TOTAL MAXIMUM DAILY LOAD (TMDL) DEVELOPMENT

- TOTAL PHOSPHORUS -

For

TAYLORSVILLE LAKE

(SPENCER COUNTY, KENTUCKY)

Natural Resources and Environmental Protection Cabinet

Kentucky Division of Water

December 2000

TOTAL MAXIMUM DAILY LOAD (TMDL) DEVELOPMENT

- TOTAL PHOSPHORUS -

For

TAYLORSVILLE LAKE

(SPENCER COUNTY, KENTUCKY)

KENTUCKY DEPARTMENT FOR ENVIRONMENTAL PROTECTION
DIVISION OF WATER

Frankfort, Kentucky

This report has been approved for release:

Jack A. Wilson
Jack A. Wilson, Director
Division of Water

Dec. 8, 2000
Date

TOTAL MAXIMUM DAILY LOAD (TMDL) DEVELOPMENT

- TOTAL PHOSPHORUS -

For

TAYLORSVILLE LAKE

(SPENCER COUNTY, KENTUCKY)

List of Contributors

Kevin J. Ruhl, Report Preparation and Data Analysis

Terry A. Anderson, Report Preparation and Data Analysis

Corrine Wells, Report Preparation and Data Analysis

Steve McMurray, Report Preparation and Data Analysis

Giles Miller, Report Preparation and Data Analysis

TOTAL MAXIMUM DAILY
LOAD (TMDL) DEVELOPMENT

- TOTAL PHOSPHORUS -

For

TAYLORSVILLE LAKE

(SPENCER COUNTY, KENTUCKY)

Table of Contents

List of Figures and Tables

Page

Figures

Tables

TMDL FACT SHEET

TAYLORSVILLE LAKE

Project Name:	Taylorsville Lake: Nutrients
Location:	Spencer County, Kentucky
Scope/Size:	Taylorsville Lake: 3050 acres
TMDL Issues:	Point and Nonpoint Sources
Data Sources:	Ky. Dept for Environmental Protection - Division of Water (DOW) U.S. Army Corps of Engineers (COE), Louisville District FTN Associates, Ltd., Little Rock, Arkansas (FTN)
Control Measures:	Kentucky Pollutant Discharge Elimination System (KPDES) Kentucky Nonpoint Source TMDL Implementation Plan, Kentucky Watershed Management Framework Kentucky Agriculture Water Quality Act
Summary:	Taylorsville Lake was determined not to be supporting the designated use of aquatic life and was therefore included on Kentucky's first 303(d) list (1990) for Total Maximum Daily Load (TMDL) development. The lake is impacted by nutrients, in particular phosphorus, mostly from nonpoint sources (agricultural operations). However, background levels of phosphorus are high because of the soils in the watershed (phosphatic limestone). Point sources of phosphorus are minor relative to nonpoint sources and background. The period of greatest contribution is during runoff events.

TMDL Development: Total maximum daily loads in pounds per day (lbs/day) were computed based on the model results presented by FTN in its 1998 report on Taylorsville Lake to the COE. The load, in lbs/day, was determined by averaging the seasonal loads for the 4 years that were modeled (1988, 1989, 1993, and 1996) and dividing that value by the number of days in the season: spring (Apr-Jun, 91 days), summer (Jul-Sep, 92 days), fall (Oct-Nov, 61 days), and winter (Dec-Mar, 121 days). Point source contribution was determined by (1) multiplying the observed phosphorus concentration from the Harrodsburg and Lawrenceburg wastewater treatment plants (WWTPs) by the design flows for those plants (93 lbs/day) and (2) adjusting that value by the ratio of the design flow for all point sources to the design flow of the Harrodsburg and Lawrenceburg WWTPs. Estimates of phosphorus loads were not available for any other (small design flows) WWTPs. This result was 100 lbs/day for all point sources. This value does not take into account uptake of phosphorus that may occur between the point source and the lake. Point sources were not considered for reduction because this value of design load (100 lbs/day) represents a minor contribution when compared to other sources of phosphorus. In addition, the two major point sources are located approximately 15 and 45 miles upstream of the headwaters of the lake and are unlikely to contribute to lake conditions. As these facilities expand in the future, phosphorus removal is likely to be imposed in order to improve local stream conditions. In February 1999, the city of Lawrenceburg requested effluent limits for an expansion of its facility, and the Division of Water issued a total phosphorus limit of 1 mg/L.

Reducing background loads was also not considered feasible for any season. Because the flushing period was short (100 days) and because of limited opportunity for plankton growth, the winter season was not included in phosphorus reduction scenarios. A decrease in phosphorus loading above existing conditions should occur during the winter with the implementation of best management practices (BMPs). Targeted reduction from nonpoint sources for the spring and summer is 50 percent, 10 percent being the Margin of Safety (MOS) and 40 percent being the value deemed necessary to achieve a significant improvement in water quality of the lake based on the modeling results. For the spring and summer periods, a 50-percent reduction in phosphorus resulted in a 10-14 point change in the Trophic State Index (TSI) during average and wet years and a 15-25 unit change during the dry year at the headwater location of the lake. At the lower and middle locations of the lake, a 50-percent reduction in phosphorus resulted in a 10-12 unit change in the TSI. Because of overturn, which occurs in early October, hypolimnetic phosphorus released from the sediments under stratified anoxic conditions mixes into surface waters. During the fall (Oct-Nov), the external load of phosphorus is of less concern than this internal load. Therefore, quantifying the improvement in water quality during this period is difficult. However, the model results indicate that a 50-percent reduction in phosphorus loading to the lake resulted in a shift in the relative abundance of blue-green algae and an increase in the abundance of diatoms (FTN, 1998).

Summary of Total Maximum Load Allocations by Season and Corresponding Daily Load:

Season	Inflow TP Load lbs/day	Point Sources lbs/day	Background lbs/day	Nonpoint Sources lbs/day	Margin of Safety lbs/day
Spring Apr-Jun	701	100	358	103	140
Summer Jul-Sep	207	100	97	0	11
Fall Oct-Nov	379	100	186	17	76
Winter Dec-Mar	1,850	100	443	1,307	---

Waste Load Allocations (WLAs) are shown under the column heading of 'Point Sources.'
Load Allocations (LAs) are the summation of "Background" and "Nonpoint Sources."
Margins of Safety (MOS) are shown under the heading "M argin of Safety."

Point Sources were determined as follows: (1) 93 lbs/day for design flow of 4.58 mgd for the Harrodsburg and Lawrenceburg WWTPs; (2) design flow of all permitted dischargers in the watershed is 4.84 million gallons/day (mgd); and (3) 93 lbs/day multiplied by the ratio of 4.84/4.58 equals 98.2 lbs/day, which was rounded up to 100 lbs/day.

The allowable nonpoint source loading for spring and fall was based on reducing the total phosphorus loading by 50 percent. This reduction has two components: (1) the targeted reduction is 40 percent; and (2) the Margin of Safety (MOS) is 10 percent. The allowable nonpoint source loading for the summer period was also based on reducing the total phosphorus loading by 50 percent. The reduction has two components: (1) the targeted reduction is 40 percent; and (2) the MOS is 2.6 percent because there is a limited amount of load during the summer period that does not allow for an MOS greater than 2.6 percent.

Implementation Controls: This will be a phas ed TMDL because of the presence of nonpoint sources of pollution on all of the stream reaches listed. A phased TMDL is necessary when the efficiency of remedial activities is unknown. Remedial activities will need to be implemented, and follow-up monitoring will need to be conducted. If water quality standards are still not being met upon review of the data from the follow-up monitoring, the remedial activities will need to be modified. To assist in developing a remediation strategy, the

Kentucky Watershed Management Framework (KWMF) will be utilized in conjunction with plans developed as required by the Kentucky Agriculture Water Quality Act (KAWQA). As part of the KWMF, a Salt River Basin Team, under the leadership of a basin coordinator, has been formed to carry out certain recommended activities. One of these activities is to identify and help develop a local watershed task force. With assistance from the various participating agencies, the river basin team, and the basin coordinator, the local task force will develop a Local Action Plan, particularly for streams impacted by nonpoint source pollution. The Local Action Plan will be the document that describes needed remediation and how implementation will be achieved. The Kentucky Agriculture Water Quality Plans will be an integral part of the Local Action Plan. The Local Action Plan will be developed in the fourth year (2002) of the five-year watershed cycle, and implementation will occur in the fifth and succeeding years of the cycle.

Remedial actions for nonpoint sources of pollution will be taken based on the establishment of BMPs as described in the Kentucky Agriculture Water Quality Plan (KAWQP) of 1996 (KAWQA, 1996). Private landowners of 10 acres or more that conduct agricultural operations (including silviculture) must develop and implement a water quality plan (based on guidance from the KAWQP) for their agricultural operation by October 23, 2001. To assist landowners in developing their plans, the KAWQA has developed the Producer Workbook (KAWQA, 1997). It provides a step-by-step process for developing plans and lists contacts at various state and federal agencies that can provide the technical assistance necessary to develop and implement plans.

Conclusions from the DOW report (1993) state that nonpoint runoff from land used for agricultural operations is the major source of phosphorus to the streams which feed into Taylorsville Lake. Channel erosion may be a contributor as well. This analysis leads to the recommendation to implement land-management practices to reduce erosion and to create riparian zones along stream channels. The FTN report (1998) notes that projects in close proximity to the lake will have the most benefit. These actions would have the greatest impact in reducing phosphorus concentrations in the streams feeding Taylorsville Lake. The Kentucky Watershed Management Framework will be the instrument by which the implementation plans within the basin are addressed.

The Upper Salt River/Taylorsville Reservoir Watershed Demonstration Project

Summary: In 1991, the DOW applied for and received Section 319(h) Nonpoint Source Implementation Grant funds for the Upper Salt River/Taylorsville Reservoir (USR/TR) Watershed Demonstration Project. Grant funds were requested to support water quality monitoring in this priority nonpoint source watershed. Funding for agricultural BMP application and implementation was secured through several U.S. Department of Agriculture (USDA) programs.

Types of BMPs: The types of BMPs implemented and planned for the USR/TR watershed are agricultural in nature. Both animal waste and agronomic (cropping) BMPs have been implemented. Controlling manure runoff from the numerous dairies in the watershed and controlling erosion from various types of farming activities were prioritized. The BMPs included (1) animal waste management (containment, application, etc.), (2) intensive rotational grazing, (3) integrated pest management, (4) riparian area establishment, (5) buffers, (6) no-till crops, and (7) numerous other types of animal waste and agronomic practices.

