	5	8	160000	9099.72	1	1	15000	853.10
Sizemore Creek	47	6.99	0	0	0	0.00	0	0	0	0.00

			Broiler				Layer			
Subwatershed	**GIS label**	**Size (mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (per mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (per mi^2**
Smith Hollow	48	12.62	1	2	40000	3169.49	1	1	15000	1188.56
Snake & Cato Creek	49	11.42	0	0	0	0.00	0	0	0	0.00
South Briggs Hollow	50	7.59	1	2	40000	5271.60	0	0	0	0.00
South Proctor Creek	51	14.63	0	0	0	0.00	0	0	0	0.00
Steeley Hollow	52	18.59	0	0	0	0.00	0	0	0	0.00
Tahlequah & Kill Hollow & Rock Br	53	8.29	1	18	360000	43417.17	0	0	0	0.00
Tailhot Creek	54	18.56	0	0	0	0.00	0	0	0	0.00
Tate Parrish Branch	55	16.68	1	2	40000	2397.71	2	8	82000	4915.30
Telamay H. & Dog Hollow	56	12.37	0	0	0	0.00	0	0	0	0.00
Terrapin Creek	57	17.44	0	0	0	0.00	0	0	0	0.00
Tyner Creek	58	42.67	5	57	1140000	26714.04	0	0	0	0.00
Walltrip Branch	59	9.96	1	3	45000	4517.56	0	0	0	0.00
Welling Creek	60	4.98	0	0	0	0.00	0	0	0	0.00
West Branch	61	7.77	3	6	105000	13518.35	2	4	70000	9012.24
Total Watershed	**T**	**821.69**	**101**	**390**	**7,775,000**	**946.00**	**22**	**57**	**892,000**	**1085.57**

			Turkey				Pullet			
Subwatershed	**GIS label**	**Size (mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (mi^2)**
Ballard Creek	1	25.19	0	0	0	0.00	0	0	0	0
Battle Branch	2	9.33	2	4	60000	6430.39	0	0	0	0
Beaver Creek	3	14.51	0	0	0	0.00	0	0	0	0
Bidding Creek	4	17.46	1	2	30000	1718.49	0	0	0	0
Blackfox & Winset Hollow	5	22.92	1	2	30000	1308.73	0	0	0	0
Blue Spring Branch	6	5.28	0	0	0	0.00	0	0	0	0
Burnt Cabin Creek	7	12.32	0	0	0	0.00	0	0	0	0
Calunchety Hollow	8	6.95	0	0	0	0.00	0	0	0	0
Cedar Hollow & Tully Hollow	9	11.12	0	0	0	0.00	0	0	0	0
Crazy Creek	10	9.41	0	0	0	0.00	0	0	0	0
Dennison Creek	11	7.89	0	0	0	0.00	0	0	0	0
Dripping Spring Branch	12	11.35	0	0	0	0.00	0	0	0	0
Dripping Springs Hollow	13	11.76	0	0	0	0.00	0	0	0	0
Dry Creek & Bolin Hollow	14	27.48	0	0	0	0.00	0	0	0	0
Elk Creek	15	21.67	0	0	0	0.00	0	0	0	0
England Hollow Creek	16	9.46	0	0	0	0.00	2	5	100000	10575.00
Evansville Creek	17	48.52	0	0	0	0.00	0	0	0	0
Fagan Creek	18	3.72	0	0	0	0.00	0	0	0	0
Fall Branch	19	8.62	0	0	0	0.00	0	0	0	0
Falls Branch	20	10.93	1	3	45000	4117.08	0	0	0	0
Field Hollow	21	6.64	0	0	0	0.00	0	0	0	0
Five Mile Hollow	22	11.23	0	0	0	0.00	0	0	0	0
Goat Mountain	23	12.60	0	0	0	0.00	0	0	0	0
Green Creek	24	15.60	0	0	0	0.00	0	0	0	0
Hazelnut Hollow	25	4.52	0	0	0	0.00	0	0	0	0
Illinois River Echota Bend Laterals	26	6.92	0	0	0	0.00	0	0	0	0
Kirk Springs & Sawmill Hollow	27	9.13	0	0	0	0.00	0	0	0	0
Linder Bend & Sawmill Hollow	28	8.46	0	0	0	0.00	0	0	0	0
Luna Branch	29	14.83	0	0	0	0.00	0	0	0	0
Mining Camp Hollow (North)	30	6.91	0	0	0	0.00	0	0	0	0
Mining Camp Hollow (South)	31	7.87	0	0	0	0.00	0	0	0	0
Mollyfield & Peavine Creeks	32	12.03	2	5	75000	6232.32	0	0	0	0
Mulberry Hollow	33	15.96	0	0	0	0.00	0	0	0	0
Negro Jake Hollow	34	16.98	1	3	45000	2650.55	0	0	0	0
North Briggs Hollow	35	2.11	0	0	0	0.00	0	0	0	0
Park Hill Branch	36	19.14	0	0	0	0.00	0	0	0	0
Peacheater Creek	37	25.34	0	0	0	0.00	0	0	0	0
Peavine Branch	38	16.14	0	0	0	0.00	0	0	0	0
Pettit Creek	39	15.51	0	0	0	0.00	0	0	0	0
Pine Hollow	40	5.12	0	0	0	0.00	0	0	0	0
Proctor Mountain Creek	41	10.03	0	0	0	0.00	0	0	0	0
Pumpkin Hollow	42	18.66	0	0	0	0.00	0	0	0	0
Ross Branch & Tahlequah Creek	43	18.35	0	0	0	0.00	0	0	0	0
Sager Creek	44	8.24	0	0	0	0.00	0	0	0	0
Scraper Hollow Creek	45	9.33	0	0	0	0.00	0	0	0	0
Shell Branch	46	17.58	1	3	30000	1706.20	0	0	0	0
Sizemore Creek	47	6.99	0	0	0	0.00	0	0	0	0

			Turkey				Pullet			
Subwatershed	**GIS label**	**Size (mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (mi^2)**
Smith Hollow	48	12.62	0	0	0	0.00	0	0	0	0
Snake & Cato Creek	49	11.42	0	0	0	0.00	0	0	0	0
South Briggs Hollow	50	7.59	2	6	90000	11861.09	0	0	0	0
South Proctor Creek	51	14.63	0	0	0	0.00	0	0	0	0
Steeley Hollow	52	18.59	0	0	0	0.00	0	0	0	0
Tahlequah & Kill Hollow & Rock Br	53	8.29	0	0	0	0.00	0	0	0	0
Tailhot Creek	54	18.56	0	0	0	0.00	0	0	0	0
Tate Parrish Branch	55	16.68	0	0	0	0.00	0	0	0	0
Telamay H. & Dog Hollow	56	12.37	0	0	0	0.00	0	0	0	0
Terrapin Creek	57	17.44	0	0	0	0.00	0	0	0	0
Tyner Creek	58	42.67	0	0	0	0.00	0	0	0	0
Walltrip Branch	59	9.96	0	0	0	0.00	0	0	0	0
Welling Creek	60	4.98	0	0	0	0.00	0	0	0	0
West Branch	61	7.77	0	0	0	0.00	0	0	0	0
Total Watershed	**T**	**821.69**	**11**	**28**	**405,000**	**492.89**	**2**	**5**	**100,000**	**122**

			Dairy				Hog			
Subwatershed	**GIS label**	**Size (mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (per mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (per mi^2)**
Ballard Creek	1	25.19	5	0	300	11.91	0	0	0	0.00
Battle Branch	2	9.33	4	0	290	31.08	0	0	0	0.00
Beaver Creek	3	14.51	0	0	0	0.00	0	0	0	0.00
Bidding Creek	4	17.46	2	0	90	5.16	0	0	0	0.00
Blackfox & Winset Hollow	5	22.92	0	0	0	0.00	0	0	0	0.00
Blue Spring Branch	6	5.28	0	0	0	0.00	0	0	0	0.00
Burnt Cabin Creek	7	12.32	0	0	0	0.00	0	0	0	0.00
Calunchety Hollow	8	6.95	2	0	70	10.08	0	0	0	0.00
Cedar Hollow & Tully Hollow	9	11.12	0	0	0	0.00	0	0	0	0.00
Crazy Creek	10	9.41	2	0	100	10.63	0	0	0	0.00
Dennison Creek	11	7.89	1	0	40	5.07	0	0	0	0.00
Dripping Spring Branch	12	11.35	2	0	130	11.45	0	0	0	0.00
Dripping Springs Hollow	13	11.76	0	0	0	0.00	0	0	0	0.00
Dry Creek & Bolin Hollow	14	27.48	0	0	0	0.00	0	0	0	0.00
Elk Creek	15	21.67	0	0	0	0.00	0	0	0	0.00
England Hollow Creek	16	9.46	2	0	120	12.69	0	0	0	0.00
Evansville Creek	17	48.52	1	0	60	1.24	0	0	0	0.00
Fagan Creek	18	3.72	0	0	0	0.00	1	0	600	161.23
Fall Branch	19	8.62	2	0	110	12.76	0	0	0	0.00
Falls Branch	20	10.93	1	0	60	5.49	0	0	0	0.00
Field Hollow	21	6.64	0	0	0	0.00	0	0	0	0.00
Five Mile Hollow	22	11.23	0	0	0	0.00	0	0	0	0.00
Goat Mountain	23	12.60	0	0	0	0.00	0	0	0	0.00
Green Creek	24	15.60	1	0	50	3.20	0	0	0	0.00
Hazelnut Hollow	25	4.52	0	0	0	0.00	0	0	0	0.00
Illinois River Echota Bend Laterals	26	6.92	0	0	0	0.00	0	0	0	0.00
Kirk Springs & Sawmill Hollow	27	9.13	0	0	0	0.00	0	0	0	0.00
Linder Bend & Sawmill Hollow	28	8.46	0	0	0	0.00	0	0	0	0.00
Luna Branch	29	14.83	0	0	0	0.00	0	0	0	0.00
Mining Camp Hollow (North)	30	6.91	0	0	0	0.00	0	0	0	0.00
Mining Camp Hollow (South)	31	7.87	0	0	0	0.00	0	0	0	0.00
Mollyfield & Peavine Creeks	32	12.03	0	0	0	0.00	0	0	0	0.00
Mulberry Hollow	33	15.96	0	0	0	0.00	0	0	0	0.00
Negro Jake Hollow	34	16.98	1	0	50	2.95	0	0	0	0.00
North Briggs Hollow	35	2.11	0	0	0	0.00	0	0	0	0.00
Park Hill Branch	36	19.14	1	0	40	2.09	0	0	0	0.00
Peacheater Creek	37	25.34	6	0	380	15.00	0	0	0	0.00
Peavine Branch	38	16.14	1	0	80	4.96	0	0	0	0.00
Pettit Creek	39	15.51	0	0	0	0.00	0	0	0	0.00
Pine Hollow	40	5.12	0	0	0	0.00	0	0	0	0.00
Proctor Mountain Creek	41	10.03	0	0	0	0.00	0	0	0	0.00
Pumpkin Hollow	42	18.66	0	0	0	0.00	0	0	0	0.00
Ross Branch & Tahlequah Creek	43	18.35	0	0	0	0.00	0	0	0	0.00
Sager Creek	44	8.24	2	0	140	17.00	0	0	0	0.00
Scraper Hollow Creek	45	9.33	0	0	0	0.00	0	0	0	0.00
Shell Branch	46	17.58	3	0	155	8.82	0	0	0	0.00
Sizemore Creek	47	6.99	0	0	0	0.00	0	0	0	0.00

			Dairy				Hog			
Subwatershed	**GIS label**	**Size (mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (per mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (per mi^2)**
Smith Hollow	48	12.62	2	0	105	8.32	0	0	0	0.00
Snake & Cato Creek	49	11.42	0	0	0	0.00	0	0	0	0.00
South Briggs Hollow	50	7.59	0	0	0	0.00	0	0	0	0.00
South Proctor Creek	51	14.63	0	0	0	0.00	0	0	0	0.00
Steeley Hollow	52	18.59	0	0	0	0.00	0	0	0	0.00
Tahlequah & Kill Hollow & Rock Br	53	8.29	0	0	0	0.00	1	12	32000	3859.30
Tailhot Creek	54	18.56	0	0	0	0.00	0	0	0	0.00
Tate Parrish Branch	55	16.68	1	0	40	2.40	0	0	0	0.00
Telamay H. & Dog Hollow	56	12.37	0	0	0	0.00	0	0	0	0.00
Terrapin Creek	57	17.44	0	0	0	0.00	0	0	0	0.00
Tyner Creek	58	42.67	4	0	265	6.21	0	0	0	0.00
Walltrip Branch	59	9.96	0	0	0	0.00	0	0	0	0.00
Welling Creek	60	4.98	0	0	0	0.00	0	0	0	0.00
West Branch	61	7.77	0	0	0	0.00	0	0	0	0.00
Total Watershed	**T**	**821.69**	**46**	**0**	**2,675**	**3.26**	**2**	**12**	**32,600**	**39.67**

			Beef Cattle			
Subwatershed	**GIS label**	**Size (mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (per mi^2)**
Ballard Creek	1	25.19	0	0	2600	103.23
Battle Branch	2	9.33	0	0	400	42.87
Beaver Creek	3	14.51	0	0	890	61.34
Bidding Creek	4	17.46	0	0	890	50.98
Blackfox & Winset Hollow	5	22.92	0	0	1600	69.80
Blue Spring Branch	6	5.28	0	0	550	104.10
Burnt Cabin Creek	7	12.32	0	0	150	12.17
Calunchety Hollow	8	6.95	0	0	300	43.18
Cedar Hollow & Tully Hollow	9	11.12	0	0	790	71.04
Crazy Creek	10	9.41	0	0	500	53.16
Dennison Creek	11	7.89	0	0	840	106.44
Dripping Spring Branch	12	11.35	0	0	1200	105.70
Dripping Springs Hollow	13	11.76	0	0	400	34.01
Dry Creek & Bolin Hollow	14	27.48	0	0	660	24.02
Elk Creek	15	21.67	0	0	50	2.31
England Hollow Creek	16	9.46	0	0	1000	105.75
Evansville Creek	17	48.52	0	0	3000	61.82
Fagan Creek	18	3.72	0	0	210	56.43
Fall Branch	19	8.62	0	0	610	70.79
Falls Branch	20	10.93	0	0	900	82.34
Field Hollow	21	6.64	0	0	500	75.30
Five Mile Hollow	22	11.23	0	0	300	26.72
Goat Mountain	23	12.60	0	0	770	61.10
Green Creek	24	15.60	0	0	1600	102.54
Hazelnut Hollow	25	4.52	0	0	400	88.41
Illinois River Echota Bend Laterals	26	6.92	0	0	0	0.00
Kirk Springs & Sawmill Hollow	27	9.13	0	0	650	71.19
Linder Bend & Sawmill Hollow	28	8.46	0	0	150	17.73
Luna Branch	29	14.83	0	0	900	60.68
Mining Camp Hollow (North)	30	6.91	0	0	730	105.67
Mining Camp Hollow (South)	31	7.87	0	0	830	105.44
Mollyfield & Peavine Creeks	32	12.03	0	0	850	70.63
Mulberry Hollow	33	15.96	0	0	1700	106.52
Negro Jake Hollow	34	16.98	0	0	1800	106.02
North Briggs Hollow	35	2.11	0	0	640	302.72
Park Hill Branch	36	19.14	0	0	250	13.06
Peacheater Creek	37	25.34	0	0	2700	106.56
Peavine Branch	38	16.14	0	0	1700	105.32
Pettit Creek	39	15.51	0	0	300	19.34
Pine Hollow	40	5.12	0	0	100	19.53
Proctor Mountain Creek	41	10.03	0	0	800	79.74
Pumpkin Hollow	42	18.66	0	0	1300	69.66
Ross Branch & Tahlequah Creek	43	18.35	0	0	150	8.18
Sager Creek	44	8.24	0	0	300	36.42
Scraper Hollow Creek	45	9.33	0	0	1190	127.54
Shell Branch	46	17.58	0	0	1800	102.37
Sizemore Creek	47	6.99	0	0	220	31.47

