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by

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1. INTRODUCTION

With national interest focused on man's ever increasing degradation of the waters in this nation, it is clearly evident that an accurate assessment of all parameters influencing water quality needs to be made. Moreover, nutrient levels and budgets reflecting eutrophication trends are important parameters in the overall factors effecting water quality in lakes and reservoirs. The ability to predict future eutrophication levels will greatly enhance the retardation of the eutrophication process. Through mathematical simulation of this process, eutrophication can be analyzed and intelligent decisions regarding water quality management can be made.

For the past three years an extensive eutrophication investigation has been underway to monitor and quantify the various phytoplankton nutrients, especially the soluble forms of nitrogen and phosphates entering and leaving Beaver Reservoir, a large impoundment in Northwest Arkansas. In May, 1969, Eley (1) published the first interim progress report summarizing the work accomplished during the initial phase of the eutrophication project. A sampling network and schedule was established for the drainage basin of Beaver Reservoir. Ammonia nitrogen, organic nitrogen and nitrate nitrogen, along with ortho and meta phosphates, were monitored and a nutrient budget estimated during the winter months from

October, 1968 to April, 1969. Eley (1) concluded that Beaver Reservoir had a seventy percent retention of entering nutrients during these months.

In June, 1969, Bennett (2) summarized the results of a water quality analysis of Beaver Reservoir. From June, 1968 to June, 1969, chemical, biological and physical parameters were evaluated and nutrient inventories were established at six different sampling stations throughout Beaver Reservoir.

In June, 1970, Feeny (3) established the nutrient fallout, through precipitation, into the benthic area of Beaver Reservoir and estimated that 1.5 million pounds of nitrogen and 0.12 million pounds of phosphorus had settled in the relatively shallow areas of the Reservoir since its impoundment in 1965.

In August, 1970, Bayliss (4) developed a kinetics model for ortho phosphates for the White River, one of the main tributaries of Beaver Reservoir. He concluded that the White River attributed approximately 600 lb./day of soluble orthophosphates and 325 lb./day of soluble nitrogen to Beaver during the low flow conditions in the summer.

In June, 1971, Stone (5) determined the water quality in the upper reaches of the White River and War Eagle Creek, the two main tributaries of Beaver. Land use, population and surface geology proved to have a pronounced effect on the water quality in these tributaries. Stone concluded that both streams contain sufficient soluble phosphates to support excessive algal growth.

2. PURPOSE AND SCOPE

The purpose of this investigation was threefold: 1) to determine the rate of nutrient accumulation in Beaver Reservoir, 2) to develop a eutrophication model to predict future eutrophication levels, and 3) to identify and isolate the major nutrient contributors of Beaver Reservoir.

Stream and reservoir sampling networks were established and monitored for the various forms of soluble nitrogen and phosphorus. A nutrient budget for Beaver Reservoir was determined, and the rate of nutrient accumulation calculated from the nutrient inflow and outflow rates.

The major nutrient contributors were based on the various types of runoff (i.e., agricultural and urban runoff occurring around the reservoir). These were ranked according to the amount contributed to total nutrient inflow.

Overall algal growth rates for the six Beaver Reservoir sampling stations were developed from a reservoir model equation. Various parameters which influence algal growth were regressed to establish an overall rate equation. Other prediction equations were established for regression for nutrient loadings from major nutrient contributors.

3. LITERATURE REVIEW

A review of the various aspects of eutrophication was made for several reasons. Paramount was the establishment of man's acceleration of the eutrophication process. At the same time, an overall assessment of the different nutrients and cultural influences associated with accelerated eutrophication was provided. Though much information is available on eutrophication, there is still controversy on this complex problem. Thus, the need for the proposed research was authenticated.

3.1. Eutrophication and Effects

Eutrophication is the natural aging process of a lake (6). As lakes age, they tend to accumulate nutrients and organic material which lead to a eutrophic or highly enriched stage. The eutrophication process defined as the enrichment due to nutrient accumulation causes a tremendous increase in biological activity, usually in the form of excessive algal blooms. The detrimental effects of increasing biological productivity have been outlined by Fruh (7) and include increase in turbidity and color, formation of algae scums and mattes, taste and odor problems, clogging of water filters causing shorter filter runs, rapid oxygen depletion in the hypolimnion during stratification, and general impairment of the esthetic enjoyment and recreational use of lakes and reserviors.

The alarming rate of eutrophication of natural and man-made lakes is well documented (8, 9, 10, 11, 12). Hasler (13) found that man induced fertilization hastens the onset of eutrophication and shortens the life span of lakes. Powers and Andrew (14) reported on man's influence on the aging process of the Great Lakes--and estimated in less than 150 years man has brought changes that would have taken many centuries under natural conditions. Clearly the acceleration of the eutrophication process by man-created fertilizers has emerged as one of the major problems of water resources management today.

3.2. Eutrophication - Nutrients

Much controversy surrounds the controlling nutrient in excessive algal blooms. However, the fertilizing elements noted most often as contributing to lake eutrophication are nitrogen and phosphorus, since they are significant components of domestic wastewater, certain industrial wastewater and agricultural and urban runoff. Of the major elements essential to algal growth, nitrogen and phosphorus are the ones most likely to be found in limited amounts in natural waters (15). Sawyer (16) reported that the limiting concentrations of inorganic nitrogen and phosphorus which may cause nuisance algal blooms to be 0.30 mg/l and 0.017 mg/l respectively. Fruh et al. (17) found that nitrogen and phosphorus have assumed prominence in nearly every lake investigation in relating nutrients to productivity.

Though sufficient evidence exists to substantiate nitrogen and phosphorus as major contributers to the eutrophication process, some investigators (18, 19, 20) believe too much emphasis is placed on these two nutrients with little attention being given to other substances. The limiting nutrient algal simulation is clearly a compley process with many interrelated factors whose roles in algal excitation are not completely understood.

3.3. Eutrophication - Sources

Primary sources of phytoplankton nutrients include wastewater effluents, agricultural runoff, forest runoff, urban drainage and rainfall (1). Since nitrogen and phosphorus appear to be the major controllable nutrients, their contents in these sources have been studied extensively.

3.3.1. Agricultural Runoff

Agricultural runoff may be the prominent contributer of nutrients to the tributary streams in many rural areas. Sylvester (21) and Sylvester and Seabloom (22) found that different soil types and water use have a pronounced effect on the concentrations of nitrogen and phosphorus in irrigation return flows, and increased amounts of fertilizers applied to the land are carried off in the drainage runoff. Sprenger (23) estimated that approximately sixty-three percent of the phosphorus and eighty-five percent of the nitrogen in the tributary-lake system he investigated originated from erosion, runoff and seepage from cultivated nearby farm land. Owens and Wood (44) found in the river they studied that fertilizers used in farming were the main source of nitrogen. Engelbrecht and Morgan (24) reported that farmland in Kaskaskia River Valley in Illinois contributed approximately 225 pounds of total phosphorus per year, per square mile of drainage area.

3.3.2. Urban runoff

With rapidly increasing urbanization in many areas, urban runoff can have a drastic effect on the water quality in streams, lakes and reservoirs. Weibel et al. (25) found that urban runoff contains approximately 0.8 lb. total phosphorus/acre/year and 8.5 lb. total nitrogen/acre/year while Woodward's (26) estimates were 0.94 lb. total phosphorus/acre/year and 7.8 lb. total nitrogen/acre/year. Sylvester (21) has shown that the nutrient concentrations in urban streams around Lake Washington to be significantly higher than concentrations in receiving lake water.

3.3.3. Rainfall

Rainfall is often excluded as a nutrient source because it cannot be controlled. However, rainfall does contain nutrients and can be of consequence in a nutrient budget. Carroll (26) reported that the nitrate and ammonia concentrations of rainfall across the United States ranged from 0.7 to 4.7 mg/l and from 0.05 to 2.2 mg/l, respectively. Weibel et al. (25) found that inorganic nitrogen as N in rainfall ranged from 0.02 to 1.4 mg/l in the Cincinnatti area. Phosphorus concentration in rainfall around Lake Erie ranged from 0.027 to 0.08 mg/l total phosphate as P which represent 2 to 6.5 percent of the total phosphate input load to Lake Erie (26). A three year study by Allen et al. (27) established that higher concentrations of inorganic nitrogen and phosphorus were found in rainwater taken over areas where intensive farming was taking place.

3.3.4. Forest Runoff

Data concerning the influence of natural forest drainage upon nutrient quantities is meager. However, Likens et al. (28) found that the nitrate nitrogen content rose from 0.9 to 53 mg/l in a stream located in a watershed deforested by clear cutting. Mathews and

Kowakzewski (29) estimated that leaf litter entering the Thames River contained approximately 0.19 g/sq m/yr of nitrogen.

3.3.5. Domestic Wastewater

Domestic wastewater is a source rich in nutrients, and conventional wastewater treatment does little or nothing to eliminate these unwanted pollutants. The total nitrogen and phosphorus concentration in domestic wastewater varies from 18 to 28 mg/l and 3.5 to 9 mg/l, respectively (30). The primary sources of nitrogen are feces, urine and waste food while the greatest contributors of phosphorus are human wastes and detergent phosphates. Fruh (31) and Missingham (32) reported the average content of nitrogen and phosphorus in domestic wastes being 9.7 lb./capita/year and 2.5 lb./capita/year, respectively.

3.4. Eutrophication Parameters

Several authors (7, 17, 34) have published articles containing the various parameters used to assess the degree of eutrophication of a body of water. Table I summarizes the major parameters and compares these parameters in an oligotrophic lake versus a eutrophic lake.

3.5. Eutrophication - Nutrient Budgets

Essential to the overall picture of eutrophication is a nutrient budget. In a nutrient budget, the concentrations of nitrogen and phosphorus for inlets, outlets and other contributing sources along with flow data are obtained. The amount of nutrients entering, remaining, and being discharged from a body of water are calculated. Thereby, the relative significance of the rate of nutrient accumulation coupled with

Table I. Eutrophication Parameters (7, 17, 34)

Parameter	Oligotrophic Lake	Eutrophic Lake
A. Hypolimnetic oxygen		
1. Dissolved	High, near saturation	depleted
2. Rate of consumption	0.04 to 0.33 mg/day/ sq cm (33)	0.05 to 0.14 mg/day/ sq cm (33)
B. Biological productivity		
1. Standing crop	minimal	large
2. Volumne of algae	minimal	large
3. Transparency	high	low
4. Chlorophyll in epilimmon	minimal	large amounts
5. Algal blooms	rare	frequent
6. Algal diversity	many species	few species
7. Characteristic algal groups	---	blue-green
Nutrient levels		
1. Nitrogen	very low	0.30 mg/1 (16)
2. Phosphorus	very low	0.017 mg/1 (16)
3. Other	---	---

the identification of nutrient sources can be determined so that the proper remedial action can be taken.

Relatively few lake nutrient budgets have been established. Rohlich and Lea (35) determined the nutrient budget for Lake Mendota, Wisconsin and estimated that 156 metric tons/year of nitrogen and 16.4 metric tons/year of phosphorus entered, while 41 metric tons/year of nitrogen and 11.6 metric tons/year left through the surface outlet. Sawyer et al. (36) constructed a partial nutrient budget for the lower Madison lakes. Other known nutrient budgets include Lake Tahoe by Mc-Gauhey (37) and Lake Washington by Edmondson (38).

Hutchinson (33) believed that nutrient inflow and outflow normally would balance closely in oligotrophic lakes, but not in eutrophic lakes. However, Williams (39) found that no apparent consistent relationship appears to exist between lake eutrophication and phosphorus retention capacity on water and sediments sampled from Wisconsin lakes.

3.6. Eutrophication - Models

The need for a means to predict eutrophic conditions in lakes and reservoirs is readily apparent. However, due to the many complex problems encountered, very little work has been accomplished in this area. Mitchell and Buzzell (40) developed a procedure to determine the potential and ecological significance of the addition of extraneous chemical and other matter to surface waters. Toro et al. (41) developed a dynamic model for estimating phytoplankton populations in estuaries. A multivariate approach to eutrophication analysis developed by Shannon and Brezonik (47) was used to determine cultural influences on the trophic states of a number of Flordia lakes. Probably the most advanced ecological model has been developed by Chen (42). This model providing resonable results, has been used to simulate the physical, chemical and biological behavior of a reservoir.

3.7. Summary of the Literature Review

Cultural eutrophication has become a major problem in many lakes and reservoirs across the nation. Nitrogen and phosphorus found in domestic and industrial wastewater, agricultural runoff and urban runoff appear to be the predominant nutrients which lead to eutrophic conditions and simulate nuisance algal blooms. Many factors have been used in assessing eutrophication and include algal productivity, hypolimnetic oxygen content and nutrient levels. Nutrient budgets and eutrophication modeling are essential to accurately assess cultural influences so that the proper remedial actions can be taken.

4. EXPERIMENTAL METHODS AND PROCEDURES

The initial field sampling networks and experimental methods and procedures used for the stream and reservoir surveys have been adequately described by foregoing investigators (1, 2). Their descriptions, method and procedures will be referenced where possible to eliminate unnecessary duplications. However, a general outline of the previous methods and procedures will be provided.

4.1. Description of Stream Sampling Stations

Originally 16 sampling stations were chosen to monitor the influx of nutrients into Beaver Reservoir. The selection procedure, location and site description of each sampling station appear in the "First Interim Progress Report" by Eley (1) and no further descriptions will follow. However, Figure 1 and accompanying list of monitoring stream sampling stations will acquaint the reader with their general location within the drainage basin of Beaver Reservoir.

Stream Sampling Stations

Station 1: West Fork White River at Fayetteville Pumphouse

Station 2: Town Branch of White River

Station 3: West Fork White River at Verna Lea Bridge

Station 4: White River at Sequoyah Dam

Station 5: White River at Wyman Bridge

Station 6: White River at White Midway

Station 7: Richland Creek

Station 8: Brush and Whitener Creeks

Station 9: War Eagle Creek

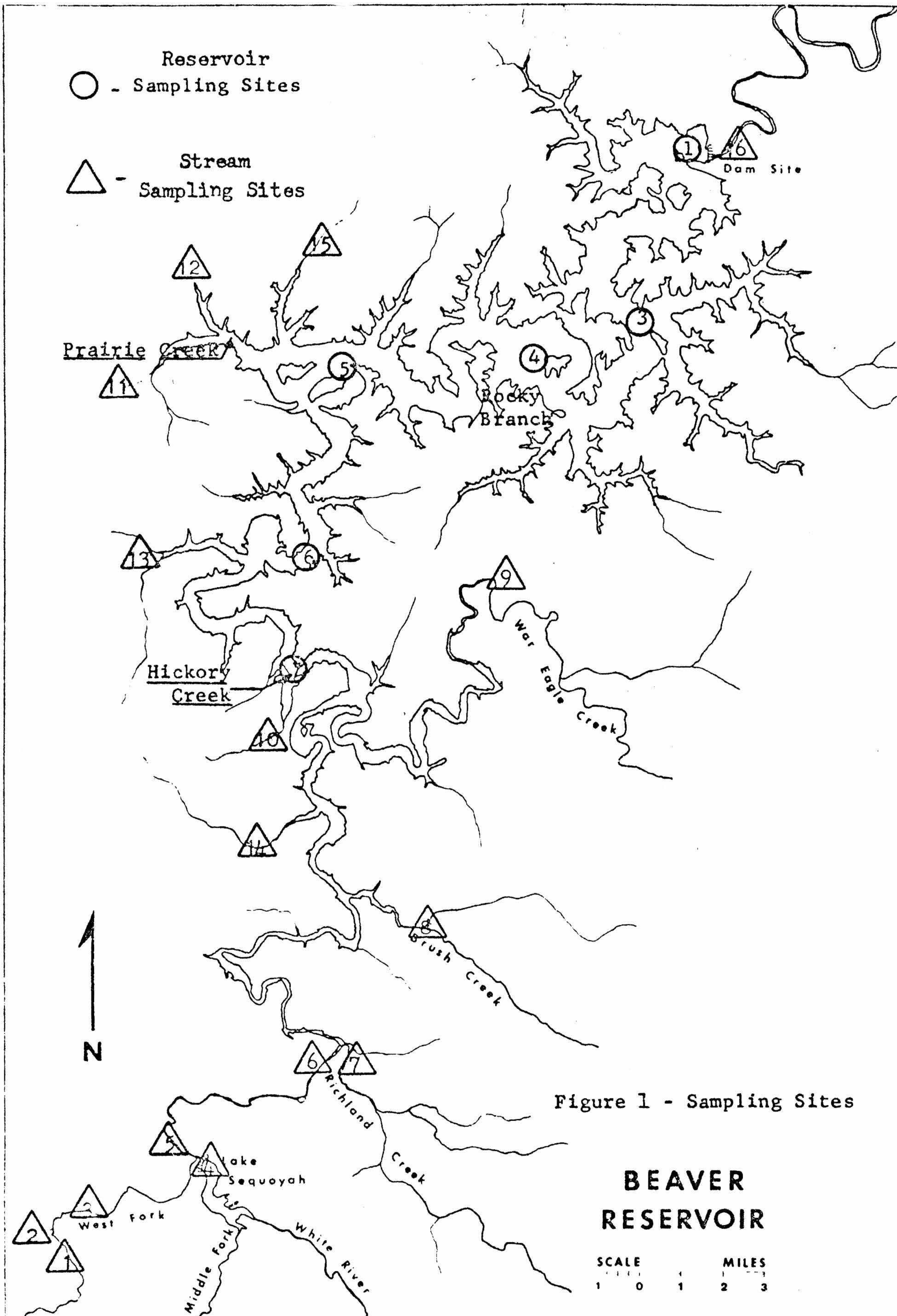

Figure 1 - Sampling Sites

Station 10: Hickory Creek

Station 11: Prairie Creek

Station 12: Avoca Creek

Station 13: Phillips Creek

Station 14: Friendship Creek

Station 15: Goose Creek

Station 16: White River below Beaver Dam

Although initially monitored by Eley (1) sampling at Hickory Creek (Station 10), Avoca Creek (Station 12), Phillips Creek (Station 13), Friendship Creek (Station 14) and Goose Creek (Station 15) was discontinued due to intermittent flow. The contributions from these creeks were minimal and were not included in the nutrient budget after April, 1969. The remaining sampling network contributes approximately 88 percent of the total runoff flowing into the reservoir and drain approximately 80 percent of the 1186 sq. mi. watershed.