Past Funding: The USR/TR Watershed Demonstration Project received federal agricultural BMP cost-share funding through several USDA programs:

- Hydrologic Unit Area Water Quality Project: 5 years of dedicated funding.
- Agricultural Conservation Program: annual cost-share allocation to counties.
- Water Quality Incentive Project: special one-time cost-share allocation to project.

Future Funding: State and federal cost-share funds for agricultural BMPs will continue to be targeted in the USR/TR watershed.

Water Quality Monitoring: Three types of monitoring were conducted in the upper Salt River basin for the USR/TR Watershed Demonstration Project: (1) bacteriological, (2) biological, and (3) physicochemical. The purpose of the monitoring was to collect pre- and post-BMP water quality data in order to document changes in water quality associated with intensive BMP application. Pre-BMP bacteriological monitoring and one year of post-BMP monitoring have been completed. The second round of post-BMP bacteriological monitoring was completed in 1999 in conjunction with biological monitoring in the Salt River basin as part of the Kentucky Watershed Management Framework. A copy of the most recent study plan for the Salt River water quality monitoring project is available through the DOW. Pre- and post-BMP biological monitoring have been completed. Pre-BMP monitoring was conducted as part of the upper Salt River Intensive Survey that was conducted in 1996. Post-BMP biological monitoring consisted of collecting fishes and macroinvertebrates from three sites. The samples have been identified, and analysis of the data is underway. Post-BMP physicochemical monitoring was completed through a Memorandum of Agreement with the United States Geological Survey (USGS). Monthly high-flow samples were collected from the USGS gaging station on the Salt River at Glensboro, Kentucky. Post-BMP physicochemical monitoring has been completed. This data will be used to assess the post-BMP nonpoint source pollution loads (particularly phosphorous) in the upper Salt River.

Other Focused Projects/Initiatives: Two other projects (Riparian Area Project and Constructed Wetland Evaluation) focused in the watershed resulted in additional BMP applications.

Evaluation of Constructed Wetlands for Animal Waste (Phase II): The study was designed to use constructed wetlands for treating animal wastewater arising primarily from milking facilities. This study resulted in one constructed wetland implemented in the upper Salt River watershed (Mercer County). The project is complete, and the final report is under development by the contractor. Information on this project is available from the DOW on request.

Riparian Area Project: The project final and close-out reports are available from the DOW. The DOW closed this project because the contractor could not meet the minimum requirement to have BMPs on the ground in time for the DOW to establish a monitoring project. Ten demonstration sites were established within the watershed: two in Boyle County, three in Mercer County, one in Shelby/Spencer County, and two in Nelson County. The Shelby/Spencer cooperator dropped from the project in 1997. Approved BMPs were recommended for each farm on a site-specific basis. A DOW biologist visited each demonstration site and evaluated each site for monitoring potential. Only one site in ten was deemed by the biologist to be suitable as a monitoring site, but the producer/cooperator at that site chose not to participate in the project. No water quality monitoring was done. However, several BMPs were implemented in the project watershed, one on each of three farms in Anderson, Boyle, and Mercer counties. A more detailed explanation of the BMPs that were implemented is available from the DOW.

The Division of Conservation (DOC) works with local conservation districts in the counties of the Taylorsville Lake area. Unfortunately, funding to establish BMPs is limited. The DOC has, over the past five years, received 102 requests for cost-share assistance. Because of limited funding, however, the DOC has been able to approve only 14 applications for a total amount of $82,000 (Coleman, DOC, written commun., 2000).

TOTAL PHOSPHORUS TMDL DEVELOPMENT

Taylorsville Lake
Spencer County, Kentucky

Introduction

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for water bodies that are not meeting designated uses under technology-based controls for pollution. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a water body based on the relation between pollution sources and in-stream water-quality conditions. States can then establish water-quality based controls to reduce pollution from both point and nonpoint sources and restore the quality of their water resources.

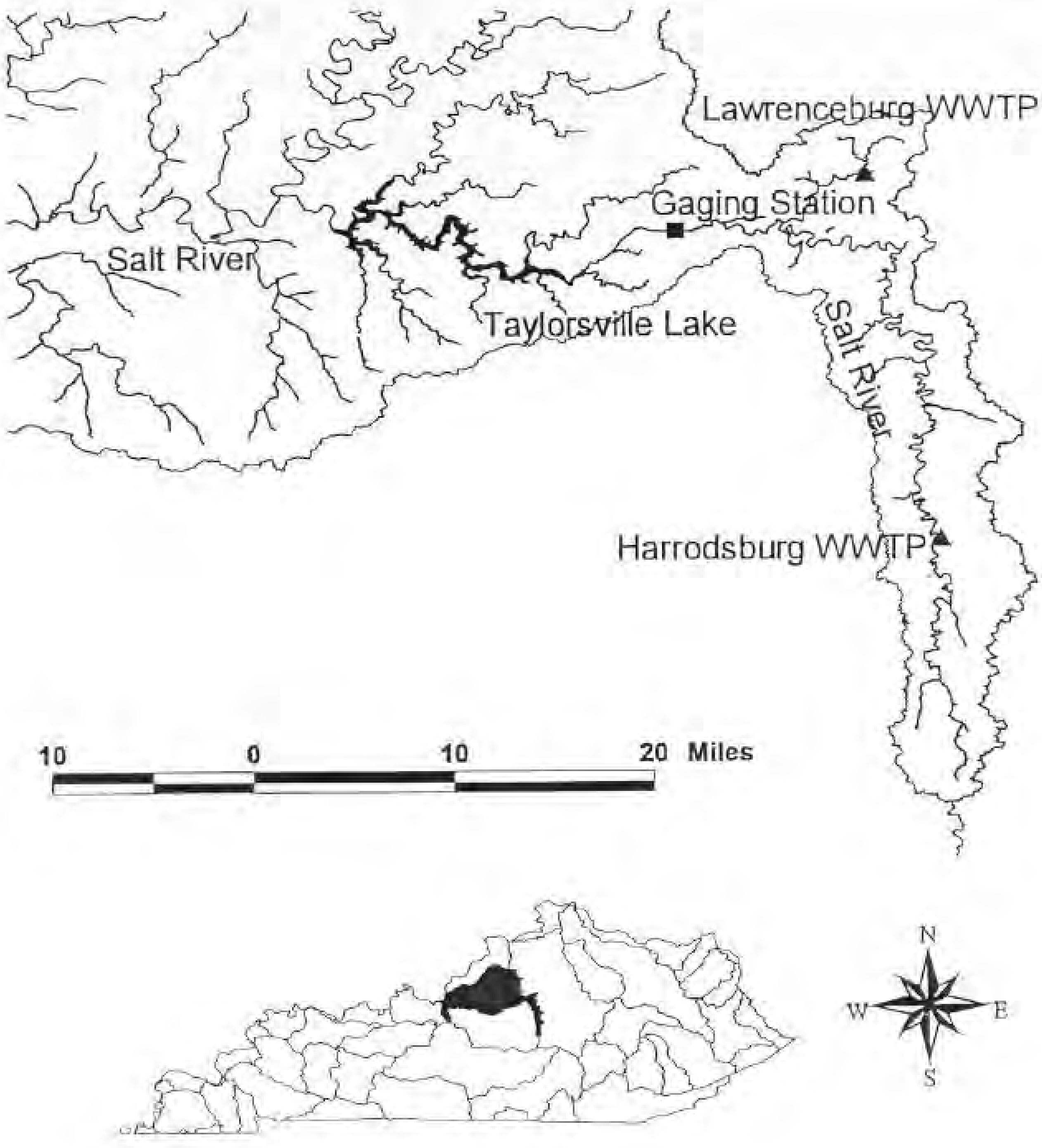
Problem Definition

Taylorsville Lake, located in Spencer County in the Salt River basin (Fig.1), was determined not to be supporting the designated use of aquatic life. It has been listed on the 1990 and subsequent 303(d) lists for TMDL development. The lake is impacted by nutrients, with phosphorus the primary nutrient of concern.

The dam, located on the Salt River at river mile 60, was completed in 1983. The dam and lake were constructed and are maintained by the U.S. Army Corps of Engineers (COE), Louisville District. Taylorsville Lake is a multipurpose structure, with flood control as its primary function. The lake covers approximately 3,050 acres at summer pool and extends for approximately 18 miles. The major tributaries to the lake include Beech Creek, Hammond Creek, Crooked Creek, and Ashes Creek. The catchment area of Taylorsville Lake is 354 square miles.

The lake has been identified as being highly eutrophic (COE, 1992; DOW, 1993) based on the Carlson Trophic State Index (TSI) and has been hypereutrophic in the upper lake

Figure 1. Upper Salt River Basin, Kentucky



areas in certain years. This means that the amount of bioavailable nutrients coming into the lake is high, resulting in an environment favorable for nuisance algal blooms instead of more balanced algal growth. The eutrophic state of the lake is characterized by low dissolved oxygen, algal blooms, impaired fish production, and occasional fish kills (DOW, 1993).

Previous Studies and Findings

Several studies have been conducted to determine the amounts and sources of nutrients (phosphorus in particular) that are impacting the lake. The COE report (1992), which includes data from three locations in the lake and a location on each of the two major inflows (Beech Creek and Salt River), indicates that the primary source of nutrients was from the streams feeding the lake. The report also states that phosphate values generally exhibited a positive correlation with flow throughout the year, indicating that phosphorus was predominantly being contributed from nonpoint sources.