			Beef Cattle			
Subwatershed	**GIS label**	**Size (mi^2)**	**Sites**	**Houses**	**Animals**	**Animal Density (per mi^2)**
Smith Hollow	48	12.62	0	0	1300	103.01
Snake & Cato Creek	49	11.42	0	0	150	13.13
South Briggs Hollow	50	7.59	0	0	540	71.17
South Proctor Creek	51	14.63	0	0	900	61.53
Steeley Hollow	52	18.59	0	0	1300	69.91
Tahlequah & Kill Hollow & Rock Br	53	8.29	0	0	590	71.16
Tailhot Creek	54	18.56	0	0	1250	67.36
Tate Parrish Branch	55	16.68	0	0	450	26.97
Telamay H. & Dog Hollow	56	12.37	0	0	880	71.15
Terrapin Creek	57	17.44	0	0	50	2.87
Tyner Creek	58	42.67	0	0	3000	70.30
Walltrip Branch	59	9.96	0	0	1270	127.50
Welling Creek	60	4.98	0	0	530	106.36
West Branch	61	7.77	0	0	820	105.57
Total Watershed	**T**	**821.69**	**0**	**0**	**53,200**	**64.74**

			Nursery		Residential Houses	NIP		NS		Feed Mill
Subwatershed	**GIS label**	**Size (mi^2)**	**Sites**	**Area**	**Houses**	**Sites**	**Houses**	**Sites**	**Houses**	**Sites**
Ballard Creek	1	25.19	0	0.00	140	10	0	3	0	1
Battle Branch	2	9.33	0	0.00	135	6	0	0	0	0
Beaver Creek	3	14.51	0	0.00	225	3	0	0	0	0
Bidding Creek	4	17.46	0	0.00	190	4	0	1	0	0
Blackfox & Winset Hollow	5	22.92	0	0.00	265	0	0	0	0	0
Blue Spring Branch	6	5.28	0	0.00	50	1	0	0	0	0
Burnt Cabin Creek	7	12.32	0	0.00	70	0	0	0	0	0
Calunchety Hollow	8	6.95	0	0.00	107	1	0	0	0	0
Cedar Hollow & Tully Hollow	9	11.12	0	0.00	20	1	0	0	0	0
Crazy Creek	10	9.41	0	0.00	173	2	0	0	0	0
Dennison Creek	11	7.89	0	0.00	0	2	0	0	0	0
Dripping Spring Branch	12	11.35	0	0.00	33	2	0	0	0	0
Dripping Springs Hollow	13	11.76	0	0.00	35	0	0	0	0	0
Dry Creek & Bolin Hollow	14	27.48	0	0.00	82	0	0	0	0	0
Elk Creek	15	21.67	0	0.00	215	0	0	0	0	0
England Hollow Creek	16	9.46	0	0.00	45	0	0	0	0	0
Evansville Creek	17	48.52	0	0.00	330	9	0	0	0	0
Fagan Creek	18	3.72	0	0.00	26	1	0	0	0	0
Fall Branch	19	8.62	0	0.00	64	0	0	0	0	0
Falls Branch	20	10.93	0	0.00	25	0	0	0	0	0
Field Hollow	21	6.64	0	0.00	30	1	0	0	0	0
Five Mile Hollow	22	11.23	0	0.00	155	1	0	0	0	0
Goat Mountain	23	12.60	0	0.00	90	1	0	0	0	0
Green Creek	24	15.60	0	0.00	140	9	0	1	0	0
Hazelnut Hollow	25	4.52	0	0.00	50	1	0	0	0	0
Illinois River Echota Bend Laterals	26	6.92	0	0.00	0	0	0	0	0	0
Kirk Springs & Sawmill Hollow	27	9.13	0	0.00	40	0	0	0	0	0
Linder Bend & Sawmill Hollow	28	8.46	0	0.00	400	0	0	0	0	0
Luna Branch	29	14.83	0	0.00	30	0	0	0	0	0
Mining Camp Hollow (North)	30	6.91	0	0.00	10	0	0	0	0	0
Mining Camp Hollow (South)	31	7.87	0	0.00	85	0	0	0	0	0
Mollyfield & Peavine Creeks	32	12.03	0	0.00	36	1	0	0	0	0
Mulberry Hollow	33	15.96	0	0.00	140	2	0	2	0	0
Negro Jake Hollow	34	16.98	0	0.00	108	0	0	0	0	0
North Briggs Hollow	35	2.11	0	0.00	150	0	0	0	0	0
Park Hill Branch	36	19.14	1	0.40	330	0	0	0	0	0
Peacheater Creek	37	25.34	0	0.00	185	9	0	0	0	0
Peavine Branch	38	16.14	0	0.00	330	2	0	1	0	0
Pettit Creek	39	15.51	1	0.28	380	0	0	0	0	0
Pine Hollow	40	5.12	0	0.00	205	0	0	0	0	0
Proctor Mountain Creek	41	10.03	0	0.00	53	1	0	0	0	0
Pumpkin Hollow	42	18.66	0	0.00	55	0	0	0	0	0
Ross Branch & Tahlequah Creek	43	18.35	0	0.00	2500	0	0	0	0	0
Sager Creek	44	8.24	0	0.00	54	4	0	0	0	0
Scraper Hollow Creek	45	9.33	0	0.00	50	1	0	1	0	0
Shell Branch	46	17.58	0	0.00	100	10	0	1	0	0
Sizemore Creek	47	6.99	0	0.00	50	0	0	0	0	0

			Nursery		Residential Houses	NIP		NS		Feed Mill
Subwatershed	**GIS label**	**Size (mi²)**	**Sites**	**Area**	**Houses**	**Sites**	**Houses**	**Sites**	**Houses**	**Sites**
Smith Hollow	48	12.62	0	0.00	60	1	0	0	0	0
Snake & Cato Creek	49	11.42	0	0.00	207	0	0	0	0	0
South Briggs Hollow	50	7.59	0	0.00	55	2	0	0	0	0
South Proctor Creek	51	14.63	0	0.00	14	1	0	0	0	0
Steeley Hollow	52	18.59	1	0.08	140	0	0	0	0	0
Tahlequah & Kill Hollow & Rock Br	53	8.29	0	0.00	30	0	0	0	0	0
Tailhot Creek	54	18.56	0	0.00	92	0	0	0	0	0
Tate Parrish Branch	55	16.68	0	0.00	64	2	0	0	0	0
Telamay H. & Dog Hollow	56	12.37	0	0.00	10	0	0	0	0	0
Terrapin Creek	57	17.44	0	0.00	120	0	0	0	0	0
Tyner Creek	58	42.67	0	0.00	210	3	0	0	0	0
Walltrip Branch	59	9.96	0	0.00	40	3	0	0	0	0
Welling Creek	60	4.98	0	0.00	10	0	0	0	0	0
West Branch	61	7.77	0	0.00	35	3	0	0	0	0
Total Watershed	**T**	**821.69**	**3**	**0.76**	**9,073**	**100**	**0**	**10**	**0**	**1**

Table 26, **Table 27**, **Table 28**, and **Table 29** list the estimated nutrients (Nitrogen and Phosphorus) excreted by confined animals in each watershed or subwatershed. Estimates were 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
- Phosphorus production = 0.34 lbs./1000 lbs. live weight/day
- Nitrogen excreted by 20,000 bird house/year = 11,000 lbs.
- Phosphorus 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
- Phosphorus production = 0.28 lbs./1000 lbs. live weight/day
- Nitrogen excreted/20,000 bird operation/year = 53,000 lbs.
- Phosphorus excreted/20,000 bird operation/year = 20,000 lbs.

Hogs/600 sow unit

- Nitrogen excreted/600 sow unit/year = 23,000 lbs.
- Phosphorus excreted/600 sow unit/year = 7,600 lbs.

			Broiler				Layer			
			lbs/yr		lbs/mi²/yr		lbs/yr		lbs/mi²/yr	
Subwatershed	**GIS label**	**Size (mi²)**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Ballard Creek	1	25.19	522500	161500	20745.55	6412.26	8250	2550	327.56	101.25
Battle Branch	2	9.33	22000	6800	2357.81	728.78	0	0	0.00	0.00
Beaver Creek	3	14.51	77000	23800	5307.23	1640.42	0	0	0.00	0.00
Bidding Creek	4	17.46	143000	44200	8191.47	2531.91	0	0	0.00	0.00
Blackfox & Winset Hollow	5	22.92	22000	6800	959.73	296.64	0	0	0.00	0.00
Blue Spring Branch	6	5.28	88000	27200	16656.62	5148.41	16500	5100	3123.12	965.33
Burnt Cabin Creek	7	12.32	0	0	0.00	0.00	0	0	0.00	0.00
Calunchety Hollow	8	6.95	0	0	0.00	0.00	99000	30600	14249.37	4404.35
Cedar Hollow & Tully Hollow	9	11.12	0	0	0.00	0.00	0	0	0.00	0.00
Crazy Creek	10	9.41	77000	23800	8185.97	2530.21	33000	10200	3508.27	1084.38
Dennison Creek	11	7.89	0	0	0.00	0.00	0	0	0.00	0.00
Dripping Spring Branch	12	11.35	88000	27200	7751.58	2395.94	44000	13600	3875.79	1197.97
Dripping Springs Hollow	13	11.76	0	0	0.00	0.00	0	0	0.00	0.00
Dry Creek & Bolin Hollow	14	27.48	33000	10200	1201.00	371.22	0	0	0.00	0.00
Elk Creek	15	21.67	0	0	0.00	0.00	0	0	0.00	0.00
England Hollow Creek	16	9.46	77000	23800	8142.75	2516.85	0	0	0.00	0.00
Evansville Creek	17	48.52	176000	54400	3627.05	1121.09	24750	7650	510.05	157.65
Fagan Creek	18	3.72	66000	20400	17735.81	5481.98	33000	10200	8867.91	2740.99
Fall Branch	19	8.62	0	0	0.00	0.00	33000	10200	3829.42	1183.64
Falls Branch	20	10.93	44000	13600	4025.59	1244.27	0	0	0.00	0.00
Field Hollow	21	6.64	33000	10200	4969.90	1536.15	0	0	0.00	0.00
Five Mile Hollow	22	11.23	0	0	0.00	0.00	22000	6800	1959.67	605.72
Goat Mountain	23	12.60	0	0	0.00	0.00	0	0	0.00	0.00
Green Creek	24	15.60	448250	138550	28728.00	8879.56	0	0	0.00	0.00
Hazelnut Hollow	25	4.52	110000	34000	24312.49	7514.77	5500	1700	1215.62	375.74
Illinois River Echota Bend Laterals	26	6.92	22000	6800	3179.43	982.73	0	0	0.00	0.00
Kirk Springs & Sawmill Hollow	27	9.13	0	0	0.00	0.00	0	0	0.00	0.00
Linder Bend & Sawmill Hollow	28	8.46	0	0	0.00	0.00	0	0	0.00	0.00
Luna Branch	29	14.83	451000	139400	30408.26	9398.92	0	0	0.00	0.00
Mining Camp Hollow (North)	30	6.91	0	0	0.00	0.00	0	0	0.00	0.00
Mining Camp Hollow (South)	31	7.87	0	0	0.00	0.00	0	0	0.00	0.00
Mollyfield & Peavine Creeks	32	12.03	0	0	0.00	0.00	0	0	0.00	0.00
Mulberry Hollow	33	15.96	0	0	0.00	0.00	0	0	0.00	0.00
Negro Jake Hollow	34	16.98	41250	12750	2429.67	750.99	0	0	0.00	0.00
North Briggs Hollow	35	2.11	22000	6800	10406.17	3216.45	0	0	0.00	0.00
Park Hill Branch	36	19.14	0	0	0.00	0.00	0	0	0.00	0.00
Peacheater Creek	37	25.34	313500	96900	12373.04	3824.39	49500	15300	1953.64	603.85
Peavine Branch	38	16.14	110000	34000	6814.57	2106.32	22000	6800	1362.91	421.26
Pettit Creek	39	15.51	0	0	0.00	0.00	0	0	0.00	0.00
Pine Hollow	40	5.12	0	0	0.00	0.00	0	0	0.00	0.00
Proctor Mountain Creek	41	10.03	33000	10200	3289.30	1016.69	0	0	0.00	0.00
Pumpkin Hollow	42	18.66	0	0	0.00	0.00	0	0	0.00	0.00
Ross Branch & Tahlequah Creek	43	18.35	0	0	0.00	0.00	0	0	0.00	0.00
Sager Creek	44	8.24	121000	37400	14691.15	4540.90	0	0	0.00	0.00
Scraper Hollow Creek	45	9.33	74250	22950	7957.80	2459.68	0	0	0.00	0.00
Shell Branch	46	17.58	88000	27200	5004.85	1546.95	8250	2550	469.20	145.03
Sizemore Creek	47	6.99	0	0	0.00	0.00	0	0	0.00	0.00

			Broiler				Layer			
			lbs/yr		lbs/mi²/yr		lbs/yr		lbs/mi²/yr	
Subwatershed	**GIS label**	**Size (mi²)**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Smith Hollow	48	12.62	22000	6800	1743.22	538.81	8250	2550	653.71	202.05
Snake & Cato Creek	49	11.42	0	0	0.00	0.00	0	0	0.00	0.00
South Briggs Hollow	50	7.59	22000	6800	2899.38	896.17	0	0	0.00	0.00
South Proctor Creek	51	14.63	0	0	0.00	0.00	0	0	0.00	0.00
Steeley Hollow	52	18.59	0	0	0.00	0.00	0	0	0.00	0.00
Tahlequah & Kill Hollow & Rock Br	53	8.29	198000	61200	23879.44	7380.92	0	0	0.00	0.00
Tailhot Creek	54	18.56	0	0	0.00	0.00	0	0	0.00	0.00
Tate Parrish Branch	55	16.68	22000	6800	1318.74	407.61	45100	13940	2703.41	835.60
Telamay H. & Dog Hollow	56	12.37	0	0	0.00	0.00	0	0	0.00	0.00
Terrapin Creek	57	17.44	0	0	0.00	0.00	0	0	0.00	0.00
Tyner Creek	58	42.67	627000	193800	14692.72	4541.39	0	0	0.00	0.00
Walltrip Branch	59	9.96	24750	7650	2484.66	767.98	0	0	0.00	0.00
Welling Creek	60	4.98	0	0	0.00	0.00	0	0	0.00	0.00
West Branch	61	7.77	57750	17850	7435.09	2298.12	38500	11900	4956.73	1532.08
Total Watershed	T	821.69	4276250	1321750	5204.21	1608.57	490600	151640	597.06	184.55