4.2. Description of Lake Sampling Stations

Six major lake sampling sites were selected by Bennett (2) to determine the effect of the tributaries on the water quality at Beaver Reservoir. Again reference is made to Figure 1 and the following list of monitoring stations to acquaint the reader with their general location throughout the reservoir.

Lake Sampling Stations (2)

Station 1: Beaver Dam

Station 3: Big Clifty

Station 4: Rocky Branch

Station 5: Hurricane Alley

Station 6: Horseshoe Bend Area

Station 7: Hickory Creek Area

More specific information on each sampling station has been given by Bennett (2).

4.3. Stream Sampling Methods

Initially the network of the sixteen stream sampling stations was divided into two sectors, an east route and a west route. However, due to the elimination of five sampling stations the network was simplified into one route around the reservoir and sampled twice a month when possible.

The samples were always collected from flowing water using 300 ml polyethylene bottles which were immediately packed in ice to preserve chemical composition during transit.

4.4. Lake Sampling Methods

The six major lake sampling sites were monitored monthly when possible throughout the duration of the project. Chemical samples were collected by a Kemmerer water sampler and stored in polyethylene bottles. All samples were cooled when necessary to preserve chemical composition during transit. Algal samples were collected with a fifty foot Wisconsin net tow. These samples were stored in 30 ml clear plastic vials and preserved with Formalin for later laboratory enumeration and identification. More specific details on lake sampling methods can be found in Bennett's (2) thesis.

4.5. Laboratory Methods

Previous laboratory methods used by Eley (1) and Bennett (2) for the respective stream and lake sample analysis can be found in their referenced reports. Generally they followed procedures outlined in the 12th edition of Standard Methods (43). All subsequent lake and stream sample analysis followed the procedures and methods as outlined in Standard Methods (43). The following list outlines the parameters and methods used during the remainder of the investigation.

Parameter	Method
Phosphate-Ortho (as PO_4)	Stannous chloride (Coleman Model 14 Universal Spectrophotometer @ 690 u)
Phosphate-Total (as PO_4)	Stannous Chloride Modification (Coleman Model 14 Universal Spectrophotometer @ 690 u)
Ammonia Nitrogen (as NH_3-N)	Direct Nesslerization (Coleman Model 14 Universal Spectrophotometer @ 410 u)
Nitrate Nitrogen (as NO_3-N)	Brucine (Coleman Model 14 Universal Spectrophotometer @ 410 u)

The only modification of the methods and procedures listed above was in the usage of Hach's ammonium molybdate reagent #110 and Hach's Nesseler's reagent #151 in the determinations of phosphate and of animonia nitrogen, respectively. These reagents offered greater stability and consistency, and therefore, the spectrophotometer could be calibrated less frequently.

Due to the inconsistency of the Kjeldahl apparatus, the results obtained for organic nitrogen were ambiguous and inaccurate. Therefore, this parameter was eliminated after April, 1969, on all stream chemical samples and after June, 1969, on all reservoir chemical samples.

Algal identification and enumeration was accomplished by a Sedgewick Rafter Slide with a magnification of one hundred. The identified phytoplankton was placed into their respective phyla and reported in areal Standard units (ASU) per ml. More detailed information on algal methodology can be found in the previously referenced thesis by Bennett (2).

4.6. Synthesis of Streamflow Data

In order to establish monthly nutrient loading (lbs./day) being contributed through runoff from tributaries and drainage areas around the reservior, it was essential that the amount of runoff or streamflow be either measured or synthesized. Difficulty was encountered in determining streamflows because only three gaging sites monitor streamflow in the entire Beaver Watershed. They record flow contributed by 658 sq. mi. or 55.5 percent of the total drainage area and account for approximately 50 to 60 percent of the mean total inflow. Therefore, the remaining inflow had to be synthesized.

The ratio of area method as developed by Eley (1) was used to synthesize the remaining streamflow. Ideally, the ratio of the drainage area of the sampling station basin to drainage area of the gaged station multiplied by the streamflow at the gaged station gave the synthesized streamflow at the various sampling stations.

Outlined below is the procedure which was developed by Eley (1) and used to synthesize the necessary streamflows.

1) During the past fifteen years, the accumulative flow recorded for the U.S. G.S. gaging stations near Greenland,

Arkansas (West Fork White River) and War Eagle Creek near Hindsville, Arkansas, has averaged approximately 32 percent of the pre-impoundment flow near Rogers. Consequently, after adjusting this value to approximately 30 percent to allow for the probable average local inflow between Rogers and Beaver Dam, the amount of total runoff for Beaver watershed can be predicted.

2) With the West Fork White River at Greenland and the White River at Wyman Bridge being continuously gaged, the local runoff between the two sites is proportioned among the intervening basins according to respective areas.

3) The mean monthly inflow contributed by War Eagle is determined by multiplying the basin area (315 sq. mi.) by the mean cubic feet per second per sq. mi. observed at the gaging station near Hindsville.

4) The mean flows attributed by Richland Creek and by Brush Creek are approximated by multiplying the respective basin areas by the combined average cubic feet per second for the White River basin at Wyman and War Eagle basin.

5) The residual inflow to the reservoir predicted total minus that of White River, War Eagle Creek, Richland Creek, and Brush Creek is attributed to the remaining basins (245 sq. mi.) on the basis of their respective area.

It should be pointed out that this procedure was used only to synthesize the necessary streamflow for the sampling network and total basin inflow. Inflows from the areas not represented by the sampling network were not calculated since they were usually minimal.

The only deviation from this procedure was the determination of the streamflow at Prairie Creek (Station 11). Throughout the sampling period, the flow at this station appeared to be constant. Therefore, several streamflow measurements were made with a Gurley meter and averaged to determine the flow.

4.7. Classification of Sources

Each tributary and drainage area included in the Beaver watershed was classified as to major type of runoff or nutrient source. These classifications represent sources that have been mentioned as major contributors of nitrogen and phosphorus. Eley (1) developed the basin classifications based on site inspections and aerial topographical maps supplied by the Bureau of Sports Fisheries and Wildlife. Agricultural land, non-agricultural areas including forest land, municipal waste treatment, and urban areas were the major classifications. The respective drainage areas of the different basins were determined by using a planimeter on a U.S. Geological Survey map.

4.8. Rate of Nutrient Accumulation

The rate of nutrient accumulation was determined from the following general equation:

$$\text{Rate}_{(in)} - \text{Rate}_{(out)} = R_{(acc)}$$

$$CV_{(in)} - CV_{(out)} = \frac{d(CV)}{dt}$$

Where: C = Nitrogen or Phosphorus Conc., (lbs./vol.)
V = Volumetric Flow Rate, (vol./day)

Based upon the general equation, the nutrient inflow and outflow curves needed to be integrated to determine the respective rates.

The overall rates of nutrient inflow and outflow were determined by two methods. The first method involved graphical integration of the nutrient inflow and outflow curves. The nutrient inflow and outflow loadings were plotted and graphically integrated to determine the respective area under each curve, and thereby the overall rates were calculated. The second method involved plotting the nutrient inflow and outflow loadings. However, instead of graphically integrating, the curves were carefully cut out and weighed on a Mettler balance. Likewise a known area was cut out and weighed. The quotient of the two weights multiplied by the known area gave the areas under the respective curves. Again this established the inflow and outflow overall rates.

The second method which is considered more accurate was used to calculate the inflow and outflow rates. The first method was used for comparison purposes and provided a close check on the second method.

The monthly average daily rates or nitrogen and phosphorus accumulation was calculated by subtracting the overall nutrient outflow rate from the inflow rate and dividing by the number of monthly observations.

4.9. Eutrophication Model Development

The development of tremendous populations of phytoplankton and, in some instances, larger aquatic plants can be accelerated by the addition of nutrients which result from man's activities or natural processes. This fertilization provides an excess of inorganic nutrients resulting in the development of nuisance algal blooms. This sequence of events is commonly referred to as eutrophication. With this in mind, the eutrophication model of Beaver Reservoir was based on phytoplankton production rather than other eutrophication measurements.

4.9.1. Model Assumptions

The overall monthly algal rate equation was derived on the following bases:

1) The reservoir consists of six separate cells--one for each sampling station;
2) Each cell is somewhat separated by natural boundaries;

3) The volume used for each cell was based on a fifty foot depth at each reservoir sampling station;

4) Each cell is completely mixed;

5) There is no net algal flow from cell to cell;

6) There is no net flow of algae in or out of the reservoir; and

7) The model is the same for stratified and non-stratified reservoirs.

4.9.2. Algal Rate Equation Development

The following is the developed algal rate model equation for each cell:

$$\text{Rate}_{(\text{in})} + \text{Rate}_{(\text{production})} - \text{Rate}_{(\text{out})} = \text{Rate}_{(\text{accumulation})}$$

$$0 + R(i)\,V(i) - 0 = C(i)\,dV(i)/dt + V(i)\,dC(i)/dt$$

where: $R(i)$ = net rate of algal growth in cell i (ASU/ml. month)

$C(i)$ = concentration of total algal biomass in cell i (ASU/ml.)

$V(i)$ = volume of cell i (acre ft.)

t = time (month)

The resulting differential equation was solved for the monthly algal rate for each cell with the following approximation.

$$R(i) = \frac{C(i)^{t} + C(i)^{t+dt}}{V(i)^{t} + V(i)^{t+dt}} \quad \frac{V(i)^{t+dt} - V^{t}}{dt} + \frac{C(i)^{t+dt} - C(i)^{t}}{dt}$$

where: $C(i)^{t}$ = concentration of total algal biomass in cell i at month 1, 2, 3. . .

$C(i)^{t+dt}$ = concentration of algal in cell i at month 2, 3, 4. . .

$V(i)^t$ = volume of cell i at month 1, 2, 3. . .

$V(i)^{t+dt}$ = volume of cell i at months 2, 3, 4. . .

dt = change in time (month)

4.9.3. Algal Rate Calculations

To determine the monthly algal rates from the derived model equation, the following calculations were needed:

1) The various monthly algal phyla concentrations were added to determine the total monthly algal phyla concentration (ASU/ml) at each station or cell (Appendix C).

2) The volume of each cell had to be calculated for different reservoir elevations. The following procedure was used for each volume calculation:

a) Bennett (2) had determined the volume of each of the six sampling stations for a reservoir elevation of 1120 ft. (Appendix C). These volumes were used for the volumes of each of six cells at elevation 1120 ft.

b) The volume contained in a fifty foot deep section of the U.S. Corp of Engineer Reservoir capacity tables. Other similar fifty foot volume calculations for different reservoir elevations were determined.

c) With the fifty foot volume determined at elevation 1120 ft. as a base, the percentages of the different elevation fifty foot volumes to the base volume were calculated.

d) These percentages multiplied by the volume of each cell at an elevation of 1120 ft. gave the new volume of each cell at various elevations.

3) To determine which fifty foot volumes were needed, the mean monthly reservoir elevation was calculated to the nearest foot from U.S. Corp of Engineer monthly elevation data.

4.10. Basin Model Equation Procedure

A stepwise multiple regression computer program was used on the following variables to develop the basin model equations.

Equation No.	Dependent Variable	Independent Variable
1	Total Mean Monthly Nitrogen Inflow (lbs/day)	Inches of Rainfall per month
2	Mean Monthly Inflow of Nitrogen from Agricultural Runoff (lbs/day)	Inches of Rainfall per month
3	Mean Monthly Inflow of Nitrogen from Urban Runoff (lbs/day)	Inches of Rainfall per month
4	Total Mean Monthly Phosphorus Inflow (lbs/day)	Inches of Rainfall per month
5	Mean Monthly Inflow of Phosphorus from Agricultural Runoff (lbs/day)	Inches of Rainfall per month
6	Mean Monthly Inflow of Phosphorus from Urban Runoff (lbs/day)	Inches of Rainfall per month
7	Mean Monthly Inflow of Nitrogen from White River (lbs/day)	Inches of Rainfall per month
8	Mean Monthly Inflow of Phosphorus from White River (lbs/day)	Inches of Rainfall per month
9	Mean Monthly Inflow of Nitrogen from War Eagle Creek (lbs/day)	Inches of Rainfall per month
10	Mean Monthly Inflow of Phosphorus from War Eagle Creek (lbs/day)	Inches of Rainfall per month

4.11. Reservoir Model Equations Procedures

Likewise, the stepwise multiple regression computer program was used on the following variables to develop the reservoir model equations.

Equation No.	Dependent Variables	Independent Variables
1	Nitrate Concentration at Station 7 (mg/l)	Flow of the White River @ Station 6 and War Eagle @ Station 9 (cfs)
2	Total Phosphate Concentration at Station 7 (mg/l)	Flow of the White River @ Station 6 and War Eagle @ Station 9 (cfs)
3	Secchi Disc Transparancy (meters)	Flow of the White River @ Station 6 and War Eagle @ Station 9 (cfs)
4	Monthly Algal Rates at Station 7 (ASU/ml month)	a) Monthly Secchi Disc trans. @ Station 7 (m)
		b) Total monthly algal conc. @ Station 7 (ASU/ml)
		c) Average Concentration of Nitrogen @ Station 7 (mg/l)
		d) Average monthly concentrations of ortho phosphates at Station 7 (mg/l)
		e) Concentration of zooplantion @ Station 7 (ASU/ml)
5	Monthly Algal Rates for all cells (ASU/ml month) for summer months from May to November	a) Total monthly algal concentration for all stations (ASU/ml)
		b) Average monthly nitrogen concentration for all stations (mg/l)
		c) Average monthly ortho phosphate concentrations for all stations (mg/l)

Independent Variables

d) Monthly concentrations of Zooplankton for all stations (ASU/ml)

The following modification was used on the variables regressed for the development of the monthly algal rate prediction equation. Due to the averaging technique used in the approximate solution of the differential equation, derived for the monthly algal rates, it was necessary to use this same averaging technique on the independent regression variables. That is, the values of the variables for the first month were averaged with the second month's values. The second month's values averaged with the third month's values and so forth. These average variable values and corresponding rates were used for regression.

5. PRESENTATION OF RESULTS

The results from this investigation appear in the tables and figures of the five sections of this chapter. Each section contains results significant to the overall study.

5.1. Monthly Nutrient Concentrations

Data displayed in Tables II thru XII represent the mean monthly nutrient concentrations for each of the remaining eleven sampling stations. The mean values were calculated by simply averaging all concentrations (Appendix A) reported during that month. Several tables show "predicted values." Due to insufficient data collected for these months, these predicted values represent the average of known adjacent monthly mean nutrient concentrations.

5.2. Streamflow Analysis Results

Table XIII gives a detailed list of sampling locations, basin size and source of runoff for each sampling station represented by the sampling network. Likewise, Table XIV gives the same information for areas not represented by the network.