A subsequent sampling effort by the Kentucky Division of Water (DOW) (1993) confirmed and further refined the determination that the primary source of phosphorus to the lake was from nonpoint source runoff from agricultural operations to the Salt River and to the major tributaries. The COE report (1992) states that agricultural operations are the primary (76 percent) land-use activity in the watershed upstream of the lake. The other land-use activities are silviculture or natural (20 percent) and urban (4 percent). Agricultural activities include 239,000 acres of farms, of which 52,000 acres are in crops and 118,000 acres are in pasture. The COE report (1992) also states that the Kentucky Resource Study from 1983 (no reference provided) estimated that (on average) 95, 65, and 70 pounds/acre of nitrogen, phosphorus, and potassium, respectively, are applied to soils in the watershed. The COE report (1992) states that there were 136 dairies totaling 5,400 cows, and there were approximately 44,000 beef cattle and 7,000 hogs in the watershed draining to the lake. In addition to these sources, the soils are developed from phosphatic limestones, siltstones, and shales (COE, 1992). As a result, the soils are naturally high in phosphorus, and the disturbance of the soils from agricultural practices makes this natural source of phosphorus available for transport to the streams (DOW, 1993). The DOW report (1993) provides a quote from a report by Schimpeler-Corradino (1978) stating that residual soils in the region are extremely rich in phosphate. There are two major point-source dischargers in the watershed: the city of Harrodsburg and the city of Lawrenceburg. Both the COE (1992) and the DOW (1993) reports conclude that these point sources appear to have only limited impact on the Salt River (and subsequently Taylorsville Lake) with respect to phosphorus loading because of their distance from the lake and their small loads relative to the other sources.

In 1996 the COE contracted FTN Associates, Ltd. (FTN), to produce a water-quality model of Taylorsville Lake. The FTN report (1998) documents the modeling effort which was done to produce a tool to: (1) evaluate water quality under existing conditions, (2) project water quality under specific environmental conditions, and (3) assist in the determination of TMDLs for nutrients, in particular for phosphorus. The report reaffirms that the lake is eutrophic and that the classification is justified based on observed chlorophyll a concentrations.

Target Identification

The goal of the TMDL is to achieve a reduction in seasonal nutrient loading (and associated load in pounds per day [lbs/day]) that allows for the sustainability of aquatic life in the lake. It is more appropriate to define contaminant loading in large lake systems in terms of seasonal or annual loadings (FTN, 1998). For the TMDL, these seasonal loadings are converted to a daily load. The Kentucky water quality standard for nutrients to protect warm water aquatic habitat (WAH) use is a narrative statement in Section 1 of the Surface Water Standards (Title 401, Kentucky Administrative Regulations, Chapter 5:031). Section 1 states that: (1) In lakes, surface impoundments and their tributaries, and other surface waters where eutrophication problems may exist, nitrogen, phosphorous, carbon, and contributing trace element discharges will be limited as appropriate by the Cabinet (Kentucky Natural Resources and Environmental Protection Cabinet – Division of Water), and (2) The affected surface waters will be designated as nutrient limited.

Because the nutrients have a narrative standard, best professional judgement is used to determine a target value of phosphorous concentration (or load) so that the designated use of aquatic life is supported. As described in the FTN report (1998), a background phosphorus concentration value was determined by assuming that a stream in a mostly forested watershed provided a representative value. The Crooked Creek watershed was selected, and phosphorus concentrations from Crooked Creek averaged about 0.11 mg/l. This value exceeds the in-stream phosphorus concentration value recommended by the EPA, which is 0.10 mg/l (FTN, 1998). If EPA guidelines are used, no additional phosphorous inputs would be allowed into any of the streams in the watershed. For certain seasons, the background concentration of 0.10 mg/l results in a corresponding load that represents up to 40 percent of the total phosphorous load being delivered to the lake (FTN, 1998). Therefore, it is plausible to limit the targeted reduction of phosphorus to the lake to a maximum of about 60 percent. The FTN report (1998) provides values of dissolved phosphorous, chlorophyll a, and Secchi disk depth for the upper (headwater), middle, and lower sections of the lake corresponding to reductions in total phosphorus to the lake (from the tributary sources) of 30, 40, 50, and 60 percent. The CE-QUAL-W2 model assumes that all of the available phosphorus is dissolved, so that it is readily available for uptake. The FTN report (1998) also provides the value of the Trophic State Index corresponding to the percent reduction in phosphorus loading to the lake.

Source Assessment

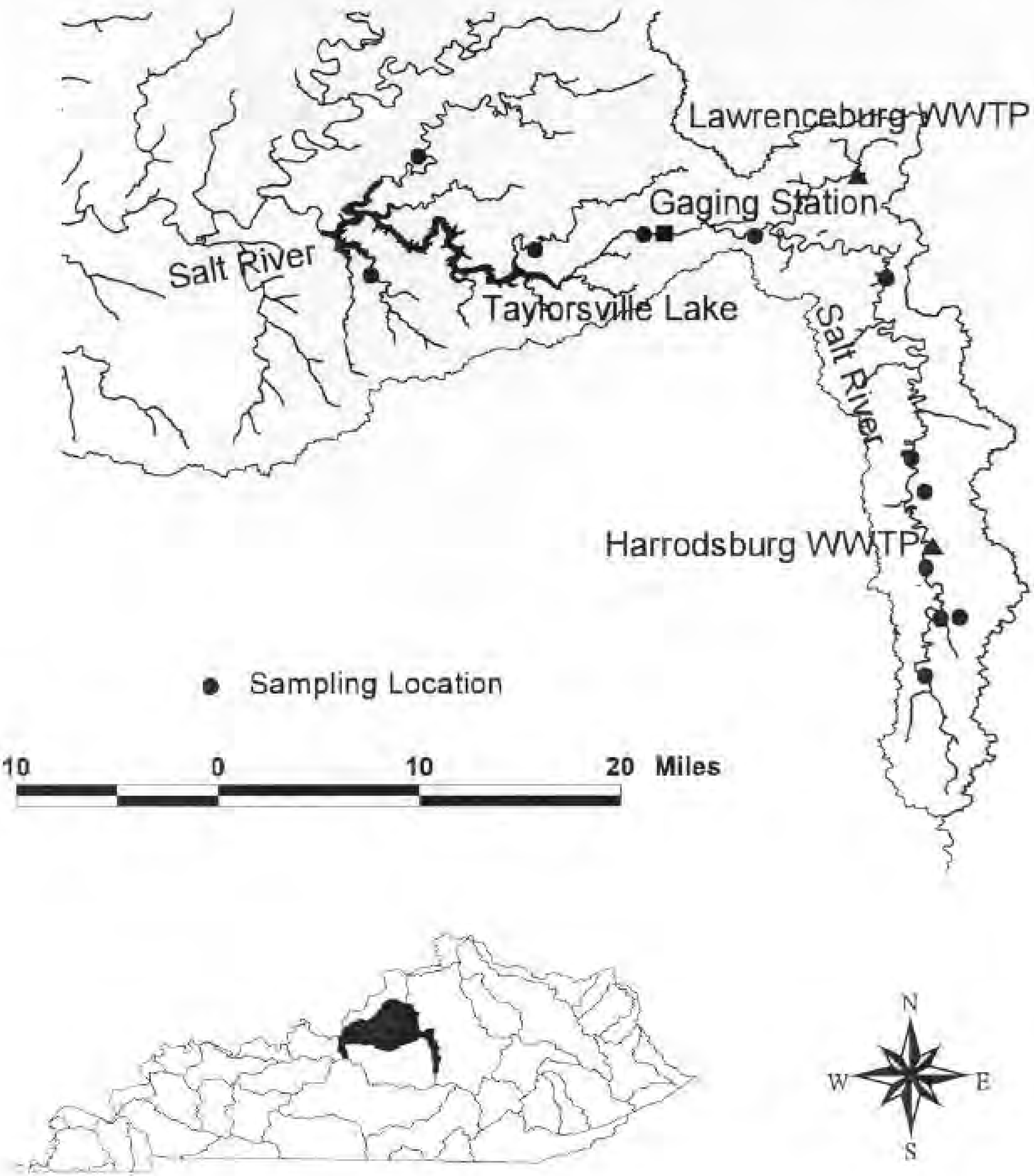
The COE report (1992) indicates that most of the effect of the phosphorus loading was occurring in the upper (headwater) part of the lake because of inputs from the Salt River. In the lower part of the lake close to the dam, the effects were less pronounced, indicating that uptake of the phosphorus was occurring and that there was little additional input of phosphorus from areas immediately adjacent to the lake. The report states that:

- 63 percent of the 211 tons/year of phosphorus entering the lake was from the Salt River,
- 77 percent of the 617 tons/year of nitrogen entering the lake was from the Salt River,
- 60 percent (126 tons) of the phosphorus entering the lake per year remained in the system (70 tons/year were exported and 15 tons/year used by plants), and
- 14 percent (86 tons) of the nitrogen entering the lake per year remained in the system (485 tons/year were exported and 46 tons/year used by plants).

The COE report (1992) also states that phosphorus concentrations remained high enough throughout the year to fuel problem algal growths.

In 1991 and 1992, the DOW (1993) conducted sampling synoptics to determine phosphorus concentrations for: (1) selected streams throughout the watershed that feed into the Salt River above Taylorsville Lake, (2) selected locations on the main stem of the Salt River, and (3) streams that feed directly into Taylorsville Lake (Figure 2). The report states that the phosphorus load to Taylorsville Lake from the Salt River is 227 tons/year (1,240 pounds/day). The value reported by the COE (1992) is approximately 133 tons/year (63 percent of 211 tons/year). The DOW report (1993) also targets the other major tributaries and reports that Beech Creek and Ashes Creek contribute approximately 31 and 8 tons/year (170 and 44 pounds/day), respectively, to Taylorsville Lake. Data indicated that the contribution of total phosphorus from the Crooked Creek basin, which is predominantly forested, was considered minor (DOW, 1993). The two major point sources of total phosphorus, the Harrodsburg and Lawrenceburg wastewater treatment plants (Figure 2 - site numbers 2 and 5, respectively), produced loads of 11 and 36 pounds/day, respectively, for the sampling period. At design flow, these plants would

Figure 2. Location of Sampling Stations, Major Wastewater Treatment Plants, and the Streamflow Gaging Station in the Upper Salt River Basin, KY



produce loads of approximately 42 and 51 pounds/day, respectively (a total of 93 lbs/day). For the sampling period, the cumulative contribution from the two plants was 47 pounds/day, which are approximately 4 percent of the total phosphorus load entering the lake. For the design-flow scenario, the total phosphorus load from the two plants would be 93 lbs/day, which is approximately 7.5 percent of the total phosphorus load entering the lake (DOW, 1993). This percentage assumes no uptake in phosphorus between the discharge point and the lake. The loading from the plants is, therefore, considered to be a minor contribution (DOW, 1993). The report also provides detailed land-use data for the areas between the sampling locations. This information was provided by the Division of Conservation (DOC), a part of the Department for Natural Resources, which is in the Natural Resources and Environmental Protection Cabinet.