			Turkey				Pullet			
			lbs/yr		lbs/mi²/yr		lbs/yr		lbs/mi²/yr	
Subwatershed	**GIS label**	**Size (mi²)**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Ballard Creek	1	25.19	0	0	0.00	0.00	0	0	0.00	0.00
Battle Branch	2	9.33	159000	60000	17040.53	6430.39	0	0	0.00	0.00
Beaver Creek	3	14.51	0	0	0.00	0.00	0	0	0.00	0.00
Bidding Creek	4	17.46	79500	30000	4554.00	1718.49	0	0	0.00	0.00
Blackfox & Winset Hollow	5	22.92	79500	30000	3468.12	1308.73	0	0	0.00	0.00
Blue Spring Branch	6	5.28	0	0	0.00	0.00	0	0	0.00	0.00
Burnt Cabin Creek	7	12.32	0	0	0.00	0.00	0	0	0.00	0.00
Calunchety Hollow	8	6.95	0	0	0.00	0.00	0	0	0.00	0.00
Cedar Hollow & Tully Hollow	9	11.12	0	0	0.00	0.00	0	0	0.00	0.00
Crazy Creek	10	9.41	0	0	0.00	0.00	0	0	0.00	0.00
Dennison Creek	11	7.89	0	0	0.00	0.00	0	0	0.00	0.00
Dripping Spring Branch	12	11.35	0	0	0.00	0.00	0	0	0.00	0.00
Dripping Springs Hollow	13	11.76	0	0	0.00	0.00	0	0	0.00	0.00
Dry Creek & Bolin Hollow	14	27.48	0	0	0.00	0.00	0	0	0.00	0.00
Elk Creek	15	21.67	0	0	0.00	0.00	0	0	0.00	0.00
England Hollow Creek	16	9.46	0	0	0.00	0.00	55000	17000	5816.25	1797.75
Evansville Creek	17	48.52	0	0	0.00	0.00	0	0	0.00	0.00
Fagan Creek	18	3.72	0	0	0.00	0.00	0	0	0.00	0.00
Fall Branch	19	8.62	0	0	0.00	0.00	0	0	0.00	0.00
Falls Branch	20	10.93	119250	45000	10910.26	4117.08	0	0	0.00	0.00
Field Hollow	21	6.64	0	0	0.00	0.00	0	0	0.00	0.00
Five Mile Hollow	22	11.23	0	0	0.00	0.00	0	0	0.00	0.00
Goat Mountain	23	12.60	0	0	0.00	0.00	0	0	0.00	0.00
Green Creek	24	15.60	0	0	0.00	0.00	0	0	0.00	0.00
Hazelnut Hollow	25	4.52	0	0	0.00	0.00	0	0	0.00	0.00
Illinois River Echota Bend Laterals	26	6.92	0	0	0.00	0.00	0	0	0.00	0.00
Kirk Springs & Sawmill Hollow	27	9.13	0	0	0.00	0.00	0	0	0.00	0.00
Linder Bend & Sawmill Hollow	28	8.46	0	0	0.00	0.00	0	0	0.00	0.00
Luna Branch	29	14.83	0	0	0.00	0.00	0	0	0.00	0.00
Mining Camp Hollow (North)	30	6.91	0	0	0.00	0.00	0	0	0.00	0.00
Mining Camp Hollow (South)	31	7.87	0	0	0.00	0.00	0	0	0.00	0.00
Mollyfield & Peavine Creeks	32	12.03	198750	75000	16515.65	6232.32	0	0	0.00	0.00
Mulberry Hollow	33	15.96	0	0	0.00	0.00	0	0	0.00	0.00
Negro Jake Hollow	34	16.98	119250	45000	7023.95	2650.55	0	0	0.00	0.00
North Briggs Hollow	35	2.11	0	0	0.00	0.00	0	0	0.00	0.00
Park Hill Branch	36	19.14	0	0	0.00	0.00	0	0	0.00	0.00
Peacheater Creek	37	25.34	0	0	0.00	0.00	0	0	0.00	0.00
Peavine Branch	38	16.14	0	0	0.00	0.00	0	0	0.00	0.00
Pettit Creek	39	15.51	0	0	0.00	0.00	0	0	0.00	0.00
Pine Hollow	40	5.12	0	0	0.00	0.00	0	0	0.00	0.00
Proctor Mountain Creek	41	10.03	0	0	0.00	0.00	0	0	0.00	0.00
Pumpkin Hollow	42	18.66	0	0	0.00	0.00	0	0	0.00	0.00
Ross Branch & Tahlequah Creek	43	18.35	0	0	0.00	0.00	0	0	0.00	0.00
Sager Creek	44	8.24	0	0	0.00	0.00	0	0	0.00	0.00
Scraper Hollow Creek	45	9.33	0	0	0.00	0.00	0	0	0.00	0.00
Shell Branch	46	17.58	79500	30000	4521.42	1706.20	0	0	0.00	0.00
Sizemore Creek	47	6.99	0	0	0.00	0.00	0	0	0.00	0.00

			Turkey				Pullet			
			lbs/yr		lbs/mi^2/yr		lbs/yr		lbs/mi^2/yr	
Subwatershed	**GIS label**	**Size (mi^2)**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Smith Hollow	48	12.62	0	0	0.00	0.00	0	0	0.00	0.00
Snake & Cato Creek	49	11.42	0	0	0.00	0.00	0	0	0.00	0.00
South Briggs Hollow	50	7.59	238500	90000	31431.89	11861.09	0	0	0.00	0.00
South Proctor Creek	51	14.63	0	0	0.00	0.00	0	0	0.00	0.00
Steeley Hollow	52	18.59	0	0	0.00	0.00	0	0	0.00	0.00
Tahlequah & Kill Hollow & Rock Br	53	8.29	0	0	0.00	0.00	0	0	0.00	0.00
Tailhot Creek	54	18.56	0	0	0.00	0.00	0	0	0.00	0.00
Tate Parrish Branch	55	16.68	0	0	0.00	0.00	0	0	0.00	0.00
Telamay H. & Dog Hollow	56	12.37	0	0	0.00	0.00	0	0	0.00	0.00
Terrapin Creek	57	17.44	0	0	0.00	0.00	0	0	0.00	0.00
Tyner Creek	58	42.67	0	0	0.00	0.00	0	0	0.00	0.00
Walltrip Branch	59	9.96	0	0	0.00	0.00	0	0	0.00	0.00
Welling Creek	60	4.98	0	0	0.00	0.00	0	0	0.00	0.00
West Branch	61	7.77	0	0	0.00	0.00	0	0	0.00	0.00
Total Watershed	T	821.69	1073250	405000	1306.15	492.89	55000	17000	66.94	20.69

			Dairy				Beef Cattle			
			lbs/yr		lbs/mi²/yr		lbs/yr		lbs/mi²/yr	
Subwatershed	**GIS label**	**Size (mi²)**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Ballard Creek	1	25.19	33852	26208	1344.07	1040.57	283920	85176	11272.87	3381.86
Battle Branch	2	9.33	32723.6	25334.4	3507.09	2715.17	43680	13104	4681.32	1404.40
Beaver Creek	3	14.51	0	0	0.00	0.00	97188	29156.4	6698.69	2009.61
Bidding Creek	4	17.46	10155.6	7862.4	581.74	450.38	97188	29156.4	5567.22	1670.17
Blackfox & Winset Hollow	5	22.92	0	0	0.00	0.00	174720	52416	7622.02	2286.61
Blue Spring Branch	6	5.28	0	0	0.00	0.00	60060	18018	11368.14	3410.44
Burnt Cabin Creek	7	12.32	0	0	0.00	0.00	16380	4914	1329.48	398.85
Calunchety Hollow	8	6.95	7898.8	6115.2	1136.90	880.18	32760	9828	4715.25	1414.57
Cedar Hollow & Tully Hollow	9	11.12	0	0	0.00	0.00	86268	25880.4	7757.29	2327.19
Crazy Creek	10	9.41	11284	8736	1199.62	928.74	54600	16380	5804.60	1741.38
Dennison Creek	11	7.89	4513.6	3494.4	571.93	442.79	91728	27518.4	11623.18	3486.96
Dripping Spring Branch	12	11.35	14669.2	11356.8	1292.15	1000.38	131040	39312	11542.81	3462.84
Dripping Springs Hollow	13	11.76	0	0	0.00	0.00	43680	13104	3713.84	1114.15
Dry Creek & Bolin Hollow	14	27.48	0	0	0.00	0.00	72072	21621.6	2622.98	786.89
Elk Creek	15	21.67	0	0	0.00	0.00	5460	1638	252.00	75.60
England Hollow Creek	16	9.46	13540.8	10483.2	1431.94	1108.60	109200	32760	11547.90	3464.37
Evansville Creek	17	48.52	6770.4	5241.6	139.53	108.02	327600	98280	6751.26	2025.38
Fagan Creek	18	3.72	0	0	0.00	0.00	22932	6879.6	6162.39	1848.72
Fall Branch	19	8.62	12412.4	9609.6	1440.37	1115.13	66612	19983.6	7729.87	2318.96
Falls Branch	20	10.93	6770.4	5241.6	619.43	479.56	98280	29484	8991.70	2697.51
Field Hollow	21	6.64	0	0	0.00	0.00	54600	16380	8222.92	2466.88
Five Mile Hollow	22	11.23	0	0	0.00	0.00	32760	9828	2918.12	875.44
Goat Mountain	23	12.60	0	0	0.00	0.00	84084	25225.2	6672.42	2001.73
Green Creek	24	15.60	5642	4368	361.59	279.94	174720	52416	11197.67	3359.30
Hazelnut Hollow	25	4.52	0	0	0.00	0.00	43680	13104	9654.27	2896.28
Illinois River Echota Bend Laterals	26	6.92	0	0	0.00	0.00	0	0	0.00	0.00
Kirk Springs & Sawmill Hollow	27	9.13	0	0	0.00	0.00	70980	21294	7773.70	2332.11
Linder Bend & Sawmill Hollow	28	8.46	0	0	0.00	0.00	16380	4914	1936.35	580.91
Luna Branch	29	14.83	0	0	0.00	0.00	98280	29484	6626.44	1987.93
Mining Camp Hollow (North)	30	6.91	0	0	0.00	0.00	79716	23914.8	11539.44	3461.83
Mining Camp Hollow (South)	31	7.87	0	0	0.00	0.00	90636	27190.8	11514.50	3454.35
Mollyfield & Peavine Creeks	32	12.03	0	0	0.00	0.00	92820	27846	7713.12	2313.94
Mulberry Hollow	33	15.96	0	0	0.00	0.00	185640	55692	11631.71	3489.51
Negro Jake Hollow	34	16.98	5642	4368	332.32	257.28	196560	58968	11577.59	3473.28
North Briggs Hollow	35	2.11	0	0	0.00	0.00	69888	20966.4	33057.55	9917.27
Park Hill Branch	36	19.14	4513.6	3494.4	235.80	182.55	27300	8190	1426.20	427.86
Peacheater Creek	37	25.34	42879.2	33196.8	1692.33	1310.19	294840	88452	11636.57	3490.97
Peavine Branch	38	16.14	9027.2	6988.8	559.24	432.96	185640	55692	11500.51	3450.15
Pettit Creek	39	15.51	0	0	0.00	0.00	32760	9828	2112.12	633.64
Pine Hollow	40	5.12	0	0	0.00	0.00	10920	3276	2132.90	639.87
Proctor Mountain Creek	41	10.03	0	0	0.00	0.00	87360	26208	8707.69	2612.31
Pumpkin Hollow	42	18.66	0	0	0.00	0.00	141960	42588	7606.47	2281.94
Ross Branch & Tahlequah Creek	43	18.35	0	0	0.00	0.00	16380	4914	892.82	267.85
Sager Creek	44	8.24	15797.6	12230.4	1918.06	1484.95	32760	9828	3977.54	1193.26
Scraper Hollow Creek	45	9.33	0	0	0.00	0.00	129948	38984.4	13927.28	4178.18
Shell Branch	46	17.58	17490.2	13540.8	994.72	770.11	196560	58968	11179.01	3353.70
Sizemore Creek	47	6.99	0	0	0.00	0.00	24024	7207.2	3436.65	1031.00

			Dairy				Beef Cattle			
			lbs/yr		lbs/mi^2/yr		lbs/yr		lbs/mi^2/yr	
Subwatershed	**GIS label**	**Size (mi^2)**	**N**	**P**	**N**	**P**	**N**	**P**	**N**	**P**
Smith Hollow	48	12.62	11848.2	9172.8	938.82	726.83	141960	42588	11248.51	3374.55
Snake & Cato Creek	49	11.42	0	0	0.00	0.00	16380	4914	1434.15	430.24
South Briggs Hollow	50	7.59	0	0	0.00	0.00	58968	17690.4	7771.39	2331.42
South Proctor Creek	51	14.63	0	0	0.00	0.00	98280	29484	6719.27	2015.78
Steeley Hollow	52	18.59	0	0	0.00	0.00	141960	42588	7634.65	2290.39
Tahlequah & Kill Hollow & Rock Br	53	8.29	0	0	0.00	0.00	64428	19328.4	7770.23	2331.07
Tailhot Creek	54	18.56	0	0	0.00	0.00	136500	40950	7355.87	2206.76
Tate Parrish Branch	55	16.68	4513.6	3494.4	270.56	209.46	49140	14742	2945.58	883.67
Telamay H. & Dog Hollow	56	12.37	0	0	0.00	0.00	96096	28828.8	7769.54	2330.86
Terrapin Creek	57	17.44	0	0	0.00	0.00	5460	1638	313.11	93.93
Tyner Creek	58	42.67	29902.6	23150.4	700.72	542.49	327600	98280	7676.77	2303.03
Walltrip Branch	59	9.96	0	0	0.00	0.00	138684	41605.2	13922.51	4176.75
Welling Creek	60	4.98	0	0	0.00	0.00	57876	17362.8	11614.47	3484.34
West Branch	61	7.77	0		0.00	0.00	89544	26863.2	11528.45	3458.54
Total Watershed	T	821.69	301847	233688	367.35	284.40	5809440	1742832	7070.10	2121.03