The area measurements plus the U.S.G.S. gaging records (Appendix B) were essential in estimating ungaged streamflow appearing in Table XV. This table lists the synthesized mean monthly streamflow for each sampling station. Included in Table XV is the nutrient inflow based on the White River at White Midway (Station 6), Richland Creek (Station 7), Brush and Whitener Creeks (Station 8), War Eagle Creek (Station 9) and Prairie Creek (Station 11) and inflow from reservoir surface rainfall which was converted to mean cfs from inches per month.

Table II. MEAN MONTHLY NUTRIENT CONCENTRATIONS FOR West Fork White River at Fayetteville Pumphouse (Station 1)

Month	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
May, 1969	0.08*	0.00	0.09*	1.58*
June	0.00	0.38	0.14	1.86
July	0.11*	0.38*	0.12	0.65
August	0.11*	0.75	0.43	3.50
September	0.23	0.25	0.52	3.08
October	0.69	0.73	0.14	2.04
November	0.41	0.02	0.05	0.94
December	0.28	0.13	0.02	0.06
January, 1970	0.20	0.23	0.00	0.02
February	0.62	0.05	0.02	0.05
March	0.51	0.00	0.03	0.31
April	0.73	0.35	0.22	0.26
May	0.60*	0.19*	0.14*	0.65*
June	0.47	0.04	0.05	1.04
July	0.03	0.00	0.04	1.09*
August	0.10	0.02	0.01	1.14
September	0.30	0.00	0.10	1.21
October	0.29*	0.00	0.07	0.61
November	0.28	0.28	0.00	0.00
December	0.39	0.29	0.02	0.75
January, 1971	0.24	0.10	0.03	1.17

*Predicted values

Table III. MEAN MONTHLY NUTRIENT CONCENTRATIONS FOR Town Branch of White River (Station 2)

Month	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
May, 1969	0.18*	0.60	0.14*	1.52*
June	0.07	1.00	0.16	2.40
July	3.11*	0.88	0.11	0.60
August	3.11*	0.75	0.58	3.10
September	6.15	0.45	0.75	3.26
October	1.11	1.48	0.29	1.89
November	1.08	0.20	0.09	0.88
December	0.47	0.69	0.11	0.06
January, 1970	0.19	0.13	0.00	0.03
February	0.78	0.33	0.00	0.06
March	0.55	0.10	0.11	0.38
April	0.43	0.27	0.23	0.32
May	0.38*	0.31*	0.13*	0.86*
June	0.33	0.36	0.03	1.40
July	0.50	0.00	0.03	1.36*
August	1.67	0.39	0.17	1.31
September	0.69	0.91	0.35	1.30
October	0.58*	0.37	0.09	0.69*
November	0.47	0.47	0.00	0.07
December	0.16	0.28	0.04	0.96
January, 1971	0.18	0.08	0.07	0.98

*Predicted values

Table IV. MEAN MONTHLY NUTRIENT CONCENTRATIONS FOR West Fork White River at Verna Lea Bridge (Station 3)

Month	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
May, 1969	0.07*	0.04	0.08*	1.32
June	0.01	0.88	0.14	1.88
July	0.53*	0.62*	0.12	0.57
August	0.53*	0.35	0.35	3.00
September	1.05	0.40	0.00	3.89
October	0.74	0.91	0.14	1.77
November	0.31	0.14	0.03	0.72
December	0.07	0.08	0.01	0.02
January, 1970	0.05	0.31	0.00	0.00
February	0.19	0.33	0.00	0.02
March	0.45	0.00	0.03	0.18
April	0.40	0.25	0.22	0.44
May	0.24*	0.17*	0.12*	0.81*
June	0.07	0.09	0.02	1.18
July	0.00	0.00	0.06	1.10*
August	0.08	0.05	0.02	1.01
September	0.91	0.42	0.26	1.37
October	0.49*	0.07	0.07	0.75*
November	0.07	0.07	0.00	0.12
December	0.07	0.00	0.01	0.87
January, 1971	0.10	0.00	0.00	0.85

*Predicted values

Table V. MEAN MONTHLY NUTRIENT CONCENTRATIONS FOR White River at Sequoyah Dam (Station 4)

Month	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates (mg/l PO_4) Ortho	Phosphates (mg/l PO_4) Total
May, 1969	0.08*	0.22	0.07*	1.40*
June	0.03	0.67	0.12	2.13
July	0.06*	0.39*	0.08	0.59
August	0.06*	0.10	0.25	3.10
September	0.12	0.00	0.02	2.86
October	0.83	0.91	0.18	1.56
November	0.15	0.15	0.03	0.99
December	0.00	0.00	0.00	0.01
January, 1970	0.07	0.40	0.00	0.00
February	0.30	0.31	0.00	0.05
March	0.49	0.17	0.08	0.18
April	0.00	0.45	0.19	0.31
May	0.03*	0.24*	0.11*	0.70*
June	0.06	0.02	0.02	1.08
July	0.03	0.00	0.01	1.28*
August	0.09	0.07	0.03	1.47
September	0.02	0.33	0.02	1.26
October	0.05*	0.00	0.08	0.64*
November	0.08	0.08	0.07	0.02
December	0.05	0.03	0.00	0.75
January, 1971	0.10	0.03	0.00	0.93

*Predicted values

Table VI. MEAN MONTHLY NUTRIENT CONCENTRATIONS FOR White River at Wyman Bridge (Station 5)

Month	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
May, 1969	0.13*	0.07	0.07*	1.47*
June	0.17	0.09*	0.11	2.30
July	0.12*	0.09	0.11	0.50
August	0.12*	0.10	0.13	2.88
September	0.08	0.34	0.00	3.15
October	0.87	0.74	0.18	1.96
November	0.19	0.82	0.01	0.96
December	0.01	0.08	0.00	0.06
January, 1970	0.07	0.19	0.00	0.00
February	0.24	0.58	0.00	0.04
March	0.50	0.00	0.12	0.20
April	0.00	0.39	0.20	0.30
May	0.14*	0.23*	0.11*	0.33*
June	0.28	0.06	0.02	0.35
July	0.03	0.00	0.00	0.89*
August	0.06	0.03	0.01	1.42
September	0.02	0.19	0.01	1.19
October	0.19*	0.55	0.08	0.64*
November	0.35	0.35	0.00	0.08
December	0.07	0.02	0.00	0.90
January, 1971	0.90	0.19	0.00	1.06

*Predicted values

Table VII. MEAN MONTHLY NUTRIENT CONCENTRATIONS FOR White River at White Midway (Station 6)

Month	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
May, 1969	0.41*	0.39	0.30*	1.88*
June	0.58	1.35	0.77	2.87
July	1.71*	1.14*	0.95	1.47
August	1.71*	1.14*	0.78*	4.15*
September	2.83	0.93	0.78*	6.83
October	0.89	1.23	0.60	1.65
November	0.62	0.39	1.18	1.53
December	0.13	0.40	0.91	0.94
January, 1970	0.32	0.13	0.19	0.19
February	0.35	0.50	0.40	0.44
March	0.47	0.00	0.12	0.19
April	0.00	0.29	0.41	0.69
May	0.06*	0.35*	0.54*	0.90*
June	0.11	0.40	0.66	1.10
July	0.22	1.52	2.50	3.02*
August	0.52	0.62	3.55	4.93
September	1.25	0.70	3.00	3.72
October	0.85*	0.57	0.97	2.00*
November	0.45	0.45	0.18	0.27
December	0.69	0.29	0.56	1.18
January, 1971	0.50	1.03	0.37	1.17

*Predicted values

Table VIII. MEAN MONTHLY NUTRIENT CONCENTRATIONS FOR Richland Creek at Goshen Twin Bridge (Station 7)

Month	Ammonia Nitrogen (mg/1 NH_3-N)	Nitrate Nitrogen (mg/1 NO_3-N)	Phosphates Ortho (mg/1 PO_4)	Phosphates Total (mg/1 PO_4)
May, 1969	0.01*	0.63	0.07*	1.32*
June	0.00	1.00	0.11	1.98
July	0.01*	0.50*	0.05	0.56
August	0.01*	0.00	2.05	2.05*
September	0.03	0.35	0.15	3.26
October	0.66	1.31	0.22	1.87
November	0.08	0.35	0.15	3.26
December	0.01	0.38	0.02	0.06
January, 1970	0.09	0.37	0.00	0.01
February	0.00	0.00	0.00	0.08
March	0.41	0.00	0.05	0.19
April	1.20	0.50	0.35	0.40
May	0.66*	0.40*	0.20*	0.73*
June	0.01	0.30	0.05	1.05
July	0.03	0.64	0.03	1.28*
August	0.83	0.39	0.82	1.51
September	0.19	0.95	0.48	1.59
October	0.13*	0.22	0.06	0.80*
November	0.07	0.07	0.00	0.00
December	0.12	0.41	0.02	0.79
January, 1971	0.03	0.40	0.01	1.10

*Predicted values

Table IX. MEAN MONTHLY NUTRIENT CONCENTRATIONS FOR Brush and Whitener Creeks (Station 8)

Month	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
May, 1969	0.06*	0.54	0.11*	0.75*
June	0.00	0.47*	0.11*	0.75*
July	0.00*	0.47*	0.08	0.75
August	0.00*	0.40	0.63	2.17*
September	0.00	0.53	0.06	3.58
October	0.69	0.58	0.10	1.93
November	0.27	0.40	0.02	1.10
December	0.09	0.12	0.01	0.02
January, 1970	0.29	0.37	0.00	0.00
February	0.00	0.24	0.00	0.05
March	0.48	0.37	0.06	0.18
April	0.00	0.38	0.19	0.23
May	0.01*	0.35*	0.12*	0.87*
June	0.02	0.31	0.04	1.50
July	0.28	0.68	0.01	1.75*
August	0.00	0.17	0.02	1.99
September	0.00	1.05	0.01	1.82
October	0.00*	0.35	0.07	0.92*
November	0.00	0.00	0.00	0.02
December	0.25	0.30	0.07	1.07
January, 1971	0.00	1.20	0.00	1.02

*Predicted values

Table X. MEAN MONTHLY NUTRIENT CONCENTRATIONS FOR War Eagle Creek at War Eagle (Station 9)

Month	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l No_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
May, 1969	0.01*	0.24	0.04*	1.38*
June	0.00	1.12	0.07	2.07
July	0.02*	0.56*	0.08	0.66
August	0.02*	0.00	1.20	1.71*
September	0.04	0.00	0.05	2.75
October	0.48	1.26	0.12	1.59
November	0.19	0.13	0.03	1.21
December	0.00	0.19	0.00	0.02
January, 1970	0.00	0.40	0.00	0.00
February	0.00	0.73	0.00	0.08
March	0.45	0.37	0.06	0.24
April	0.23	0.34	0.15	0.23
May	0.16*	0.36*	0.09*	0.90*
June	0.08	0.38	0.03	1.57
July	0.27	0.59	0.01	1.73*
August	0.01	0.01	0.02	1.88
September	0.00	0.51	0.01	1.46
October	0.03*	0.32	0.03	0.78*
November	0.05	0.05	0.00	0.10
December	0.25	0.39	0.01	0.97
January, 1971	0.05	0.38	0.00	1.13

*Predicted values

Table XI. MEAN MONTHLY NUTRIENT CONTRIBUTIONS FOR Prairie Creek (Station 11)

Month	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates (mg/l PO_4) Ortho	Phosphates (mg/l PO_4) Total
May, 1969	0.00*	1.46	0.07*	1.44*
June	0.00	1.48*	0.14	2.10
July	0.00*	1.48*	0.06	0.53
August	0.00*	1.50	0.03*	0.91*
September	0.00	0.55	0.00	0.91*
October	0.38	2.50	0.13	1.28
November	0.18	1.18	0.13	1.28
December	0.00	1.74	0.01	0.04
January, 1970	0.00	1.60	0.00	0.07
February	0.00	2.15	0.00	0.02
March	0.42	1.28	0.04	0.19
April	0.00	2.25	0.15	0.23
May	0.05*	2.00*	0.09*	0.66*
June	0.09	1.74	0.03	1.09
July	0.05	0.66	0.02	1.28*
August	0.00	1.60	0.04	1.46
September	0.00	0.81	0.00	1.35
October	0.19*	1.13	0.05	0.69*
November	0.37	0.37	0.02	0.03
December	0.03	2.00	0.00	0.83
January, 1971	0.00	1.92	0.00	0.97

*Predicted values

Table XII. MEAN MONTHLY NUTRIENT CONTRIBUTIONS FOR White River below Beaver Dam (Station 16)

Month	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
May, 1969	0.00*	0.28*	0.05*	0.94*
June	0.00	0.28*	0.08	1.47
July	0.00*	0.28*	0.05	0.36
August	0.00*	0.40	0.73	1.54
September	0.00	0.43	0.10	2.71
October	0.33	1.16	0.03	1.56
November	0.07	0.23	0.02	0.73
December	0.11	0.30	0.00	0.02
January, 1970	0.00	0.06	0.01	0.01
February	0.00	0.00	0.00	0.05
March	0.38	0.00	0.03	0.16
April	0.06	0.25	0.13	0.26
May	0.04*	0.24*	0.07*	0.31*
June	0.01	0.22	0.00	0.36
July	0.18	0.81	0.01	0.37*
August	0.01	0.31	0.02	0.38
September	0.00	0.03	0.00	0.44
October	0.16*	0.17	0.07	0.22*
November	0.33	0.33	0.05	0.05
December	0.05	0.20	0.03	0.21
January, 1971	0.00	0.00	0.00	0.15

*Predicted values

Table XIII. Drainage Areas and Major Source of Runoff for Tributaries of the Beaver Watershed (1)

Station	Location	Drainage Area (sq. mi.)	Source of Runoff
1	West Fork White River @ Fayetteville Pumphouse	100.2	Agricultural Land
2	Town Branch of White River	12.8	Urban Area
3	West Fork White River @ Verna Lea Bridge	113.0	
4	White River @ Sequoyah Dam	273.0	Agricultural Land
5	White River @ Wyman Bridge	396.0	Non-agricultural Area
6	White River @ Midway	406.0	Municipal sewage & Agricultural Land
7	Richland Creek @ Goshen Bridge	140.0	Agricultural Area
8	Brush and Whitener Creeks	45.0	Agricultural Area
9	War Eagle Creek @ War Eagle	310.0	Agricultural Area
10	Hickory Creek	-Discontinued-	
11	Prairie Creek	10.6	Non-agricultural Area
12	Avoca Creek near Avoca	-Discontinued-	
13	Phillips Creed	-Discontinued-	
14	Friendship Creek	-Discontinued-	
15	Goose Creek	-Discontinued-	

Table XIV. Drainage Areas and Sources of Runoff Not Represented by Sampling Network (1)

Location	Drainage Area (sq. mi.)	Source of Runoff
Total Area of Discontinued Stations	39.5	Forest Land
Southern Section		
Upper White River Adj. Lower End of Reservoir	23.5	Agricultural Area
South-Central Section		
Adj. Brush Creek, War Eagle Creek and Reservoir	19.0	Non-agricultural Area
Western Section		
Near Friendship and Hickory Creeks;	12.0	Non-agricultural Area
Near Phillips and Prairie Creeks	15.0	Forest Land
Northern Section		
Area from Goose Creek to Dam Site	32.0	Forest Land
Eastern Section		
Adj. North Clifty Creek	13.5	Forest Land
North Clifty Creek	15.5	Forest Land
Big Clifty Creek	15.5	Forest Land
East Fork Creek and Adj. Area	17.0	Forest Land
Central Section		
Little Clifty Creek	6.0	Forest Land
Area Between War Eagle Creek and Reservoir	26.0	Forest Land
Total Basin Area not Represented by Sampling Network	234.5	

Table XV. ACTUAL AND SYNTHESIZED MEAN MONTHLY STREAMFLOW FOR THE SAMPLING NETWORK (cfs)

Location	May 1969	June	July	August	September	October	November
1) West Fork White River @ Fayetteville Pumphouse	115	30	4.9	0.6	0.2	75	19.3
2) Town Branch of White River	14.7	3.8	0.6	0.1	0.0	9.6	2.5
3) West for White River @ Verna Lea Bridge	130	33.9	5.5	0.7	0.2	85	21.8
4) White River @ Sequoyah Dam	259	139	10.8	2.3	2.6	113	50
5) White River @ Wyman Bridge	400	176	16.8	3.0	2.8	206	73
6) White River @ White Midway	410	180	17.2	3.1	2.9	211	75
7) Richland Creek @ Goshen Bridge	121	43	9.5	3.9	5.0	77	31
8) Brush & Whitener @ Intersection	39	13.8	3.0	1.2	1.6	24.8	10
9) War Eagle Creek @ War Eagle	225	53	28.9	14.8	19.9	181	80
11) Prairie Creek	27.6	27.6	27.6	27.6	27.6	27.6	27.6
Total Inflow Due to Sampling Network	795	317	86.2	50.6	57	521.4	223.6
Inflow Due to Rainfall	125	195	78	43	55	252	40

