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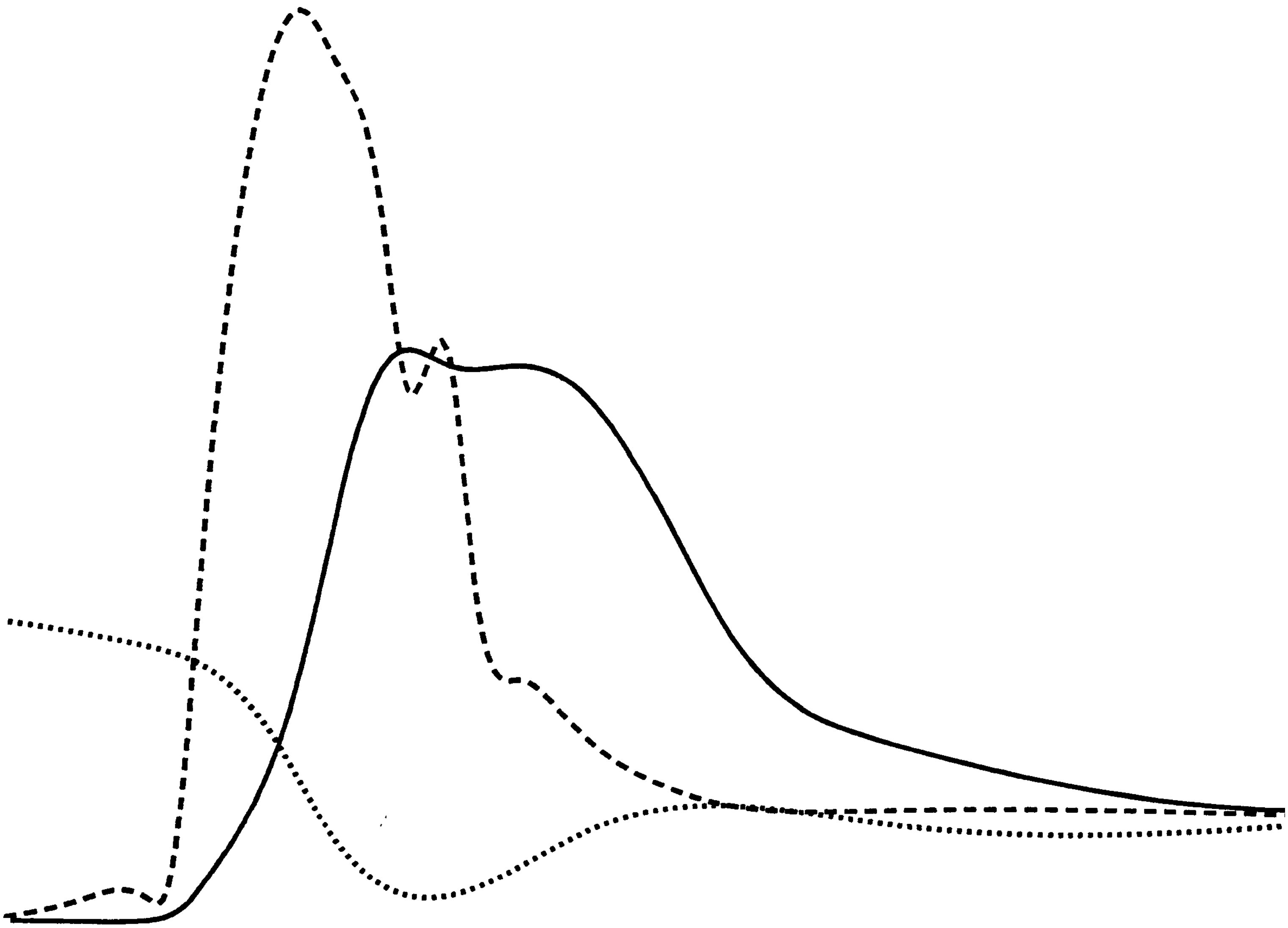
NONPOINT-SOURCE POLLUTANT DISCHARGES OF THE THREE MAJOR TRIBUTARIES TO REELFOOT LAKE, WEST TENNESSEE, OCTOBER 1987 THROUGH SEPTEMBER 1989



Prepared by the
U.S. GEOLOGICAL SURVEY

in cooperation with the
TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT,
DIVISION OF WATER POLLUTION CONTROL

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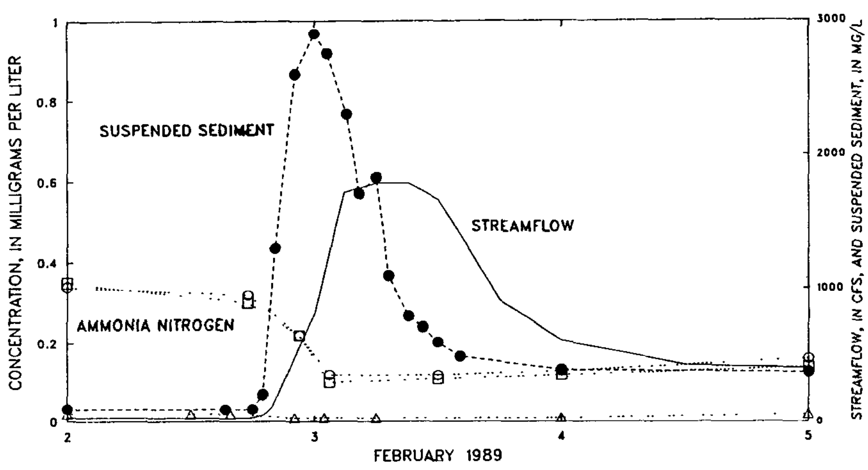
NOTE: The Tennessee Department of Health and Environment became the Tennessee Department of Environment and Conservation in mid-1991.



Cover: Relation between streamflow and selected constituents in storm runoff to Reelfoot Lake.

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Memphis, Tennessee
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CONVERSION TABLE

Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
square mile (mi^2)	2.590	square kilometer
ton, short (2,000 lb)	0.9072	megagram
ton per acre (ton/acre)	224.2	megagram per square kilometer
pound (lb)	0.4535	kilogram
pound per acre (lb/acre)	448.4	kilogram per square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Temperatures are given in degrees Celsius. Degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) by the equation:

$$°F = 9/5\ °C + 32$$

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ABSTRACT

An investigation of the concentration and loads of nitrogen, phosphorus, and suspended sediment in storm runoff to Reelfoot Lake, in western Tennessee, was conducted from October 1987 through September 1989. Concentrations of selected herbicides also were defined. Reelfoot Lake, with a surface area of about 15,500 acres, is the largest natural lake in Tennessee and an important recreation and fisheries resource. Previous studies showed that the lake is hypereutrophic, a condition caused by high concentrations of nutrients in water and sediments discharged from the three principal tributaries (South Reelfoot Creek, North Reelfoot Creek, and Running Slough) to the lake. Pesticides, including herbicides, have been detected in the lake's bottom sediments.

Storm runoff contributed about 87 percent of the total water discharge of the three main tributaries to Reelfoot Lake. South Reelfoot Creek contributed about 4.7 tons per acre per year of suspended sediment, while North Reelfoot Creek contributed about 1.9 tons per acre per year. Running Slough contributed only about 0.31 ton per acre per year of suspended sediment. Most of the suspended sediment was transported by storm runoff between October and March. About 80 percent of the annual streamflow of the three tributaries occurs during these months.

The North Reelfoot Creek basin contributed 8.2 pounds per acre per year of total nitrogen and 2.4 pounds per acre per year of total phosphorus. South Reelfoot Creek basin contributed about 6.5 and 1.3 pounds per acre per year of total nitrogen and phosphorus, respectively, while Running Slough basin contributions were 3.4 and 0.86 pounds per acre per year, respectively. The differences in nutrient yields appear to result from more row-crop agriculture and the relatively steeply sloping agricultural land in the North Reelfoot Creek basin. Ninety-one percent of the total nitrogen load and 95 percent of the total phosphorus load in the three streams was transported by storm runoff. Significant differences in the mean concentrations of nutrients in runoff were defined between the active agricultural months (April through September) and the inactive months (October through March).

Storm-runoff samples were analyzed for 11 selected triazine herbicides. Alachlor and atrazine were the most commonly detected herbicides. Thirty-two percent of the samples contained detectable levels of alachlor and 93 percent of the samples contained detectable levels of atrazine. Ninety percent of the samples collected during the active agricultural months

contained detectable levels of alachlor and all 29 samples contained detectable levels of atrazine. Sixteen samples exceeded lifetime health-advisory levels for atrazine in drinking water (3 micrograms per liter); two samples collected from the April 18, 1988, storm at North Reelfoot Creek and South Reelfoot Creek contained 42 and 57 micrograms per liter of atrazine, respectively. Concentrations of the other nine triazine herbicides were generally less than the level of detection (0.1 microgram per liter).

INTRODUCTION

Reelfoot Lake in western Tennessee is the largest natural lake in the State. The lake covers about 15,500 acres and has a drainage area of about 240 mi^2 in Lake and Obion Counties, Tennessee, and Fulton County, Kentucky. The three major tributaries to Reelfoot Lake are North Reelfoot Creek, South Reelfoot Creek, and Running Slough (fig. 1).

Reelfoot Lake has been referred to as hypereutrophic (Denton, 1987), which is a condition that threatens the existence of the lake as a valuable natural and economic resource. This condition is largely the result of a large influx of sediment and nutrients from the three major tributaries which drain the agricultural areas north and east of the lake. In addition to the occurrence of relatively large concentrations of suspended sediment and nutrients in runoff from these areas, the occurrence of smaller concentrations of herbicides in the runoff also is of concern.