			Hog			
			Pounds per year		lbs/mi^2/yr	
Subwatershed	**GIS label**	**Size (mi^2)**	**N**	**P**	**N**	**P**
Ballard Creek	1	25.19	0	0	0.00	0.00
Battle Branch	2	9.33	0	0	0.00	0.00
Beaver Creek	3	14.51	0	0	0.00	0.00
Bidding Creek	4	17.46	0	0	0.00	0.00
Blackfox & Winset Hollow	5	22.92	0	0	0.00	0.00
Blue Spring Branch	6	5.28	0	0	0.00	0.00
Burnt Cabin Creek	7	12.32	0	0	0.00	0.00
Calunchety Hollow	8	6.95	0	0	0.00	0.00
Cedar Hollow & Tully Hollow	9	11.12	0	0	0.00	0.00
Crazy Creek	10	9.41	0	0	0.00	0.00
Dennison Creek	11	7.89	0	0	0.00	0.00
Dripping Spring Branch	12	11.35	0	0	0.00	0.00
Dripping Springs Hollow	13	11.76	0	0	0.00	0.00
Dry Creek & Bolin Hollow	14	27.48	0	0	0.00	0.00
Elk Creek	15	21.67	0	0	0.00	0.00
England Hollow Creek	16	9.46	0	0	0.00	0.00
Evansville Creek	17	48.52	0	0	0.00	0.00
Fagan Creek	18	3.72	23000	7600	6180.66	2042.31
Fall Branch	19	8.62	0	0	0.00	0.00
Falls Branch	20	10.93	0	0	0.00	0.00
Field Hollow	21	6.64	0	0	0.00	0.00
Five Mile Hollow	22	11.23	0	0	0.00	0.00
Goat Mountain	23	12.60	0	0	0.00	0.00
Green Creek	24	15.60	0	0	0.00	0.00
Hazelnut Hollow	25	4.52	0	0	0.00	0.00
Illinois River Echota Bend Laterals	26	6.92	0	0	0.00	0.00
Kirk Springs & Sawmill Hollow	27	9.13	0	0	0.00	0.00
Linder Bend & Sawmill Hollow	28	8.46	0	0	0.00	0.00
Luna Branch	29	14.83	0	0	0.00	0.00
Mining Camp Hollow (North)	30	6.91	0	0	0.00	0.00
Mining Camp Hollow (South)	31	7.87	0	0	0.00	0.00
Mollyfield & Peavine Creeks	32	12.03	0	0	0.00	0.00
Mulberry Hollow	33	15.96	0	0	0.00	0.00
Negro Jake Hollow	34	16.98	0	0	0.00	0.00
North Briggs Hollow	35	2.11	0	0	0.00	0.00
Park Hill Branch	36	19.14	0	0	0.00	0.00
Peacheater Creek	37	25.34	0	0	0.00	0.00
Peavine Branch	38	16.14	0	0	0.00	0.00
Pettit Creek	39	15.51	0	0	0.00	0.00
Pine Hollow	40	5.12	0	0	0.00	0.00
Proctor Mountain Creek	41	10.03	0	0	0.00	0.00
Pumpkin Hollow	42	18.66	0	0	0.00	0.00
Ross Branch & Tahlequah Creek	43	18.35	0	0	0.00	0.00
Sager Creek	44	8.24	0	0	0.00	0.00
Scraper Hollow Creek	45	9.33	0	0	0.00	0.00
Shell Branch	46	17.58	0	0	0.00	0.00
Sizemore Creek	47	6.99	0	0	0.00	0.00

			Hog			
			Pounds per year		lbs/mi²/yr	
Subwatershed	**GIS label**	**Size (mi²)**	**N**	**P**	**N**	**P**
Smith Hollow	48	12.62	0	0	0.00	0.00
Snake & Cato Creek	49	11.42	0	0	0.00	0.00
South Briggs Hollow	50	7.59	0	0	0.00	0.00
South Proctor Creek	51	14.63	0	0	0.00	0.00
Steeley Hollow	52	18.59	0	0	0.00	0.00
Tahlequah & Kill Hollow & Rock Br	53	8.29	1226666.7	405333.33	147939.99	48884.52
Tailhot Creek	54	18.56	0	0	0.00	0.00
Tate Parrish Branch	55	16.68	0	0	0.00	0.00
Telamay H. & Dog Hollow	56	12.37	0	0	0.00	0.00
Terrapin Creek	57	17.44	0	0	0.00	0.00
Tyner Creek	58	42.67	0	0	0.00	0.00
Walltrip Branch	59	9.96	0	0	0.00	0.00
Welling Creek	60	4.98	0	0	0.00	0.00
West Branch	61	7.77	0	0	0.00	0.00
Total Watershed	T	821.69	1249666.7	412933.33	1520.85	502.54

Based on these numbers, an estimated total of 13,256,000 lbs. of nitrogen and 4,284,800 lbs of phosphorus will be excreted by confined animals in the Oklahoma portion of the Illinois River Basin each year. In Oklahoma, chickens produce 36% and 34%, turkeys produce 9% and 10%, dairy cattle produce 2% and 5%, hogs produce 9% and 10%, and beef cattle produce 44% and 41%, respectively of the nitrogen and phosphorus excreted in the watershed. These numbers reflect a large increase over the previous measurement taken in 1987 and given recent trends it should be expected that current animal populations have increased substantially over these figures.

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 estimated total number of chickens in the Oklahoma portion of the watershed would increase from 8,667,000 to 16,362,200.

If all houses capable of production were being used, it is estimated that a total of 17,502,000 lbs. of Nitrogen and 5,597,240 lbs. of phosphorus would be produced in the Oklahoma portion of the watershed per year.

In the past, much of the attention concerning nutrient sources in the Illinois River Watershed has focused on the poultry industry, and indeed this industry is a significant primary source of many of the nutrients available to the river and lake. However, the cattle industry is also a significant source of nutrients. Although some of the nutrients secreted by cattle originally came from the poultry industry (via pasture fertilized with poultry litter), certainly not all nutrients cattle secrete originated in chicken feed and/or litter. In addition, cattle process nutrients (some of which were originally from the poultry industry) in grass into a more readily available form to algae, compounding the problem. Given direct access to water, cattle frequent the riparian areas, as on hot days, these areas provide the most shade. Thus, the cattle act almost as a point source, depositing nutrients directly in the stream. Due to the magnitude of the potential source of nutrients from cattle, efforts to reduce nutrient transport to the streams should focus not only on the poultry industry, but also on the cattle industry.

In addition, grazing land is at a premium in the watershed. As a result, pastures are frequently overgrazed during part, if not all of the year. The result is not only poor forage crops, but a significant reduction in the ability of the pasture vegetation to trap and utilize the animal waste applied to it (either by livestock or the landowner). In addition, root systems are curbed and surface vegetation is sparser so the land is more prone to erosion. Although certain grazing areas in the watershed are properly maintained, a significant number are exploited with corresponding affects on water quality.

It is very important to note that the above 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 the Illinois River. 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.

Phosphorus, 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. However, recent studies indicate that phosphorus mobility in soil is greater than once believed; Phosphorus has been shown to move through the soil layers into the groundwater and runoff from Phosphorus-rich soils contains significant concentrations. One troublesome thing about Phosphorus 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 phosphorus settles out of the liquid phase. The lagoon will eventually be pumped out and the phosphorus 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 Lake Tenkiller, it is apparent that a significant portion of them do and that they are having an impact. This is demonstrated by the steady increase in total nitrogen and phosphorus concentrations seen at the monitoring sites in the watershed over the last twenty years (OWRB 1995). It's also manifested in the lake as steadily increasing chlorophyll values (OWRB 1995). 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 1997. 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 phosphorus 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 chickens in the watershed is equal to 538,300 humans in terms of nitrogen excreted, and 1,605,000 humans in terms of phosphorus excreted. Averaging these two numbers and dividing by the number of square miles in the watershed, we arrive at a human density equivalent of 1,304 humans per square mile or 2 humans per acre. This is in addition to the humans that actually live there and the waste produced is not subject to the same treatment as that of humans, i.e. it generally does not pass through a treatment plant or septic system.

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 was demonstrated by the fact that Lake Tenkiller is still in fairly good shape. There is still much room for improvement and trends indicate that the lake will continue to decline at an increasingly rapid rate if something is not done to decrease the nutrient load it receives. 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 Tenkiller and the Illinois River 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.

The disposal of wastes produced by these facilities provides a serious management dilemma for landowners as the amount of animal wastes produced exceeds the amount of land available for waste application. In addition, wastes are produced and must be disposed of year-round, despite the problems associated with application during the non-growing season. In addition, the soils in the watershed are becoming phosphorus-saturated. Additional applications of litter result merely in higher concentration of nutrients in runoff, rather than increased forage growth. Research has shown that runoff of nutrients from areas where these wastes are applied has the potential to contain high levels of nutrients (Agricultural Research Service, Bulletin T-169).

a. POTENTIAL SOLUTIONS

1. Development and adoption of a basin-wide animal waste management strategy

2. Development of individual waste management plans

3. Reduction in animal numbers

4. Removal of waste from the watershed

<u>Discussion of Potential Solutions</u>

1. Although waste management has been addressed towards individual landowners in some watersheds, a basin wide approach has not been developed. Management of wastes on this scale will be necessary if solutions such as transferring wastes out of the basin are to be considered. A waste management strategy would involve identification of the waste carrying capacity of land in the basin as well as plans for the fate of additional wastes produced in the future. The Oklahoma Registered Poultry Feeding Operations Act went into effect July 1, 1997 which requires registration of new poultry feeding operations, utilization of best management practices (soil testing, litter application on a soil phosphorus basis, etc.), development of animal waste management plans, and other specific provisions to protect water resources. Another measure put in effect in July 1997 was the Oklahoma Poultry Waste Transfer Act which encourages the transfer of poultry waste out of environmentally-sensitive watersheds, and the Poultry Waste Applicators Certification Act which requires applicators of poultry waste to be certified by the State Department of Agriculture. Also included was a provision

requiring integrators to contract with Oklahoma State University through the Cooperative Extension Service for an educational training program for both poultry feeding operations and poultry waste applicators.

2. Implementation work completed in the Battle Branch watershed showed that management of wastes was largely based upon the need for disposal. In other words the driving force behind waste disposal was the need to get the waste out of feeding facilities with little consideration being given to proper application rates. Application rates were determined by the amount of waste produced divided by the acres available for disposal, rather than by the amount of nutrients in the soil or the ability of plants to utilize those nutrients. Individual waste management plans determine proper application rates through soil testing and land availability and identify those areas which are suitable or unsuitable for waste disposal. Included in this plan should be establishment of buffer strips and/or protection of riparian areas which are free from application of poultry waste and/or cattle access. The water quality problems and threats produced by improper management of poultry waste have become severe enough that regulatory action has been taken. Litter must now be applied based on soil phosphorus levels, rather than the size of the litter pile and the area of the field. Growers must have animal waste management plans on file. Measures are underway to transport excess litter outside of sensitive watersheds like the Illinois River to areas with phosphorus-poor soil. In addition, the OCC has committed over 2 million dollars towards implementation of BMPs and monitoring the success of BMPs in the Illinois Watershed between FY 1999 and 2004. Included in the project is an education component aimed at reducing nonpoint source pollution from all sources (urban, agricultural, etc) in the watershed. Many of the BMPs will focus on reducing the impacts of animal production operations on the watershed. The project will be overseen by a Watershed Advisory Group (WAG), made up of local leaders. The WAG will decide which BMP practices should be supported with cost-share funds and where the project should be targeted in the watershed. Likely BMPs which will be written into farm and waste management plans include measures to protect riparian areas and streambanks (fencing, planting, off-site watering, alternate shade sources), measures to reduce overland runoff (buffer strips, pasture maintenance, fencing, correct fertilizer application rates), and various other measures to reduce the impacts of animal production operations. Funds will be administered through local conservation districts.

3. The most obvious solution to reducing the waste produced in the basin is to reduce the number of animals. During the development of individual waste management plans, the carrying capacity of individual operations could be determined. This would be based upon the amount of waste produced and the acres available for disposal. It is likely that this approach would be unpopular as in many cases it would be determined that too many animals were being produced. The solution to the problem will have to be economically feasible for

the producer and also allow the poultry industry to meet the public's demand for poultry products.

4. Assuming that the amount of waste being produced exceeds the number of acres on which it can be applied, the basic problem is obvious. As part of a basin wide waste management strategy, a plan to transfer wastes out of the watershed is under development. These wastes would be a welcome resource in many areas. Waste volume could be significantly reduced through composting which could be accomplished at a central facility. The cost of waste transfer is the primary limiting factor; however, when the cost of this option is weighed against a reduction in animal production or increasing the efficiency of municipal WWTFs, it approaches feasibility.

b. RESPONSIBLE ENTITIES

The Oklahoma State Department of Agriculture is responsible for programs which deal with animal production. Cost-share programs directed at agriculture based nonpoint source pollution are conducted through the Oklahoma Conservation Commission and the Natural Resources Conservation Service.

c. STATE GOALS

The state has completed the first project designed to demonstrate the effectiveness of BMP implementation in reducing nonpoint source pollution in rural areas of the Illinois River Basin. Additional implementation projects are being directed at two high priority sub-basins in the Baron Fork watershed, Peacheater and Tyner Creeks. A Section 319 National Monitoring Project is underway in the two watersheds, aimed at developing and implementing the most effective best management practices to protect water quality in the basin. Implementation will begin in March of 1999. The long term state goal is to transfer the information and techniques learned in these projects to the entire Illinois River Basin. This will begin with the high priority watersheds and move downwards; however, some watersheds may not require implementation of BMPs. This will be funded through an FY99 Section 319 project aimed at improving and protecting water quality in the Illinois River Basin. The project will provide cost-share assistance to landowners for installation of BMPs to reduce nonpoint source pollution in the watershed. Many of these BMPs will focus in reducing the impacts of animal production operations. The initial step in this process will be the development of a Conservation Plan of Operation for all producers within the river basin, beginning in priority areas. Significant cost-share funds are available to implement BMPs throughout the watershed. These BMPs will target litter management, riparian development and protection, and streambank erosion.

An additional goal of the state is to ensure that all relevant rules and regulations

County	Population	Housing Units	On-Site Disposal(%)	On-Site Disposal(#)
Adair	18,421	7124	70.9	5051
Delaware	34,049	16808	80.2	13480
Cherokee	28,070	15935	62.2	9112
Total	**39,867**			**27643**

which apply to animal operations, particularly those which apply to waste management, are applied in a fair and consistent manner. This specifically refers to rules and regulations concerning Confined Animal Feeding Operations (CAFOs) and to land application of poultry litter.

d. COSTS

If it is assumed that the Battle Branch watershed was typical, it can be estimated that BMP implementation in the Oklahoma portion of the Illinois River Basin would cost upwards of 10 million dollars.

The economic costs of reducing animal numbers is not possible to predict until projected reductions can be calculated.

4. ON-SITE WASTE DISPOSAL

The on-site disposal of domestic liquid waste in Oklahoma is accomplished primarily through the use of septic tanks and lateral lines. These systems provide an adequate means of preventing contact with human waste; however, in some cases they do not provide for adequate protection of environmental resources. This can occur when groundwater resources are shallow or when the geology allows for rapid infiltration rates. Information surveys conducted in several parts of the state have shown that many of the poorer residences have inadequate or completely lack septic systems. Many people also fail to properly maintain the systems they have to ensure optimal operation. In Oklahoma's 319 Assessment Report, on-site sewage disposal is listed as one on the major sources of nonpoint source pollution in Oklahoma.

In rural areas of Oklahoma, most residences rely on septic tanks. When residences are not on public sewage collection systems it can be assumed that on-site sewage disposal is taking place. For the three main counties in the Illinois River Basin, the use of on-site sewage disposal is listed in **Table 30** (U.S. Census Bureau Structural, Plumbing, and Equipment Characteristics: 1990).

Based upon the combination of 1990 county population figures and data from the SCS Agricultural Waste Management Field Handbook (1992) it can be calculated that rural residents dispose of the waste amounts through on-site systems as listed in **Table 31**. Four factors should be considered when assessing these data:

1) The numbers represent entire county figures, although only a portion of each county is within the Illinois River watershed. In this regard these numbers should be regarded as liberal estimates.
2) Work in the Battle Branch watershed indicated that only about 25% of on-site waste disposal systems met state requirements. Examples of disposal inadequacies include lack of or insufficient lateral lines, lack of or insufficient septic tanks, direct disposal of grey water into streams, ditches, or land surfaces, and improperly located septic tanks and lateral fields.

3) The soils of most of these counties consist of chert rubble which has a very high percolation rate. With this characteristic, contamination of shallow ground water, and subsequently surface water, is likely.