Table XV (cont.) ACTUAL AND SYNTHESIZED MEAN MONTHLY STREAMFLOW FOR THE SAMPLING NETWORK (cfs)

Location	December	January 1970	February	March	April	May	June
1) West Fork White River @ Fayetteville Pumphouse	93	147	81	304	378	139	26.2
2) Town Branch of White River	11.9	18.8	10.3	38.9	48.3	17.7	3.3
3) West Fork White River @ Verna Lea Bridge	105	166	91	343	426	157	29.4
4) White River @ Sequoyah Dam	250	320	189	838	996	463	40.6
5) White River @ Wyman Bridge	365	500	288	1211	1460	633	73
6) White River @ White Midway	374	513	296	1242	1497	649	75
7) Richland Creek @ Goshen Bridge	107	179	106	390	502	235	35.7
8) Brush & Whitener Intersection	34.3	58	34	125	162	76	11.5
9) War Eagle Creek @ War Eagle	137	403	243	780	1082	547	101
11) Prairie Creek	27.6	27.6	27.6	27.6	27.6	27.6	27.6
Total Inflow Due to Sampling Network	729.9	1180.6	706.6	2564.6	3270.6	1534.8	350.8
Inflow Due to Rainfall	102	28	35	126	186	137	163

Table XV (cont.) ACTUAL AND SYNTHESIZED MEAN MONTHLY STREAMFLOW FOR THE SAMPLING NETWORK (cfs)

Location	July	August	September	October	November	December	January 1971
1) West Fork White River @ Fayetteville Pumphouse	1.0	0.0	163	33.3	88	102	135
2) Town Branch of White River	0.1	0.0	20.8	4.3	11.3	13	17.3
3) West Fork White River @ Verna Lea Bridge	1.1	0.0	184	37.6	100	114	153
4) White River @ Sequoyah Dam	2.5	3.3	368	128	136	402	373
5) White River @ Wyman Bridge	3.8	3.4	568	169	244	526	539
6) White River @ White Midway	3.8	3.4	582	174	250	540	553
7) Richland Creek @ Intersection	5.7	3.9	190	64	92	155	151
8) Brush & Whitener Intersection	1.8	1.2	61	20.4	29.5	50	48.6
9) War Eagle Creek @ War Eagle	22.3	14.5	396	149	215	275	247
11) Prairie Creek	27.6	27.6	27.6	27.6	27.6	27.6	27.6
Total Inflow Due to Sampling Network	61.2	50.6	1256.6	435	614.1	1047.6	1027.2
Inflow Due to Rainfall	15	68	363	346	95	101	106

For comparison purposes, Figure 2 depicts the mean monthly percentage of network runoff to total basin runoff. This averaged approximately 88 percent for May, 1969 to January, 1971.

5.3. Nutrient Source Contribution

Tables XVI and XVII summarize the nutrient loadings for the various tributaries and basins represented by the sampling network. The values for both nitrogen and phosphorus were calculated from the following equation:

N Loading (lbs/day) = 5.38 x streamflow (cfs) x nitrogen concentrations (mg/l)

P Loading (lbs/day) = 1.75 x streamflow (cfs) x total phosphate concentration (mg/l)

Rainfall contributions appearing in Table XVI were calculated from concentrations of 0.477 mg/l ammonia nitrogen and 0.265 mg/l nitrate nitrogen. These concentrations were found by Eley (1) to be representative for this area. Phosphorus concentrations in rainfall in this area were negligible; therefore, rainfall phosphorus contributions were not calculated for this investigation.

Tables XVIII and XIX give estimates of mean monthly nutrient contributions from the various sources within the Beaver drainage area. The different contributions were determined by distributing the nutrient loading in Tables XVI and XVII based on source classifications of Table XIII. Figures 3 and 4 illustrate the mean monthly percentage that the two major sources contribute to total nutrient inflow of sampling network. Table XX shows the ranking of the various nutrient sources based percentage contributed to the total nutrient inflow from October, 1968 to January, 1971.

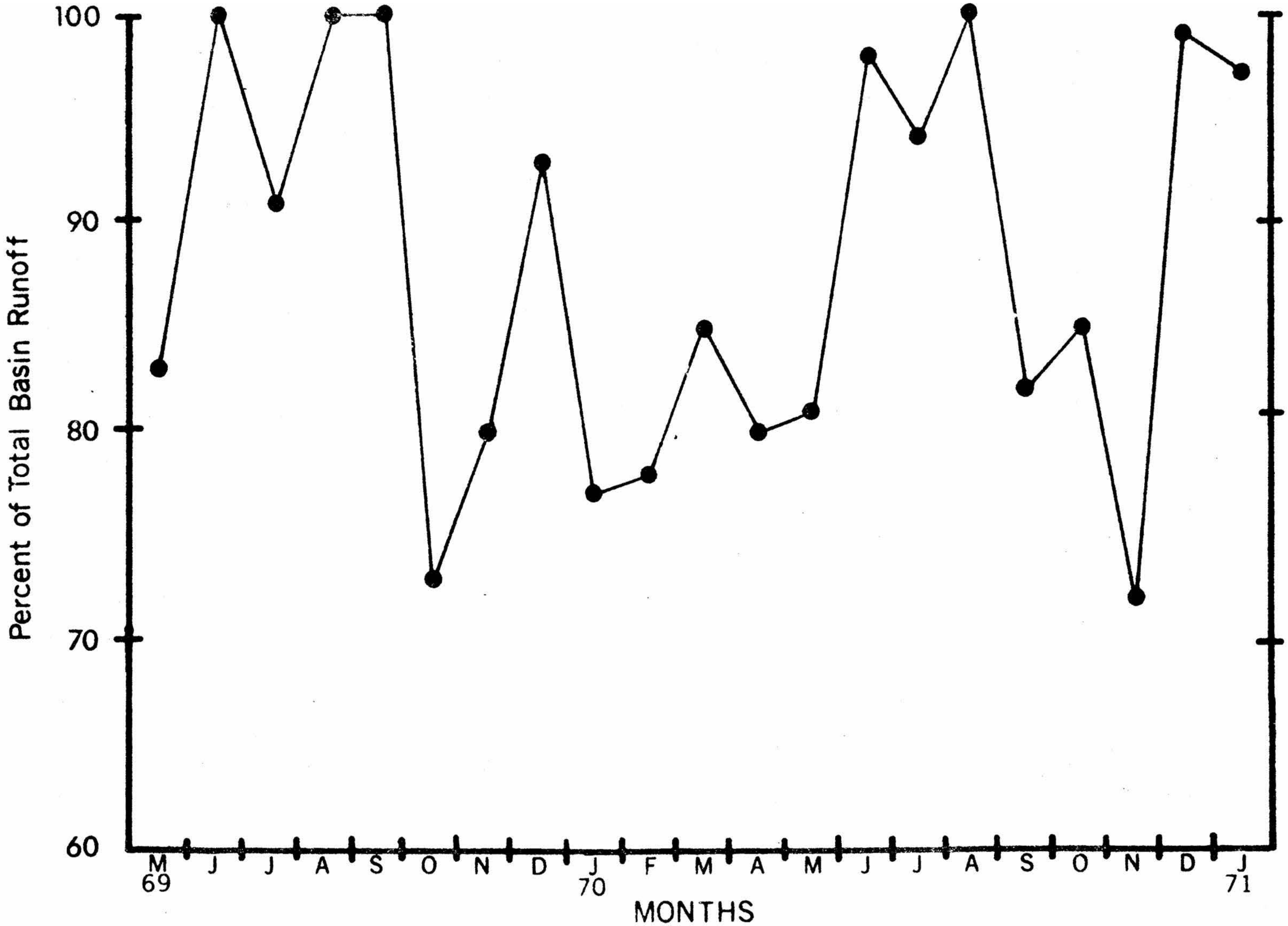

Figure 2 Percent of Total Basin Runoff Contributed by Sampling Network

Table XVI. NUTRIENT LOADING FOR THE WHITE RIVER DRAINAGE SYSTEM OF BEAVER RESERVOIR
Ammonia and Nitrate Nitrogen (lbs./day)

Location	May 1969	June	July	August	September	October	November
1) West Fork White River @ Fayetteville Pumphouse	50	61	13	3	0	575	45
2) Town Branch of White River	62	22	13	2	1	134	17
3) West Fork White River @ Verna Lea Bridge	77	162	34	3	1	753	53
4) White River @ Sequoyah Dam	418	524	26	2	2	1062	80
5) White River @ Wyman Bridge	430	246	19	4	6	1783	398
6) White River @ White Midway	1765	1874	373	377	426	2407	486
7) Richland Creek @ Goshen Bridge	418	231	26	0	10	819	85
8) Brush & Whitener Creeks	126	35	8	3	5	170	36
9) War Eagle Creek @ War Eagle	302	318	90	2	4	1697	137
11) Prairie Creek	217	220	220	223	82	428	202
Rainfall Contributions	498	776	312	170	218	1007	159
Nutrient Inflow	3327	3454	1029	774	745	6527	1105
Nutrient Outflow	2776	1424	2831	3215	1841	5515	1837

Table XVI (cont.) NUTRIENT LOADING FOR THE WHITE RIVER DRAINAGE SYSTEM OF BEAVER RESERVOIR
Ammonia & Nitrate Nitrogen (lbs./day)

Location	December	January 1970	February	March	April	May	June
1) West Fork White River @ Fayetteville Pumphouse	206	341	291	835	2196	590	72
2) Town Branch of White River	74	32	62	136	182	66	12
3) West Fork White River @ Verna Lea Bridge	85	322	254	831	1490	345	25
4) White River @ Sequoyah Dam	0	808	622	2975	2412	672	17
5) White River @ Wyman Bridge	176	700	1272	3258	3064	1260	133
6) White River @ White Midway	1066	1242	1352	3140	2336	1432	362
7) Richland Creek @ Goshen Bridge	224	444	0	861	4596	1342	60
8) Brush & Whitener Creeks	39	205	44	574	330	147	20
9) War Eagle Creek @ War Eagle	191	866	954	3441	3318	1529	251
11) Prairie Creek	258	238	319	252	334	304	272
Rainfall Contributions	408	113	138	503	740	548	648
Nutrient Inflow	2185	3107	2807	8771	11654	5302	1612
Nutrient Outflow	2089	600	0	732	1311	575	418

Table XVI (cont.) NUTRIENT LOADING FOR THE WHITE RIVER DRAINAGE SYSTEM OF BEAVER RESERVOIR
Ammonia & Nitrate Nitrogen (lbs/day)

Loading	July	August	September	October	November	December	January 1971
1) West Fork White River @ Fayetteville Pumphouse	0	0	263	52	266	511	248
2) Town Branch of White River	0	0	179	22	57	31	24
3) West Fork White River @ Verna Lea Bridge	0	0	1315	113	75	43	82
4) White River @ Sequoyah Dam	1	3	692	35	117	173	261
5) White River @ Wyman Bridge	36	2	641	674	920	255	3163
6) White River @ White Midway	328	447	6106	1327	1212	2845	4551
7) Richland Creek @ Goshen Bridge	21	25	1164	120	69	442	349
8) Brush & Whitener Creeks	9	1	344	38	0	147	313
9) War Eagle Creek @ War Eagle	103	2	1086	280	116	946	571
11) Prairie Creek	105	238	120	196	110	301	285
Rainfall Contributions	61	272	1447	1330	379	401	421
Nutrient Inflow	627	983	10267	3341	1886	5083	6491
Nutrient Outflow	8336	3300	123	1163	6569	3373	0

Table XVII. NUTRIENT LOADING FOR THE WHITE RIVER DRAINAGE SYSTEM OF BEAVER RESERVOIR
Phosphate phosphorus (lbs/day)

Location	May 1969	June	July	August	September	October	November
1) West Fork River @ Fayetteville Pumphouse	319	98	6	4	1	269	32
2) Town Branch of White River	39	16	1	0	0	32	4
3) West Fork White River @ Verna Lea Bridge	301	112	6	4	1	214	28
4) White River & Sequoyah Dam	636	520	11	12	13	311	86
5) White River @ Wyman Bridge	1032	711	15	15	15	708	124
6) White River @ White Midway	1354	909	154	156	176	611	202
7) Richland Creek @ Goshen Bridge	281	150	9	13	29	254	53
8) Brush & Whitener Creeks	51	18	4	5	10	84	19
9) War Eagle Creek @ War Eagle	545	192	33	44	96	506	170
11) Prairie Creek	70	102	26	44	44	62	62
Nutrient Inflow	2301	1370	226	262	355	1517	506
Nutrient Outflow	3041	2439	1188	4039	3787	1884	1458

Table XVII (cont.) NUTRIENT LOADING FOR THE WHITE RIVER DRAINAGE SYSTEM OF BEAVER RESERVOIR
Phosphate Phosphorus (lbs/day)

Location	December	January 1970	February	March	April	May	June
1) West Fork White River @ Fayetteville Pumphouse	10	5	7	112	172	158	48
2) Town Branch of White River	1	1	1	26	27	27	8
3) West Fork White River @ Verna Lea Bridge	4	0	3	108	329	223	61
4) White River @ Sequoyah Dam	4	0	17	265	542	569	77
5) White River @ Wyman Bridge	38	0	20	425	769	367	45
6) White River @ White Midway	617	186	268	414	1814	1026	308
7) Richland Creek @ Goshen Bridge	11	3	15	130	353	302	66
8) Brush & Whitener Creeks	1	0	3	40	65	116	30
9) War Eagle Creek @ War Eagle	7	0	34	329	437	864	279
11) Prairie Creek	2	3	1	9	11	32	53
Nutrient Inflow	638	193	321	922	2680	2339	736
Nutrient Outflow	33	0	85	101	359	208	214

Table XVII (cont.) NUTRIENT LOADING FOR THE WHITE RIVER DRAINAGE SYSTEM OF BEAVER RESERVOIR
Phosphate Phosphorus (lbs/day)

Location	July	August	September	October	November	December	January 1971
1) West Fork White River @ Fayetteville Pumphouse	2	0	346	36	0	134	278
2) Town Branch of White River	0	0	48	5	1	22	30
3) West Fork White River @ Verna Lea Bridge	2	0	442	49	21	175	228
4) White River @ Sequoyah Dam	6	9	813	144	5	529	609
5) White River @ Wyman Bridge	6	8	1186	190	34	832	1004
6) White River @ White Midway	154	123	3801	610	360	1118	1136
7) Richland Creek @ Goshen Bridge	13	10	530	89	0	215	292
8) Brush & Whitener Creeks	6	4	195	33	1	94	87
9) War Eagle Creek @ War Eagle	68	48	1014	203	38	468	490
11) Prairie Creek	62	71	65	33	1	40	47
Nutrient Inflow	302	256	5605	969	400	1935	2051
Nutrient Outflow	1017	1279	588	253	0	925	694

Table XVIII. ESTIMATE OF MEAN MONTHLY NITROGEN CONTRIBUTIONS FROM VARIOUS SOURCES REPRESENTED BY NETWORK
Ammonia & Nitrate Nitrogen

Month	Agricultural Land (lbs/day)	Non-Agricultural Land (lbs/day)	Urban Runoff (lbs/day)	Municipal* Waste (lbs/day)	Rainfall+ (lbs/day)
May, 1969	1989	217	62	561	498
June	1961	220	22	475	776
July	110	220	13	373	312
August	3	223	2	377	170
September	18	82	1	426	218
October	4393	428	134	566	1007
November	241	202	17	486	159
December	848	258	74	596	408
January, 1970	2147	238	32	577	113
February	1884	319	62	405	138
March	7225	252	136	655	503
April	9642	334	182	756	740
May	4014	304	66	370	548
June	318	272	12	362	648
July	133	105	0	328	61
August	28	238	0	447	272
September	7834	120	179	687	1447
October	719	196	22	1024	1380
November	340	110	57	1000	379
December	3676	301	31	674	401
January, 1971	4583	285	24	1178	421

*Fayetteville Pollution Control Plant Records
+Based on Reservoir Surface Rainfall

Table XIX. ESTIMATE OF MEAN MONTHLY PHOSPHORUS CONTRIBUTIONS FROM VARIOUS SOURCES REPRESENTED BY NETWORK
Total Phosphate Phosphorus