Storm runoff is believed to deliver most of the annual load of nonpoint-source pollutants from the lake tributaries, although the relation between storm runoff and transport of nonpoint-source pollutants is not well understood. A quantitative analysis of annual and storm contributions of sediment, nutrients, and herbicides by the three major tributaries is required to address the control of nonpoint-source pollutant loadings to Reelfoot Lake. In 1987, the U.S. Geological Survey (USGS), in cooperation with the Tennessee Department of Health and Environment, Division of Water Pollution Control, initiated a study to define nonpoint-source pollutant loads to Reelfoot Lake from the three major tributaries.

Purpose and Scope

This report summarizes the results of the investigation to assess nonpoint-source pollutant contributions by the three major tributaries to Reelfoot Lake. The investigation had three objectives:

- Computation of annual and storm-runoff loads of suspended sediment and nutrients for the three major tributaries to Reelfoot Lake,
- Definition of the relations between concentrations of suspended sediment and nutrients with storm runoff from the three major tributaries to Reelfoot Lake, and
- Evaluation of the seasonal variation in concentrations of suspended sediment, nutrients, and selected herbicides in the three major tributaries to Reelfoot Lake.

Data were collected for the investigation from October 1987 through September 1989, the 1988 and 1989 water years. Mean daily streamflow data were collected at North Reelfoot Creek at Highway 22, near Clayton, Tennessee (station number 07026370); South Reelfoot Creek near Clayton, Tennessee (station number 07026400); and Running Slough near Ledford, Kentucky (station number 07026640) (fig. 1). Mean daily suspended-sediment data were collected at the North Reelfoot Creek station from October 1987 through September 1989 and at the South Reelfoot Creek station from October 1988 through September 1989. Storm sampling was

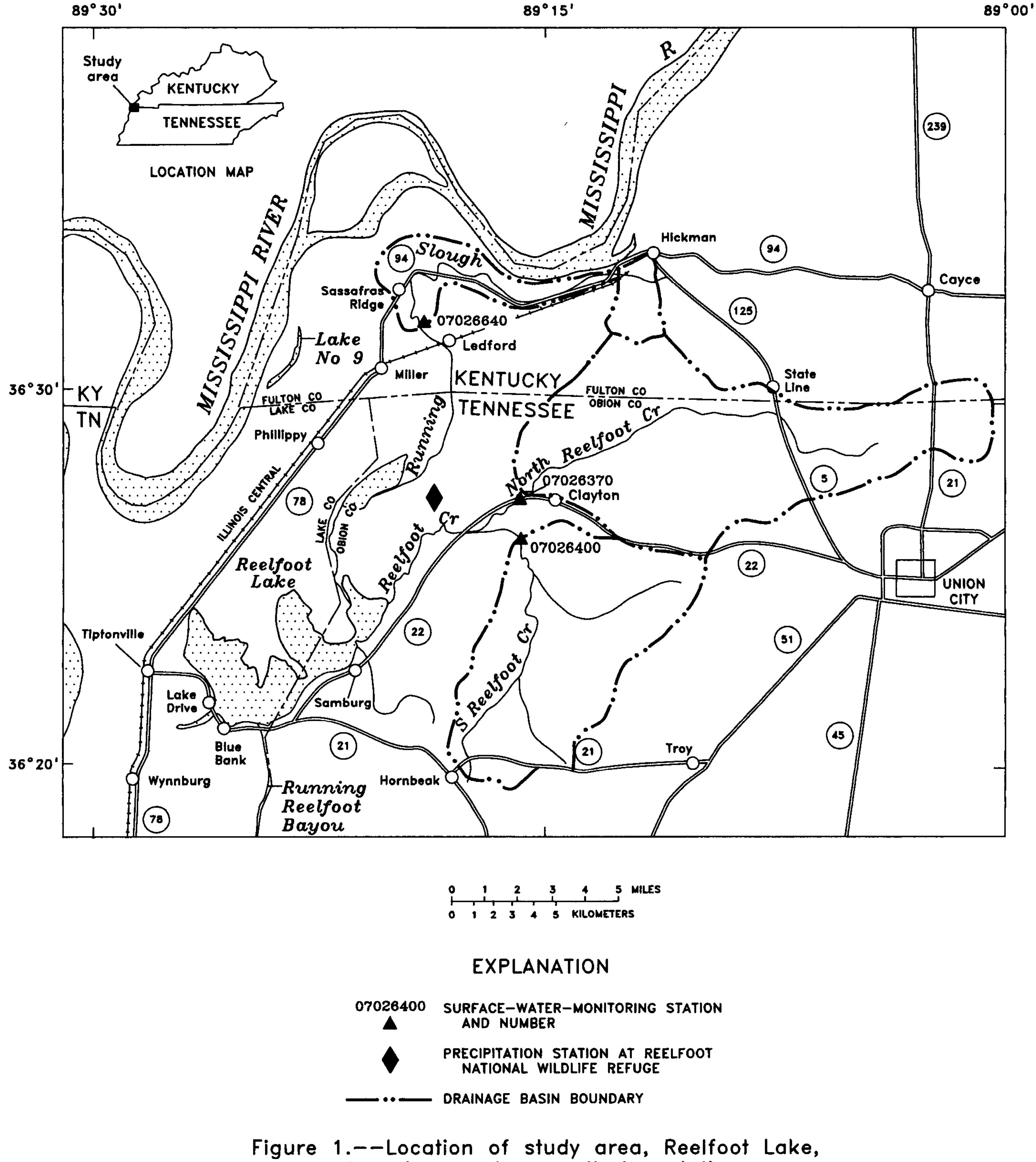

Figure 1.--Location of study area, Reelfoot Lake, and surface-water-monitoring stations.

conducted throughout the study period at the three stations for suspended sediment, nutrients, and selected triazine herbicides. Periodic base-flow sampling was conducted at the North Reelfoot station during the entire study period and at the other two stations from October 1988 through September 1989.

Previous Investigations

Several previous investigations of the hydrology and water quality of Reelfoot Lake and tributaries have been conducted. Denton and Dobbins (1984), as part of the U.S. Environmental Protection Agency Clean Lakes Program, completed a detailed report of the Upper Duck basin of Reelfoot Lake. They concluded that the lake is severely impacted by nonpoint-source pollution, mostly in agricultural runoff. Sediment cores from the lake's bottom were analyzed for pesticides, nutrients, and radioactive isotopes. They concluded that nutrients and other components are released from the sediments to the water column. Robbins (1985a) provided the first quantitative analysis of the hydrology of the Reelfoot Lake basin. Robbins (1985b) provided a water budget and estimated suspended-sediment inflow for Reelfoot Lake for May 1984 through April 1985. Hoos and others (1988) and Lewis and others (in press) provided updated water budgets for Reelfoot Lake and evaluated the potential effects of proposed lake-management strategies on local ground-water levels and flow.

The Tennessee Department of Public Health (1985) reported that the Reelfoot Creek, Indian Creek, and Running Slough basins contribute about 93 percent of the total annual sediment load to Reelfoot Lake. Kung and Garrett (1986) used the universal soil-loss equation to estimate that average soil loss in the North and South Reelfoot Creek basins is 17.7 and 36.3 ton/acre/yr, respectively. Denton (1986) provided a summary of sedimentation studies of Reelfoot Lake.

Lowery and others (1986, 1987, 1988) reported that about 500,000 tons of suspended sediment were transported past three gaging stations on North Reelfoot Creek, South Reelfoot Creek, and Running Slough during water years 1985, 1986, and 1987.

The U.S. Environmental Protection Agency (1976) estimated that 525 tons of total nitrogen and 129 tons of total phosphorus were contributed annually to Reelfoot Lake from nonpoint sources. FTN Associates (1987) estimated that direct runoff from the Reelfoot Lake basin contributes 22 tons of total phosphorus and 133 tons of total nitrogen annually to the lake. Additionally, FTN Associates estimated that Reelfoot Creek (downstream from the confluence of North and South Reelfoot Creeks) contributes 35 tons of total phosphorus and 70 tons of total nitrogen annually to the lake, and Running Slough contributes 3 tons of total phosphorus and 19 tons of total nitrogen annually. Denton (1987) provided a comprehensive report of water quality in Reelfoot Lake and tributaries. Denton (1987) reported that Reelfoot Creek was the tributary stream to Reelfoot Lake with the poorest water quality mainly from high concentrations of suspended solids, nutrients, and metals (copper, lead, and zinc).

DESCRIPTION OF STUDY AREA

The study area encompasses about 106 mi^2 of agricultural land east and northeast of Reelfoot Lake. The topography, soils, geology, land use, and climate of the study area influence the contribution of nonpoint-source pollutants by the three major tributaries to Reelfoot Lake.

Topography

The Reelfoot Lake basin can be divided into two distinct topographic regions: rolling to steep uplands and Mississippi River flood plain. North and South Reelfoot Creeks drain the uplands east of the lake. With the exception of the eastern one-half of the North Reelfoot Creek drainage area, which is relatively flat to rolling terrain, this area consists of relatively level creek bottoms surrounded by gently rolling to steeply sloping (10 to 40 percent slopes) ridges. The North and South Reelfoot Creek drainage areas are 56.3 and 38.6 mi^2, respectively. The Running Slough basin covers 10.8 mi^2 located primarily within the level Mississippi River flood plain northeast of the lake. The eastern one-fourth of the Running Slough basin is comprised of steep woodlands and pastures.

Geology and Soils

The study area includes both the low alluvial flood plain and the West Tennessee (loess) Plain, which is an upland area, east of the lake. The alluvium is of Quaternary age and is composed of 0 to about 200 feet of sand and gravel grading upward into silt and clay. The West Tennessee Plain is capped by the Pleistocene loess with Eocene, Pliocene, and Pleistocene sediments forming the lower one-third of the loess hill bluffs. The loess is about 80 feet thick and is divided into an upper unit, composed of silt and some clay, and a lower unit, composed entirely of silt.