County	Waste (dry tons)	Nitrogen (lbs.)	Phosphorus (lbs.)
Adair	1174	141942	14194
Delaware	2019	244636	24522
Cherokee	1898	230031	23094
Total	5091	616609	61810

4) The Oklahoma Department of Environmental Quality (ODEQ) completed a study of potential impact of septic systems in the Illinois River Watershed in 1997. Results of the study suggested little potential threat to the Illinois River from improperly constructed and/or maintained septic systems. Reasons for this conclusion included small wastewater volumes, facilities located significant distances from the river and its tributaries, and low nutrient concentrations. It should be noted that the ODEQ study focused on non-residential septic systems, including residential systems only when there were multiple dwellings using the same system, a significant number of dwellings were concentrated in the same area, or if the system was utilized as part of a commercial activity. Thus, individual septic systems were largely ignored. These individual septic systems are more likely to be the suspect systems as they are more likely to be poorly constructed or maintained than large or commercial systems.

a. POTENTIAL SOLUTIONS

1. Connecting houses to WWTFs.

2 Installation of proper on-site waste disposal.

Discussion of Potential Solutions

1. Installation of interceptor lines for transferring domestic wastes to municipal WWTFs would be very expensive to implement. Given the number of residences which would have to be reached, their scattered locations, and the distance from treatment plants, this not appear to be a feasible solution. Benefits of this option include increasing the potential for economic development but a negative consequence would be increasing the load on WWTFs.

2. Given the experience in the Battle Branch watershed, it is likely that as many as 75% of on-site waste disposal systems are inadequately constructed or located. Bringing these systems up to standard would involve considerable expense to landowners; however, the experience in the Battle Branch watershed demonstrated that most landowners will voluntarily cooperate in upgrading their systems if cost-share funds are available. Probably the most feasible way to facilitate this installation is through an overall water quality improvement cost-share program administered through local conservation districts. Another important component is an education program to inform people about the importance of proper tank installation and maintenance. This will be provided both by the Oklahoma Scenic Rivers Education Program and the Cherokee County Conservation District Education Programs.

b. RESPONSIBLE ENTITIES

Oklahoma Department of Environmental Quality
Oklahoma Conservation Commission is generally responsible for cost-share programs

c. STATE GOALS

A complete inventory of on-site waste disposal systems and their status is desirable in order to assess the impacts of this practice. This inventory might be limited to high priority watersheds to reduce the manpower costs of this action. The state goal is to have all on-site waste disposal systems installed according to state standards. New systems are required to be inspected by a sanitarian and installed according to state standards; however, older systems may be "grandfathered" to fall under the rules which existed when they were installed. In many cases, these systems were installed before there were state rules. In cases where clear violations occur, such as the direct disposal of grey or black water onto the ground surface, these systems should be required to be brought into compliance.

d. COSTS

Current manpower levels are inadequate to accomplish complete inventories. If it assumed that six systems can be evaluated per man-day then it would take 4607 man days to inspect all systems in the three county area. Assuming a cost of $120 per man-day, the cost of this action would be $552,840.

If 75% of on-site waste disposal systems are inadequate as estimated, then approximately 20,000 new systems will need to be installed in the three county area. Cost of installation in average residence varies between $1500 and $2500 but for the purpose of discussion a figure of $2,000 per residence will be used. Using these two estimates it can be calculated that the cost of re-fitting houses in need within the three county area would be approximately 40 million dollars.

5. GRAVEL MINING

In-stream and near stream mining of gravel poses a threat to water quality through the exposure of bed load material and stream banks to erosion. Removal of material from the riverbed can cause more erosion upstream, as the river struggles to naturalize itself and fill in the void left by excavated material. In addition, gravel mining destroys wildlife habitat and has negative aesthetic effects.

There are currently six active operations in the basin within Oklahoma. Also, of concern, are several small un-licensed operations on river tributaries.

Name	Location	County
Addielee Sand and Gravel	Baron Fork	Adair
T&M Sand and Gravel	Illinois River	Sequoyah
Wade’s Backhoe & Gravel	Illinois River	Cherokee
Tri-B Nursery, Inc.	Illinois River	Cherokee
Greenleaf Nursery Company	Illinois River	Cherokee
Phillip Rayls	Illinois River	Cherokee

a. POTENTIAL SOLUTIONS

1. Setting effluent limits
2. Banning mining
3. Site Restoration

Discussion of Potential Solutions

1. Effluent limits could be placed on mining operators to insure that the water leaving operations does not cause water quality problems. This would require monitoring by the operators and mine inspectors as well as a process to enforce permit values. Given the small number of operations this would not appear to place a significant burden on mine inspectors; however, adequate monitoring might fall outside of the technical and financial capabilities of mine operators. This effort might provide some water quality benefits, but would likely have little impact on habitat degradation. Habitat degradation is one of the most severe impacts of near or in-stream gravel mining.

2. In-stream and/or near stream mining could be totally banned. This might cause a significant financial loss to mine operators if alternative locations were not available.

3. Near stream mining often involves the destruction of the vegetation which stabilizes sediment and prevents streambank erosion. Restoration of these sites through re-shaping and re-vegetation would help to prevent further erosion. These processes might be beyond the technical capabilities of mine operators as they would require some level of site engineering. However, technical expertise is available through the NRCS and OCC to accomplish this task.

b. RESPONSIBLE ENTITIES

The Oklahoma Department of Mines has jurisdiction over mining activities in Oklahoma. In this capacity they are responsible for issuing permits to gravel mining operations. Permits include restrictions on the location and type of mining including provisions to protect stream quality.

In the event that gravel mining operations were required to have discharge permits, they would be subject to enforcement by the Department of Environmental Quality (DEQ). DEQ has jurisdiction over all aspects of NPDES permitting.

The Oklahoma Scenic Rivers Commission (OSRC) has jurisdiction over activities in scenic rivers. Since much of the Illinois River, Baron Fork, and Flint Creek are designated as scenic rivers, OSRC would appear to have controlling influence over these operations.

c. STATE GOALS

The goal of the state in regard to gravel mining in the Illinois River Basin is to develop a strategy which will minimize their effects on river quality. This strategy will be developed through a joint effort of the Oklahoma Department of Mines and the Oklahoma Scenic Rivers Commission.

d. COSTS

There is currently no model available which can predict the cost of improving or eliminating the effects of gravel mining in the river or its tributaries.

6. STREAMBANK EROSION

Streambank erosion poses a major threat to Oklahoma's waterbodies. Eroded materials increase turbidity, fill in valuable aquatic habitat, and are often rich in nutrients. This erosion is primarily the result of poorly managed riparian areas both through clearing of native vegetation and overuse by livestock. It has long been recognized that the banks of the Illinois River were significantly eroding in certain places. However, the consequences of bank erosion of smaller tributaries have only recently become apparent. Many local landowners are complaining that their creeks are "drying up". Landowners often blame the problem on increased water usage upstream such as poultry houses or irrigation. However, these activities cannot account for the apparent decrease in water levels in the streams. In fact, water flowing through the streams has not decreased, as the flows on the mainstem are not decreasing over time. The cause of the decreased upstream stream depth is that eroded streambanks and hillsides are actually filling in pools with gravel, causing the stream to be dominated by subsurface flow. The water is still there, it is just no longer on the surface. The consequences of such change are drastic, not only for headwater fisheries, but also for larger order streams and Lake Tenkiller. The bedload in the Illinois River and its tributaries continues to increase and local scuba divers are noting the effects of this bedload as it fills in the upper reaches of Lake Tenkiller. An additional concern are the nutrients contained in this eroded material. Eroded sediment adds yet another nutrient addition to an already nutrient-overloaded system.

The magnitude of the problem is not well understood and documentation of the problem is still in its early stages. In 1997, the OCC and OSU Biosystems and Agricultural Engineering conducted a study of the major eroding banks on the Upper Illinois River, a 63 mile stretch from Lake Frances to Lake Tenkiller. Details of this study are presented earlier in this report. Conclusions of the study indicate that bank erosion is indeed a significant problem in the basin.

a. POTENTIAL SOLUTIONS

1. Establish riparian corridors, let the river stabilize itself

2. Site restoration of eroding banks

3. Do nothing

Discussion of Potential Solutions

1. Establishing a protected riparian corridor along the river and its tributaries would, over time, help stabilize the river. In addition, a protected riparian zone would filter effects of upland land use practices before they reached the streams and river as well as providing valuable habitat for wildlife species. Implementation would require landowner agreement to discontinue practices in the riparian zone, including cattle grazing, clearing, litter spreading, etc. Thus, implementation would require incentives to guarantee landowner cooperation. Implementation would also require fencing, development of alternate watering facilities, and perhaps relocation of structures or septic systems on some of the smaller streams. To institute a basin-wide riparian corridor could be a very expensive undertaking and it is likely to meet with significant opposition from landowners. A protected riparian corridor might also negatively impact gravel mining operations and canoe operators. Finally, the time frame for stabilization is unknown. Certain areas may stabilize within a year, while others may remain unstable decades later. It may be that anthropogenic influences have been too strong in certain areas for the river to correct itself. It is also possible that inability to protect the entire riparian corridor or all of the significant areas of the corridor will compromise the function of the corridor. An upstream disturbance may still impact downstream areas with stable, protected riparian areas and even compromise their stability. Education programs, like those run by the OSRC and the Cherokee County Conservation District, are important to inform landowners and other watershed users about the importance of maintaining a proper riparian area.

2. Actual restoration activities in eroding areas has already been implemented by the OCC at one site on the Illinois River (Echota Bend) and is scheduled to be implemented at another (Hanging Rock). Echota Bend is located on the Illinois River northeast of Tahlequah, Oklahoma about one mile north of U.S. Highway 62 in the northwest quarter of Section 24, Township 17 North, Range 22 East, Cherokee County. Echota Bend was an unstable bend of the Illinois River characterized by a 15 to 20 foot high eroding bank. Aerial photography indicated that the bank migrated approximately 500 feet down valley between 1938 and 1990. The banks continued to erode at a rate of approximately 10 feet a year since that time. It has been roughly estimated that approximately 200,000 yd^3 of material has been lost from this site since 1938 (OCC 1997). **Figure 13** displays an aerial view of Echota Bend prior to restoration work in May 1997. **Figure 14** displays an aerial view of Echota Bend following the restoration work. The restoration method uses natural materials to reconfigure the channel and follow the natural tendency of the river, based on stable configurations of the river in other locations. Rock veins and rootwads were used to send the force of high

flows to the center of the channel, rather than the outside bank. Vegetation in the form of trees and grasses was planted in the riparian area to help stabilize the banks. The initial effort to stabilize the channel was compromised by high flow events in late winter of 1998. The fault was repaired in February, 1998 by installing more rock veins and using larger rocks. The resulting bank has held through at least two bankfull storm events and is well established with vegetation.

The type of restoration work completed at Echota Bend, using Rosgen methods, is typically much less expensive than more traditional bank stabilization techniques, such as rip rap or gabions. In addition, this method results in fewer downstream blowouts, because the energy of the flow is dissipated by the root wads and rock veins, rather than sent somewhere downstream. Implementation of Rosgen type restoration at the major eroding sites (approximately 20 river miles) along the Illinois River would cost an estimated 3.5 million dollars, based on cost/ft of restoring the Echota Bend site. Rip rap or more traditional methods would cost an estimated 12 million dollars.

3. The option of doing nothing could have a wide range of consequences. The river banks alone lost an estimated 62 million cubic feet of material between 1979 and 1991. Current erosion rates vary between -0.03 ft - 26.5 ft, averaging 4.5 feet over a ten month study period. In addition, the channel is changing courses, at some points moving as much as 220 feet within the space of ten months (Harmel 1997). The river is assuming more characteristics of a wide braided channel with unstable banks and shifting courses, rather than its original meandering channel with stable banks and courses. If nothing is done to correct the problems causing the erosion, this shift may continue. Or, if left alone, the river may correct itself. However, the types of disturbances which have led to the current erosion rates are likely to continue and may even increase in frequency and magnitude, thus the river is unlikely to be left alone to correct itself. The Baron Fork once sustained a canoe float industry but has become too shallow to canoe. This decrease in depth is due to sedimentation not change in water tables. The Illinois River could suffer a similar fate without intervention. However, long before the river became unnavigatable, the biological community would be severely impacted, as would Lake Tenkiller. Although streambank erosion adds a tremendous volume of gravel bedload to the streams and river, which will eventually be carried to Lake Tenkiller, it also adds silt and nutrients which are carried more quickly to the lake. These can dramatically speed up the eutrophication process. Failure to curb streambank erosion will likely have irreparable consequences to the river and Lake Tenkiller.

b. RESPONSIBLE ENTITIES

The U.S. Army Corp of Engineers (USACE) has jurisdiction over channel altering activities such as instream dredging or streambank stabilization in Oklahoma. In this capacity they are responsible for issuing permits for these types of activities. Also necessary for this type of activity is Oklahoma Water Quality (401) certification issued by the Department of Environmental Quality (ODEQ).

The Oklahoma Scenic Rivers Commission (OSRC) has jurisdiction over activities in scenic rivers. Since much of the Illinois River, Baron Fork, and Flint Creek are designated as scenic rivers, OSRC would appear to have controlling influence over these operations.

The Oklahoma Conservation Commission has devoted significant resources towards training an engineer to implement these practices and towards implementation of streambank restoration methods. In addition, as the agency responsible for monitoring and reducing sources of nonpoint source pollution, the OCC should be involved in efforts to reduce streambank erosion.

c. STATE GOALS

The goal of the state in regard to streambank erosion in the Illinois River Basin is to develop a strategy which will minimize its effects on river quality. This strategy will be developed through a joint effort of the Oklahoma Scenic Rivers Commission, the OCC, the ODEQ, and the USACE.

7. OTHER NONPOINT SOURCES

A number of other nonpoint sources exist in the watershed which are not detailed in this report or this plan. The reason for these ommissions are either insufficient ability to make estimates of the significance of these sources or known lack of significance considering the other nonpoint sources identified in this document. These other sources include but are not limited to wildlife, natural background loading due to geology and natural vegetation of the basin, illegal dumping, county road erosion, and smaller livestock facilities such as people who keep a few head or horses or cattle.

The potential impact from wildlife is not known. It is extremely difficult to estimate the negative impacts from such mobile animals. We cannot prove that wildlife in the basin do not contribute a significant load to the river. This seems unlikely though because due to the relative homogeneity of the basin (mostly forested, rather than half forested and half marshland) the wildlife should be fairly evenly spread throughout out the watershed. Thus their impacts should be fairly even throughout the watershed. However, not all streams appear to be negatively affected by nutrients; several streams where land use intensities are low (and thus, you might suspect wildlife are even more concentrated) appear to be in very good condition with good water quality and healthy aquatic communities. Thus, wildlife do not appear to have a negative impact on those streams. However, it is possible that wildlife negatively impact water quality somewhere in the watershed and that these impacts may be magnified by the implementation of practices to control other sources of pollution.

Natural background loading due to native vegetation and the geology of the basin is not believed to be a significant contributor to the pollution in the basin. This belief is based on the fact that the subwatersheds where land use intensity is lowest (and thus the loading is mostly from natural sources) have good water quality and healthy aquatic communities. If background loading were significant, these communities might show some impact and water quality data would indicate some impairment.

Runoff from unpaved and paved roads and the bridges necessary for those roads may contribute significant loads to the system. Although this has not specifically been suspected as a problem by water quality professionals or residents in the area, it has been shown to impact streams in other areas. This is not likely to be a watershed-wide problem but may need to be addressed on a case-by-case basis at a later date.