The FTN report (1998) uses the DOW (1993) and the COE (1992) information to determine the total phosphorus loading to the lake on a seasonal and annual basis, which matches the response time frame of the ecosystem. The first step was to model the water budget (hydrology) of the system. The water inflow to Taylorsville Lake was determined by separating the change in lake storage from outflow. The total inflow was divided among the various sources by using drainage area ratios. Then regression analysis was used to produce a relation between phosphorus concentration values and streamflow. The 1992 COE report states, and the 1993 DOW report provides a graph showing, that there was a strong correlation between streamflow and phosphorus concentrations, indicating a significant nonpoint source loading of phosphorus. The phosphorus concentrations and loads were computed on a seasonal basis. These values are given in Table 1, together with delineation of the point source and background loads. Subtracting these values from the total phosphorus load yields the nonpoint source load contribution. The table shows the percentage contribution of total phosphorus from background, point, and nonpoint sources. The listing that follows provides the phosphorus loading by season (in pounds). The seasonal data show that background accounts for about 24 percent, up to a maximum of 45 percent, of the total load, and the total nonpoint source contribution is approximately 73 percent for each of the seasons based on the four years of data.

Table 1. Taylorsville Lake phosphorus distribution (Modified from FTN Associates Ltd. Report, 1998, page 8-5)
[Avg, Average; Harrods, Harrodsburg Wastewater Treatment Plant; Lawrence, Lawrenceburg Wastewater Treatment Plant; Bkgrnd, Background; Total P, Total Phosphorus; cfs, cubic feet per second; ug/L, micrograms per liter; mgd, million gallon day; mg/L, milligrams per liter; N/A, Not Available]

Year	Season	Avg Daily Lake Inflow (cfs)	Avg Daily Salt River Total P (ug/L)	Avg Daily Harrods Discharge (mgd)	Avg Daily Harrods Total P (mg/L)	Avg Daily Lawrence Discharge (mgd)	Avg Daily Lawrence Total P (mg/L)	Avg Daily Bkgrnd Total P (mg/L)	Seasonal Total Lake Inflow Total P (pounds)	Seasonal Total Harrods Total P (pounds)	Seasonal Total Lawrence Total P (pounds)	Seasonal Total Nonpoint Total P (pounds)	Seasonal Total Bkgrnd Total P (pounds)	Seasonal Total Nonpoint - Bkgrnd Total P (pounds)	Percent Seasonal Total Nonpoint - Bkgrnd Total P	Percent Seasonal Total Point Total P	Percent Seasonal Total Bkgrnd Total P
1988	Spring	454.1	405.0	0.93	1.88	1.14	3.2	0.11	90187	1330	2764	86093	24322	61771	68	5	27
	Summer	150.2	400.0	0.70	1.88	1.14	3.2	0.11	29782	1009	2806	25967	8035	17932	60	13	27
	Fall	224.8	N/A	0.95	1.88	1.36	3.2	0.11	N/A	907	2214	N/A	N/A	N/A	N/A	N/A	N/A
1989	Winter	1116.6	601.0	1.28	1.88	1.26	3.2	0.11	437568	1819	3051	432689	79806	352892	81	1	18
	Spring	454.1	244.7	1.27	1.88	1.19	3.2	0.11	54485	1806	2894	49785	24291	25494	47	9	45
	Summer	150.2	970.6	1.03	1.88	1.02	3.2	0.11	72267	1478	2493	68296	8018	60278	83	5	11
	Fall	224.8	505.5	1.10	1.88	1.02	3.2	0.11	37361	1051	1665	34645	8011	26634	71	7	21
1993	Winter	576.3	301.3	1.25	1.88	1.61	3.2	0.11	113209	1782	3921	107506	41020	66486	59	5	36
	Spring	365.9	319.3	0.93	1.88	1.14	3.2	0.11	57293	1330	2764	53196	19562	33637	59	7	34
	Summer	23.2	286.0	0.70	1.88	1.14	3.2	0.11	3293	1009	2806	-522	0	0	0	116	0
	Fall	409.4	409.0	0.95	1.88	1.36	3.2	0.11	55048	907	2214	51927	14676	37251	68	6	27
1996	Winter	558.5	332.0	1.10	1.88	1.15	3.2	0.11	120910	1568	2795	116547	39811	76736	63	4	33
	Spring	1159.2	542.3	1.17	1.88	1.51	3.2	0.11	308289	1663	3676	302950	62306	240644	78	2	20
	Summer	359.2	264.7	0.87	1.88	1.09	3.2	0.11	47139	1249	2681	43209	19425	23784	50	8	41
	Fall	305.9	N/A	0.90	1.88	0.88	3.2	0.11	N/A	861	1430	N/A	N/A	N/A	50	8	41

Spring = April through June (91 days)
Summer = July through September (92 days)
Fall = October and November (61 days)
Winter = December through March (121 days)

Percent Seasonal Total Point, Total P (column 17) includes both the Harrodsburg, KY and Lawrenceburg, KY Wastewater Treatment Plant values

From Table 1, the average observed seasonal and daily loading of total phosphorus for all years is:

Season	Inflow TP Load		Point Sources		Background		Nonpoint Sources (not including Background)	
	lbs	lbs/day	lbs	lbs/day	lbs	lbs/day	lbs	lbs/day
Spring (Apr-Jun 91 days)	127,560	1,401	4,560	50	32,620	358	90,380	993
Summer (Jul-Sep 92 days)	38,120	414	3,883	42	8,870	96	25,499	276
Fall (Oct-Nov 61 days)	46,210	757	2,820	46	11,340	186	32,050	525
Winter (Dec-Mar 121 days)	223,900	1,850	4,980	41	53,550	443	165,370	1,366

Although winter (Dec–Mar) loads are the highest of the seasons presented, the FTN report (1998) states that the residence time of the phosphorus input to the lake during the heavy rain season is only about 100 days. This short residence period also corresponds to the non-growing season; therefore the phosphorous was considered not to be available to the plankton during the winter. Thus, the FTN report (1998) does not consider the winter period in the phosphorus reduction scenarios.

The DOW also conducted a biological assessment of the upper Salt River watershed from June 1989 to August 1990 (DOW, 1997). The purpose of the study was to (1) compile background biological and water quality data for the upper Salt River watershed, (2) determine the number of stream miles attaining designated uses, and (3) determine the extent of nonpoint source impacts to the upper Salt River watershed. The report provides a detailed list of the references that contain information and data on the upper Salt River and Taylorsville Lake. The report states that one stream segment in the very upper watershed of the Salt River above Taylorsville Lake (river mile 134.3 to 144.1) does not support WAH use (the lake starts at approximately river mile 78 for summer pool conditions). Other main stream segments (river mile 81.6 to 98.4 and 101.0 to 134.3) were determined to be in partial support of WAH use. The impairment is from elevated levels of nutrients from nonpoint sources. These stream segments will probably be included on the next 303(d) list of impaired waters. These findings correspond to the FTN report (1998) conclusion that, with respect to improving water quality conditions in Taylorsville Lake, watershed BMPs should be located in areas in close proximity to the lake – that placing BMPs in the upper watershed will probably have limited effect on lake water quality. However, as indicated by the DOW report (1997), nutrients in the upper part of the watershed are adversely impacting main stream water quality, and BMPs in this section of the watershed are needed to control nutrient input to the stream from nonpoint sources.

Linkage Between Numeric Targets and Sources – Model Development

As stated previously, in 1996 the COE contracted FTN Associates, Ltd., to produce a water-quality model of Taylorsville Lake. The FTN report (1998) documents the modeling effort and was done to assist in the determination of TMDLs for nutrients, in particular for phosphorus. Much of what follows is taken directly from the FTN report (1998) that was prepared for the COE, Louisville District.

The CE-QUAL-W2 (Cole, 1995) water quality model was used for the study. The modeling focused on that portion of the Salt River and the major tributaries that impact the lake directly. The model was calibrated for a "normal" (1989), "dry" (1993), and "wet" (1996) year using available data. Data from 1988 were used as a confirmation data set to test the validity of the rate coefficients and assumptions used in the calibration step. The DOW water quality data were used extensively in the calibration and confirmation steps, supplemented by COE water quality data (FTN, 1998). Modeling of inputs to the lake was done for six tributaries based on data collected on the Salt and Beech Creeks. The data from these two sites were used to estimate constituent concentrations for the other tributaries. These estimates were based on land use and relative-flow contributions from the individual tributaries and any available data for the other tributaries from the COE (1992) and DOW (1993) studies.

Daily values were required output from the model for selected constituents such as dissolved oxygen (DO). Therefore, a daily time step was used to estimate all constituents. Daily values of most constituents were estimated by linear interpolation between observed values. However, daily total suspended solids and orthophosphorus values for the Salt River were estimated from daily flows (FTN, 1998). A relation was also developed to estimate total phosphorus from orthophosphorus (or dissolved phosphorus) because the CE-QUAL-W2 models orthophosphorus. Ammonia and nitrate-nitrogen are also simulated in CE-QUAL-W2. Algae is simulated as chlorophyll a. Chlorophyll a data were available for all three calibration years (1989, 1993, and 1996).

As noted earlier, because the background concentration was determined as being a maximum of approximately 40 percent of the loading to the lake (Table 1 – spring 1989 is 45 percent), the maximum reduction in phosphorous loading to the lake that can reasonably be expected is about 60 percent. Therefore, model simulations were run for reductions in phosphorus from the six tributaries of 30, 40, 50, and 60 percent. The resulting median values of dissolved phosphorus, chlorophyll a, and Secchi depth are given in Table 2 for the upper, middle, and lower portions of the lake. The TSI values for the upper, middle, and lower portions of the lake are given in Table 3. For both tables, 1989 represents a "normal" year, 1993 a "dry" year, and 1996 a "wet" year. Box and whisker plots of the simulated values are given in figures 3, 4, and 5. Figure 3 is the "normal" year, Figure 4 the "dry" year, and Figure 5 the "wet" year. Only the spring, summer, and fall periods are presented. The heavy winter rain causes the lake to be flushed out in approximately 100 days, and phosphorus delivered to the lake during this period is unavailable for plankton growth. Therefore, the periods for consideration for reductions in phosphorus load are the spring, summer, and fall.