Soils in the North and South Reelfoot Creek drainage basins consist primarily of the Adler-Convent-Falaya association in the creek bottoms and the Memphis association on the ridges which border the creeks (U.S. Department of Agriculture, 1973). These associations include moderately well-drained loam soils on the ridges and somewhat poorly drained loams in the creek bottoms. The soils in the Running Slough drainage area consist of the Commerce-Robinsonville association in the low, level flood plain and the Memphis-Loring association in the uplands (U.S. Department of Agriculture, 1987). The Commerce-Robinsonville association consists of somewhat poorly drained to well-drained loam soils. The Loring-Memphis association consists of moderately well-drained to well-drained loam soils.

All the soils in the study area formed in transported material. Soils on uplands developed in thick loess deposited by the wind. Loess is 70 to 80 percent silt, 20 to 30 percent clay, and 1 to 2 percent fine sand. Soils on flood plains associated with the uplands formed in alluvium washed from the loess uplands, and, like the soils on the uplands, are silty. The soils in the Mississippi River flood plain in the Running Slough drainage basin formed in alluvium transported by the Mississippi River. The deposited alluvium ranges in texture from fine sand and silt to clay (U.S. Department of Agriculture, 1987).

Land Use

Agriculture is the principal land use in the study area. Corn and soybeans are the major row crops grown (Jim Needham, Soil Conservation Service, oral commun., 1990). The Reelfoot Lake basin is one of the most intensively farmed areas in western Tennessee. It is included as a priority basin in the draft plan for control of nonpoint sources of pollution (Tennessee Department of Health and Environment, written commun., 1989).

Row-crop land comprises about 20,000, 10,000, and 5,000 acres of the North Reelfoot Creek, South Reelfoot Creek, and Running

Slough basins, respectively, which represents 56, 40, and 72 percent, respectively, of each basin. About 30 percent of the steeply sloping (10 to 40 percent slopes) uplands in the North and South Reelfoot Creek basins are used for row crops while 68 percent of the area is forests, pastures, and gullied lands. About 83 percent of the relatively level eastern part of the North Reelfoot Creek basin is used for row crops (L.W. Moore, Memphis State University, oral commun., 1990). Row crops dominate land use in the flood plain of the Running Slough basin and forests and pastures dominate land use in the uplands in the eastern part of the basin.

Climate

The climate of the study area is characterized by hot, humid summers and mild winters. The average daily maximum temperature ranges from 33 °C in July to 9 °C in December. The 20-year (1969-88) mean annual precipitation for the study area is about 51 inches. Rainfall typically is greatest in the winter and early spring and least in the late summer and early fall. Intense rain storms are commonly associated with convective storms from early spring through early autumn. Rainfall produced by frontal storms that commonly occur during the winter and spring is generally less intense but produces much greater runoff.

DATA COLLECTION

The data-collection network consisted of continuous stage recorders at the North Reelfoot Creek, South Reelfoot Creek, and Running Slough stations, and automatic samplers at the North and South Reelfoot Creek stations. Stage-discharge relations were developed for each station to provide a continuous record of instantaneous and mean daily discharge. Automatic samplers were operated at the North Reelfoot Creek station during the 1988 and 1989 water years and at the South Reelfoot Creek station during the 1989 water year. Because of budget constraints, all Running Slough samples were collected manually.

Water samples were collected from the three tributaries during selected storms and base flows for suspended sediment, nutrient, and herbicide analyses (table 1). The automatic samplers were used to collect storm-runoff samples for suspended-sediment and nutrient analyses. Storm-runoff samples for herbicide analyses were collected manually. Storm-runoff samples were collected from the rising limb, peak, and falling limb of the storm hydrograph until the stage stabilized near its pre-storm level. All base-flow sampling was done manually.

Table 1.--*Water-quality constituents monitored*

Inorganic constituents and physical properties
Suspended sediment
Total kjeldahl nitrogen
Total ammonia nitrogen
Dissolved nitrite plus nitrate nitrogen
Total phosphorus
Organic constituents
Triazine herbicides:
Alachlor
Atrazine
Cyanazine
Metolachlor
Metribuzin
Prometon
Prometryne
Propazine
Simatryne
Simazine
Trifluralin

Suspended-sediment samples also were collected manually over a range of discharge values for the North and South Reelfoot Creek stations to verify that the automatic samplers collected representative samples in the stream cross section. Suspended-sediment samples were collected manually by either the equal discharge incremental method (EDI) or the equal width incremental method (EWI), depending upon discharge conditions (Guy and Norman, 1970). Comparison of the analyses of suspended-sediment concentrations from the automatic and manually collected samples indicates the results were generally within 10 percent of each other.

All analytical determinations were made by the USGS. Suspended-sediment samples were analyzed by personnel of the Water Resources Division in Nashville, Tennessee. Nutrient and herbicide analyses were conducted by the U.S. National Water Quality Laboratory in Arvada, Colorado. Samples shipped to Arvada were chilled to 4 °C from the time of collection to analysis. Sample processing and analytical procedures are described by Feltz and others (1985), Fishman and Friedman (1985), and Wershaw and others (1987).

The streamflow and water-quality data collected during this study have been published in an annual series of reports (Lowery and others, 1988, 1989) and are stored in WATSTORE (Water Storage and Retrieval System of the USGS).

HYDROLOGIC CONDITIONS DURING THE STUDY PERIOD

Hydrologic conditions in the study area were assessed throughout the investigation to evaluate the water-quality data that were collected. Precipitation and streamflow are two important factors considered in this evaluation.

Precipitation

Daily precipitation data are collected at the Reelfoot National Wildlife Refuge near Samburg, Tennessee (fig. 1) (National Oceanic and Atmospheric Administration, National Weather Service, oral commun., 1989). The 20-year (1969-88) mean annual precipitation for the station is 51.3 inches. During the 1988 water year (October 1987 through September 1988) 47.3 inches of precipitation were recorded and during the 1989 water year (October 1988 through September 1989) 68.7 inches of precipitation were recorded. Sixty-two percent of the total precipitation for the 1988 water year and 65 percent of the total precipitation for the 1989 water year occurred during the months of October through March of each year.

Streamflow

Most of the streamflow in the study area occurs as the result of storms from October through March (figs. 2-4 and table 2). Streamflow for the study period was generally below normal during the 1988 water year and above normal during the 1989 water year. Seventy-nine percent of the total streamflow for the 1988 water year and 85 percent of the total streamflow for the 1989 water year for North Reelfoot Creek occurred from October through March of each year. For both South Reelfoot Creek and Running Slough, 76 percent of the total streamflow for the 1988 water year and 81 percent of the total streamflow for the 1989 water year occurred from October through March of each year. North Reelfoot Creek and South Reelfoot Creek had no-flow days frequently during the summer and autumn months. Running Slough generally had no streamflow during the summer and autumn months. Streamflow data for Running Slough were considered poor.

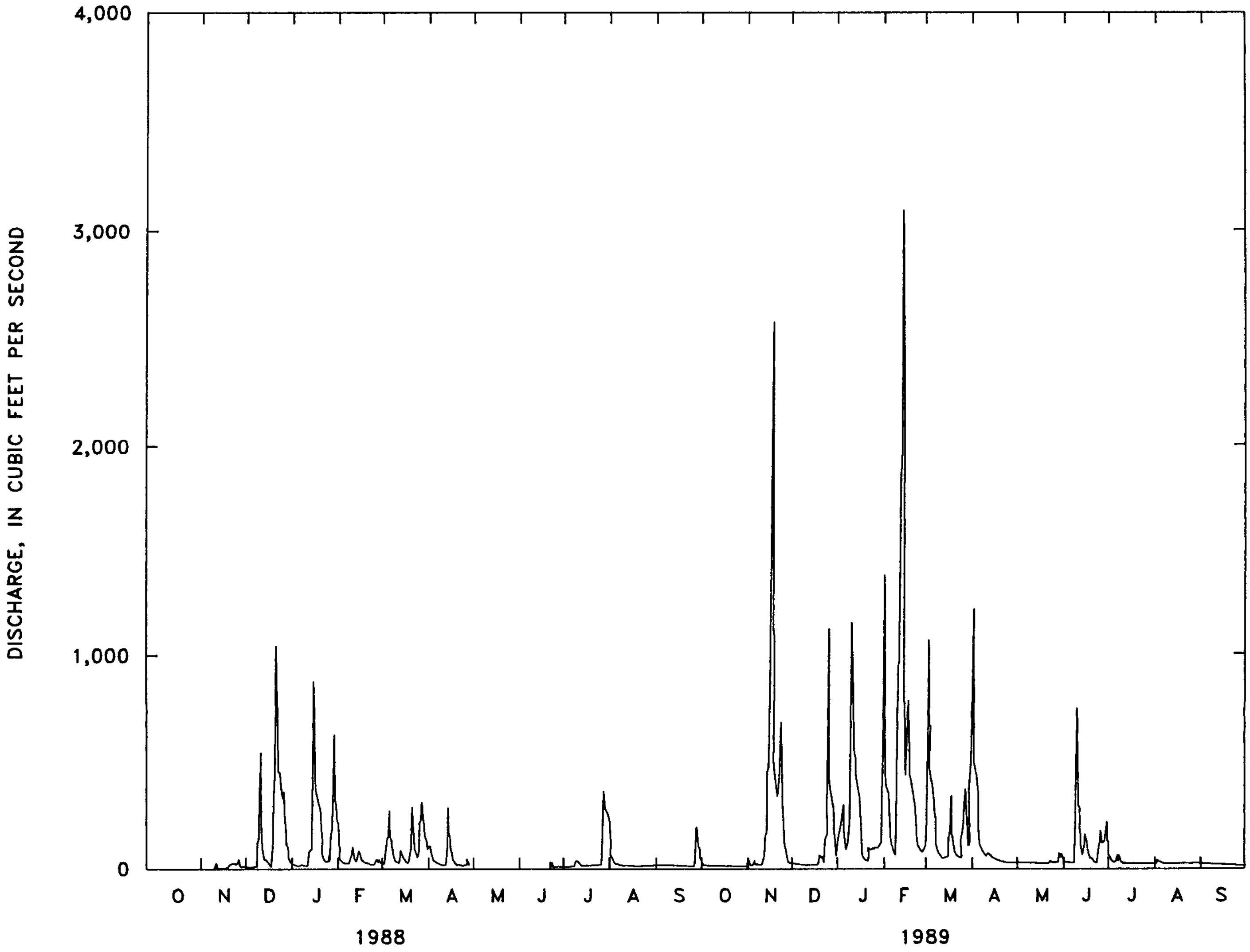

Figure 2.--Mean-daily discharge of North Reelfoot Creek (07026370), water years 1988 and 1989.