Small animal operations and other low intensity land uses may also contribute to the problem. Again though, correlations between land use and water quality data indicate that watersheds where landuses are primarily low intensity have significantly better water quality than watersheds where land use is more intensive.

Although all of these other sources currently seem to be insignificant in the total scheme of things, reduction in the impacts from other sources may magnify the effects of these sources. Thus, it may be necessary to revisit and better define the magnitude of these sources once steps have been taken to reduce the impacts of other sources. In addition, education programs like those run by the OSRC and Cherokee County Conservation District are critical to reducing all type of nonpoint source pollution. Their goal is to cause people to understand how pollutants reach the water, what types of effect they can have, and things people can do to reduce the impacts of pollution. Those education programs may be a significant tool towards reducing other, minor sources.

C. COMBINED SOURCES

1. URBAN RUNOFF

Urban runoff combines the effects of both point sources and nonpoint sources in that at times it contains pollution from both point sources (in the form of overflows and system breaks) and nonpoint sources in the form of runoff from urban areas. The effects of stormwater runoff from urban areas within the basin is unknown. The primary pollutants from small urban areas are solids, oil and grease, and nutrients. In large urban areas, these contributions can be significant; however, given the small size of urban areas in the basin within Oklahoma, it is probably relatively small. Tahlequah and Stilwell are the two major urban areas and contain 10,400 and 2,660 citizens, respectively (1990 census).

a. POTENTIAL SOLUTIONS

1. Bringing all municipalities into urban stormwater permitting process.

2. Education programs to reduce pollutants in urban runoff.

<u>Discussion of Potential Solutions</u>

1. If municipalities participate in the urban stormwater permitting process, then the attainment of certain standards will be required. This could involve the

construction of retention or detention lagoons or other practices which could ameliorate the effects of urban runoff. Tahlequah is the only municipality which is currently large enough to fall under federal guidelines.

2. Education programs to inform citizens about the dangers of nonpoint source pollution, including urban runoff, are in place and active at both the Oklahoma Scenic Rivers Commission (OSRC) and the Cherokee County Conservation District (CCCD). The OSRC has 84 programs schedule between 19 Jan 99 and 29 Apr 99 which will reach approximately 3,000 students. Also planned are events at local fairs and newspaper articles for education purposes. The CCCD Illinois Jones Program is long-standing and aimed mainly at educating children and their parents about nonpoint source pollution and offering solutions to the problem. The CCCD also educates general audiences on means to prevent nonpoint source pollution through fairs, festivals, programs aimed at ag-producers, one-on-one meetings and phone information services and various other means. The Oklahoma Conservation Commission's Statewide Blue Thumb Program is available to assist in these education efforts.

b. RESPONSIBLE ENTITIES

The Oklahoma Department of Environmental Quality is responsible for stormwater permitting. Municipalities or other entities which fall under stormwater regulations can also be listed as responsible parties.

The Oklahoma Scenic Rivers Commission, Conservation Districts, and Oklahoma Conservation Commission's Statewide Blue Thumb Program are responsible for providing education programs to reduce urban nonpoint source pollution.

c. STATE GOALS

The current state strategy to address urban nonpoint source issues is to follow the federal guidance under which the stormwater program is operated.

d. COSTS

Implementation of stormwater regulations could entail considerable costs to municipalities; however, those costs cannot be determined at this point.

2. NURSERIES

Two major nurseries are located along the Illinois river and one on the shores of Lake Tenkiller. Irrigation tail waters of the two largest nurseries have been shown to contribute significant quantities of nutrients to the basin. Following implementation of Best Management Practices resulting from cooperative agreements between the nurseries and the Oklahoma State Department of Agriculture, one nursery on the river was shown to contribute as much as 0.3% of the yearly NO3-N load and 0.19 % of the yearly total phosphorus load in the river. The nursery on the shore of Lake Tenkiller was shown to contribute 1.95% of the total NO3-N content each year. The total phosphorus contribution is 1.13 % (OSDA 1992). These loadings are based on estimated irrigation return flows. Storm runoff from the nurseries was not monitored.

a. POTENTIAL SOLUTIONS

1. Setting effluent limits
2. Additional BMP implementation
3. Total retention
4. Site pre-approval
5. No Action
6. CAFO model

Discussion of Potential Solutions

1. In 1990 voluntary compliance agreements were established between each nursery and the Oklahoma State Department of Agriculture. Agreement effluent limits were set where input would not increase the nitrate concentration in the river by more than 0.1 mg/l NO_3-N or total phosphorus by more than 0.01 mg/l. This involved an average NO_3-N limit of 18.5 ppm and a total phosphorus limit of 1.0 ppm in the tailwater of each nursery. Pesticide limits were set to meet water quality standards, but also called for suspending the use of any pesticide that was detected in tailwater samples until methods of its use could be studied. More stringent limits may be required to meet load allocations as result of a TMDL for nutrients within the basin.

2. The Illinois River Irrigation Tailwater Project was initiated in 1989 following concern about impacts of irrigation tailwater leaving nurseries along the Illinois River. The project was designed to limit the release of nutrients and pesticides from the nurseries. The project involved sampling irrigation tailwater at Blue Valley Nursery, Greenleaf Nursery, Midwestern Nursery, and Park Hill Nursery

for nitrate-nitrogen (NO_3-N), total phosphorus (TP), and pesticide residues. Samples were taken monthly between May 1989 and December 1992. The 1992 Curtis Report summarized water quality results and recommended continued monitoring of nursery tailwaters. Sampling continued and is presently ongoing. Annual results of the project are available in the OSDA Curtis Reports.

The 1992 OSDA "Curtis Report" outlined 16 sediment control BMPs and 9 cultural and physical control BMPs which had been, or were in process of being implemented. The sediment controls included:

- access road location, construction, and maintenance
- grass and brush management to improve plant cover and reduce erosion
- drainage way design to slow water speed, allowing solids precipitation
- alternate uses of irrigation tailwater to minimize volume of discharge
- contour arrangement- group crops to maximize water infiltration & retention
- use of silt or settling basins to give time for solids precipitation and pesticide degradation
- use of rough or porous surfacing materials to encourage water retention and infiltration
- heavy use area protection suing hard surfacing and/or containment to minimize stormwater contributions.
- use of piped or lined drainage structures to reduce drainage ditch contributions to effluents
- irrigation water management- determining & controlling rate & amount of irrigations to minimize soil erosion & runoff
- use of mulch in planting and drainage area to reduce evaporation and increase filtration of suspended solids
- minimize soil disturbances- reduce number of tills and road grading.
- precision land forming- reshaping surface to planned plateaus from continuous slopes
- trickle irrigation- apply small quantities of water to individual plants
- use of underwater outlets to control bank erosion of tailwaters to streams

The cultural and physical control BMPs included:

- mechanical or biological control of pests
- improve pest scouting techniques to encourage use of pesticides based upon economic threshold determinations
- schedule irrigation based on plant needs to minimize water, fertilizer, and pesticide runoff
- lower pesticide and fertilizer application rates where feasible
- use of slow-release encapsulated pesticide and fertilizers
- substitute effective pesticides with lower solubilities
- use of resistant varieties to reduce pesticide usage

- use of chemicals with no environmental impact to encourage precipitation of dissolved or suspended particles in the tailwaters
- evaluation of storage and mixing facilities to minimize possibility of accidental discharges or spills

Results of nursery tailwater monitoring from the 1992 Curtis Report are seen in **Table 32**. Although average NO_3-N concentrations generally decreased over time, maximum NO_3-N values and average and maximum Total P values did not decrease over time. However, Blue Valley Nursery maintained NO_3-N and Total P tailwater concentrations below the compliance agreement. Greenleaf Nursery's NO_3-N yearly average concentration was below the compliance agreement average for 1991 and 1992. Greenleaf exceeded the compliance agreement maximum on three dates at three tailwater sites, once in 1991 at site IT-6, and twice in 1992 at site IT-3a and IT-12. Although Greenleaf's yearly average total P concentrations increased from 0.387 ppm in 1989 to 0.701 ppm in 1992, the compliance agreement average concentration of 1.0 ppm was not exceeded. Midwestern Nursery exceeded compliance agreement maximum NO_3-N concentrations twice in 1991, at sites IT-25 and IT-27, and once in 1992 at site IT-25. The yearly average total P concentrations increased between 1989 and 1992. The 1992 yearly average total p concentration was above the compliance agreement of 1.0 ppm. The compliance agreement maximum was exceeded twice in 1991 at sites IT-23 and IT-26, one in 1992 at site IT-25, and four times in 1992 at site IT-27.

Table 33 contains annual nutrient loadings to the Illinois River/Lake Tenkiller from nursery tailwaters. Although loadings from nursery tailwaters comprise only a small percentage of the total annual load to the Illinois River and Lake Tenkiller (less than two percent), the loading represents a sizeable mass of nutrients contributed to the system.

Site	NO_3-N ppm				Total P ppm			
	1989	1990	1991	1992	1989	1990	1991	1992
IT-30d		2.11	2.38	3.62		0.46	0.6	0.36
BVmax		11.14	5.93	8.41		0.72	0.88	0.60
IT-2	30.22	32.91	12.05	8.58	1.63	1.10	1.86	1.13
IT-3a	18.08	14.44	18.31	15.65	0.37	0.55	0.65	0.46
IT-6	44.75	21.45	24.94	14.48	0.43	0.47	0.60	0.44
IT-12	26.25	41.60	19.68	16.68	0.63	0.53	0.78	1.18
GLmax	71.3	144.9	51.62	52.48	2.30	4.40	4.70	2.90
IT-23	12.05	9.92	6.97	6.75	0.94	0.44	0.82	0.2
IT-25	29.61	21.08	15.60	10.71	1.83	0.51	0.43	0.93
IT-26	4.17	8.02	8.05	13.25	2.12	1.23	1.93	2.0
IT-27	12.76	12.27	7.67	9.02	1.83	0.82	0.61	1.54
MWmax	58.9	56.22	25.6	45.45	5.4	2.40	4.10	4.40
IT-18	1.16	1.42	1.19	0.81	0.61	0.20	0.45	0.52
IT-19b	0.48	2.14	2.06	0.24	0.71	0.89	0.96	1.74
PHmax	6.04	7.51	7.07	5.28	1.10	0.46	1.28	1.80

BV: Blue Valley Nursery, GL: Greenleaf Nursery, MW: Midwestern Nursery, PH: Park Hill Nursery.

	Greenleaf		Midwestern	
	NO_3-N	TP	NO_3-N	TP
1989 Annual load (lbs. per year)	231.36	3.20	46.22	5.92
1990 Annual load (lbs. per year)				2.54
1991 Annual load (lbs. per year)				3.03
1992 Annual load (lbs. per year)	105.55	5.79	25.45	3.69
1992 % of 1992 Total load to Lake/River	1.95	1.13	0.30	0.19

In 1994, Plant Industry and Consumer Services (PICS) negotiated with each of the nurseries a new compliance agreement which set limits for nutrients. The compliance agreement limits are seen in **Table 34**. The agreement stated individual sample maximum values may be no more than fifty percent above the compliance agreements yearly average on two consecutive samples.

	1993	1994	1995	1996
Yearly Average NO_3-N	18.5 ppm	15.5 ppm	14.5 ppm	10.0 ppm
Individual Sample Maximum NO_3-N	27.0 ppm	23.25 ppm	21.75 ppm	15.00 ppm
Yearly Average Total-P	1.0 ppm	1.0 ppm	1.0 ppm	1.0 ppm
Individual Sample Maximum Total-P	2.0 ppm	1.5 ppm	1.5 ppm	1.5 ppm
Pesticides	suspend use of any detected	suspend use of any detected	suspend use of any detected	suspend use of any detected

Nursery tailwaters continue to be monitored by PICS as a result of the compliance agreement (**Table 35**). Blue Valley Nursery was dropped from the project in 1996 as a result of no activity at the nursery. Nitrate-nitrogen and total phosphorus were under compliance agreement maximum values at Blue Valley Nursery in 1993, 1994, and 1995.

Yearly average NO_3-N concentrations and overall yearly average total phosphorus concentrations (0.74 ppm) were below compliance levels in 1993 at Greenleaf Nursery. However, one tailwater site, IT-2, had a yearly average (1.09 ppm) greater than the compliance agreement. Nitrate-nitrogen concentrations were lower at three tailwater sites in 1994, however one site, IT-2, reported a concentration (29.5 ppm) in excess of the compliance maximum in August. IT-2 also reported a yearly average total phosphorus concentration of 1.37 ppm which was over the compliance agreement concentration. Other tailwater sites at Greenleaf Nursery were below compliance agreement maximums in 1994. Nitrate-nitrogen and total phosphorus concentrations above compliance agreement maximum concentrations were also reported for IT-2 in 1995, with two excessive value for NO_3-N in July and September and two consecutive violations for total phosphorus in June. The runoff from IT-2 is in the process of being diverted to a retention facility for reuse on the nursery. Concentrations of NO_3-N and total phosphorus were below compliance agreement levels at other sites in 1995. 1996 yearly average NO_3-N concentrations exceeded compliance agreement levels at IT-6.

Three consecutive samples exceeded the compliance agreement maximum at site IT-6. These violations were believed to be due to the movement of dirt during construction of the retention basins in addition to use of a new fertilizer and correcting a fertilizer deficiency problem. No tailwater sites at Greenleaf nursery exceeded compliance agreement levels

Site	NO_3-N ppm				Total P ppm			
	1993	1994	1995	1996	1993	1994	1995	1996
IT-30a	1.84	1.60	1.53	NA	0.15	0.14	0.17	NA
IT-30b	0.13			NA	0.06			NA
IT-30c	1.27	1.11	0.61	NA	0.08	0.95	0.24	NA
IT-30d	2.79	2.28	3.33	NA	0.33	0.35	0.37	NA
IT-31			1.74	NA			0.14	NA
IT-32			1.80	NA			0.13	NA
BVmax	3.26	9.68	6.62	NA	0.46	0.80	0.80	NA
IT-1	1.11	1.10	0.81	1.18	0.11	0.16	0.09	0.12
IT-1b			0.97	1.01			0.08	0.11
IT-2	6.24	10.53	10.13	8.65	1.09	1.37	1.29	0.8
IT-3a	11.85	6.97	6.56	9.01	0.61	0.43	0.68	0.51
IT-6	9.30	8.57	4.27	13.12	0.06	0.44	0.51	0.41
IT-11	0.42	0.15	0.44	0.62	0.03	0.07	0.05	0.03
IT-12	12.09				0.66			
GLmax	27.45	29.46	39.2	33.47	1.65	2.6	2.5	1.18
IT-23	2.79	2.71	3.19	3.98	0.44	0.26	0.51	0.41
IT-24			1.5	1.47			0.12	0.24
IT-25	2.54	2.80	3.46	3.58	0.62	0.47	0.63	0.67
IT-26a	2.23	2.34	2.29	2.50	0.06	0.11	0.07	0.06
IT-27	3.29	2.86	3.83	5.58	0.81	0.52	0.77	0.71
IT-28	1.87	1.82	1.26	1.64	0.13	0.10	0.15	0.15
IT-29			1.41	1.38			0.13	0.16
MWmax	58.9	56.22	25.6	45.45	5.4	2.40	4.10	4.40
IT-15			1.31	0.98			0.47	0.27
IT-16a	1.52	1.49	1.45	1.62	0.13	0.12	0.12	0.08
IT-16b			1.08	1.79			0.11	0.11
IT-16c			0.64	0.71			0.09	0.14
IT-18	2.32	1.01			0.36	0.57		
IT-18a			1.02	0.65			0.22	0.16
IT-19a	4.63	4.18	2.88	2.04	0.07	0.05	0.06	0.04
IT-19b	0.94	1.36	0.49	0.69	1.37	1.04	0.40	0.35
PH max	5.56	5.55	4.3	3.67	1.9	3.4	0.76	0.88

BV: Blue Valley Nursery, GL: Greenleaf Nursery, MW: Midwestern Nursery, PH: Park Hill Nursery, NA: Not Active.

for total phosphorus in 1996.