Month	Agricultural Land (lbs/day)	Non-Agricultural Land (lbs/day)	Urban Runoff (lbs/day)	Municipal* Waste (lbs/day)
May, 1969	1960	70	39	232
June	1058	102	16	195
July	46	26	1	154
August	62	44	0	156
September	134	44	0	176
October	1189	62	32	234
November	239	62	4	201
December	388	2	1	246
January, 1970	2	3	1	186
February	51	1	1	268
March	502	9	26	385
April	2434	11	27	207
May	1968	32	27	812
June	367	53	8	308
July	86	62	0	184
August	62	71	0	123
September	5195	65	48	297
October	552	33	5	378
November	37	1	1	360
December	1658	40	22	214
January, 1971	1700	47	30	274

*Fayetteville Pollution Control Plant Records

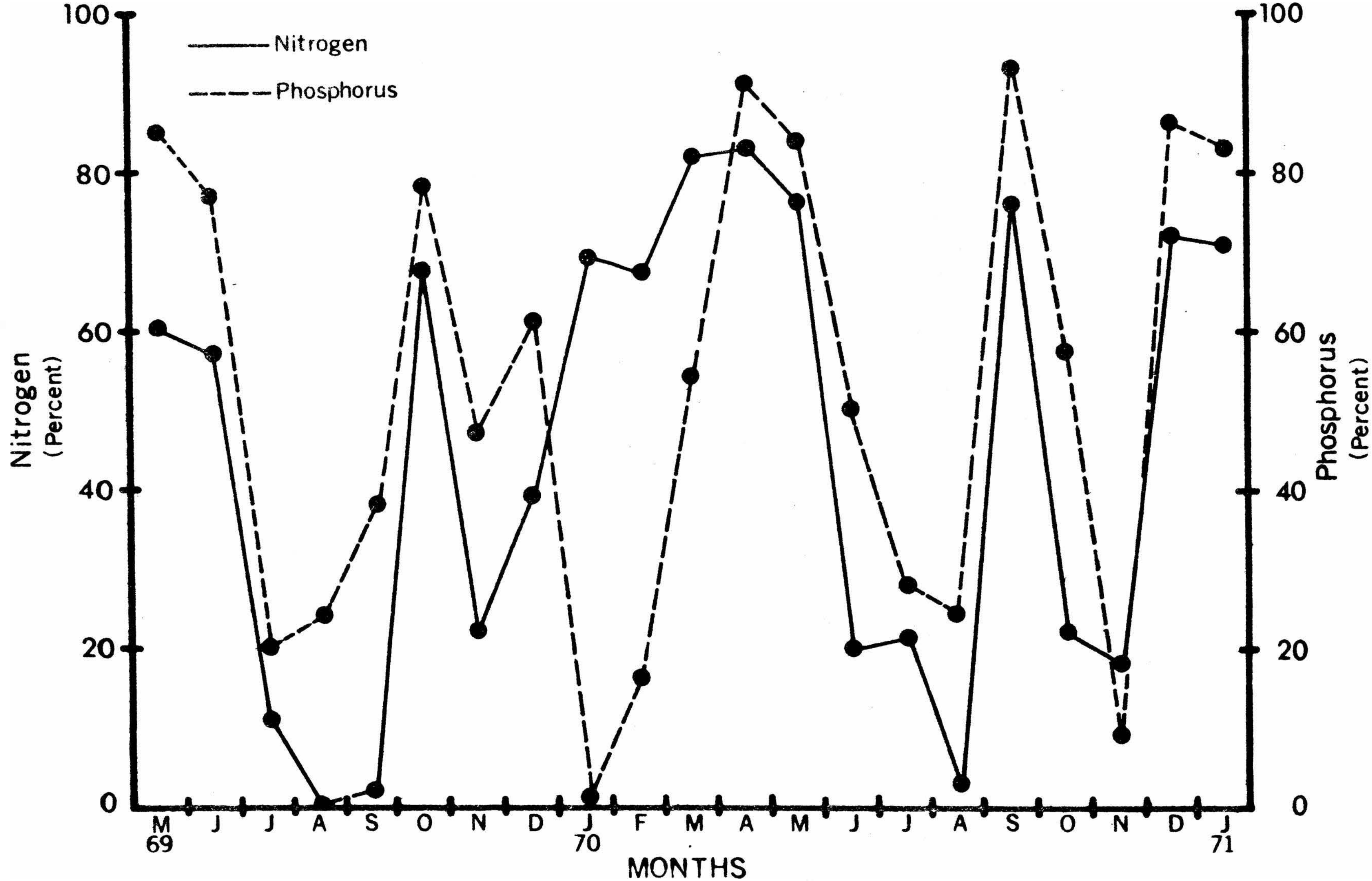

Figure 3 Percent Mean Nutrient Contributions From Agricultural Runoff

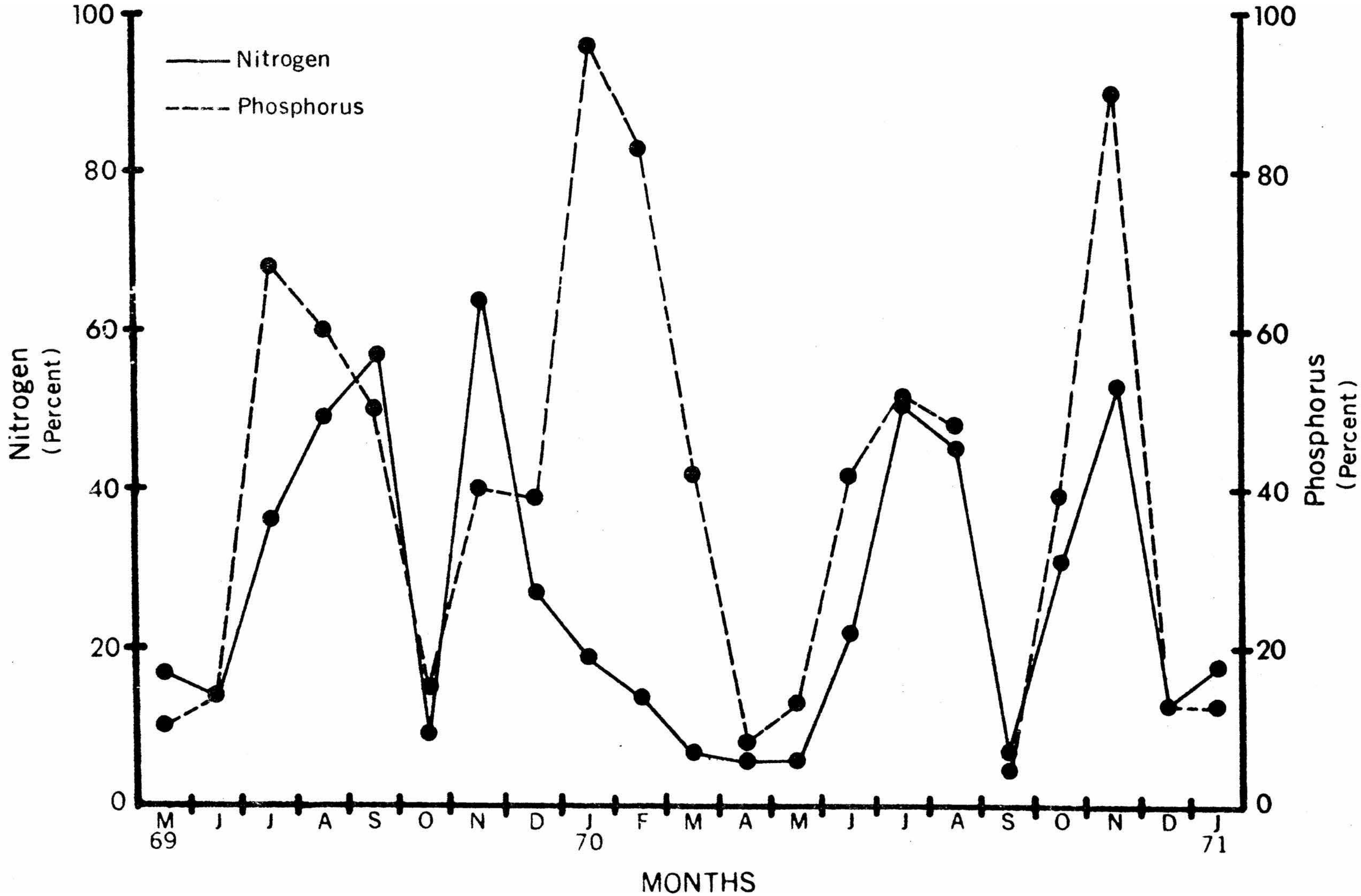

Figure 4 Percent Mean Nutrient Contributions From Domestic Waste

Table XX. RANKING OF NUTRIENT SOURCES

Major Nitrogen Contributors*

Rank	Source	% Contributed
1	Agricultural Land	60
2	Municipal Waste	20
3	Rainfall	9.5
4	Non-Agricultural Land	8
5	Urban Runoff	2.5

Major Phosphorus Contributors*

Rank	Source	% Contributed
1	Agricultural Land	72
2	Municipal Waste	21
3	Non-Agricultural Land	5
4	Urban Runoff	2

*Based on nutrient inflow from October, 1968 to January, 1971 - of which inflow from October, 1968 to April, 1969 can be found in Eley's (1) report.

5.4. Rate of Nutrient Accumulation

Table XXI lists the average rate of nitrogen and phosphorus accumulation in the reservoir developed from inflow and outflow curves as depicted by Figures 5 and 6. These figures illustrate variations with time of the nutrient inflow and outflow patterns. The first seven months of data (October, 1968 to April, 1969) appearing in Figures 5 and 6 were determined by Eley (1).

5.5. Model Equations

Tables XXII and XXIII summarize the various nutrient inflow and reservoir model equations. Included in Table XXII are model equations for total nutrient inflow, nutrient inflow from agricultural land and urban runoff plus nutrient inflow from the two major tributaries of Beaver Reservoir, the White River and War Eagle Creek. Table XXIII has model equations for Secchi disc transparency, nitrate concentration, phosphate phosphorus concentration and algal growth rate for Station 7 along with overall summer algal growth rate model for the entire reservoir.

Table XXI. MONTHLY AVERAGED DAILY NUTRIENT ACCUMULATION RATES

Nutrient	Rate
Nitrogen	2800 lbs/day
Phosphate Phosphorus	31 lbs/day

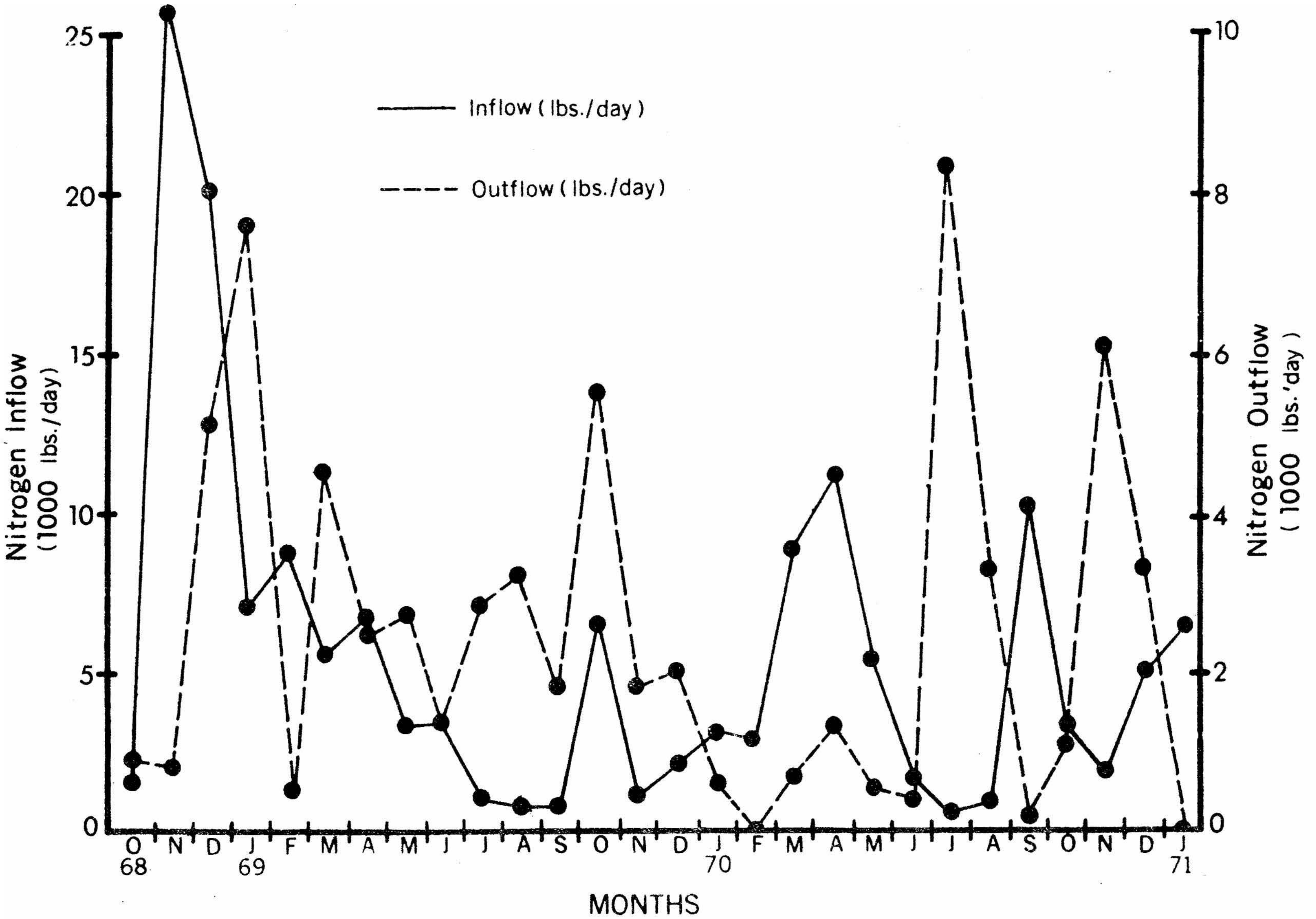

Figure 5 Mean Monthly Nitrogen Inflow and Outflow

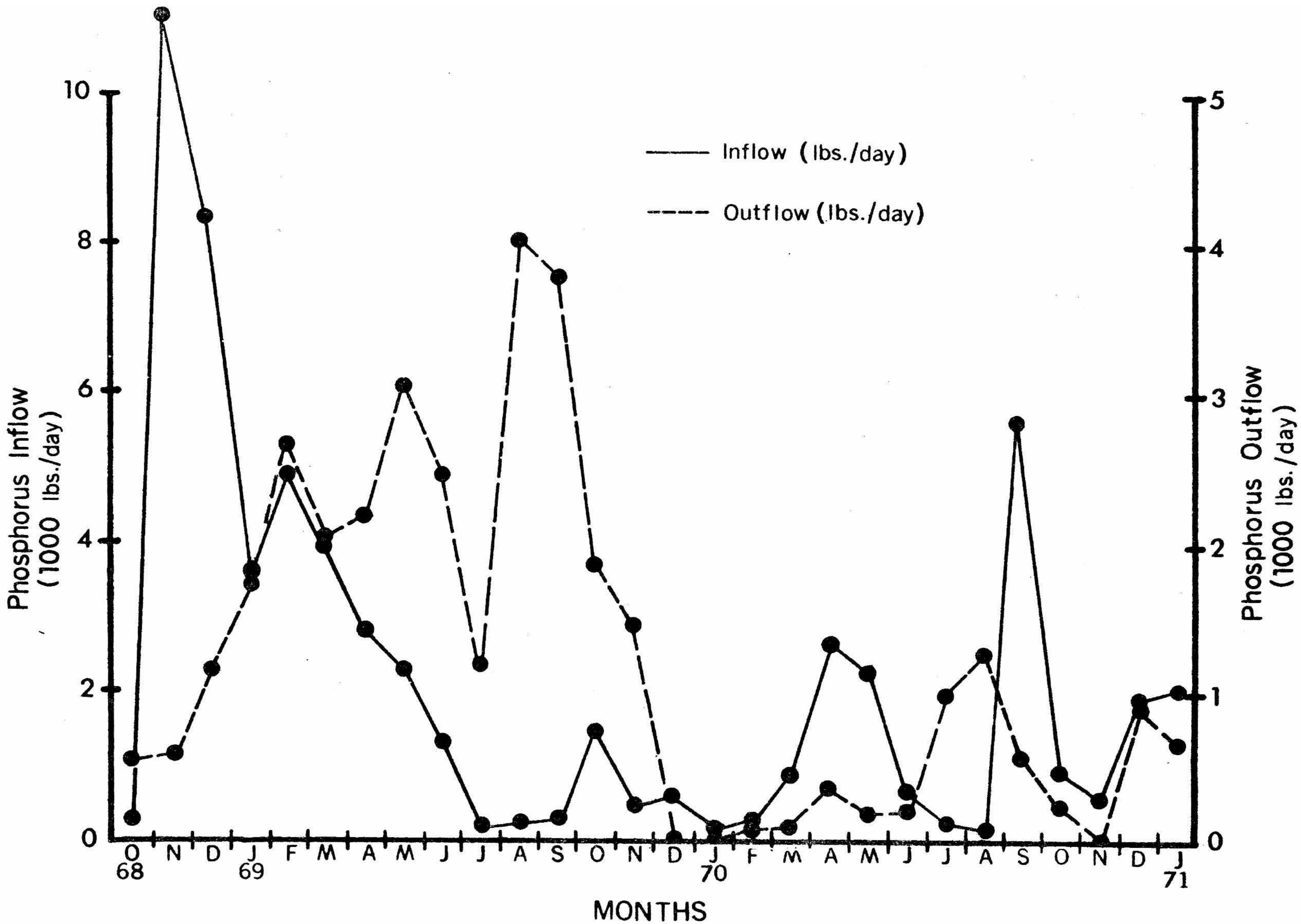

Figure 6 Mean Monthly Phosphorus Inflow and Outflow

Table XXII. NUTRIENT INFLOW MODEL EQUATIONS

Parameter	EQ No.	EQ	Correlation Coefficient
Total Nitrogen Inflow	1	$X_1 = -81.7 + (1662.2)*b$	0.676
Nitrogen Inflow from Agricultural Land	2	$X_1 = 25.6 + (904)*b$	0.695
Nitrogen Inflow from Urban Runoff	3	$X_1 = 7.2 + (25.9)**b$	0.438
Total Phosphate Inflow from Phosphorus Inflow	4	$X_2 = -476.9 + (763.3)*b$	0.668
Phosphate Phosphorus Inflow from Agricultural Land	5	$X_2 = -315.2 + (535.4)*b$	0.689
Phosphate Phosphorus Inflow from Urban Runoff	6	$X_2 = 8.6 + 7.8b$	0.367
Nitrogen Inflow from White River	7	$X_1 = -548.7 + (1057.3)*b$	0.588
Phosphate Phosphorus Inflow from White River	8	$X_2 = -511.6 + 492.3*b$	0.710
Nitrogen Inflow from War Eagle Creek	9	$X_1 = 156.4 + (302)*b$	0.523
Phosphate Phosphorus Inflow from War Eagle Creek	10	$X_2 = -0.04 + 147.7*b$	0.531