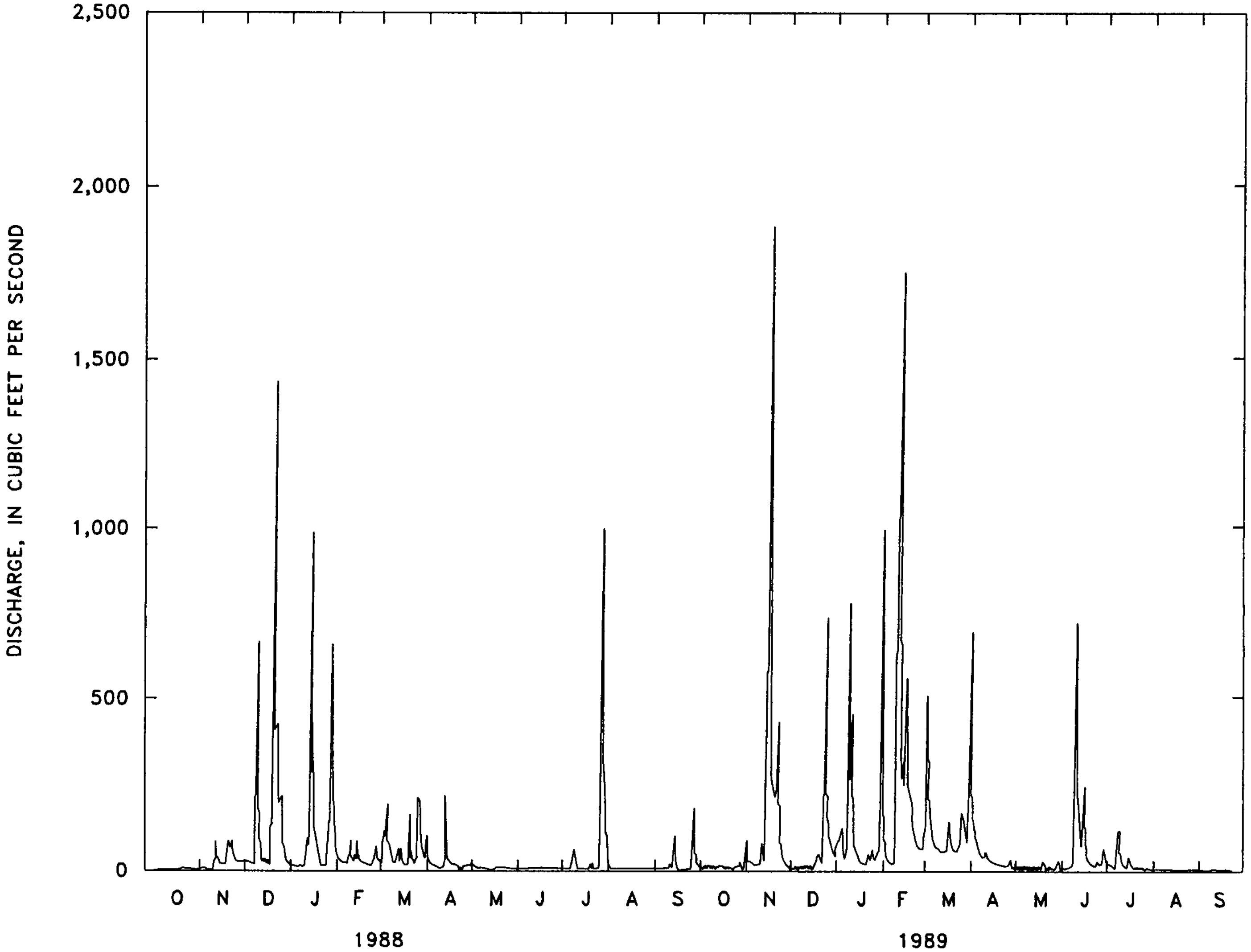

Figure 3.--Mean-daily discharge of South Reelfoot Creek (07026400), water years 1988 and 1989.

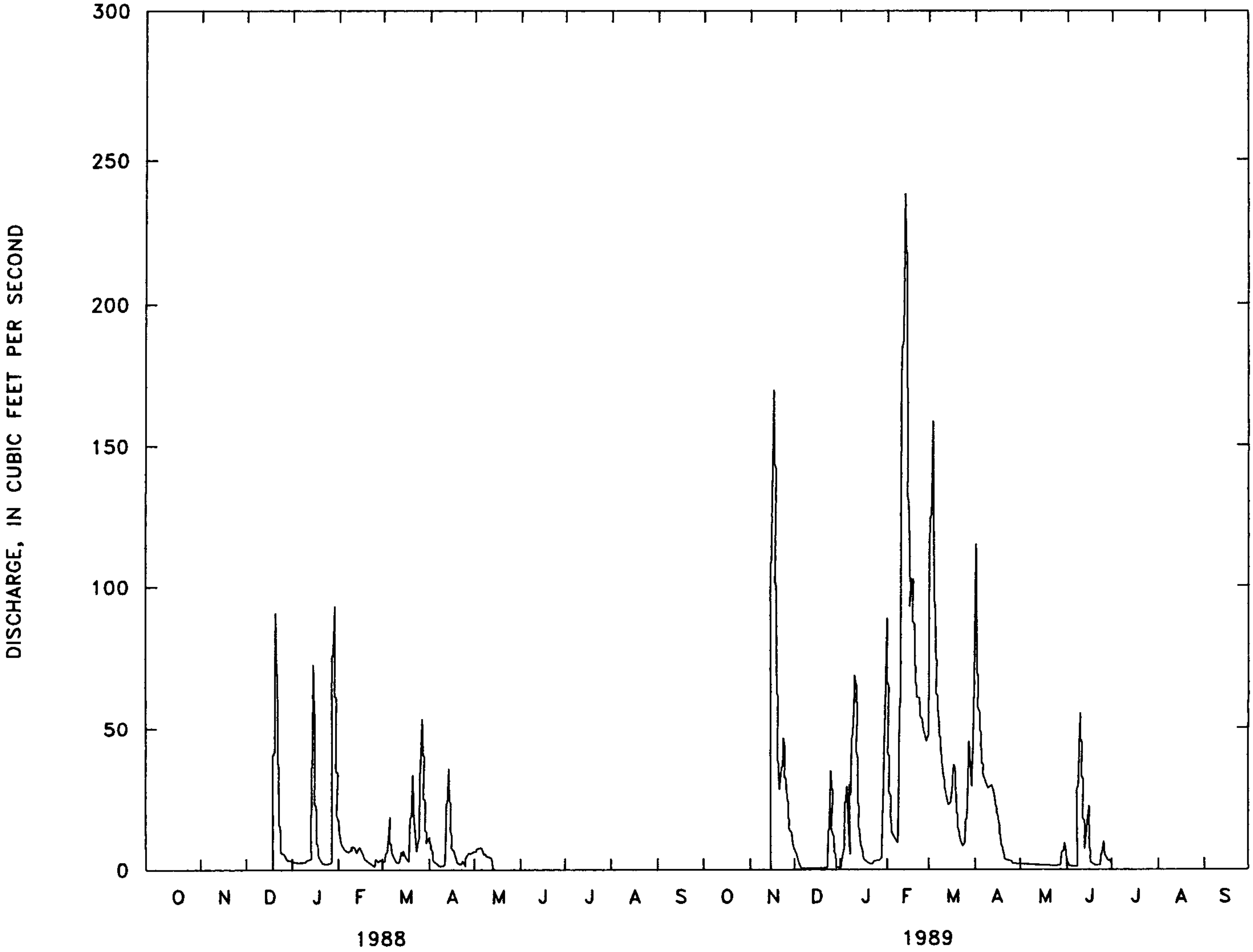

Figure 4.--Mean-daily discharge of Running Slough (07026640), water years 1988 and 1989.

Table 2.--*Total storm flow and base flow of North Reelfoot Creek, South Reelfoot Creek, and Running Slough, in cubic feet per second, for water years 1988 and 1989*

[Winter, October through March; Summer, April through September]

Water year and measurement period	North Reelfoot Creek		South Reelfoot Creek		Running Slough	
	Storm flow	Base flow	Storm flow	Base flow	Storm flow	Base flow
1988						
Winter	11,361	1,859	10,553	2,071	944	222
Summer	2,739	705	2,988	720	346	36
Total	14,100	2,564	13,541	2,971	1,290	258
1989						
Winter	38,215	2,463	19,443	3,335	4,726	116
Summer	6,331	1,121	3,728	1,754	1,121	15
Total	44,546	3,584	23,171	5,089	5,847	131

In the 1988 water year, storm runoff accounted for 85, 82, and 83 percent of total streamflow in North and South Reelfoot Creeks and Running Slough, respectively. In the 1989 water year, storm runoff generally accounted for a larger percentage of total streamflow: 93, 82, and 98 percent for North and South Reelfoot Creeks and Running Slough, respectively. For this study, a storm was defined as beginning with the first rise in stage and ending when the change in streamflow was less than 10 percent in 1 hour, or until the stage approached pre-storm level. Streamflow was assumed to consist entirely of baseflow when the hydrograph returned to the pre-storm level, or the change in streamflow was less than 10 percent in 1 hour.