While Table 2 provides the reductions for dissolved phosphorus, chlorophyll a, and Secchi depth, the TSI given in Table 3 provides a means for evaluating the reductions in each of the constituents to a common index to evaluate the improvement to water quality in the lake. As stated in the FTN report (1998), it is the difference realized between the

Table 2. Median dissolved phosphorus, chlorophyll a, and Secchi depth transparencies predicted in Taylorsville Lake by year, season, and location for the base case and nutrient reduction scenarios (Modified from FTN Associates Ltd. Report, 1998, page 8-9)

1989

			Spring					Summer					Fall		
Station	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%
Dissolved phosphorus, in milligrams per liter															
Upper	0.126	0.095	0.081	0.069	0.054	0.118	0.081	0.071	0.059	0.047	0.151	0.110	0.095	0.082	0.067
Middle	0.071	0.049	0.040	0.030	0.025	0.090	0.061	0.051	0.041	0.032	0.193	0.157	0.145	0.134	0.121
Lower	0.029	0.024	0.023	0.023	0.022	0.060	0.036	0.028	0.019	0.011	0.186	0.157	0.148	0.140	0.129
Chlorophyll a, in micrograms per liter															
Upper	74.935	60.805	55.787	52.005	49.447	23.133	19.136	17.986	17.117	16.040	47.368	45.273	44.586	45.156	46.052
Middle	87.822	77.581	74.405	70.789	65.507	26.400	23.500	22.625	22.326	22.358	48.464	47.038	46.814	47.438	49.158
Lower	83.719	76.901	73.390	69.755	67.309	21.440	19.966	19.926	20.688	22.320	29.523	28.456	28.242	28.590	29.312
Secchi depth, in meters															
Upper	0.420	0.442	0.457	0.464	0.477	0.668	0.716	0.740	0.764	0.796	0.436	0.447	0.453	0.461	0.470
Middle	0.403	0.436	0.452	0.467	0.482	0.727	0.768	0.787	0.801	0.820	0.455	0.471	0.479	0.488	0.497
Lower	0.424	0.451	0.464	0.480	0.491	0.813	0.848	0.861	0.864	0.882	0.586	0.600	0.605	0.612	0.621

1993

			Spring					Summer					Fall		
Station	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%
Dissolved phosphorus, in milligrams per liter															
Upper	0.033	0.022	0.015	0.012	0.010	0.051	0.028	0.018	0.011	0.008	0.108	0.080	0.070	0.061	0.051
Middle	0.010	0.008	0.007	0.007	0.006	0.011	0.008	0.007	0.007	0.007	0.168	0.145	0.137	0.131	0.124
Lower	0.009	0.007	0.007	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.062	0.048	0.045	0.043	0.041
Chlorophyll a, in micrograms per liter															
Upper	52.069	46.125	42.956	40.728	36.977	28.363	28.182	29.364	28.095	25.398	47.208	52.937	54.983	57.546	59.204
Middle	46.151	40.341	39.311	37.997	37.610	39.256	30.942	28.405	25.653	23.213	64.444	69.174	71.058	70.849	71.144
Lower	36.514	34.923	34.873	34.728	34.729	27.551	21.357	19.079	17.317	15.157	47.375	50.142	50.897	50.382	49.301
Secchi depth, in meters															
Upper	0.579	0.597	0.615	0.630	0.655	0.730	0.757	0.766	0.792	0.828	0.509	0.520	0.521	0.522	0.521
Middle	0.607	0.638	0.646	0.654	0.661	0.665	0.755	0.782	0.816	0.866	0.464	0.470	0.473	0.476	0.481
Lower	0.670	0.674	0.674	0.675	0.676	0.819	0.912	0.952	0.987	1.029	0.596	0.596	0.601	0.611	0.624

1996

			Spring					Summer					Fall		
Station	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%
Dissolved phosphorus, in milligrams per liter															
Upper	0.228	0.167	0.143	0.125	0.104	0.128	0.089	0.075	0.062	0.048	0.182	0.128	0.111	0.094	0.076
Middle	0.154	0.118	0.100	0.080	0.062	0.109	0.070	0.057	0.045	0.032	0.192	0.147	0.133	0.118	0.104
Lower	0.082	0.057	0.049	0.043	0.036	0.070	0.039	0.028	0.017	0.006	0.116	0.089	0.071	0.061	0.051
Chlorophyll a, in micrograms per liter															
Upper	44.185	39.134	36.444	34.307	32.437	28.623	24.649	23.751	22.489	21.730	43.826	42.050	42.245	42.247	44.303
Middle	54.323	51.311	50.146	48.674	45.960	29.285	27.014	26.829	26.621	27.427	31.912	30.102	30.307	30.311	31.716
Lower	66.207	60.089	57.155	53.581	48.878	25.418	24.541	25.181	26.591	28.787	32.016	30.565	30.804	30.720	32.993
Secchi depth, in meters															
Upper	0.366	0.374	0.377	0.384	0.386	0.631	0.677	0.694	0.712	0.729	0.421	0.437	0.444	0.451	0.458
Middle	0.372	0.378	0.379	0.386	0.392	0.625	0.662	0.673	0.684	0.693	0.486	0.506	0.513	0.528	0.535
Lower	0.358	0.378	0.383	0.400	0.414	0.701	0.736	0.740	0.749	0.752	0.561	0.595	0.607	0.623	0.640

Table 3. Trophic State Index values based on predicted median dissolved phosphorus, chlorophyll a, and Secchi depth transparencies predicted in Taylorsville Lake by year, season, and location for the base case and nutrient reduction scenarios (Modified from FTN Associates Ltd. Report, 1998, page 8-10)

1989

	Spring					Summer					Fall				
Station	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%
Dissolved phosphorus, in milligrams per liter															
Upper	74.0	69.9	67.7	65.2	61.8	73.1	67.7	65.7	63.0	59.8	76.6	72.0	70.0	67.7	64.8
Middle	65.8	60.4	57.4	53.3	50.9	69.2	63.5	61.0	57.8	54.1	80.1	77.1	76.0	74.9	73.5
Lower	52.8	49.8	49.4	49.2	48.7	63.4	55.9	52.1	47.0	38.7	79.6	77.2	76.3	75.5	74.4
Chlorophyll a, in micrograms per liter															
Upper	73.0	70.9	70.1	69.4	68.9	61.4	59.6	59.0	58.5	57.8	68.5	68.0	67.9	68.0	68.2
Middle	74.5	73.3	72.9	72.4	71.6	62.7	61.6	61.2	61.1	61.1	68.7	68.4	68.4	68.5	68.8
Lower	74.1	73.2	72.8	72.3	71.9	60.7	60.0	60.0	60.3	61.1	63.8	63.5	63.4	63.5	63.8
Secchi depth, in meters															
Upper	72.5	71.8	71.3	71.1	70.7	65.8	64.8	64.3	63.9	63.3	72.0	71.6	71.4	71.2	70.9
Middle	73.1	72.0	71.4	71.0	70.5	64.6	63.8	63.5	63.2	62.9	71.3	70.8	70.6	70.4	70.1
Lower	72.4	71.5	71.1	70.6	70.3	63.0	62.4	62.2	62.1	61.8	67.7	67.4	67.2	67.1	66.9

1993

	Spring					Summer					Fall				
Station	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%
Dissolved phosphorus, in milligrams per liter															
Upper	54.7	49.0	43.1	40.2	37.1	61.1	52.1	46.0	39.1	33.8	71.8	67.5	65.5	63.5	61.0
Middle	38.0	33.5	32.4	31.6	30.4	39.0	33.8	33.0	32.3	31.8	78.2	76.0	75.2	74.5	73.8
Lower	35.5	32.5	31.3	30.2	28.9	30.3	28.6	28.0	27.4	27.0	63.8	59.9	59.2	58.6	57.9
Chlorophyll a, in micrograms per liter															
Upper	69.4	68.2	67.5	67.0	66.0	63.4	63.4	63.8	63.3	62.3	68.4	69.6	69.9	70.4	70.7
Middle	68.2	66.9	66.6	66.3	66.2	66.6	64.3	63.4	62.4	61.5	71.5	72.2	72.4	72.4	72.5
Lower	65.9	65.5	65.5	65.4	65.4	63.1	60.6	59.5	58.6	57.3	68.5	69.0	69.2	69.1	68.9
Secchi depth, in meters															
Upper	67.9	67.4	67.0	66.7	66.1	64.5	64.0	63.8	63.4	62.7	69.7	69.4	69.4	69.4	69.4
Middle	67.2	66.5	66.3	66.1	66.0	65.9	64.1	63.5	62.9	62.1	71.1	70.9	70.8	70.7	70.6
Lower	65.8	65.7	65.7	65.7	65.6	62.9	61.3	60.7	60.2	59.6	67.5	67.5	67.3	67.1	66.8

1996

	Spring					Summer					Fall				
Station	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%	Base	30%	40%	50%	60%
Dissolved phosphorus, in milligrams per liter															
Upper	82.6	78.0	75.8	73.9	71.2	74.2	69.0	66.6	63.9	60.2	79.3	74.3	72.2	69.8	66.7
Middle	76.9	73.0	70.6	67.4	63.9	71.9	65.6	62.6	59.0	54.3	80.1	76.2	74.7	73.0	71.2
Lower	67.9	62.4	60.4	58.4	55.9	65.6	57.1	52.3	45.0	30.5	72.8	69.0	65.7	63.5	61.0
Chlorophyll a, in micrograms per liter															
Upper	67.8	66.6	65.9	65.3	64.7	63.5	62.1	61.7	61.2	60.8	67.7	67.3	67.3	67.3	67.8
Middle	69.8	69.3	69.0	68.7	68.2	63.7	63.0	62.9	62.8	63.1	64.6	64.0	64.1	64.1	64.5
Lower	71.8	70.8	70.3	69.7	68.8	62.4	62.0	62.3	62.8	63.6	64.6	64.2	64.2	64.2	64.9
Secchi depth, in meters															
Upper	74.5	74.2	74.1	73.8	73.7	66.6	65.6	65.3	64.9	64.6	72.5	71.9	71.7	71.5	71.3
Middle	74.3	74.0	74.0	73.7	73.5	66.8	65.9	65.7	65.5	65.3	70.4	69.8	69.6	69.2	69.0
Lower	74.8	74.0	73.8	73.2	72.7	65.1	64.4	64.3	64.2	64.1	68.3	67.5	67.2	66.8	66.4