X_1 = Nitrogen Inflow, lbs/day

X_2 = Phosphate Phosphorus Inflow, lbs/day

b = Rainfall, inches/month

*99% significant
**95% significant

Table XXIII. RESERVOIR MODEL EQUATIONS

Parameter	EQ No.	EQ	Correlation Coefficient
Nitrate EQ @ Station 7	1	$X_1 = 0.23 + (0.0002)*B$	0.672
Total Phosphate EQ @ Station 7	2	$X_2 = 0.44 + (0.0002)*B$	0.289
Secchi Disc EQ @ Station 7	3	$X_3 = 1.5 - (0.0005)*B$	0.664
Algal Rate EQ @ Station 7	4	$X_4 = 24.5 + 0.1C + 33.4D - 29.6E + 0.5F + 5.7X_3$	0.454
Overall Summer Algal Rate EQ	5	$X_5 = 36.8 + (0.6)*C + 48.4D + 159.6E + (0.004)*F$	0.541

X_1 = Nitrate Concentration, mg/l

X_2 = Total Phosphate Concentration, mg/l

X_3 = Secchi Disc Transparency, meters

X_4 = Algal Rate, ASU/ml-month

X_5 = Algal Rate, ASU/ml-month

B = Combined Streamflow at White River and War Eagle Creek, cfs

C = Algal Concentration, ASU/ml

D = Nitrogen Concentration, mg/l

E = Total Phosphate Concentration, mg/l

F = Zooplankton Concentration, ASU/ml

*99% significant

6. DISCUSSION OF RESULTS

The following five sections contain a discussion of the various results found during the investigation. Hopefully, each discussion will provide a better understanding of the more important aspects of the study and answer some of the questions about the results.

6.1. Discussion of Monthly Nutrient Concentrations

Concentrations of nitrogen and phosphorus in streams and receiving waters usually depend upon the edaphic effects of a particular drainage basin. However, this natural land fertility coupled with additional nutrient contributions of man-induced pollution only augment the problems of eutrophication; particularly in a case where nutrients are already at critical concentrations. Ammonia nitrogen (NH_3-N) and nitrate nitrogen (NO_3-N) appear to be the major inorganic forms of nitrogen which serve as nutrients. In the Beaver Reservoir drainage basin, the highest concentrations of ammonia nitrogen (Tables II to XII) were observed at Town Branch (Station 2) which received predominantly urban runoff and White Midway (Station 6) primarily due to Fayetteville's Pollution Control Plant discharge. The relatively high concentrations found at Fayetteville Pumphouse (Station 1) could be attributed to the urbanization along the river at the cities of West Fork and Greenland, located upstream from this sampling point; however, drainage from the land is still generally of an agricultural type. The majority of the remaining stations reported relatively small ammonia nitrogen concentrations, ranging from 0.00 to 1.20 mg/l NH_3-N.

As concluded by Eley (1), nitrate nitrogen accounted for the major portion of total nitrogen (NH_3-N+NO_3-N) observed in the various streams of the Beaver Watershed. The highest nitrate concentrations of the White River sampling stations (Station 1 - Station 6) were found at Town Branch (0.00 to 1.48 mg/l NO_3-N) and White Midway (0.00 to 1.52 mg/l NO_3-N). Again these values can be attributed to urban runoff and domestic wastewater discharge, respectively. The agricultural areas of Richland Creek (Station 7), Brush Creek (Station 8) and War Eagle (Station 9) had nitrate concentrations which ranged from 0.00 to 1.31 mg/l NO_3-N. Prairie Creek (Station 11) had the highest nitrate concentrations (0.37 to 2.50 mg/l NO_3-N) of the eleven sampling stations. Originally, Eley (1) reported the drainage from this area as urban runoff from the city of Rogers. However, subsequent investigations revealed that subsurface drainage contributed this high concentrations rather than surface runoff, since groundwater usually has greater nitrate concentrations.

Ortho and total phosphates were the other major nutrients studied during this investigation. Tables II to XII reveal that the highest concentrations of both ortho and total phosphates were observed for White Midway (Station 6) as a result of Fayetteville's municipal wastewater effluent. Again Town Branch (Station 2), composed primarily of urban runoff, reported high concentrations of ortho and total phosphates, ranging from 0.00 to 0.75 mg/l ortho-PO_4 and 0.03 to 3.26 mg/l total PO_4. The remaining stations' concentrations of ortho phosphate and total phosphate were usually low. However, due to the concentrating low flow conditions during the relatively dry summer months, an increase in total phosphate concentrations was observed at the majority of the stations. Apparently, the cold water release during reservoir stratification increased the total phosphate level in the White River below Beaver Dam (Table XII). It was theorized that the anaerobic conditions found in the hypolimnion during stratification released the phosphates from the bottom sediments and consequently, the cold water discharge increased in phosphate concentrations.

6.2. Discussion of Streamflows

The sampling network, covering 80.2 percent of the total basin area, contributed between 72 to 100 percent of the total inflow (Figure 2) into Beaver Reservoir and averaged approximately 88 percent. The higher percentages of network inflow to total inflow were observed during low inflow conditions, especially during the summer months.

6.3. Discussion of Nutrient Loading

Figures 5 and 6 represent the mean monthly nutrient inflows (lbs/day) to the reservoir and the respective nutrient loadings (lbs/day) carried through the outflow turbine releases at the dam for the entire 28-month study period. The seven months (October, 1968 to April, 1969) nutrient inflow and outflow loadings appearing in Figure 4 and 5 were taken from Eley's (1) report. Eley's (1) inflow loadings were consistently greater than the loading found during the remaining twenty-one months of the investigation. This can be attributed to: 1) a larger sampling network (83 percent compared to 80 percent of total basin area), 2) greatest amount of runoff inflow was recorded during this seven month period and 3) Fayetteville's old ineffective wastewater treatment was still in operation.

Generally, the nutrient inflows were cyclic in nature. The higher nutrient inflows were observed during the wet months of October through May, while the lower nutrient inflows were found during the relatively dry summer months. Derivation and fluctuations from this pattern can be directly attributed to the amount of precipitation and inflow recorded during that particular month.

The monthly variations in the power demand determined the turbine releases for Beaver Reservoir and, consequently, the nutrient outflows appeared not to follow a definite pattern. However, greater nutrient outflows were observed during the months of reservoir stratification (May to November) than destratification (December to April). As theorized, the release of nutrients from the bottom sediments into the deoxygenated hypolimnetic waters could possibly account for the increased nutrient outflows.

6.4. Discussion of Nutrient Sources

From the results illustrated in Tables XVIII, XIX, and XX, agricultural runoff was the major source of nitrogen and phosphorus in the Beaver drainage basin, contributing approximately 60 percent of the nitrogen and 72 percent of the phosphorus during this investigation. Agricultural land represented 913 sq. mi. or 80 percent of the total watershed (1). The total nitrogen and phosphorus contributed from agricultural land averaged 3.4 lbs. N/day/sq. mi., and 1.7 lbs. P/day/sq. mi., respectively. Figure 3 illustrates the percentages of total nitrogen and phosphorus inflow to the reservoir resulting from agricultural activity. The high percentages found in Figure 5 occur during periods of high runoff and inflow usually during the relatively wet spring months. The low percentages occur during the dry summer months and periods of low inflow.

The next major source was domestic wastewater contributing approximately 20 percent of the nitrogen and 21 percent of the phosphorus. Assuming a population of 30,000 for the city of Fayetteville, the per capita contributions of domestic wastewater for nitrogen and phosphorus were 13.4 lb. N/capita/year and 5.4 lb. P/capita/year, respectively. Figure 4 depicts the percentages of total nutrient inflow contributed by domestic wastewater. Though only contributing around 20 percent of the total nutrient inflow during this study, Figure 4 clearly reveals that during low inflow conditions (especially in the summer) the domestic wastewater becomes the major source of nutrient inflow to Beaver Reservoir.

The minor nutrient sources for nitrogen were rainfall (4.5%), non-agricultural runoff (8%) and urban runoff (2.5%). The minor sources for phosphorus were non-agricultural runoff (5%) and urban runoff (2%).

6.5. Discussion of Nutrient Accumulation Rates

The month averaged rates of nutrient accumulation found in Table XXI appear to be on the conservative side. Based on reports by Stone (45) and Carahan (46), the rapid urbanization along the shores of Beaver Reservoir has a pronounced effect on the rate of nutrient influx into the reservoir. The effluents of various malfunctioning septic tank systems are apparently draining into the reservoir, thus providing a tremendous source of nutrients.

Based on the results of the first seven months, Eley (1) concluded that nutrient retention for Beaver Reservoir averaged approximately 70 percent. However, based on the entire investigation results, the retention of nitrogen and phosphorus for Beaver Reservoir averaged approximately 55 percent and 42 percent, respectively. The difference in these percentages is reflected by the reservoir cycle. Normally, during the wet months the inflow is greater than outflow caused by the power demand and the reservoir volume increases. During the dry summer months, the outflow due to power demand is greater than the inflow, and the reservoir volume decreases. Eley's (1) percentages were based on relatively wet months (October, 1968 to April, 1969) with high inflow (inflow greater than outflow), and he did not take into account the dry summer months, consequently reporting higher values.

6.6. Discussion of Model Equations

As previously stated, one of the primary objectives of this study was the development of reasonable model equations for the Beaver drainage basin and reservoir. Presented in the next two sections is a discussion on the basin model equations, followed by a discussion on reservoir model equations.

6.6.1. Discussion on Basin Model Equations

The development of the basin model equations found in Table XXII appeared to be straightforward. The major influence on the influx of nutrients into the reservoir apparently was rainfall. Thus, rainfall was chosen as the independent variable for the regression. Rainfall data (Appendix B) was obtained for the basin drainage from the U.S. Corps of Engineers. The dependent variables chosen for regression were total nutrient inflow for nitrogen and phosphorus, agriculturally contributed inflow for nitrogen and phosphorus and urban runoff inflow for nitrogen and phosphorus. Other dependent variables included nutrient inflows for the White River and War Eagle, the two major tributaries of Beaver Reservoir. Municipal waste was not modeled, since rainfall should not greatly influence a wastewater discharge. Likewise, non-agricultural runoff (groundwater, forest drainage, etc.) was not modeled because inflow of this type is usually considered normal and is not controlled.

The model equations appear to give reasonable results. Rainfall regression constant (inches/month) was 99 percent significant in six of the ten model equations or 99 percent of the time this variable will not be zero. In the remaining four equations, the rainfall regression constant was 95 percent significant. The low correlation coefficients could possibly be explained by the time lag of the runoff during wet and dry periods. In dry weather, more of the rainfall is absorbed into the ground before runoff commences. Thus, a large amount of runoff is lost from a large rainfall, and the resultant runoff, though possibly high in nutrient content, does not appreciably affect the flow and thereby the overall loading.

6.6.2. Discussion of Reservoir Model Equations

In trying to develop an overall monthly algal growth model for Beaver Reservoir (Table XXIII - EQ 5), various approaches were taken. The first approach attempted to regress monthly nitrogen and ortho phosphate concentrations at the various stations to the developed monthly algal rates by using the Michaelis Menton equation for one and two limiting substrates. The monthly rates divided by the monthly algal concentrations were always the dependent variable, and the monthly nitrogen (NH_3+NO_3) and orthophosphates were independent variables along with monthly zooplankton concentration. The zooplankton concentration was included to simulate the prey-predator relationship and thereby account for some of the negative growth rates.

An attempt was made to account for temperature by grouping the data according to summer months (May to November) and winter months (December to April). The resulting regressions yielded very inconclusive results with multiple correlation coefficients around 0.15 for all variations of the Michaelis Menton equation for one and two limiting substrates.

Another variation in regression was the use of the sine function to simulate the algal blooms accurring in the spring and late fall with the substrate limiting equations. Again this proved to be inconclusive. There did not appear to be a significant relationship between the developed monthly algal growth rates and the monthly nitrogen and orthophosphate concentrations based on the variations on the Michaelis Menton equations regressed.

An explanation of this failure could possible lie in the inconsistency of data collection for all the variables needed for algal monthly rate calculations and regression variables. Of the 39 months (October, 1968 to August, 1971) of reservoir data, the necessary monthly data found at Station 1, Station 3, Station 4 and Station 5 was 24 months. Station 6 and Station 7 reported 26 months and 28 months of data. With intervals between data collections as long as four months, the procedure used for algal rate calculations became highly suspect. Another factor may be the failure to record the silica concentration at the various stations. Though monthly algal rate calculations were based on total algal biomass at each station, diatoms were the predominant algae in the reservoir. Since silica is an essential requirement for the growth rate of diatoms, silica may have been a limiting nutrient.

With the abandonment of the Michealis Menton approach, algal rate model development centered on the multiple regression of the various monthly algal growth rates against monthly algal concentrations, monthly orthophosphate concentrations and monthly zooplankton (Appendix C). Though nothing outstanding was found, the overall algal model equation finally adopted (Table XXIII - EQ 5) was based on the best multiple correlation coefficient of 0.541. The concentrations of monthly algal biomass and zooplankton were 99 percent significant (student T test) or these variables will only be zero, one percent of the time. The concentrations of nitrogen and orthophosphates appearing in the model equation were not significant. This equation was developed for the summer months of May through November.

The other equations (EQ 1 - 4) found in Table XXIII were developed solely for Station 7. This station was chosen primarily to assist in water quality planning. Since Station 7 was the closest to the Beaver Water Intake (approximately two reservoir miles), it could provide valuable information of water quality near the intake. Model equations 1, 2 and 3 provided a means to predict the various independent variables used in model equation 4, the monthly algal rates at Station 7.

Interesting to note was the average of the developed monthly growth rate divided by the monthly concentrations. The overall average of rate to concentration was 0.01 $month^{-1}$, thus indicating a net growth rate throughout the reservoir.

7. CONCLUSIONS

Based on the results of the study, the following conclusions are made:

1) Nutrients are accumulating in Beaver Reservoir.

2) The major nutrient contributors are agricultural runoff and municipal wastewater.

3) The nutrient inflow can be adequately predicted from the amount of rainfall per month.

4) There is no statistical significant relationship found between the algal growth rate and concentrations of nitrogen (NO_3+NH_3) and orthophosphates in Beaver Reservoir.