Park Hill nursery tailwater sites were well below compliance agreement concentrations of NO_3-N in 1993, 1994, 1995, and 1996. Yearly average total phosphorus concentrations were above the agreement at site 19-b but below at the other 3 sites in 1993 and 1994. Yearly average total phosphorus concentrations were below the agreement at all sites in 1995 and 1996.

3. Total retention

Total retention is the most desirable control for waste water from all sources. The Greenleaf nursery has constructed facilities to capture, treat, and recirculate their runoff. Thus, the system now operates as a total retention structure and Greenleaf no longer discharges to Lake Tenkiller. Although some runoff likely still occurs during storm events, the magnitude is greatly decreased as is the annual loading of nutrients, pesticides, and sediments from the nursery.

4. Site pre-approval

Additional nurseries should be situated away from the river and lake to minimize impacts to water quality and to maintain integrity of riparian areas. Sites should be located to allow implementation of BMPS, terracing and diversion of runoff and construction of retention lagoons.

5. No Action

Current controls may already be sufficient to control pollution from this source.

6. Following the strategies employed to control pollution from confined animal facilities, runoff from nurseries should be bermed and channeled into a limited number of permitable "point source" discharge points for issuance of an NPDES permit. This action would have to be done at the state level because of the specific prescriptions against this in the Clean water Act at the federal level.

b. RESPONSIBLE ENTITIES

The OSDA is designated as the state agency with authority to establish Best Management Practices or other measures to control those potential pollutants of agricultural origin.

A specific exemption for the agricultural nonpoint category of "Agricultural Return Flows " from NPDES permitting is outlined in CWA, section 402(k)(1).

c. COSTS

Implementation of load allocations could entail considerable costs to nurseries; however, those costs cannot be determined at this point.

EFFECTIVENESS OF NONPOINT SOURCE NUTRIENT CONTROL PROGRAMS

Control of nonpoint source pollution on a complete watershed basis has been completed on only one watershed in the Illinois River Basin. This was Oklahoma's first 319(h) demonstration project and was completed over a three year period. Initial analysis of water quality data indicate that this project was successful in reducing nutrient loading to surface waters. Given the relatively consistent patterns of land use with the Illinois River Basin as whole, transfer of the information gathered from this project should be easily accomplished; however, success will be closely tied to the availability of cost-share funds for land use improvements.

The total cost of BMP implementation on this watershed was approximately $100,000. This includes technical assistance, landowner contact, and BMP implementation. The cost for BMP implementation was $50,000. The Battle Branch watershed covers 5970 acres; therefore, it can be calculated that the cost of remediation was $16.75 per acre. If it is assumed that land uses in the Battle Branch watershed represent typical or average conditions across the Illinois River Basin, the basin wide cost for remediation is:

$16.75 x 576,000 acres = $9,648,000

It should be obvious that this figure only loosely estimates the funds that will be required for BMP implementation in the Illinois River Basin considering the assumptions on which it was based. Despite the shortcomings of this estimate it should be useful in discussions of the relative costs of nutrient control programs in point versus nonpoint source programs. It should also be noted that some of this cost has already been spent in the monitoring and implementation activities that have already occurred in the watershed. It is possible that less than the $10 million estimate will be necessary to implement practices since we already have water quality data. However, a survey of all the county District Conservationists requesting estimated needs for BMP implementation (and this figure includes only funding for implementation and technical assistance) estimated approximately $7 million necessary for implementation across the basin. When costs for monitoring to assess the effectiveness (in some cases, both “before and “after” monitoring may be necessary, rather than just “after”) and education are added, the $10 million dollars may be accurate.

A. Battle Branch Demonstration Project

Oklahoma's first Section 319h project was completed during FY 93. The Battle Branch watershed was identified as one of Oklahoma’s highest priority watersheds in the 1991 watershed prioritization efforts. This project can be viewed as a successful endeavor by several different measures. Although the original meaning of the term 'demonstration project' may have been BMP-oriented, that is, the projects were intended to demonstrate the efficacy of BMPs in reducing NPS pollution, this project has 'demonstrated' other important factors as well. It was demonstrated in this project that the implementation of BMPs reduced levels of nutrients in Battle Branch; however, equally important to the ability of BMPs to reduced pollution is the level of voluntary public participation. This project 'demonstrated' that public interest was high as 84% of landowners participated in the project. The importance of project administration cannot be overlooked as this project involved the coordination of efforts between local, state, and federal agencies, landowners, and contractors. The fact that this project was a success 'demonstrates' that the administrative mechanism through EPA and OCC is adequate to ensure that 319h projects are properly administered and carried out. It was also 'demonstrated' that project successes could be transferred to other areas as witnessed by the inclusion of the entire Flint Creek watershed as a SCS Hydrologic Unit Area and the start of an implementation project in the Peacheater Creek watershed.

Table 36 lists of the final totals for BMP implementation:

Number of "Conservation Plan of Operation"	16
Total Acres under "Conservation Plan of Operation"	1424
Waste Management Plans	9
Rural Wastewater Systems (Septic Tanks)	10
Dairy Lagoons	3
Waste Utilization Management Operations (acres)	774
Pasture and Hayland Operations (acres)	592
Poultry Composters	6
Forest Land Management (acres)	32
Tree Planting (acres)	172
Waste Storage Structures	4
Soil Testing	129

Data Analysis:

Battle Branch was monitored regularly between early 1986 and mid-1987, and was monitored monthly between January of 1990 and August of 1994. The monitoring during these periods has consisted of the collection of both runoff event and base flow samples. Runoff event samples have been collected by means of an automated sampler which is triggered by a float switch in the stream, while base flow samples consist of monthly grab samples. Thirty-five base flow samples and fourteen runoff event samples had been collected through July, 1992.

The intent of sampling was to characterize pre-implementation conditions and to monitor water quality improvements as they occurred. BMP implementation is described in **Table 36**; however, it is difficult to accurately draw a line where implementation was complete and to base water quality assessments on changes which occur after this point in time. There are several reasons which can explain the difficulty in identifying a point in time which to separate pre- from post- implementation: 1) actual implementation was spread out over more than one year between early 1991 and mid-1992, 2) some BMPs have a much more direct and rapid effect on water quality than others; therefore, the precise times that these were installed would be known and it is unlikely that installation of these practices was within a short time span, 3) many land use improvements were made through landowner contacts (prior to the actual date of 'official' BMP implementation) and do not constitute identifiable or quantifiable management practices as they are not necessarily included in the Conservation Plan of Operation and, 4) flushing of contaminated shallow ground water may take a considerable period; therefore, benefits may not be noticeable until some time in the future.

After consideration of all of these factors a cut-off date between pre- and post-implementation of August 1, 1991 was chosen. The represents more or less the mid-point between the beginning of landowner contacts and the completion of BMP implementation. A summary of the data can be seen in **Table 37**.

Pre-Implementation							
Nitrate		Kjeldahl		T. Phosphorus		o-phosphate	
BF	RE	BF	RE	BF	RE	BF	RE
1.98	2.33	1.62	0.73	0.053	0.062	0.067	0.406
Post-Implementation							
Nitrate		Kjeldahl		T. Phosphorus		o-phosphate	
BF	RE	BF	RE	BF	RE	BF	RE
2.20	4.40	0.22	0.20	0.031	0.040	0.024	0.035

(BF = Baseflow; RE = Runoff Event)

NITRATE

Nitrate values do not show any appreciable trends over the course of sampling and there is considerable variation among results over relatively short periods. As seen in **Table 37**, there was a slight decrease in base flow samples (1.62 to 0.22 mg/L, respectively); however, this would not appear to be significant due to the relatively high standard deviation of results for both periods (1.21 and 0.91, respectively).

There was also little difference between pre-implementation base flow and runoff event nitrate values. This indicates that entry of organic matter into the stream from overland runoff was not an important issue. It also indicates that the majority of nitrogen is in the form of benthic algae and represents drifting cells and not allocthonous materials, such as animal litter.

Mean runoff event values increased from 2.33 to 4.40 between pre- and post-implementation. This would appear to be a significant increase; however, the post-implementation value is based on only two data points so some caution should be taken in making inferences concerning this increase. A casual look at the runoff event data indicates a trend towards increasing nitrate values in runoff samples and this phenomenon will be closely observed as additional samples are taken.

Total Kjeldahl Nitrogen (TKN)

There was considerable variation among TKN values under both runoff and baseflow conditions; however, post-implementation baseflow values have been low and fairly uniform (mean = 0.22 mg/L; SD = 0.11). This compares with pre-implementation values of mean = 1.62 mg/L; SD = 1.77. There would appear to be adequate data to suggest that baseflow TKN levels have been reduced.

TKN values during runoff events were lower than during baseflow conditions during both pre- and post- implementation. This indicates two conditions: 1) TKN is not entering the stream in runoff (TKN levels in the stream are actually being diluted by runoff water) and, 2) the major source of stream TKN is drifting benthic organic material. Post-implementation runoff values are lower than pre-implementation values; however, this is based on a very small number of data points and any actual differences are probably more attributable to reductions in groundwater than surface contributions.

Pre-implementation TKN values ranged as high as 8.77 mg/L while the maximum post-implementation value was 0.50 mg/L. With a baseflow mean value of 0.22 mg/L it may not be realistic to expect further reductions. If this value could be achieved in all creeks of the Illinois River Basin, it would represent a significant reduction in nitrogen loading to the Illinois River.

Phosphorus

Phosphorus analysis has been somewhat inconsistent during the period of the project. For the first period of the study, only ortho-phosphate was measured and during the second part of pre-implementation only total phosphorus was measured. These differences are due to different laboratory protocols and project emphasis. While this may present some problems in data analysis it does not preclude making some conclusions concerning changes in water quality.

Approximately 80% of the phosphorus present was in the ortho-phosphate form which indicates a readily available supply of phosphorus for algal growth. Ortho-phosphate decreased from a mean of 0.067 during pre-implementation baseflow conditions to 0.024 mg/L during post-implementation. Although there is no uniformly accepted level of ortho-phosphate which is considered to be deleterious, it is generally accepted that values greater than 0.050 mg/L can cause stream problems and values in excess of 0.020 mg/L can result in downstream loading problems. From this data it is apparent that a significant decrease has occurred; however, the stream and its receiving waters could benefit from further reductions.

Ortho-phosphate values during runoff events were very high during the early period of monitoring ranging from 0.030 to 0.96 mg/L with a mean of 0.41. These are very high values and represent environmentally significant runoff of nutrients from land surfaces. These values were reduced to 0.035 mg/L during post-implementation, and despite the small number of samples upon which this mean is based, it is apparent that a significant reduction in runoff contributions has occurred.

Mean total phosphorus values also decreased somewhat between pre- (0.053 mg/L) and post-implementation (0.031 mg/L) during baseflow conditions. This phenomenon also occurred during runoff event samples.

Although total phosphorus values are not available from the early monitoring period, conclusions can be drawn about them. With the extremely high ortho-phosphate values that were found, the total phosphorus values would of necessity been correspondingly higher. With this in mind, it is obvious that very significant reductions in phosphorus loading has occurred in this stream.

FUTURE PROGRAMS

These future programs, already planned, make up the final segment of the Illinois River Comprehensive Basin Management Plan. Following the implementation of these plans, and assessing the success of the practices implemented, it may be necessary to add a supplementary plan to address either newly realized concerns or problems that were not adequately dealt with by these planned programs.

a. Total Maximum Daily Load (TMDL)

Given the variety and number of point and nonpoint sources and the economic impacts of remediation, it is essential that clean-up efforts be directed towards the most cost-effective and beneficial endeavors. The first step towards completing this process is the development and implementation of a TMDL.

The TMDL will determine the level at which nutrients can be discharged to the river without causing water quality violations. The entire process of watershed restoration will be predicated on the accurate determination of the carrying capacity of the watershed. In this regard, the effects of nutrient loading on Lake Tenkiller must also be considered. It is likely that the levels of loading which would protect Lake Tenkiller will be less than those which would protect the Illinois River.

After determination of the TMDL, the difficult task of allocating permissible waste loads to various discharges must be undertaken. This will be a difficult process as it will involve some expense to all parties involved. Given the high levels of nutrients which currently exist in the river, it is likely that the TMDL process will determine that a significant decrease will be required before water quality standards can be met. Research has suggested that the majority of the loading is due to nonpoint source pollution, although point sources still contribute significantly to the problem. Most of the point sources in Oklahoma have already undergone significant upgrades. Thus efforts should focus primarily on reducing nonpoint sources although consideration should still be given to upgrading point source treatment. Consideration must also be given to the proportion of loading from the various subwatersheds and the two states. Oklahoma and Arkansas should coordinate implementation of pollution reduction measures to maximize the benefits of individual state efforts. In conclusion, the pros and cons of reducing point versus nonpoint sources must be considered in light of feasibility, cost-effectiveness, maintainability, and long-term effectiveness.

b. TMDL Development

There are two inter-related issues which must be considered and addressed in the development of a TMDL for the Illinois River Basin: 1) the size of the Illinois River watershed complicates the development of a TMDL and, 2) cross border issues aggravate the issue as the two states have water quality goals and priorities which are not necessarily congruent.

The most appropriate solution to the first issue is to divide the Illinois River Basin into smaller sub-basins. This would not only serve to reduce the size of the area under consideration but would also solve some of the problems associated with the second issue. In Oklahoma it would appear that separate TMDLs should be developed for the Baron Fork, Flint Creek, and the Illinois River. The problem with division into subbasins arises when it becomes necessary to explain to landowners why they are not eligible for cost-share assistance based on where they live in the basin. The rapport between conservation districts and local landowners is damaged when the district conservationist must turn down an application for cost-share assistance because the landowner lives in the Telemay and Dog Hollow watershed (priority 7- OCC priority list) but his brother in the Peacheater Creek watershed (priority 1- OCC priority list) receives assistance.

The Oklahoma Department of Environmental Quality is currently in the process of developing a TMDL for the Oklahoma portion of the river, incorporating the 40% phosphorus reduction recommended by the Lake Tenkiller Clean Lakes Study, to help the Illinois River meet its beneficial use criteria. Portions of the Illinois River and tributaries are currently listed on the Oklahoma 1998 303(d) list as being impaired by metals, nutrients, siltation, organic enrichment/dissolved oxygen depletion, and noxious aquatic plants. Sources of these problems are identified as nonpoint source, nonirrigated crop production, pasture land, rangeland, feedlots, animal holding/management facilities, highway construction, road construction, bridge construction, land development, on-site wastewater systems, dam construction, flow regulation/modification, and municipal sewage systems.

The second issue will involve considerable technical and political skill. USEPA Region VI attempted to address this issue through the establishment of a technical committee composed of state agency personnel from both states. The purpose of this committee is to establish water quality goals and a procedure for establishing the TMDL. This committee agreed to work towards a 40% reduction (based on the recommendations of the 1994 Clean Lakes Report) of the total phosphorus load to Lake Tenkiller. State and Federal Agencies in both states have agreed to work towards this goal.