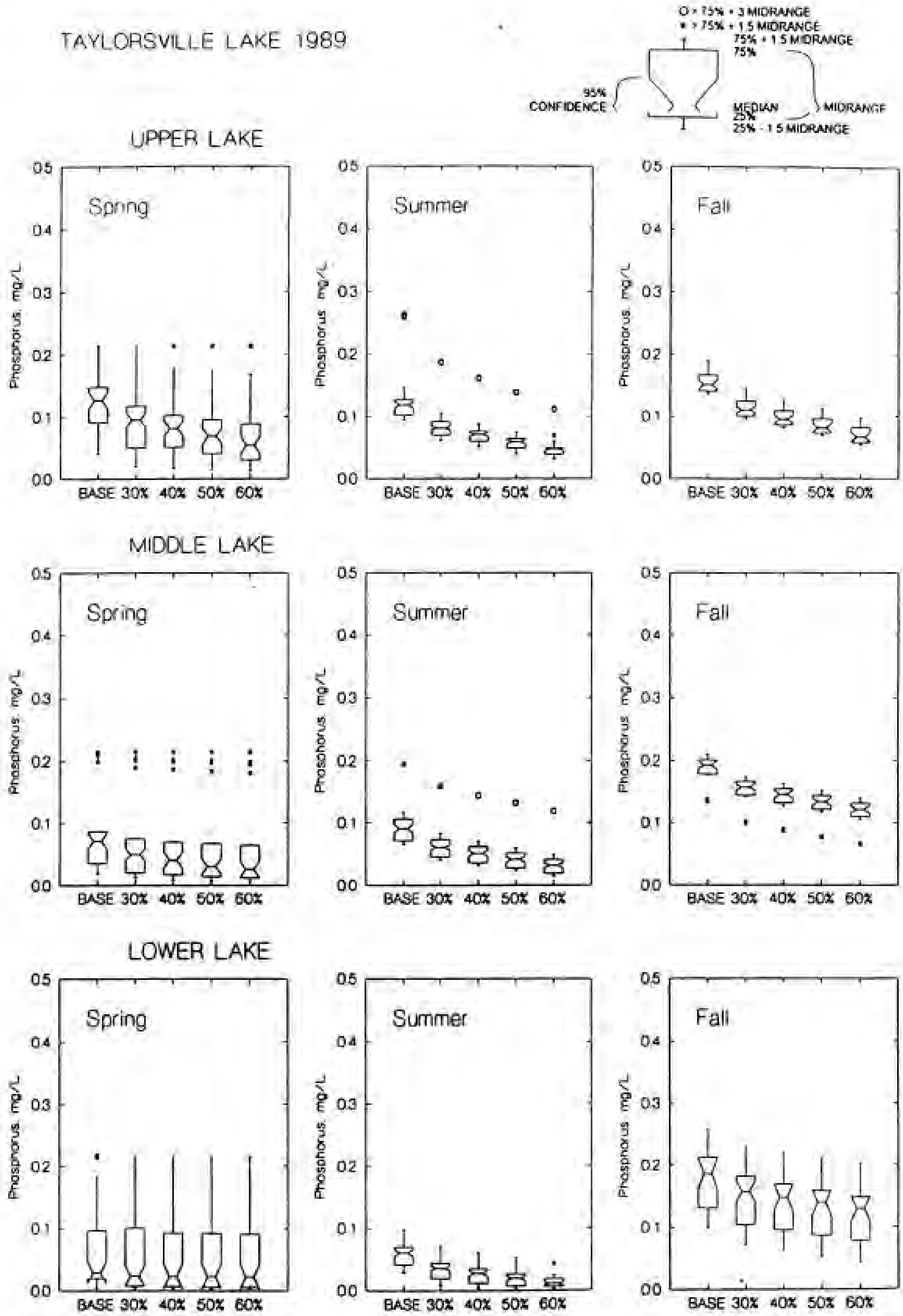


Figure 3 Box and whisker plots of dissolved phosphorus concentrations (ug/L) under different nutrient reduction scenarios by season in the headwater, mid-lake, and lower reservoir areas for 1989.
(Reproduced from FTN Associates Ltd. Report, 1998, page D-3)

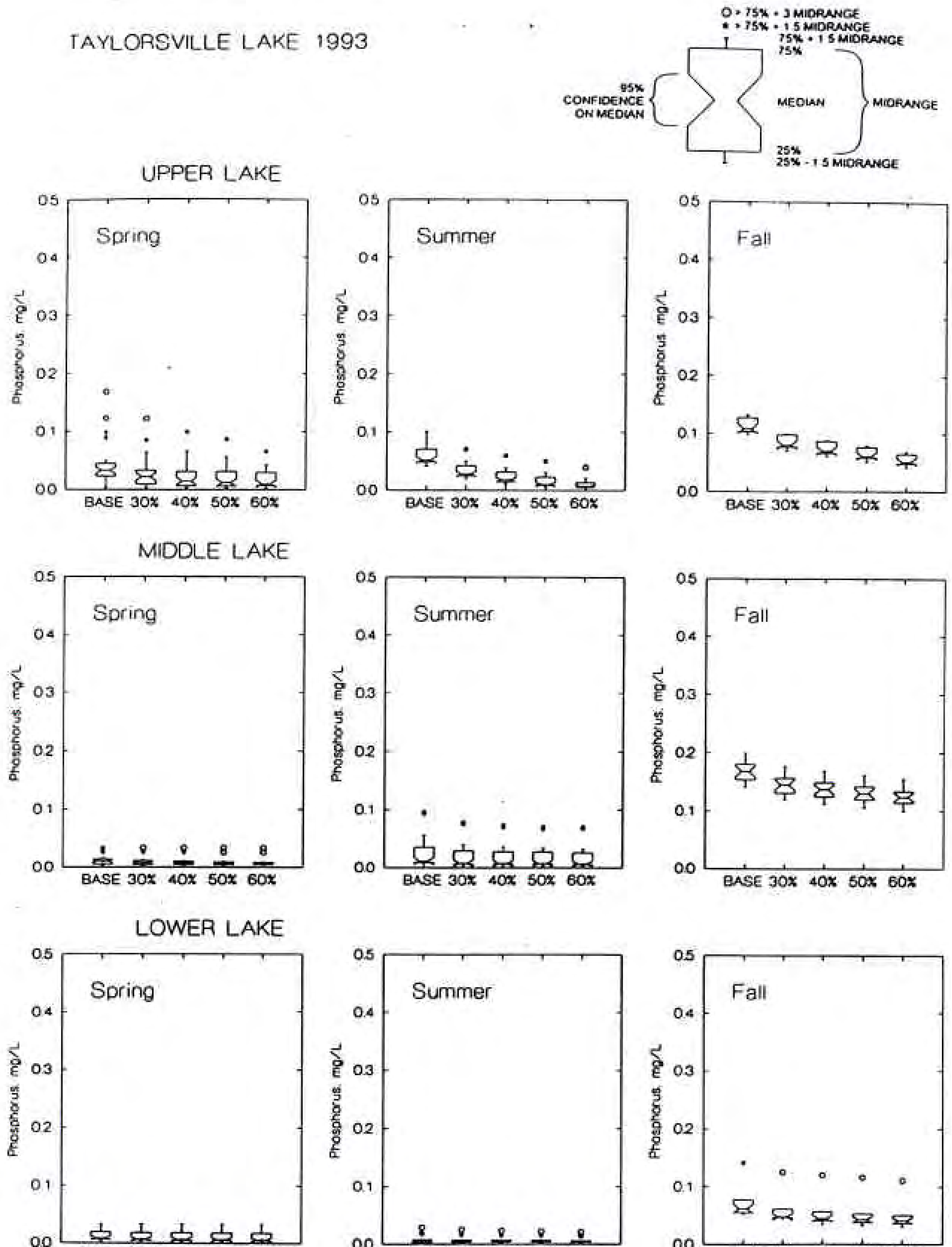


Figure 4. Box and whisker plots of dissolved phosphorus concentrations (ug/L) under different nutrient reduction scenarios by season in the headwater, mid-lake, and lower reservoir areas for 1993.
(Reproduced from FTN Associates Ltd. Report, 1998, page D-4)