5) Flow from the major tributaries, White River and War Eagle Creek, influences water quality at Station 7, near the Beaver Water District intake structure.

6) There was an overall net positive algal growth rate during the investigation.

8. FUTURE WORK

As a continuing effort to provide a representative eutrophication model of Beaver Reservoir the following suggestions are made for future work:

1) Determine the nutrient loadings from the various malfunctioning septic tank systems around the reservoir.

2) Determine the nutrient loadings from the recreational areas around the reservoir.

3) Establish sampling stations up stream from Hickory Creek (Station 7).

4) Develop a more sophisticated model for Station 7 and the water intake area.

5) Determine if the algal rate model assumptions were valid.

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APPENDIX A

Stream Water Analysis Data

Table A-1. WATER ANALYSIS DATA
West Fork White River at Fayetteville Pumphouse (Station 1)

Date	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.00	--	0.14	1.86
7/1/69	--	--	0.12	0.65
8/14/69	--	0.75	0.43	3.50
9/12/69	0.45	0.50	--	3.08
9/22/69	0.00	0.00	0.52	--
10/13/69	0.85	0.50	0.12	2.63
10/20/69	0.53	0.96	0.16	1.44
11/10/69	0.30	0.00	0.00	0.69
11/17/69	0.73	0.06	0.15	1.10
11/24/69	0.21	0.00	0.00	1.02
12/1/69	0.01	0.00	0.00	0.01
12/8/69	0.55	0.26	0.03	0.10
1/29/70	0.20	0.23	0.00	0.02
2/26/70	0.62	0.05	0.02	0.05
3/24/70	0.51	0.00	0.03	0.21
4/9/70	--	0.06	0.21	0.26
4/23/70	0.73	0.63	0.23	--
6/6/70	0.40	0.05	0.05	0.82
6/12/70	--	0.00	0.04	1.25
6/29/70	0.54	0.08	0.05	--
7/11/70	0.00	0.00	0.00	--
7/18/70	0.06	0.00	0.07	--
8/3/70	0.04	0.08	0.02	1.50
8/16/70	0.08	0.00	0.00	--
8/22/70	--	0.00	0.02	--
8/29/70	0.19	0.00	0.00	0.78
9/3/70	0.04	0.00	0.03	1.19
9/14/70	0.55	0.00	0.17	1.22
9/28/70	--	0.00	--	--
10/5/70	--	0.00	0.07	--
11/21/70	0.28	0.28	0.00	--
12/4/70	0.32	--	0.01	0.93
12/19/70	0.45	0.29	0.02	0.57
1/29/71	0.24	0.10	0.03	1.17

Table A-2. WATER ANALYSIS DATA
Town Branch of White River (Station 2)

Date	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates (mg/l PO_4) Ortho	Total
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.07	1.00	0.16	2.40
7/1/69	--	--	0.11	0.60
8/14/69	--	--	0.58	3.10
9/12/69	2.30	0.90	--	3.26
9/22/69	10.00	0.00	0.75	--
10/13/69	1.30	1.15	0.43	2.13
10/20/69	0.91	1.80	0.14	1.64
11/10/69	1.68	0.15	0.10	0.61
11/17/69	1.11	0.25	0.06	1.20
11/24/69	0.44	0.19	0.11	0.82
12/1/69	0.31	0.55	0.12	0.10
12/8/69	0.63	0.83	0.10	0.10
1/29/70	0.19	0.13	0.00	0.03
2/26/70	0.78	0.33	0.00	0.06
3/24/70	0.55	0.10	0.11	0.38
4/9/70	--	0.17	0.28	0.32
4/23/70	0.43	0.36	0.18	--
6/6/70	0.25	0.60	0.01	1.20
6/12/70	--	0.18	0.05	1.60
6/29/70	0.41	0.30	0.04	--
7/11/70	0.00	0.00	0.00	--
7/18/70	0.93	0.00	0.00	--
8/3/70	0.08	0.25	0.04	1.56
8/16/70	0.33	0.15	0.02	--
8/22/70	--	0.93	0.54	--
8/29/70	4.60	0.22	0.09	1.05
9/3/70	0.35	0.70	0.32	1.06
9/14/70	1.02	1.53	0.37	1.54
9/28/70	--	0.50	--	--
10/5/70	--	0.37	0.09	--
11/21/70	0.47	0.47	0.00	0.07
12/4/70	0.28	--	0.08	1.16
12/19/70	0.03	0.28	0.00	0.76
1/29/71	0.18	0.08	0.07	0.98

Table A-3. WATER ANALYSIS DATA
West Fork White River at Verna Lea Bridge (Station 3)

Date	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates (mg/l PO_4) Ortho	Total
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.01	0.88	0.14	1.88
7/1/69	--	--	0.12	0.57
8/14/69	--	0.35	0.35	3.00
9/12/69	2.05	0.80	--	3.89
9/22/69	0.05	0.00	0.00	--
10/13/69	1.00	0.75	0.25	1.80
10/20/69	0.47	1.07	0.03	1.73
11/10/69	0.03	0.38	0.00	0.39
11/17/69	0.17	0.05	0.00	0.93
11/24/69	0.73	0.00	0.08	0.85
12/1/69	0.00	0.00	0.00	0.03
12/8/69	0.13	0.15	0.01	0.01
1/29/70	0.05	0.31	0.00	0.00
2/26/70	0.19	0.33	0.00	0.02
3/24/70	0.45	0.00	0.03	0.18
4/9/70	--	0.27	0.22	--
4/23/70	0.40	0.23	0.22	--
6/6/70	0.05	0.03	0.00	1.03
6/12/70	--	0.16	0.07	1.32
6/29/70	0.08	0.07	0.00	--
7/11/70	0.00	0.00	0.00	--
7/18/70	0.00	0.00	0.12	--
8/3/70	0.06	0.13	0.02	1.26
8/16/70	0.06	0.00	0.00	--
8/22/70	--	0.08	0.02	--
8/29/70	0.13	0.00	0.03	0.75
9/3/70	0.69	0.70	0.12	1.35
9/14/70	1.12	0.56	0.39	1.38
9/28/70	--	0.00	--	--
10/5/70	--	0.07	0.07	--
11/21/70	0.07	0.07	0.00	0.12
12/4/70	0.03	--	0.01	0.96
12/19/70	0.10	0.00	0.01	0.77
1/29/71	0.10	0.00	0.00	0.85

Table A-4. WATER ANALYSIS DATA
White River at Sequoyah Dam (Station 4)

Date	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates (mg/l PO_4) Ortho	Phosphates (mg/l PO_4) Total
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.03	0.67	0.12	2.13
7/1/69	--	--	0.08	0.59
8/14/69	--	0.10	0.25	3.10
9/12/69	0.23	0.00	--	2.86
9/22/69	0.00	0.00	0.02	--
10/13/69	1.00	0.15	0.28	--
10/20/69	0.65	1.66	0.08	1.56
11/10/69	0.18	0.25	0.05	0.82
11/17/69	0.10	0.21	0.00	0.93
11/24/69	0.18	0.00	0.03	1.22
12/1/69	0.00	0.00	0.00	0.02
12/8/69	0.00	0.00	0.00	0.00
1/29/70	0.07	0.40	0.00	0.00
2/26/70	0.30	0.31	0.00	0.05
3/24/70	0.49	0.17	0.08	0.18
4/9/70	--	0.20	0.22	0.31
4/23/70	0.00	0.69	0.15	--
6/6/70	0.11	0.05	0.01	0.90
6/12/70	--	0.00	0.03	1.25
6/29/70	0.00	0.00	0.03	--
7/11/70	0.05	0.00	0.00	--
7/18/70	0.00	0.00	0.01	--
8/3/70	0.02	0.00	0.02	1.74
8/16/70	0.03	0.00	0.00	--
8/22/70	--	0.27	0.06	--
8/29/70	0.22	0.00	0.03	1.20
9/3/70	0.04	0.00	0.04	1.54
9/14/70	0.00	0.00	0.00	0.97
9/28/70	--	1.00	--	--
10/5/70	--	0.00	0.08	--
11/21/70	0.08	0.08	0.07	0.02
12/4/70	0.08	--	0.00	0.90
12/19/70	0.01	0.03	0.00	0.59
1/29/71	0.10	0.03	0.00	0.93

Table A-5. WATER ANALYSIS DATA
White River at Wyman Bridge (Station 5)

Date	Ammonia Nitrogen (mg/1 NH_3-N)	Nitrate Nitrogen (mg/1 NO_3-N)	Phosphates (mg/1 PO_4) Ortho	Phosphates (mg/1 PO_4) Total
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.17	--	0.11	2.30
7/1/69	--	--	0.11	0.50
8/14/69	--	0.10	0.13	2.88
9/12/69	0.15	0.67	--	3.15
9/22/69	0.00	0.00	0.00	--
10/13/69	1.20	0.40	0.27	1.75
10/20/69	0.53	1.07	0.09	2.17
11/10/69	0.12	0.43	0.00	0.39
11/17/69	0.21	0.21	0.00	0.95
11/24/69	0.23	1.83	0.03	1.55
12/1/69	0.00	0.00	0.00	0.11
12/8/69	0.01	0.15	0.00	0.00
1/29/70	0.07	0.19	0.00	0.00
2/26/70	0.24	0.58	0.00	0.04
3/24/70	0.50	0.00	0.12	0.20
4/9/70	--	0.31	0.25	0.30
4/23/70	0.00	0.46	0.14	--
6/6/70	0.14	0.19	0.01	0.35
6/12/70	--	0.00	0.04	--
6/29/70	0.42	0.00	0.00	--
7/11/70	0.05	0.00	0.00	--
7/18/70	0.00	0.00	0.00	--
8/3/70	0.05	0.08	0.02	1.71
8/16/70	0.05	0.04	0.00	--
8/22/70	--	0.00	0.02	--
8/29/70	0.08	0.00	0.00	1.13
9/3/70	0.04	0.22	0.01	1.12
9/14/70	0.00	0.33	0.01	1.25
9/28/70	--	0.01	--	--
10/5/70	--	0.55	0.08	--
11/21/70	0.35	0.35	0.00	0.08
12/4/70	0.08	--	0.00	1.07
12/19/70	0.05	0.02	0.00	0.72
1/29/71	0.90	0.19	0.00	1.06

Table A-6. WATER ANALYSIS DATA
White River at Midway (Station 6)

Date	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates (mg/l PO_4) Ortho	Phosphates (mg/l PO_4) Total
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.58	1.35	0.77	2.87
7/1/69	--	--	0.95	1.47
8/14/69	--	--	--	--
9/12/69	0.65	1.45	--	6.83
9/22/69	5.00	0.40	--	--
10/13/69	1.20	0.50	0.30	1.65
10/20/69	0.58	1.96	0.89	1.65
11/10/69	0.98	0.60	1.22	1.80
11/17/69	0.51	0.57	1.43	1.93
11/24/69	0.36	0.00	0.90	0.86
12/1/69	0.02	0.63	0.82	0.82
12/8/69	0.23	0.16	1.00	1.06
1/29/70	0.32	0.13	0.19	0.19
2/26/70	0.35	0.50	0.40	0.44
3/24/70	0.47	0.00	0.12	0.19
4/9/70	--	0.17	0.69	0.69
4/23/70	0.00	0.41	0.13	--
6/6/70	0.15	0.23	0.20	1.03
6/12/70	--	0.28	0.02	1.17
6/29/70	0.07	0.68	1.10	--
7/11/70	0.26	1.32	1.90	--
7/18/70	0.18	1.71	3.10	--
8/3/70	0.12	1.00	3.85	3.60
8/16/70	0.18	0.04	0.19	--
8/22/70	--	0.60	4.96	--
8/29/70	1.25	0.85	5.20	6.25
9/3/70	2.00	0.10	5.91	4.80
9/14/70	0.50	2.00	0.11	2.63
9/28/70	--	0.01	--	--
10/5/70	--	0.57	0.97	--
11/21/70	0.45	0.45	0.18	0.27
12/4/70	0.79	--	0.57	1.42
12/19/70	0.58	0.29	0.55	0.93
1/29/71	0.50	1.03	0.37	1.17

Table A-7. WATER ANALYSIS DATA
Richland Creek at Goshen (Station 7)

Date	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.00	1.00	0.11	1.98
7/1/69	--	--	0.05	0.56
8/14/69	--	0.00	2.05	--
9/12/69	0.05	0.30	--	3.26
9/22/69	0.00	0.40	0.15	--
10/13/69	0.95	0.85	0.37	1.65
10/20/69	0.37	1.77	0.06	2.08
11/10/69	0.00	0.68	0.13	0.65
11/17/69	0.00	0.41	0.00	0.95
11/24/69	0.23	0.19	0.00	1.35
12/1/69	0.01	0.50	0.00	0.08
12/8/69	0.00	0.25	0.03	0.03
1/29/70	0.09	0.37	0.00	0.01
2/26/70	0.00	0.00	0.00	0.08
3/24/70	0.41	0.00	0.05	0.19
4/9/70	--	0.35	0.31	0.40
4/23/70	1.20	0.65	0.39	--
6/6/70	0.00	0.42	0.00	0.92
6/12/70	--	0.26	0.10	1.17
6/29/70	0.01	0.23	0.05	--
7/11/70	0.07	1.28	0.00	--
7/18/70	0.00	0.00	0.05	--
8/3/70	0.02	0.00	0.03	1.71
8/16/70	2.34	1.51	3.00	--
8/22/70	--	0.05	0.21	--
8/29/70	0.14	0.00	0.03	1.31
9/3/70	0.00	0.65	0.04	1.41
9/14/70	0.00	1.00	0.91	1.77
9/28/70	--	1.20	--	--
10/5/70	--	0.22	0.06	--
11/21/70	0.00	0.07	0.00	0.00
12/4/70	0.50	--	0.03	0.97
12/19/70	0.00	0.41	0.00	0.60
1/29/71	0.00	0.40	0.01	1.10

Table A-8. WATER ANALYSIS DATA
Brush Creek and Whitener Creek at Intersection (Station 8)

Date	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.00	--	--	--
7/1/69	--	--	0.08	--
8/14/69	--	0.40	0.63	--
9/12/69	0.00	0.50	--	3.58
9/22/69	0.00	0.55	0.06	--
10/13/69	0.80	0.55	0.13	2.22
10/20/69	0.58	0.60	0.07	1.64
11/10/69	0.63	0.43	0.03	0.86
11/17/69	0.00	0.36	0.00	1.23
11/24/69	0.19	0.00	0.03	0.86
12/1/69	0.12	0.13	0.00	0.02
12/8/69	0.05	0.11	0.02	0.01
1/29/70	0.29	0.37	0.00	0.00
2/26/70	0.00	0.24	0.00	0.05
3/24/70	0.48	0.37	0.06	0.18
4/9/70	--	0.30	0.31	0.23
4/23/70	0.00	0.46	0.07	--
6/6/70	0.00	0.46	0.07	--
6/12/70	--	0.20	0.02	--
6/29/70	0.03	0.08	0.10	--
7/11/70	0.56	1.36	0.00	--
7/18/70	0.00	0.00	0.02	--
8/3/70	0.00	0.28	0.03	2.22
8/16/70	0.00	0.23	0.02	--
8/22/70	--	0.15	0.02	--
8/29/70	0.00	0.00	0.00	1.75
9/3/70	0.00	0.53	0.00	2.00
9/14/70	0.00	1.53	0.01	1.63
9/28/70	--	1.10	--	--
10/5/70	--	0.35	0.07	--
11/21/70	0.00	0.00	0.00	0.02
12/4/70	0.50	--	0.03	1.37
12/19/70	0.00	0.30	0.10	0.77
1/29/71	0.00	1.20	0.00	1.02

Table A-9. WATER ANALYSIS DATA
War Eagle Creek at War Eagle (Station 9)

Date	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.00	1.12	0.07	2.07
7/1/69	--	--	0.08	0.66
8/14/69	--	0.00	1.20	--
9/12/69	0.08	0.00	--	2.75
9/22/69	0.00	0.00	0.50	--
10/13/69	0.60	0.85	0.21	1.64
10/20/69	0.35	1.66	0.03	1.54
11/10/69	0.31	0.20	0.03	1.05
11/17/69	0.00	0.19	0.00	1.06
11/24/69	0.25	0.00	0.02	1.53
12/1/69	0.00	0.25	0.00	0.03
12/8/69	0.00	0.13	0.00	0.01
1/29/70	0.00	0.40	0.00	0.00
2/26/70	0.00	0.73	0.00	0.08
3/24/70	0.45	0.37	0.06	0.24
4/9/70	--	0.17	0.22	0.23
4/23/70	0.23	0.50	0.07	--
6/6/70	0.01	0.42	0.00	1.43
6/12/70	--	0.30	0.03	1.70
6/29/70	0.15	0.43	0.05	--
7/11/70	0.54	1.18	0.00	--
7/18/70	0.00	0.00	0.02	--
8/3/70	0.00	0.00	0.01	2.22
8/16/70	--	0.05	0.03	--
8/22/70	--	0.05	0.03	--
8/29/70	0.00	0.00	0.00	1.53
9/3/70	0.00	--	0.01	1.76
9/14/70	0.00	0.00	0.00	1.15
9/28/70	--	1.02	--	--
10/5/70	--	0.32	0.03	--
11/21/70	0.05	0.05	0.00	0.10
12/4/70	0.50	--	0.02	1.57
12/19/70	0.00	0.39	0.00	0.37
1/29/71	0.05	0.33	0.00	1.13