NONPOINT-SOURCE POLLUTANTS

The water-quality data collected at the North and South Reelfoot Creek and Running Slough stations were used to evaluate the contributions of nonpoint-source pollutants to Reelfoot Lake by the three main tributaries. The water-quality data collected included suspended sediments, total kjeldahl nitrogen, total ammonia nitrogen, dissolved nitrite plus nitrate nitrogen, total phosphorus, and selected triazine herbicides.

Loads and Yields of Suspended Sediment and Nutrients

Daily storm-runoff and base-flow loads were computed for suspended sediment, total kjeldahl nitrogen, total ammonia nitrogen, dissolved nitrite plus nitrate nitrogen, and total phosphorus at the North and South Reelfoot Creek and Running Slough stations. Storm-runoff loads were computed with streamflow hydrograph and water-quality data-integration techniques described by Porterfield (1972) and with regression analyses. Loads were calculated with the integration techniques for storms for which enough samples were collected to adequately define the constituent chemographs. Regression equations that predict total daily constituent loads, using stream discharge as the independent variable, were used to compute constituent loads for the storms with few or no samples. Base-flow water-quality constituent loads were computed as the product of the mean constituent concentrations of all base-flow samples collected from a station during the study period and the base-flow volume for the period of computation. Herbicide loads were not computed because samples were not collected for every storm and no statistically significant relation was detected between herbicide concentration and streamflow; therefore, missing data could not be estimated.

Annual suspended-sediment and nutrient loads of North and South Reelfoot Creeks and Running Slough were calculated for the 1988 and 1989 water years (table 3). Records for North and South Reelfoot Creeks are considered good, while those for Running Slough are rated poor. This is because of the limited data to define a precise stage-discharge relation at the Running Slough gaging station. The total suspended-sediment load at the three stations for the study period was about 376,000 tons. South Reelfoot Creek had the largest sediment yield in both years. The mean suspended-sediment yield of South Reelfoot Creek for the study period was about 4.7 ton/acre/yr, which was 245 percent greater than the yield of North Reelfoot Creek and 1,500 percent greater than the yield of Running Slough. The suspended-sediment yield for 1989 was about 160 percent greater than the suspended-sediment yield for 1988, for North Reelfoot Creek and Running Slough, and was about 70 percent greater for South Reelfoot Creek (table 3). The increased suspended-sediment yield was a result of increased precipitation and surface runoff in the 1989 water year.

Mass-loading curves were constructed to compare the characteristics of suspended-sediment and nutrient yields of North and South Reelfoot Creeks and Running Slough. By plotting the cumulative monthly constituent yield (figs. 5-9) and cumulative inches of runoff, comparisons can be made between stations. Steeper curves indicate higher loadings.

The slopes of the suspended-sediment curves (fig. 5) show major differences between the three stations. Land use and topography appear to be the primary influences on erosion and suspended-sediment yields in the Reelfoot Lake basin. Most of the agricultural land in the Running Slough basin is relatively flat (0 to 2 percent slopes) and generates little surface runoff and suspended sediment. Both the North and South Reelfoot Creek basins have relatively steeply sloping agricultural row crop land; the South Reelfoot basin has a larger percentage of such land, in addition to steep, gullied lands that are susceptible to high erosion rates. About 80 percent of the total suspended-sediment load of the three streams was transported from October through March, the period when the agricultural land generally lacks vegetative cover and when most runoff occurs.

Table 3.--*Total storm-flow and base-flow loads of suspended sediment and nutrients of North Reelfoot Creek, South Reelfoot Creek, and Running Slough, in tons, for water years 1988 and 1989*

[Winter, October through March; Summer, April through September]

Constituent	Water year and time period	North Reelfoot Creek		South Reelfoot Creek		Running Slough	
		Storm-flow loads	Base-flow loads	Storm-flow loads	Base-flow loads	Storm-flow loads	Base-flow loads
Suspended sediment.	1988						
	Winter	31,360	658	71,320	1,440	612	27
	Summer	7,040	358	20,810	334	154	3
	Total	38,400	1,016	92,130	1,774	766	30
	1989						
	Winter	80,500	1,220	110,600	2,080	2,980	20
	Summer	18,500	714	23,470	750	593	3
	Total	99,000	1,934	134,070	2,830	3,573	23
Total ammonia nitrogen.	1988						
	Winter	7.37	2,19	5.44	0.35	0.62	0.11
	Summer	2.88	0.83	1.20	0.12	0.37	0.02
	Total	10.25	3.02	6.64	0.47	0.99	0.13
	1989						
	Winter	17.82	2.78	8.65	0.57	2.34	0.07
	Summer	5.46	1.26	1.59	0.28	0.76	0.00
	Total	23.28	4.04	10.24	0.85	3.10	0.07
Total kjeldahl nitrogen.	1988						
	Winter	36.10	6.63	33.94	3.51	3.44	0.81
	Summer	9.76	2.53	9.09	1.25	1.47	0.13
	Total	45.86	9.16	43.03	4.76	4.91	0.94
	1989						
	Winter	127.27	8.38	69.18	5.59	16.51	0.42
	Summer	29.97	3.83	7.60	2.91	3.97	0.04
	Total	157.24	12.21	76.78	8.50	20.48	0.46

Table 3.--*Total storm-flow and base-flow loads of suspended sediment and nutrients of North Reelfoot Creek, South Reelfoot Creek, and Running Slough, in tons, for water years 1988 and 1989*--Continued

[Winter, October through March; Summer, April through September]

Constituent	Water year and time period	North Reelfoot Creek		South Reelfoot Creek		Running Slough	
		Storm-flow loads	Base-flow loads	Storm-flow loads	Base-flow loads	Storm-flow loads	Base-flow loads
Dissolved nitrite plus nitrate nitrogen.	1988						
	Winter	13.47	1.79	9.29	1.19	1.26	0.13
	Summer	4.28	0.68	2.27	0.43	0.52	0.02
	Total	17.75	2.47	11.56	1.62	1.78	0.15
	1989						
	Winter	31.70	2.28	14.21	1.90	5.71	0.07
	Summer	15.52	1.04	5.35	0.98	1.67	0.02
	Total	47.22	3.32	19.56	2.88	7.38	0.09
Total phosphorus.	1988						
	Winter	15.45	1.08	9.00	0.71	1.13	0.31
	Summer	2.78	0.43	2.31	0.25	0.25	0.05
	Total	18.23	1.51	11.31	0.96	1.38	0.36
	1989						
	Winter	53.15	1.40	21.35	1.11	6.34	0.14
	Summer	9.93	0.62	3.38	0.59	1.13	0.01
	Total	63.08	2.02	24.73	1.70	7.47	0.15

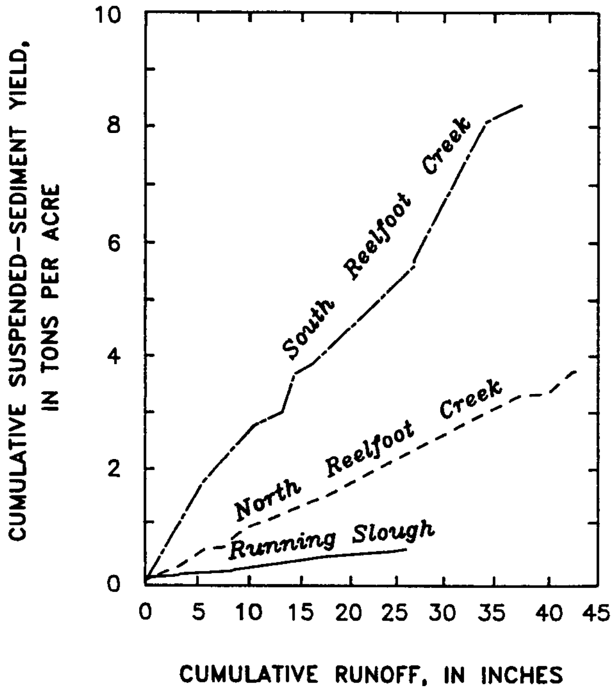

Figure 5.--Mass-accumulation curves for suspended-sediment yields, water years 1988 and 1989.

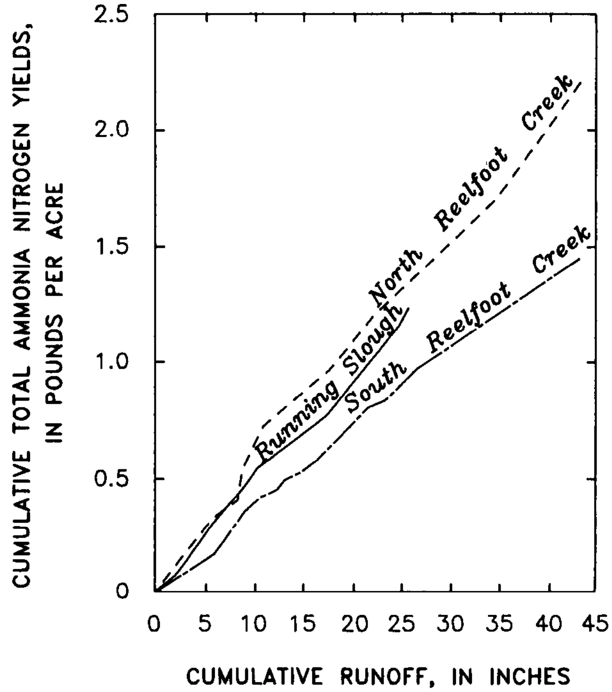

Figure 6.--Mass-accumulation curves for total ammonia nitrogen yields, water years 1988 and 1989.