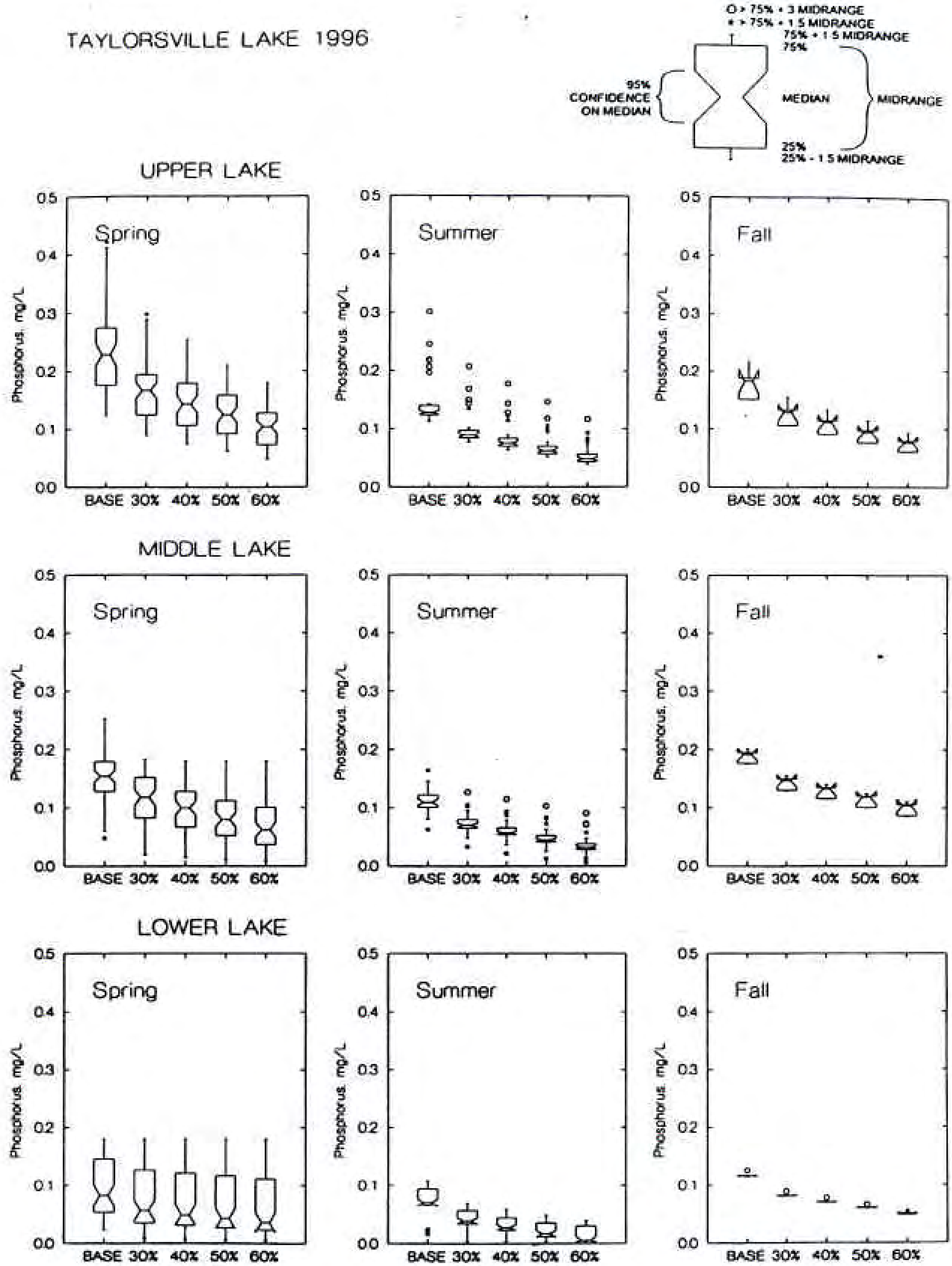


Figure 5. Box and whisker plots of dissolved phosphorus concentrations (ug/L) under different nutrient reduction scenarios by season in the headwater, mid-lake, and lower reservoir areas for 1996.
(Reproduced from FTN Associates Ltd. Report, 1998, page D-5)

base case and the various reduction scenarios which is important because no water-quality model can accurately predict absolute values of constituent concentrations and, therefore, loads. Phosphorus reduction did not show an improvement in water quality in all years at all locations. Phosphorus reduction appeared to be greatest in the upper part of the lake for all seasons during most years.

TMDL Development

The TMDL is comprised of the sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background levels, and a margin of safety (MOS). The MOS can be implicit or explicit. The sum of these components must not result in the exceedance of water quality standards. The TMDL is the total amount of pollutant that can be assimilated by the receiving stream without violating water quality standards. The TMDL document establishes the allowable stream loadings that are less than or equal to the TMDL and thereby provide the basis to establish water-quality based controls. This relation can be expressed as:

$$TMDL = WLA\ (point) + LA\ (nonpoint) + BACKGROUND + MOS$$

Point Sources

As stated previously, the point sources constitute a minor percentage of the total phosphorus load being delivered to Taylorsville Lake.

From the DOW report (1993):

	Harrodsburg WWTP	Lawrenceburg WWTP	Total Point Source Load	Percent of Total Observed Load
Observed Phosphorus Load	11 lbs/day	36 lbs/day	47 lbs/day	4.0
Design Phosphorus Load	42 lbs/day	51 lbs/day	93 lbs/day	7.5

Also, the values shown do not account for uptake of phosphorus between the location of the plant discharge and the upper part of the lake. The Harrodsburg and Lawrenceburg WWTPs are located approximately 45 miles and 15 miles, respectively, upstream of the upper part of the lake. The FTN report (1998) shows that the point source contribution by season (Table 1) ranges between 1 and 9 percent during the non-summer seasons based on model results. However, for the "dry" year (1993), the point source contribution during the summer accounted for all of the load. This load, however, is less than half of the background load determined for all other periods (Table 1). For the three years 1989, 1993, and 1996, the point source loads accounted for 3 percent, 7 percent, and 3 percent, respectively, of the total phosphorus load for the year. Therefore, point source loading is considered minor, particularly when compared to background loads, which can account for as much as 45 percent of the total load for selected seasons. For load allocation, no increase in phosphorus discharge above current design levels will be permitted at existing WWTPs. To account for discharges from the other permitted dischargers in the watershed, the 93 lbs/day was increased to 100 lbs/day by multiplying the 93 lbs/day by the ratio of the design of all permitted dischargers to the design flow of the summation of the Harrodsburg and Lawrenceburg WWTPs (4.84/4.58) and rounding up to the next tens digit.

Background

As mentioned throughout the report, background levels constitute a significant percentage of the phosphorus load entering Taylorsville Lake. The soils are naturally high in phosphorus, and background levels can constitute as much as 45 percent of the phosphorus load. The range was 10 to 45 percent based on model results. There is no means of reducing this contribution to the stream and lake system.

Nonpoint Sources and MOS

From the model results (FTN, 1998), the nonpoint source contribution ranged from 50 percent to 80 percent of the seasonal loading. Based on the FTN findings (FTN, 1998), the DOW concurs with the FTN recommendations that a 50-percent reduction in phosphorus load to Taylorsville Lake for the spring and summer seasons is the appropriate target value. Spring corresponds to the period April through June, and summer corresponds to the period July through September. Because background phosphorus levels can be as high as 45 percent, it is not reasonable to target a reduction in phosphorus of a value greater than about 60 percent. The targeted 50-percent reduction incorporates a 40-percent lower bound plus an MOS of 10 percent (FTN, 1998). The DOW concurs with the FTN findings (1998) that the MOS of 10 percent is reasonable in accounting for the uncertainty in assessing the efficiency of BMPs. The MOS for the summer period was 2.6 percent because of the low observed loading rate from nonpoint sources compared to point sources and background values. The 50-percent reduction in phosphorus loading produced a TSI improvement of from 10-14 points from the model simulations. This should result in an improvement in water quality by reducing the eutrophic state of Taylorsville Lake, particularly in the upper (headwater) portion of the lake where the worst water quality conditions occur. As previously stated, attaining a reduction in phosphorus loading to the lake of greater than 50 percent is probably not realistic, given that the background load can be as much as 45 percent of the total phosphorus load. Because the flushing period was short (100 days) and because of limited opportunity for plankton growth, the winter season was not included in phosphorus reduction scenarios in the model runs. A decrease in phosphorus loading above existing conditions should occur during the winter with the implementation of BMPs. Also, with a 50-percent reduction in phosphorus, the model simulations indicated a decrease in the number of blue-green algae and an increase in diatoms and greens during the fall when nutrients were supplied to the epilimnion during the fall overturn (FTN, 1998). There should be no base increase in phosphorus load above the existing external loads during either the fall or winter seasons.

Table 4 gives the total maximum daily load for phosphorus by season. Total inflow from the table on page 8 was multiplied by 50 percent to determine the allowable Inflow TP Load shown in Table 4. The Margin of Safety is 10 percent of the Inflow TP Load shown in the table on page 8 (except for the summer period). The allowable Nonpoint Source Load shown in Table 4 is, therefore, the Inflow TP Load minus the Point Source Load, minus the Background Load, and minus the Margin of Safety.

Table 4. Summary of Total Maximum Daily Allocation by Season and by Corresponding Daily Load

Season	Inflow TP Load		Point Sources		Background		Nonpoint Sources		Margin of Safety	
	lbs	lbs/day	lbs	lbs/day	lbs	lbs/day	lbs	lbs/day	lbs	lbs/day
Spring Apr-Jun 91 days	63,780	701	9,100	100	32,620	358	9,320	103	12,760	140
Summer Jul-Sep 92 days	19,060	207	9,200	100	8,870	96	0	0	990	11
Fall Oct-Nov 61 days	23,100	379	6,100	100	11,340	186	1,040	17	4,620	76
Winter Dec-Mar 121 days	223,900	1,850	12,100	100	53,550	443	158,250	1,307	---	---

Waste Load Allocations (WLAs) are shown under the column heading of "Point Sources."
Load Allocations (LAs) are the summation of "Background" and "Nonpoint Sources."
Margins of Safety (MOS) are shown under the heading "Margin of Safety."

Point Sources were determined by (1) 93 lbs/day for design flow of 4.58 mgd for the Harrodsburg and Lawrenceburg WWTPs, (2) design flow of all permitted dischargers in the watershed is 4.84 million gallon day (mgd), and (3) 93 lbs/day multiplied by the ratio of 4.84/4.58 equals 98.2 lbs/day, which was rounded up to 100 lbs/day.

The allowable nonpoint sources for spring, summer, and fall were based on reducing the total phosphorus loading by 50 percent. This reduction has two components: (1) the targeted reduction is 40 percent, and (2) the Margin of Safety (MOS) is 10 percent, except for the summer period, where the MOS is 2.6 percent.

Implementation Plan

This will be a phased TMDL because of the presence of nonpoint sources of pollution on all of the stream reaches listed. A phased TMDL is necessary when the efficiency of remedial activities is unknown. Remedial activities will need to be implemented, and follow-up monitoring will need to be conducted. If water quality standards are still not being met upon review of the data from the follow-up monitoring, the remedial activities will need to be modified. To assist in developing a remediation strategy, the Kentucky Watershed Management Framework (KWMF) will be utilized in conjunction with plans developed as required by the Kentucky Agriculture Water Quality Act (KAWQA). As part of the KWMF, a Salt River Basin Team, under the leadership of a basin coordinator, has been formed to carry out certain recommended activities. One of these activities is to identify and help develop a local watershed task force. With assistance from the various participating agencies, the river basin team, and the basin coordinator, the local task force will develop a local action plan, particularly for streams impacted by nonpoint source pollution. The local action plan will be the document that will describe the needed remediation activities and how implementation will be achieved. The KAWQPs will be an integral part of the action plan, which will be developed in the fourth year (2002) of the 5-year watershed cycle. Implementation will occur in the fifth and succeeding years of the cycle.

Remedial actions to nonpoint sources of pollution will be taken based on the establishment of BMPs as described in the Kentucky Agriculture Water Quality Plan (KAWQP) of 1996 (KAWQA, 1996). Private landowners of 10 acres or more who conduct agricultural operations (including silviculture) must develop and implement a water quality plan, based on guidance from the KAWQP, for their agricultural operations by October 23, 2001. To assist landowners in developing their plan, the KAWQA has developed the Producer Workbook (KAWQA, 1997). It provides a step-by-step process for developing plans and lists contacts to various state and federal agencies that can provide the technical assistance necessary to develop and implement plans.