Whatever approach is taken, it will be necessary to establish water quality goals in specific stream reaches. At a minimum, water quality goals must be established at the Oklahoma/Arkansas border and at the head of Lake Tenkiller. In Oklahoma it would be desirable for water quality goals to be established at the mouths of major river tributaries.

Due to the high levels of nutrients which are found at the border and at the head of Lake Tenkiller, it can be predicted that any TMDL will determine that significant reductions in nutrient loading must occur. The ultimate determination of the cost and feasibility of reduction, as well as the allocation of loads to various sources, will be a difficult process; however, this issue must be faced if an effective plan to manage river and downstream water quality is to be established.

C. Best Management Practice (BMP) Implementation Plan

Implementation of the TMDL in Oklahoma may require further point source controls as well as significant nonpoint source controls. One of the difficulties in reducing nonpoint source pollution is that most efforts at reduction must be made on a voluntary basis as few rules and regulations apply to nonpoint source pollution. However, Oklahoma has made an attempt to regulate nonpoint sources of pollution in sensitive watersheds. The 1998 poultry bill passed in the state of Oklahoma sets specific limits with regards to the application of poultry litter in sensitive watersheds such as the Illinois River. Soils and litter must be tested before litter can be applied and litter must be applied on a phosphorus basis by state certified litter applicators. In addition, poultry growers must attend water quality based training courses provided by the integrators in order to participate in the program. A program is also being developed to transport excess litter outside of the basin to areas where soil phosphorus supplementation is needed. These efforts will likely reduce the rate at which poultry litter is applied to the land and thus reduce the concentrations of nutrients in the stream.

In addition, the governor of Oklahoma set aside monies to be used on a cost-share basis to implement BMPs in the basin. These BMPs will likely focus on protection of riparian areas and streambank stabilization techniques. Federal Environmental Quality Incentives Program (EQIP) monies are also available in the watershed for implementation of BMPs. Federal monies have the advantage that they can be used in both Oklahoma and Arkansas, whereas state monies are state-specific. This advantage is critical in the Illinois basin where much of the headwaters are in Arkansas. More and more research indicates that BMPs must be implemented starting in the headwaters and then move downstream to be successful in improving water quality. The most cost-effective BMPs are those that reduce NPS pollution at its source. The political boundaries are still an issue, however, because Oklahoma and Arkansas draw their federal money from different pots as they are in different EPA Regions. Spending Oklahoma dollars in Arkansas is a hard sell, just as spending Arkansas dollars in Oklahoma would be a hard sell.

Fortunately, the poultry industry, in particular, has taken significant steps to curb the impact from their operations. All Tyson growers (thus, both in Oklahoma and Arkansas) must have their litter and soil tested prior to litter application. All Tyson growers must apply litter on an approved phosphorus-ratio basis, rather than on a nitrogen basis. All Tyson growers must attend mandatory water quality training courses. Failure to comply with these rules results in termination of the Tyson-Grower contract. Other poultry companies are likely to follow Tyson’s lead and require these steps of their growers.

Oklahoma plans to implement BMPs which address the priority issues in priority areas. The Oklahoma Nonpoint Source Working Group, a group of federal, state, and nonprofit agencies with water quality concerns was asked to rank watersheds in the state of Oklahoma as priorities for future work. The Illinois River and Baron Fork watersheds were ranked in the top five. The OCC plans to use this information to focus efforts in priority watersheds.

The OCC has allocated a significant portion of their FY1999 funds to address nonpoint source pollution problems in the Illinois River. Over 2 million dollars will be used to provide cost-share assistance to landowners to install BMPs in the watershed. The money will also be used to monitor water quality and other factors to verify the effects of these installations. The program will be administered by a Watershed Advisory Group (WAG), made up of local citizens and decision makers. The WAG will determine what types of BMPs will receive cost-share assistance and where the program should be concentrated.

The work will involve both implementation of BMPs and educational programs to reduce nonpoint source pollution in the Illinois River Basin. It is likely that many of the initial efforts in Oklahoma will focus in the Baron Fork watershed as it was identified as a priority, both by the Nonpoint Source Working Group, and by previous water quality studies. Water quality studies indicated that the Baron Fork was one of the most impacted streams in the system. Funds available at this time for implementation, although substantial, are likely not sufficient to implement necessary BMPs throughout the watershed. Thus initial §319 and state cost-share implementation funds will be targeted at areas where the need is greatest and the Baron Fork watershed contains the highest concentration of these in Oklahoma. Federal EQIP funds will be likely be targeted throughout the Illinois basin as will future §319 and state cost-share funds once implementation is complete in Baron Fork. Education efforts, however, will have a basin-wide focus. The OCC will continue to address water quality issues in the Illinois River Watershed through the implementation of BMPs as long as the Nonpoint Source Working Group identifies it as a priority watershed.

Corresponding to this effort, the Oklahoma Scenic Rivers Commission has focused on protection of the Illinois River. Beginning in 1993, the OSRC, the National Park Service, Oklahoma State University, and concerned local citizens began developing a plan to address the problems in the Illinois River corridor and set specific goals towards that end (OSRC 1998). The public felt that the river should be managed to emphasize naturalness and aesthetics. The group felt that attempts should be made to influence river users by education, such that their actions will protect and promote the health of the aquatic ecosystem. Should these efforts prove insufficient, rules and regulations should be designed to protect the environment. The effort organized three working teams to address specific issues related to the river. The teams identified the following goals (OSRC 1998):

Corridor Values

- Create constructive relationships with landowners by providing information and assistance regarding the full range of voluntary private land protection techniques.
- Minimize the impacts of development and construction within the Illinois River

basin by encouraging local governments to adopt regulations to control development in flood plain areas; monitor population and growth trends in the basin.

- Seek voluntary compliance with private landowners to establish and maintain a vegetated buffer of 60-100 feet along the river and its tributaries and to utilize existing cost-share programs and grant opportunities to enter cooperative agreements with riverfront property owners.
- Evaluate causes of streambank destabilization and determine the best possible actions for restoration by identifying and monitoring bank erosion and exploring opportunities to enter cooperative agreements with riverfront property owners.

Recreation Resources

- Provide a high quality recreation opportunity while protecting the river's outstanding resources and recognizing the needs of river outfitters and individual users. Place the highest priority on recreation opportunities requiring a quiet and high-quality natural ecosystem. Evaluate the authorized OSRC float areas and maintain ongoing research programs to track visitor patterns.
- Provide all visitors with the proper orientation to types of activities available, river safety information and expected behavior. Educate visitors on the outstanding natural, cultural, and historical values of the Illinois River basin.
- Encourage river users to respect the resources available to them through education and proper facility placement, thus reducing trespass on private lands. Develop a management plan for public access areas for day use and camping.

Water Quality

- Minimize alteration of stream habitat and sedimentation due to destabilization of stream beds; work with Arkansas to designate the Illinois River and its tributaries in that state as "outstanding resource waters."
- Reduce nutrient and pesticide loading into the basin from commercial nursery tailwater and pollutant loading into the river from urban runoff.
- Reduce nutrient pollution due to animal waste by requiring contracted producers to complete and implement approved conservation plans.
- Protect riparian areas from the impacts of livestock by educating livestock producers on negative consequences and promoting cost-incentive programs.
- Implement training and utilize volunteer labor to collect water quality data. Help with public education.

Implementation of measures to address these goals is a daunting effort and the OSRC plan recommends prioritizing issues and strategies to address each issue in order that limited funds available can be used in a the most cost-effective manner. Such a proposal seems to indicate that water quality issues be given highest priority, as other issues depend on the continued quality of the water. This suggests that measures must be put in place that will stop pollution at it source, that is to retain pollutants on the land surface, riparian area, and stream bank rather than allowing them to enter the stream.

Whatever methods are implemented towards reaching goals defined by the public and concerned agencies, the OSRC plan stresses the importance of continued monitoring in the basin, both to determine the success and/or failure of implementation measures and to plan for the future of the resource. The plan recommends continued monitoring of land use, visual quality, cultural resources, vegetation and wildlife, recreational use - both of concerning the river user and physical impacts caused by river users, water quality, habitat quality, and fish species and abundance.

The OSRC plan also discussed issues which were perceived as having secondary importance compared to the main issues of corridor maintenance, recreational value, and water quality. Although these issues were considered secondary, they are nonetheless important and should be addressed when possible. These issues include:

- Visual Resources- the Oklahoma and National Wild and Scenic Rivers Act specifically identified scenery as an important resource which should be preserved and enhanced. Areas within the river corridor and viewshed should be managed to preserve visual qualities.
- River Setbacks- Agencies should work with landowners on a volunteer basis to develop adequate setbacks from the rivers edge. A 60-100 foot riparian buffer is generally considered minimum to screen most activities beyond that distance.
- Cultural Resources- State Agencies should work closely with Native American groups in identifying and protecting cultural resources located within the river corridor. Agencies should prepare and maintain an inventory of historical and archeological resources within the river corridor.
- Fire- Direct and indirect efforts towards fire suppression have led to a buildup of fuel load which increases the opportunities for wildfires to develop. Wildfire suppression actions should be coordinated with adjoining landowners, volunteer fire departments, and appropriate state agencies.
- Exotic Vegetation Management-To reduce the likelihood of exotic plant take-overs, agencies should work with landowners to clip and burn non-native plants. Any non-native plants introduced should be annuals, primarily grasses or other species that would provide temporary cover, but not persist over time.
- Wildlife- Maintenance of habitat diversity and wildlife viewing opportunities should be coordinated between state and federal agencies.
- Joint Oklahoma and Arkansas Management of the River- Management should consider needs of both states and should incorporate efforts by both states on the behalf of the watershed.
- Maintaining Water Quality- Agencies should take all action necessary to prevent further degradation of water quality, including regular water quality monitoring and stringent sewage and erosion controls. Efforts should also be maintained to promote adequate healthy aquatic habitat.
- Chemical Spills- Procedures should be formulated for handling hazardous material spills that might threaten resources within or near the river corridor.

- Floodplain Issues-The potential loss of life and monetary damage arising from a major flood has risen due to residential and commercial development within the floodplain. Floodplain zoning may be the best way to accommodate local development in accordance with the National Flood Insurance Act of 1968.
- Commercial Floatation Device Operators- The number of commercial operators on the river has grown from 5 in 1970 to 16 in 1993. To reduce the impact of river users, the OSRC recommends limiting the distribution of canoes aerially and temporally to reduce the impacts of recreation on any one area of the river.
- High Water- Floating during high water can be extremely dangerous. A management goal is to provide all users with sufficient information so they can make intelligent decisions about whether to float. No permit system to restrict use during high flows should be imposed at this time.
- Fishing- issues concerning conflict between anglers and nonanglers, angler trespassing, and limited resources should be addressed through appropriate education.
- Swimming and bathing- swimming should be permitted as long as state and local health standards are maintained. The use of soap, shampoo, detergents, and other cleaning agents while in the river is prohibited.
- Sightseeing- A scenic byway management plan to address the needs of sightseers, including pull-offs and parking area development should be developed.
- Motorized boating- Motorized boating which disturbs wildlife and solitude and may also cause safety problems should be discouraged along the river corridor.
- Camping and Day Use- Based on observations of crowding, resource degradation, and increasing maintenance requirements, there is a need for more intensive management of primitive camping areas operated by the OSRC. A system to enforce visitor carrying capacity and allocate use among user groups should be implemented when monitoring indicates environmental or social capabilities are being reached or that increased supervision is needed to properly utilize the river's physical capacity.
- User fees- Floaters who rent from commercial operators pay $1.00 per boat for a float permit. No fee is charged for camping at public access areas. It is suggested that the fee system continue.
- Human Waste and Litter Problems- Human waste and litter present obvious detriments to the corridors natural resources, aesthetics, and recreational opportunities. Vault toilets are being offered at reasonable intervals, but use is dependant upon conscientiousness of river users. A "pack it in - pack it out" philosophy should be encouraged among river users through signs and brochures. All canoes should be equipped with a litter bag. A current ban on use of glass and Styrofoam containers should be continued.
- Information and Education- the OSRC should emphasize the development of a coordinated public education program that utilizes signs, brochures, maps, and other material to gain pubic understanding of rules, regulations, and activities which affect water quality.
- Interpretation- OSRC rangers performing routine work should be encouraged to

maintain a high level of rapport with river users and in addition to law enforcement and resource monitoring responsibilities should assist in providing interpretive services to river corridor users.

- Access- Additional planning and development is needed to improve access and reduce potential impacts.
- Signing- Signs should be in the same format and located a predictable places. More of the various agency directed projects should be labeled with information identifying the agency responsible and education concerning the project, when appropriate.
- Land Acquisition and Easement Policy- the OSRC should seek acquisition of scenic or conservation easements on high priority tracts of land within the corridor based on the potential for future development, the potential for use by the public, the sensitivity of the land, and the opportunity for acquisition.

COST OF REMEDIATION

The estimated cost of remediation programs are summarized in this section. The accuracy of these estimates vary; however, for the purpose of discussion they are useful for comparing the costs of different approaches to controlling pollution within the Illinois River Basin. These values primarily represent the cost of implementation activities and do not take into account the positive or negative economic impacts of some potential solutions. In addition, this list does not include all of the potential solutions although it does address most of the major issues.

I.	Upgrading WWTFs	$5,300,000
II.	Recreation	$400,000
III.	Lake Frances	$500,000
IV.	Animal Production	$10,000,000
V.	On-Site Waste Disposal	$40,500,000
VI.	Gravel Mining	?
V.	Nurseries	?

The overall cost of remediating the problems in the Oklahoma portion of the Illinois River Watershed will be quite high. The OCC has allocated a significant portion of their FY1999 funds to address nonpoint source pollution problems in the Illinois River. Over 2 million dollars will be used to provide cost-share assistance to landowners to install BMPs in the watershed. The money will also be used to monitor water quality and other factors to verify the effects of these installations. The program will be administered by a Watershed Advisory Group (WAG), made up of local citizens and decision makers. The

WAG will determine what types of BMPs will receive cost-share assistance and where the program should be concentrated. The plan will also be forwarded to members of the Nonpoint Source Working Group (a group, led by the OCC, made up of federal and state government agencies, nonprofit organizations, tribes, and agricultural producer organizations for the purpose of providing review of and direction to the State's Nonpoint Source Program) for review and comment.

Given the economic resources available, it may be impossible to fix all of the problems in the watershed. Thus, remediation efforts should focus in the most cost-effective manner. Thus, most of the future efforts should probably focus on reducing the impacts to the watershed from animal production operations. Much is already being done to reduce nutrient impacts to the watershed and substantial funds have been allocated towards reducing point and nonpoint source loading. Additional funds necessary to protect the water resources are difficult to estimate before the success of the currently planned activities can be determined.

It is impossible to know whether the planned activities referenced in this document will solve or curb the water quality problems in the river basin. Thus, the most appropriate course of action may be to continue to follow the phase program of implementation that is currently in place. Now that most of the point sources have been upgraded and a significant nonpoint source program is planned to focus on the main sources of water quality problems, it may be best to wait to determine the impact of these programs. Based on the success of these programs, it may or may not be necessary to revisit the basin with a second-phased approach to focus on areas such as Lake Frances, pit toilet facilities, use reduction provisions, or intensive streambank restoration measures.

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