Table A-10. WATER ANALYSIS DATA
Prairie Creek (Station 11)

Date	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.00	--	0.14	2.10
7/1/69	--	--	0.06	0.53
8/14/69	--	1.50	--	--
9/12/69	--	--	--	--
9/22/69	0.00	0.55	0.00	--
10/13/69	0.45	2.00	0.19	1.72
10/20/69	0.30	3.00	0.06	0.88
11/10/69	0.33	1.70	0.35	1.49
11/17/69	0.00	1.63	0.00	1.57
11/24/69	0.20	0.20	0.03	0.78
12/1/69	0.00	1.68	0.00	0.03
12/8/69	0.00	1.79	0.01	0.04
1/29/70	0.00	1.60	0.00	0.07
2/26/70	0.00	2.15	0.00	0.02
3/24/70	0.42	1.78	0.04	0.19
4/9/70	--	2.10	0.23	0.23
4/23/70	0.00	2.40	0.07	--
6/6/70	0.00	1.73	0.00	0.86
6/12/70	--	1.48	0.06	1.31
6/29/70	0.17	2.00	0.03	--
7/11/70	0.10	1.32	0.00	--
7/18/70	0.00	0.00	0.03	--
8/3/70	0.00	1.55	0.02	1.69
8/16/70	0.00	1.64	0.08	--
8/22/70	--	1.62	0.02	--
8/29/70	0.00	1.60	0.05	1.22
9/3/70	0.00	1.60	0.00	1.55
9/14/70	0.00	0.00	0.00	1.15
9/28/70	--	0.83	--	--
10/5/70	--	1.13	0.05	--
11/21/70	0.37	0.37	0.02	0.03
12/4/70	0.06	--	0.00	0.96
12/19/70	0.00	2.00	0.00	0.70
1/29/71	0.00	1.92	0.00	0.91

Table A-11. WATER ANALYSIS DATA
White River below Beaver Dam (Station 16)

Date	Ammonia Nitrogen (mg/l NH_3-N)	Nitrate Nitrogen (mg/l NO_3-N)	Phosphates Ortho (mg/l PO_4)	Phosphates Total (mg/l PO_4)
-- Data for October, 1968 to May, 1969 in Eley's (1) Report --				
6/10/69	0.00	--	0.08	1.47
7/1/69	--	--	0.05	0.36
8/14/69	--	0.40	0.73	1.54
9/12/69	0.00	0.30	--	2.71
9/22/69	0.00	0.55	0.10	--
10/13/69	0.35	0.56	0.05	1.32
10/20/69	0.30	1.77	0.01	1.79
11/10/69	0.00	0.25	0.03	0.73
11/17/69	0.00	0.25	0.00	0.77
11/24/69	0.21	0.19	0.03	0.63
12/1/69	0.00	0.30	0.00	0.03
12/8/69	0.21	0.30	0.00	0.00
1/29/70	0.00	0.06	0.00	0.00
2/26/70	0.00	0.00	0.00	0.05
3/24/70	0.38	0.00	0.03	0.16
4/9/70	--	0.01	0.24	0.26
4/23/70	0.06	0.48	0.01	--
6/6/70	0.01	0.23	0.00	0.17
6/12/70	--	0.13	0.00	0.55
6/29/70	0.00	0.29	0.00	--
7/11/70	0.36	1.62	0.00	--
7/18/70	0.00	0.00	0.01	--
8/3/70	0.00	0.28	0.01	0.39
8/16/70	0.03	0.35	0.00	--
8/22/70	--	0.23	0.02	--
8/29/70	0.00	0.38	0.05	0.37
9/3/70	0.00	0.10	0.00	0.39
9/14/70	0.00	0.00	0.00	0.48
9/28/70	--	0.00	--	--
10/5/70	--	0.17	0.07	--
11/21/70	0.33	0.33	0.05	0.00
12/4/70	0.01	--	0.05	0.29
12/19/70	0.08	0.20	0.00	0.12
1/29/71	0.00	0.00	0.00	0.15

APPENDIX B

Hydrological and Streamflow Data

Table B-1. BEAVER RESERVOIR REGULATIONS DATA
(Mean Monthly Values)

Month	Pool Elevation (M.S.L.)	Basin Rainfall (inches)	Turbine Release (cfs)
-- Data from October, 1968 to April, 1969 in Eley's (1) Report --			
May, 1969	1119	3.2	1843
June	1117	4.1	945
July	1115	2.1	1879
August	1111	1.2	1494
September	1108	1.6	796
October	1106	7.6	688
November	1106	1.2	1138
December	1103	3.2	947
January, 1970	1102	0.9	1860
February	1102	1.1	965
March	1104	3.9	358
April	1110	5.3	786
May	1117	3.6	382
June	1118	4.2	338
July	1117	0.4	1565
August	1112	1.9	1917
September	1109	10.5	761
October	1114	9.4	655
November	1120	2.4	1850
December	1118	2.6	2508
January, 1971	1116	2.8	2636

Table B-2. ACTUAL STREAMFLOW DATA FROM MAY, 1969 TO JANUARY, 1971

Month	Gage #0480 West Fork, White River @ Greenland (cfs)	Gage #0486 White River near Fayetteville (cfs)	Gage #0490 War Eagle Creek near Hindsville (cfs)
-- Data for October, 1968 to April, 1969 in Eley's (1) Report --			
May, 1969	95.30	400.00	190.00
June	24.90	176.00	44.60
July	4.05	16.80	24.40
August	0.51	3.02	12.50
September	0.13	2.80	16.80
October	62.30	205.80	153.20
November	16.00	73.30	67.50
December	77.40	364.50	157.70
January, 1970	122.00	500.30	340.30
February	66.80	288.40	205.30
March	252.00	1211.30	659.20
April	313.00	1460.30	914.50
May	115.00	633.20	462.00
June	21.70	72.80	85.60
July	0.81	3.75	18.81
August	0.01	3.36	12.26
September	135.00	567.70	334.50
October*	27.60	169.40	125.60
November*	73.10	244.20	181.60
December*	84.10	526.30	232.20
January, 1971	112.20	539.30	208.60

*Flow = Average monthly flows/number of years of record

Table B-3. VOLUMES, AREAS, AND DEPTHS OF SECTIONS ABOVE SAMPLING SITE IN BEAVER RESERVOIR (2)

The volumes and areas above each of the six sampling sites are given below. All figures are based on a water level of 1,120 feet above m.s.l.

Plankton Volume and Areas

Station	Area Acres	Volume A. ft.
1	7,219	134,263
3	6,809	100,685
4	5,401	90,077
5	4,403	115,509
6	2,816	42,557
7	5,376	88,500

APPENDIX C

Lake Water Analysis Data

Table C-1. WATER ANALYSIS DATA
Beaver Dam (Station 1)

Date	Phyto-plankton (ASU/ml)	Zoo-plankton (ASU/ml)	Secchi Disc (meters)	Nitrogen (NH_3+NO_3) (mg/1)	Phosphates (Ortho) (mg/1)
-- Data June, 1968 to June, 1969 in Bennett's (2) Thesis --					
July, 1969	--	--	6.40	--	--
August	28.436	27.600	6.30	0.20	0.00
September	--	--	7.70	0.00	0.00
October	29.710	8.130	6.70	0.15	0.00
November	--	--	--	--	--
December	112.238	26.300	6.20	0.23	0.03
January, 1970	--	--	--	--	--
February	20.840	1.070	6.80	0.00	0.00
March	57.840	4.050	6.70	0.00	--
April	--	--	--	--	--
May	1.660	2.310	4.75	0.00	0.38
June	281.620	5.560	6.20	0.00	0.09
July	--	--	5.90	0.00	0.03
August	--	--	--	--	--
September	--	--	--	--	--
October	--	--	--	--	--
November	90.860	11.000	--	0.00	0.02
December	--	--	--	--	--
January, 1971	0.290	0.000	4.20	--	--
February	--	--	--	--	--
March	4.240	0.850	3.75	0.33	0.00
April	--	--	--	--	--
May	183.480	0.450	3.50	0.35	0.02
June	86.836	5.650	5.00	0.42	0.29
July	13.512	3.730	3.20	0.00	0.15
August	1.281	00.081	3.60	--	--

Table C-2. WATER ANALYSIS DATA
Big Clifty (Station 3)

Date	Phyto-plankton (ASU/ml)	Zoo-plankton (ASU/ml)	Secchi Disc (meters)	Nitrogen (NH_3+NO_3) (mg/1)	Phosphates (Ortho) (mg/1)
-- Data June, 1968 to June, 1969 in Bennett's (2) Thesis --					
July, 1969	--	--	6.00	--	---
August	23.736	17.700	5.50	0.25	0.00
September	5.607	6.450	7.20	0.00	0.00
October	9.997	27.200	--	0.15	0.00
November	--	--	--	--	--
December	153.791	27.600	5.10	0.17	0.01
January, 1970	--	--	--	--	--
February	17.726	1.940	5.40	0.00	0.03
March	12.120	9.960	4.00	0.08	0.03
April	--	--	--	--	--
May	1.700	47.870	2.40	0.00	0.00
June	638.510	3.000	4.70	0.00	0.10
July	--	--	5.90	0.00	0.00
August	--	--	--	--	--
September	--	--	3.50	--	--
October	--	--	--	--	--
November	35.580	15.420	--	0.32	0.00
December	--	--	--	--	--
January, 1971	1.600	0.270	3.90	--	--
February	--	--	--	--	--
March	26.010	7.930	3.00	0.22	0.00
April	--	--	--	--	--
May	35.540	17.460	3.25	0.25	0.02
June	147.550	5.180	4.50	0.62	0.26
July	18.987	1.650	3.20	0.00	0.04
August	3.230	1.800	--	--	--

Table C-3. WATER ANALYSIS DATA
Rocky Branch (Station 4)

Date	Phyto-plankton (ASU/ml)	Zoo-plankton (ASU/ml)	Secchi Disc (meters)	Nitrogen (NH_3+NO_3) (mg/l)	Phosphates (Ortho) (mg/l)
-- Data June, 1968 to June, 1969 in Bennett's (2) Thesis --					
July, 1969	--	--	--	--	--
August	6.224	1.820	4.30	0.25	0.00
September	1.667	3.170	6.80	0.40	0.00
October	33.217	12.870	3.60	0.00	0.00
November	--	--	--	--	--
December	202.01	13.300	3.10	0.06	0.00
January, 1970	--	--	--	--	--
February	3.690	1.730	4.20	0.00	0.00
March	12.200	3.410	3.60	0.13	--
April	--	--	--	--	--
May	3.042	28.170	1.40	0.17	0.04
June	922.770	12.610	--	0.00	0.01
July	--	--	4.30	0.00	0.00
August	--	--	--	--	--
September	--	--	--	--	--
October	--	--	--	--	--
November	21.990	5.110	--	0.00	0.00
December	--	--	--	--	--
January, 1971	3.870	8.130	3.60	--	--
February	--	--	--	--	--
March	52.280	3.030	--	0.55	0.01
April	--	--	--	--	--
May	36.850	78.940	2.75	0.61	0.01
June	71.758	1.570	--	0.34	0.10
July	--	--	--	0.00	0.13
August	5.170	3.570	--	--	--

Table C-4. WATER ANALYSIS DATA
Hurricane Alley (Station 5)

Date	Phyto- plankton (ASU/ml)	ZoZoo- plankton (ASU/ml)	Secchi Disc (meters)	Nitrogen (NH_3+NO_3) (mg/1)	Phosphates (Ortho) (mg/1)
-- Data June, 1968 to June, 1969 in Bennett's (2) Thesis --					
July, 1969	--	--	--	--	--
August	3.770	3.510	3.60	0.12	0.00
September	2.960	0.541	4.00	0.30	0.00
October	42.010	5.780	2.60	0.00	0.00
November	--	--	--	--	--
December	41.805	23.700	1.60	0.03	0.00
January, 1970	--	--	--	--	--
February	--	--	1.80	0.07	0.01
March	67.440	20.370	1.80	0.33	--
April	--	--	--	--	--
May	1.020	23.720	0.60	0.00	0.00
June	541.264	7.020	--	0.00	0.05
July	--	--	3.70	0.00	0.00
August	--	--	--	--	--
September	--	--	--	--	--
October	--	--	--	--	--
November	18.440	4.000	--	0.32	0.00
December	--	--	--	--	--
January, 1971	1.220	0.810	0.90	--	--
February	--	--	--	--	--
March	76.380	3.700	1.00	0.43	0.01
April	--	--	--	--	--
May	52.940	39.660	2.25	0.65	0.01
June	43.945	9.080	3.00	0.30	0.19
July	5.515	2.360	2.90	0.03	0.13
August	2.040	6.460	3.60	--	--

Table C-5. WATER ANALYSIS DATA
Horseshoe Bend Area (Station 6)

Date	Phyto-plankton (ASU/ml)	Zoo-plankton (ASU/ml)	Secchi Disc (meters)	Nitrogen (NH_3+NO_3) (mg/1)	Phosphates (Ortho) (mg/1)
-- Data June, 1968 to June, 1969 in Bennett's (2) Thesis --					
July, 1969	--	--	--	--	--
August	3.147	5.960	3.30	0.20	0.10
September	15.237	0.940	4.00	0.00	0.00
October	31.180	9.130	1.60	0.00	0.00
November	--	--	--	--	--
December	119.219	5.960	1.30	0.40	0.00
January, 1970	--	--	--	--	--
February	5.432	2.490	1.10	0.23	0.19
March	3.410	0.570	0.50	0.55	--
April	--	--	--	--	--
May	1.650	0.300	0.45	0.00	0.00
June	108.270	1.240	1.60	0.00	0.04
July	--	--	2.60	0.13	0.01
August	--	--	--	--	--
September	--	--	--	--	--
October	--	--	--	--	--
November	1.340	0.160	--	0.32	0.02
December	--	--	--	--	--
January, 1971	1.740	0.570	1.20	--	--
February	--	--	--	--	--
March	7.070	3.080	1.00	0.72	0.05
April	--	--	--	--	--
May	82.180	27.030	2.25	0.37	0.00
June	70.570	21.460	--	0.10	0.20
July	15.660	2.610	2.80	0.00	0.12
August	5.340	1.800	3.30	--	--

Table C-6. WATER ANALYSIS DATA
Hickory Creek Area (Station 7)

Date	Phyto-plankton (ASU/ml)	Zoo-plankton (ASU/ml)	Secchi Disc (meters)	Nitrogen (NH_3+NO_3) (mg/l)	Phosphates (Ortho) (mg/l)
-- Data June, 1968 to June, 1969 in Bennett's (2) Thesis --					
July, 1969	--	--	--	--	--
August	1.120	3.690	2.30	0.43	0.00
September	0.829	3.350	1.80	0.00	0.00
October	5.070	9.610	1.10	0.30	0.00
November	--	--	--	--	--
December	77.087	8.840	1.00	0.45	0.00
January, 1970	--	--	--	--	--
February	2.510	0.656	0.60	0.43	0.30
March	0.680	0.000	0.40	0.70	--
April	--	--	--	--	--
May	4.320	40.730	0.35	1.53	0.10
June	98.230	1.510	1.50	0.37	0.05
July	--	--	--	0.06	0.00
August	0.730	5.370	1.40	0.04	0.05
September	0.980	7.550	--	0.13	0.00
October	10.890	0.540	0.90	0.75	0.17
November	0.990	0.380	0.90	0.88	0.03
December	--	--	--	--	--
January, 1971	0.330	2.340	0.35	1.01	0.14
February	--	--	--	0.91	0.15
March	0.110	1.000	0.75	0.43	0.07
April	--	--	--	--	--
May	39.380	10.040	2.00	0.37	0.03
June	38.950	36.510	1.00	0.286	0.15
July	3.023	1.870	1.75	0.00	0.08
August	0.783	0.760	1.80	--	--