Conclusions from the DOW report (1993) state that nonpoint runoff from land used for agricultural operations is the major source of phosphorus to the streams which feed into Taylorsville Lake. This analysis leads to the recommendation to implement land-management practices to reduce erosion and to create riparian zones along stream channels. These actions would have the greatest impact in reducing phosphorus concentrations in the streams feeding Taylorsville Lake. The DOW will continue to utilize 319 funding and other forms of assistance to local conservation agencies to accomplish these goals and encourage other resource agencies to direct funds toward reducing nutrient loading. The Salt River Unit Management Plan, once developed, will also address implementation strategies.

The Upper Salt River/Taylorsville Reservoir Watershed Demonstration Project

Summary: In 1991, the DOW applied for and received Section 319(h) Nonpoint Source Implementation Grant funds for the Upper Salt River/Taylorsville Reservoir (USR/TR) Watershed Demonstration Project. Grant funds were requested to support water quality monitoring in this priority nonpoint source watershed; funding for agricultural BMP application and implementation was secured through several U.S. Department of Agriculture (USDA) programs.

Types of BMPs: The types of BMPs implemented and planned for the USR/TR watershed are agricultural in nature. Both animal waste and agronomic (cropping) BMPs have been implemented. Controlling manure runoff from the numerous dairies in the watershed and controlling erosion from various types of farming activities were prioritized. The BMPs included (1) animal waste management (containment, application, etc.), (2) intensive rotational grazing, (3) integrated pest management, (4) riparian area establishment, (5) buffers, (6) no-till crops, and (7) numerous other types of animal waste and agronomic practices.

*Past Funding***:** The USR/TR Watershed Demonstration Project received federal agricultural BMP cost-share funding through several USDA programs:

- Hydrologic Unit Area Water Quality Project: five years of dedicated funding.
- Agricultural Conservation Program (ACP): annual cost-share allocation to counties.
- Water Quality Incentive Project (WQIP): special one-time cost-share allocation to project.

*Future Funding***:** State and federal cost-share funds for agricultural BMPs will continue to be targeted in the USR/TR watershed.

Water Quality Monitoring: Three types of monitoring were conducted in the upper Salt River basin for the USR/TR Watershed Demonstration Project: (1) bacteriological, (2) biological, and (3) physicochemical. The purpose of the monitoring was to collect pre- and post-BMP water quality data in order to document changes in water quality associated with intensive BMP application. Both pre-BMP and post-BMP bacteriological monitoring have been completed. Pre-BMP monitoring was conducted as part of the upper Salt River Intensive Survey that was conducted in 1989. Post-BMP biological monitoring consisted of collecting fishes and macroinvertebrates from three sites. Two of the sites were used to compare conditions after BMPs were installed. Post-BMP physicochemical monitoring was completed through a Memorandum of Agreement with the United States Geological Survey (USGS). Monthly high-flow samples were collected from the USGS gaging station on the Salt River at Glensboro, Kentucky. Post-BMP physicochemical monitoring has been completed. The final report (DOW, 2000) shows an improvement in the macroinvertebrate community at the station in the upper basin, which indicates an improvement in water quality. Figure 6 (G. Miller, DOW, 2000) shows a trend analysis of total phosphorus concentration at the station nearest the lake and indicates a significant decline from 1989 to 1998. Further monitoring is required to verify these indications of improved water quality.

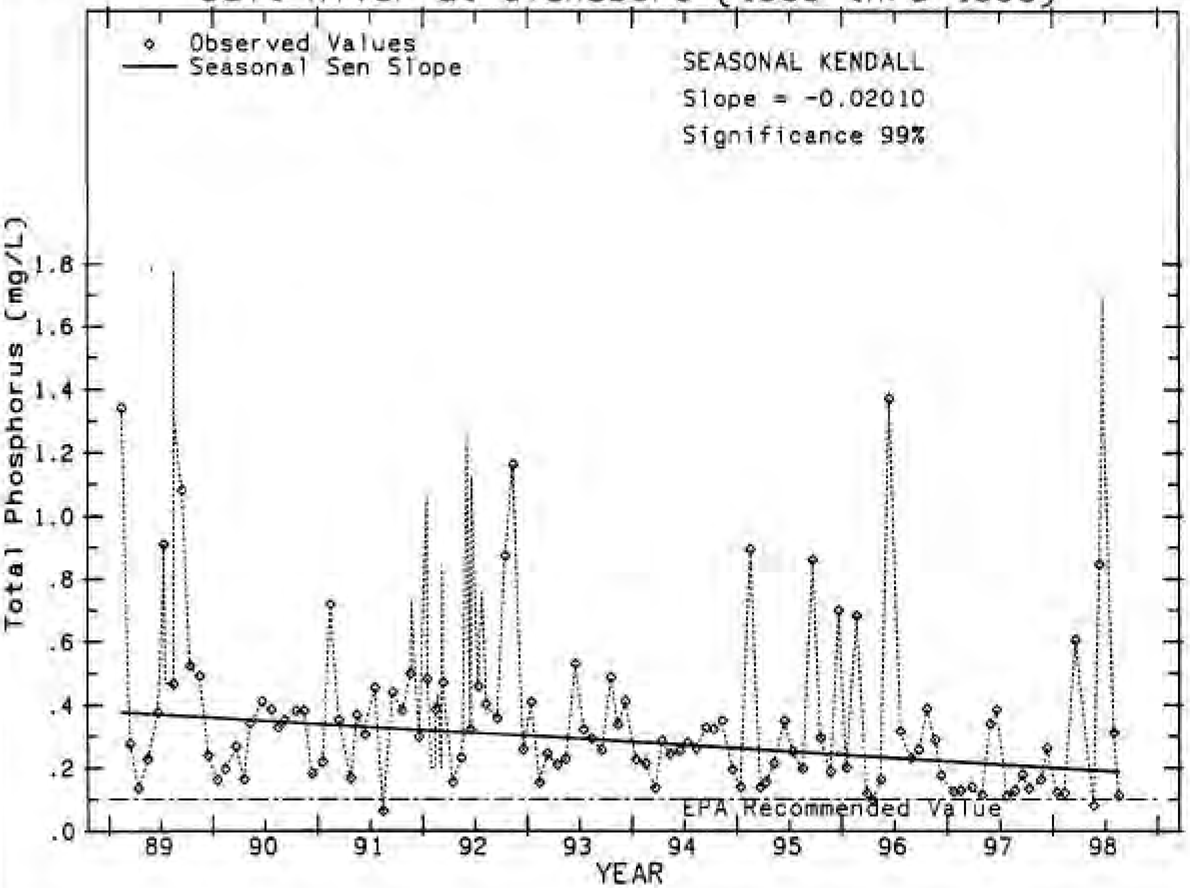
<u>Other Focused Projects/Initiatives</u>

Two other projects focused in the watershed resulted in additional BMP applications. They are:

Riparian Area Project: The project final and close-out reports are available from the DOW. The DOW closed this project because the contractor could not meet the minimum requirement to have BMPs on the ground in time for the DOW to establish a monitoring project. Ten demonstration sites were established within the watershed: two in Boyle County, three in Mercer County, one in Shelby/Spencer County, and two in Nelson County. The Shelby/Spencer cooperator withdrew from the project in 1997. Approved BMPs were recommended for each farm on a site-specific basis. A DOW biologist visited each demonstration site and evaluated each site for monitoring potential. Only one site in ten was deemed by the biologist to be suitable as a monitoring site, but the producer/cooperator at that site chose not to participate in the project. No water quality monitoring was done. However, several BMPs were implemented in the project watershed, one on each of three farms in Anderson, Boyle, and Mercer counties. A more detailed explanation of the BMPs that were implemented is available from the DOW.

Evaluation of Constructed Wetlands for Animal Waste (Phase II): The study was designed to use constructed wetlands for treating animal wastewaters arising primarily from milking facilities. This study resulted in one constructed wetland implemented in

Figure 6. Seasonnal Kendall Trend Plot of Total Phosphorus
Salt River at Glensboro (1989 thru 1998)



the upper Salt River watershed (Mercer County). The project is complete, and the final report is under development by the contractor. Information on this project is available from the DOW on request.

The Division of Conservation (DOC) works with local conservation districts in the counties of the Taylorsville Lake area. Unfortunately, funding to establish BMPs is limited. The DOC has, over the past five years, received 102 requests for cost-share assistance. However, because of limited funding, the DOC has been able to approve only 14 applications for a total amount of $82,000 (Coleman, DOC, written commun., 2000).

References

Cole, T.M. 1995. CE-QUAL-W2: A two-dimensional, laterally averaged, hydrodynamic and water quality model. Version 2.0. Users Manual. Instruction Report EL-95-1. U.S. Army Corps of Engineers Waterways Experimentation Station, Vicksburg, MS.

FTN Associates, Ltd. 1998. Taylorsville Lake Water Quality Model; for the US Army Corps of Engineers Louisville District.

(KAWQA) Kentucky Agriculture Water Quality Authority. 1996. The Kentucky Agriculture Water Quality Plan. The Kentucky Agriculture Water Quality Authority, Frankfort, Ky.

_____ 1997. The Producer Handbook. The Kentucky Agriculture Water Quality Authority, Frankfort, Ky.

(DOW) Kentucky Department for Environmental Protection – Division of Water. 1993. Sources and Loadings of Total Phosphorus into Taylorsville Lake. Department for Environmental Protection. Kentucky Natural Resources and Environmental Protection Cabinet, Frankfort, Ky.

_____ 1997. Upper Salt River Biological and Water Quality Investigation. Department for Environmental Protection. Kentucky Natural Resources and Environmental Protection Cabinet, Frankfort, Ky.

_____ 2000. Upper Salt River/Taylorsville Reservoir Watershed Nonpoint Source Demonstration Project. Kentucky Department for Environmental Protection. Kentucky Natural Resources and Environmental Protection Cabinet, Frankfort, Ky.

Schimpeler-Corradino Associates. 1978. Water Quality Management Plan for Kentucky, Salt River Basin: prepared for the Division of Water Quality, Dept. for Natural Resources and Environmental Protection.

(USCOE) U.S. Army Corps of Engineers. 1992. The Distribution of Nutrients and Phytoplankton in Taylorsville Lake, Kentucky. U.S. Army Corps of Engineers, Louisville, Ky.