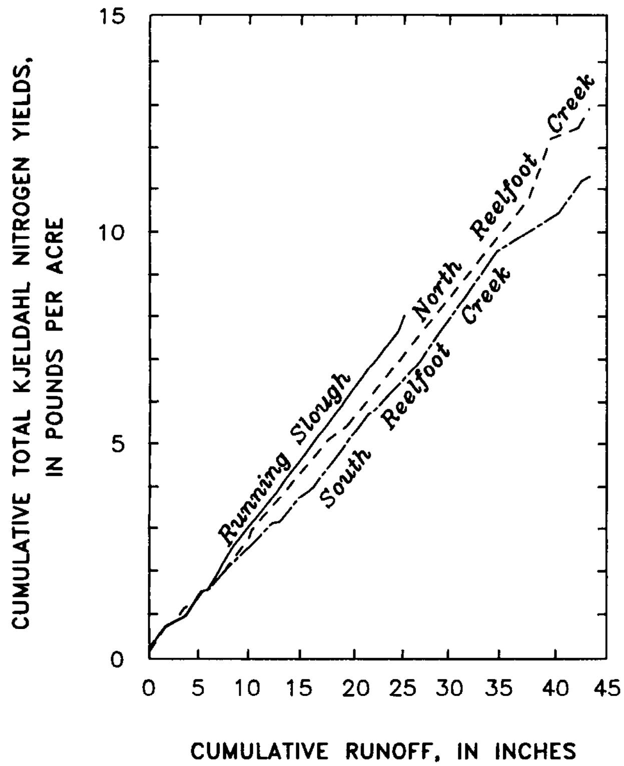

Figure 7.--Mass-accumulation curves for total kjeldahl nitrogen yields, water years 1988 and 1989.

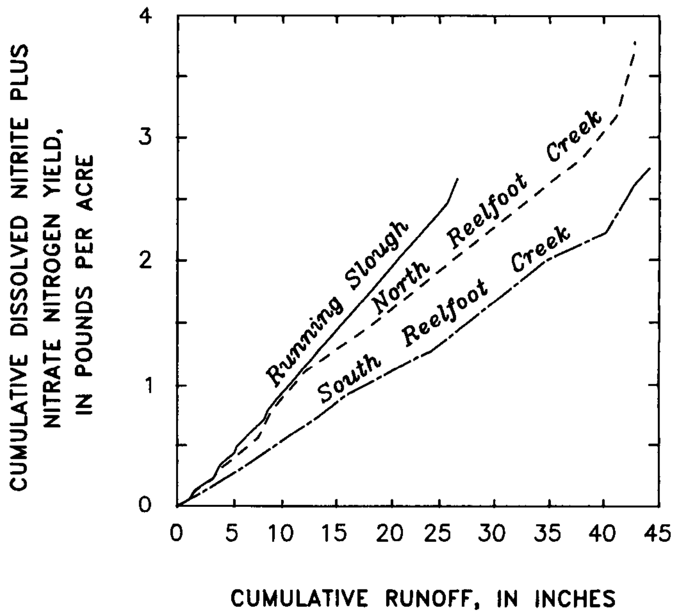

Figure 8.--Mass-accumulation curves for dissolved nitrite plus nitrate nitrogen yields, water years 1988 and 1989.

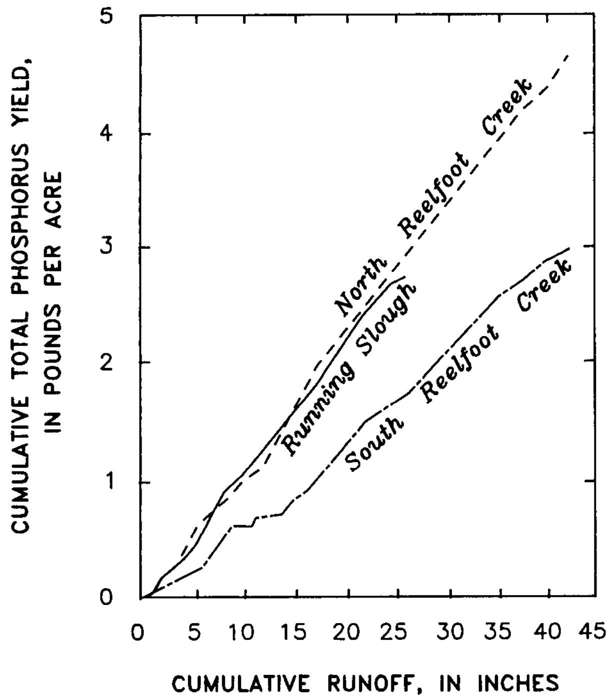

Figure 9.--Mass-accumulation curves for total phosphorus yields, water years 1988 and 1989.

About 98 percent of the total suspended-sediment load for the three streams was transported by storm runoff (table 3). Much of the suspended-sediment load at the three stations was transported by storm runoff in only a few days. During the December 24-31, 1987 storm, South Reelfoot Creek transported 33,800 tons of suspended sediment, which is 36 percent of the total annual load for the 1988 water year. North Reelfoot Creek transported 22,100 tons of suspended sediment during the February 13-16, 1989 storm, which is 22 percent of the total annual load for the 1989 water year. Running Slough transported 391 tons during the March 5-7, 1989 storm, which is 11 percent of the total annual load for the 1989 water year.

North Reelfoot Creek contributed more nitrogen and phosphorus to Reelfoot Lake than the other two tributaries during the study period (table 3). The total nitrogen load of North Reelfoot Creek for the study period was 295 tons; the total phosphorus load was 85 tons. North Reelfoot Creek nutrient yields were 8.2 lb/acre/yr of total nitrogen and 2.4 lb/acre/yr of total phosphorus. The nitrogen yield of North Reelfoot Creek was 21 percent greater than the yield of South Reelfoot Creek and 58 percent greater than the yield of Running Slough. The phosphorus yield from North Reelfoot Creek was 44 percent larger than the South Reelfoot Creek yield and 64 percent larger than the Running Slough yield.

The differences in nutrient yields of the three basins appear to result from differences in land use and topography. The North Reelfoot Creek basin has a larger percentage of row-crop acreage than the South Reelfoot Creek basin and, consequently, has more fertilizer application. A large percentage of the Running Slough basin is row-crop agricultural land. The relatively flat land (0 to 2 percent slopes) in the Running Slough basin generates little runoff; therefore, the nutrient yield from this basin is less than the nutrient yields of the North or South Reelfoot Creek basins.

Generally, the nutrient curves (figs. 6-9) are steeper for the Running Slough and North Reelfoot Creek basins than for the South Reelfoot Creek basin. The kjeldahl nitrogen curves are similar for all three stations (fig. 7). Relatively large concentrations of suspended solids (inorganic and organic) in South Reelfoot Creek are believed to be responsible for the larger concentrations of organic nitrogen than in the other basins. This concentration results in nearly equivalent yields of kjeldahl nitrogen per inch of runoff in all three basins.

Nutrient yields in the 1989 water year were substantially larger than in the 1988 water year (table 3). These larger yields were largely a result of increased precipitation and runoff in the 1989 water year. Total nitrogen yields (kjeldahl nitrogen and dissolved nitrite plus nitrate nitrogen) of 4.2, 4.9, and 2.2 lbs/acre were computed for the 1988 water year for North Reelfoot Creek, South Reelfoot Creek, and Running Slough, respectively. Total nitrogen yields of 12.2, 8.7, and 8.2 lbs/acre, roughly three times the values computed for the 1988 water year, were computed for the 1989 water year, respectively. The same trend was observed with total phosphorous. Total phosphorous yields of 1.1, 1.0, and 0.5 lbs/acre were computed for the 1988 water year for North Reelfoot Creek, South Reelfoot Creek, and Running Slough, respectively. Computed total phosphorous yields for the 1989 water year were 3.6, 2.1, and 2.2 lbs/acre, respectively.

Nutrient concentrations in the three tributaries were generally larger during the spring and summer months when fertilizer application was greatest, but most of the nutrient load was transported during the fall and winter months when precipitation, runoff, and erosion were greatest (table 3). During the study period, about 72 percent of the total nitrogen load, (kjeldahl nitrogen and dissolved nitrite plus nitrate nitrogen) and about 80 percent of the total phosphorus load of the three basins (calculated from table 3) were transported in storm runoff between the months of October and March.

Correlation Between Water-Quality Constituents and Instantaneous Stream Discharge

The concentration of suspended and dissolved constituents in a stream is related to many factors. Two of these factors are (1) the capacity of the stream to transport large concentrations of suspended sediment (including chemicals in the sediment matrix and those chemicals adsorbed onto the sediment) and (2) the volume of water available for diluting dissolved solids. Spearman's correlation coefficients rho measures the strength of an *increasing* (or decreasing) relation between two variables (water quality and streamflow) (table 4). The test is nonparametric, which means it is based on the ranks of the data; therefore, extreme outliers in the data have no more effect on the test outcome than any other observation. A rho value close to 1 (or -1) indicates a strong increasing (or decreasing) relation between the data. The indicated relations may be linear or nonlinear. The relations indicated by the correlation coefficients were tested for statistical significance at an alpha level of 0.05 (Conover, 1980). This level reflects only a 5-percent probability that a statistically significant correlation between water quality and stream discharge will not be indicated when in fact such a correlation does exist.

Significant relations between discharge and the specified constituents are examined and theorized as follows:

(1) Negative correlation between dissolved nitrite plus nitrate and discharge at North and South Reelfoot Creeks. Nitrite plus nitrate nitrogen concentrations characteristically exhibit negative correlation with surface runoff at high flows as a result of dilution of ground-water inflow, believed to be the source of these constituents. The intermittent nature of flow in Running Slough may be the cause for the deviation from this common relation.

(2) Positive correlation of suspended sediment and phosphorus with discharge.

Increases in discharge cause increasing soil erosion, re-suspension of bottom materials from the beds, and overland sediment transport, which result in increased suspended-sediment concentrations. Phosphorus is believed to be associated with the eroded soil that is transported to the streams during storms. Thus, increased concentrations

Table 4.--*Spearman's correlation coefficients for instantaneous discharge and concentrations of selected water-quality constituents in milligrams per liter*

[Coefficients in parenthesis indicate statistical significance at an alpha level of 0.05; positive (or negative) coefficients indicate that a positive (or negative) correlation exists between discharge and the constituent value]

Station name	Total ammonia nitrogen as N	Dissolved nitrite plus nitrate nitrogen as N	Total kjeldahl nitrogen as N	Total phosphorus as P	Suspended sediment
North Reelfoot Creek.	-0.2	(-0.5)	+0.003	(+0.3)	(+0.3)
South Reelfoot Creek.	+.02	(-.4)	+.1	(+.3)	(+.3)
Running Slough.	-.2	+.3	+.3	(+.6)	(+.5)

of phosphorus result from increased concentrations of sediment during high flows.

Concentrations of suspended and dissolved chemicals in a stream in an agricultural setting are related to other complex factors. Time since application, different rates of uptake by plants, and transformation and degradation of the original chemical compounds all affect constituent concentrations in streams. Additionally, samples taken at similar stream stages during the same or different storms, but on different parts of the storm hydrograph (rise, peak, or fall), will contain different concentrations of chemical constituents. This relation is attributed to many factors which include intensity of precipitation, antecedent soil concentrations, and seasonality. The analysis of the effects of these additional factors is beyond the scope of this report. No significant correlation was detected between herbicide concentrations and instantaneous discharge. This result is expected because herbicides degrade relatively rapidly after application.

Seasonality in Water Quality

Seasonality in the concentrations and loads of suspended and dissolved constituents in a stream in an agricultural setting is related to many factors including (1) precipitation and streamflow magnitude, (2) timing of agricultural chemical application and field cultivation, and (3) transformation or degradation of chemical constituents.

The average growing season in the study area is from April through September and, thus, most of the agricultural activity (chemical application and field cultivation) occurs during these months. The effect that this activity has on water quality in the three streams in the study area was evaluated with the Wilcoxon-Mann-Whitney rank sum test (Iman and Conover, 1983, p. 280-285). The test was used to evaluate statistically significant differences in water-quality constituent concentrations during the summer (April through September) and winter (October through March) months of the 1988 and 1989 water years. The results of the tests indicate whether mean constituent concentrations in a given stream during different times of the year are equivalent or different (table 5). The tests were performed at an alpha level of 0.05.

The test results indicate more significant differences exist between summer and winter constituent concentrations in North Reelfoot Creek and Running Slough than in South Reelfoot Creek. The differences may be influenced by more row-crop agriculture (56 and 72 percent) and more fertilizer application per acre in the North Reelfoot Creek and Running Slough basins than in the South Reelfoot Creek basin. Fertilizer application and less dilution of constituents by smaller volumes of surface runoff would be expected to cause summer concentrations to be greater than winter concentrations.

Most winter mean constituent concentrations were greater than the mean summer concentrations in Running Slough. Relatively little surface runoff occurs in the Running Slough basin during the most active period of agricultural activity (May through July). Storms that occur early in the winter effectively flush relatively large concentrations of nutrients from the soil.

Table 5.--*Results of Wilcoxon-Mann-Whitney tests for significant differences between mean water-quality constituent concentrations in storm runoff during the summer (April through September) and winter (October through March) months*

[S, mean constituent concentrations for the summer months; W, mean constituent concentrations for the winter months; >, greater than; <, less than; =, equal to; test results are reported for an alpha level of 0.05]

Station name	Total ammonia	Total kjeldahl nitrogen	Dissolved nitrite plus nitrate	Total phosphorus	Suspended sediment
North Reelfoot Creek.	S > W	S > W	S > W	S < W	S = W
South Reelfoot Creek.	S = W	S < W	S > W	S = W	S = W
Running Slough.	S > W	S < W	S < W	S < W	S = W

Most of the suspended-sediment and nutrient loads were transported in the three streams in the winter months. About 80 percent of the combined suspended-sediment load of the three streams was transported between October and March. About 70 to 75 percent of the combined nitrogen load and about 80 percent of the combined total phosphorus load were transported between October and March. Increased precipitation, surface runoff, and the lack of vegetative cover on many fields appear to cause the higher suspended-sediment and nutrient loads between October and March.

Triazine Herbicides

Storm runoff from agricultural areas may contain potentially harmful concentrations of herbicides. Water samples for herbicide analysis were collected from several storms at North Reelfoot Creek, South Reelfoot Creek, and Running Slough throughout the study period. A total of 93 water samples were collected at several points on the storm hydrograph (rise, peak, fall) to adequately characterize herbicide concentrations throughout the storms. Samples were analyzed for concentrations of 11 triazine herbicides. Breakdown products of the 11 triazine herbicides were not included in the analysis; consequently, the full effect of herbicide use on water quality in the study area cannot be determined.

Many of the samples collected contained herbicide concentrations that were below the level of detection (0.1 μg/L) for the analytical method (table 6) used and do not indicate the presence or absence of a herbicide. Herbicide concentrations below the level of detection were estimated from least-squares regressions between the log-transformed values above the level of detection and the normal quantiles. Less than values were assumed to follow the lower percentiles of a log-normal distribution fit of the data above the detection level (Gilliom and Helsel, 1984, p. 6-7).

Alachlor and atrazine were detected at concentrations above the detection limit in more samples than any other herbicides. Detectable levels of alachlor were found in 32 percent of the 93 water samples collected from the three streams during the study period. Twenty-six of the 29 samples collected between April and September contained detectable concentrations of alachlor. About 5 percent of the samples collected between October and March contained detectable levels of alachlor.

Detectable levels of atrazine were found in 93 percent of the 93 water samples collected from the three streams during the study period. All 29 samples collected between April and September contained detectable levels of atrazine. About 90 percent of the samples collected between October and March had concentrations above the detection limit. No significant correlation was observed between herbicide concentrations and instantaneous discharge.

Atrazine concentrations exceeded 3 μg/L in 17 percent of the samples collected: seven samples each from North and South Reelfoot Creeks and two samples from Running Slough. All the samples were collected from April through June; when most herbicides are applied in the study area. Two samples collected at North and South Reelfoot Creeks during a storm on April 18, 1988, had atrazine concentrations of 42 and 57 μg/L, respectively. A sample collected about 30 minutes later at South Reelfoot Creek had an atrazine concentration of 3.8 μg/L. The lower concentration of the second sample indicates that the storm may have effectively flushed atrazine that had recently been applied to nearby agricultural land. The relatively high concentrations of atrazine detected during the April 18 storm are believed to be representative of only a short period of the storm hydrograph.

Relatively rapid degradation of the herbicides and rapid transport in storm runoff are

Table 6.--*Statistical summary of herbicide analyses for samples from North Reelfoot Creek, South Reelfoot Creek, and Running Slough, water years 1988 and 1989*

[N, number of observations; concentrations in micrograms per liter; values given as < (less than) indicate that the concentration was below the level of detection for the analytical method used and do not indicate the presence or absence of a herbicide; level of detection for all analyses was 0.1 microgram per liter; "--", statistics not computed with less than three samples above the level of detection; statistics reported below the level of detection are estimates based on least-squares regressions between the logarithms of uncensored concentration observations and their standard normal quantiles]

			Percentiles			
Herbicide	N	N < level of detection	25th	Median 50th	75th	Maximum
			North Reelfoot Creek			
Alachlor	42	15	0.001	0.01	0.1	37
Atrazine	42	1	.2	.4	2.2	58
Cyanazine	41	31	.004	.02	.08	1.2
Metolachlor	40	34	.002	.007	.03	.5
Metribuzin	41	41	--	--	--	<.1
Prometon	42	41	--	--	--	.1
Prometryne	42	42	--	--	--	<.1
Propazine	42	39	.0002	.002	.009	.4
Simatryne	42	42	--	--	--	<.1
Simazine	42	41	--	--	--	.1
Trifluralin	42	33	.005	.02	.07	1.6
			South Reelfoot Creek			
Alachlor	38	26	0.0	0.01	0.1	45
Atrazine	38	2	.01	.3	1.6	57
Cyanazine	38	35	--	--	--	.1
Metolachlor	38	31	.004	.01	.05	.7
Metribuzin	38	33	.01	.03	.05	.2
Prometon	38	36	--	--	--	.2
Prometryne	38	38	--	--	--	<.1
Propazine	38	35	.0003	.002	.01	.6
Simatryne	38	38	--	--	--	.1
Simazine	38	37	--	--	--	.2
Trifluralin	38	35	.006	.02	.06	.7

Table 6.--*Statistical summary of herbicide analyses for samples from North Reelfoot Creek, South Reelfoot Creek, and Running Slough, water years 1988 and 1989*--Continued

Herbicide	N	N < level of detection	Percentiles 25th	Percentiles Median 50th	Percentiles 75th	Maximum
			Running Slough			
Alachlor	13	9	0.01	0.03	0.1	0.3
Atrazine	13	3	.06	.2	4.8	10
Cyanazine	13	13	--	--	--	.1
Metolachlor	13	8	.05	.1	.3	.7
Metribuzin	13	10	.1	.2	.4	.7
Prometon	13	11	--	--	--	.1
Prometryne	13	13	--	--	--	<.1
Propazine	13	10	--	--	--	.1
Simatryne	13	13	--	--	--	<.1
Simazine	13	10	--	--	--	.1
Trifluralin	13	9	.02	.04	.08	.2

believed to be the primary reasons that the largest concentrations were detected in the spring and early summer months. Most samples collected during the fall and winter months had concentrations near or below detection limits.

SUMMARY

Reelfoot Lake in western Tennessee is the largest natural lake in the State and is a valuable natural and economic resource to the region. The three major tributaries to Reelfoot Lake are the source of relatively large loads of suspended sediment and nutrients, in addition to smaller amounts of pesticides. A quantitative analysis was made of annual and storm-runoff contributions of suspended sediment, nutrients, and selected triazine herbicides to the lake by North and South Reelfoot Creeks and Running Slough.

Runoff was below normal during the 1988 water year and above normal during the 1989 water year. About 79 to 83 percent of the total study period runoff for the three streams occurred during the months of October through March. Storm runoff represented 82 to 95 percent of the total study period runoff in the three streams. Days with no flow were common occurrences during the late summer and early autumn months at all stations.

The South Reelfoot Creek basin contributed 4.7 ton/acre/yr of sediment during the study period. This yield is 245 percent greater than the sediment yield of North Reelfoot Creek and 1,500 percent greater than the yield of Running Slough. The larger sediment yield of South Reelfoot Creek is related to a larger percentage of relatively steeply sloping agricultural land in the South Reelfoot Creek basin. Most of the suspended sediment was transported by storm runoff. About 80 percent of the total suspended-sediment load for the study period was transported during October through March.

North Reelfoot Creek contributed 8.2 lb/acre/yr of total nitrogen and 2.4 lb/acre/yr of total phosphorus. These yields are 21 percent larger than the nitrogen yield and about 44 percent larger than the phosphorus yield from South Reelfoot Creek. The yield of North Reelfoot Creek is 58 percent greater than the nitrogen yield and 64 percent greater than the phosphorus yield of Running Slough. The higher yields in the North Reelfoot Creek basin are believed to be a result of more row-crop agriculture than in the other basins, in addition to relatively steeply sloping agricultural land. Ninety-one percent of the total nitrogen load and 95 percent of the total phosphorus load were transported by storm runoff.

Significant negative correlation was defined between nitrite plus nitrate concentrations and instantaneous discharge. This correlation appears to be the result of dilution at high flows. Significant positive correlation between suspended-sediment concentrations and discharge, and phosphorus concentrations and discharge were observed. Increased soil erosion, overland transport of sediments, and suspended-sediment concentrations result from increases in storm runoff. Phosphorus concentrations, which are associated with the eroded agricultural soils, also increase with increases in storm runoff.

Significant differences in mean nutrient concentrations for the summer months (April through September) and the winter months (October through March) were observed. Significant differences were more prevalent in the North Reelfoot Creek and Running Slough basins than in the South Reelfoot Creek basin. These differences appear to be the result of more row-crop agriculture in the North Reelfoot Creek and Running Slough basins than in the South Reelfoot Creek basin. Seventy to 75 percent of the total nitrogen load and 80 percent of the total phosphorus load for the study period were transported by the three streams during October through March.

Results of analyses of storm runoff for selected triazine herbicides indicate that concentrations of most herbicides are below the detection limit in most of the samples. Alachlor concentrations exceeded the detection limit (0.1 μg/L) in about 32 percent of the samples. Ninety percent of the samples collected during the summer months contained detectable concentrations of alachlor. Ninety-three percent of all samples contained detectable concentrations of atrazine. All 29 samples from the active agriculture period contained detectable levels of atrazine.

An atrazine concentration of 3 μg/L was exceeded in 16 samples. These samples were collected during April through September; the majority of the pesticide application in the study area occurs during this period. Two samples collected from North and South Reelfoot Creeks during a storm on April 18, 1988, contained atrazine concentrations of 42 and 57 μg/L, respectively. The high atrazine concentrations in these samples are representative of only a small part of the storm hydrograph, because samples collected 30 minutes later had concentrations of 3.8 μg/L.

REFERENCES CITED

Conover, W.J., 1980, Practical nonparametric statistics (2d ed.): New York, John Wiley and Sons, 493 p.

Denton, G.M., 1986, Summary of sedimentation studies of Reelfoot Lake, 1982-1986: Tennessee Department of Health and Environment, Office of Water Management, 35 p.

----- 1987, Water quality of Reelfoot Lake 1976-1986: Tennessee Department of Health and Environment, Office of Water Management, 81 p.

Denton, G.M., and Dobbins, W.R., editors, 1984, A clean lakes study: The Upper Buck Basin of Reelfoot Lake, Tennessee: Tennessee Department of Health and Environment, Division of Water Management, 145 p.

Feltz, H.F., Duncan, S.S., and Zepp, A., eds., 1985, 1986-87-88 National Water Quality Laboratory Services Catalog: U.S. Geological Survey Open-File Report 86-232.

Fishman, M.J., and Friedman, L.C., 1985, Methods for the determination of inorganic substances in water and fluvial sediments: Techniques of Water-Resources Investigations of the United States Geological Survey, Book 5, Chapter A1, 709 p.

FTN Associates, LTD., 1987, Water quality analysis task series 300 report, Reelfoot Lake, Tennessee: prepared for U.S. Environmental Protection Agency Region IV, Atlanta by FTN Associates, Inc., Little Rock, Ark.

Gilliom, R.J., and Helsel, D.R., 1984, Estimation of distribution parameters for censored trace-level water-quality data: U.S. Geological Survey Open-File Report 84-729, p. 24.

Guy, H.P., and Norman, V.W., 1970, Field measurements of fluvial sediment: Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter C2, 50 p.

Hoos, A.B., Tucci, Patrick, Bryan, B.A., and Carey, W.P., 1988, Hydrology of the Reelfoot Lake basin, Obion and Lake Counties, Tennessee, May 1984 to May 1987, and potential effects on proposed lake-level manipulations, *in* Final Environmental Impact Statement, Reelfoot Lake Water Level Management, Obion and Lake Counties, Tennessee and Fulton County, Kentucky: Atlanta, Georgia, U.S. Fish and Wildlife Service, Southeast Region, appendix D, p. 1-74.

Iman, R.L., and Conover, W.J., 1983, A modern approach to statistics: New York, John Wiley and Sons, 497 p.

Kung, Hsiang-te, and Garrett, J.W., 1986, Sediment loads in Reelfoot Creek watershed, Tennessee, *in* Mississippi Water Resources Conference, Jackson, Mississippi, 1986, Proceedings.

Lewis, M.E., Doyle, W.H., Jr., and Tucci, Patrick, in press, Quantitative hydrology of the Reelfoot Lake basin, Lake and Obion Counties, Tennessee, and Fulton County, Kentucky: U.S. Geological Survey Water-Resources Investigations Report 90-4013.

Lowery, J.F., Counts, P.H., Edminston, H.L., and Edwards, F.D., 1986, Water resources data, Tennessee, Water year 1985: U.S. Geological Survey Water-Data Report TN-85-1, 411 p.

Lowery, J.F., Counts, P.H., Edminston, H.L., and Edwards, F.D., 1987, water resources data, Tennessee, Water year 1986: U.S. Geological Survey Water-Data Report TN-86-1, 330 p.

Lowery, J.F., Counts, P.H., Edminston, H.L., and Edwards, F.D., 1988, Water resources data, Tennessee, Water year 1987: U.S. Geological Survey Water-Data Report TN-87-1, 438 p.

Lowery, J.F., Counts, P.H., Edwards, F.D., and Garrett, J.W., 1989, Water resources data, Tennessee, Water year 1988: U.S. Geological Survey Water-Data Report TN-88-1, 383 p.

Lowery, J.F., Counts, P.H., Edwards, F.D., and Garrett, J.W., 1990, Water resources data, Tennessee, water year 1989: U.S. Geological Survey Water-Data Report TN-89-1, 282 p.

Porterfield, George, 1972, Computation of fluvial-sediment discharge: Techniques of Water Resources Investigations of the United States Geological Survey, Book 3, Chapter C3, 66 p.

Robbins, C.H., 1985a, Hydrology of the Reelfoot Lake basin, Obion and Lake Counties, northwestern Tennessee: U.S. Geological Survey Water-Resources Investigations Report 85-4097, 29 p.

----- 1985b, Water budget and estimated suspended-sediment inflow for Reelfoot Lake, Obion and Lake Counties, northwestern Tennessee, May 1984-April 1985: U.S. Geological Survey Water-Resources Investigations Report 85-4284, 1 sheet.

Tennessee Department of Public Health, 1985, Reelfoot Lake-Rural clean water program project annual progress report: Division of Water Quality Control, 36 p.

U.S. Department of Agriculture, 1973, Soil survey of Obion County, Tennessee: U.S. Department of Agriculture, 60 p.

----- 1987, Soil survey of Fulton County, Kentucky: U.S. Department of Agriculture, 72 p.

U.S. Environmental Protection Agency, 1976, Report on Reelfoot Lake in the National Eutrophication Survey: U.S. Environmental Protection Agency, 36 p.

----- 1989, Health advisory summaries: U.S. Environmental Protection Agency.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., 1987, Methods for the determination of organic substances in water and fluvial sediments: Techniques of Water-Resources Investigations of the United States Geological Survey, Book 5, Chapter A3, 80 p.