EVALUATION OF NUTRIENT EXPORTS FROM THREE AGRICULTURAL WATERSHEDS IN THE BATTLE BRANCH SUBBASIN

By

MICHEAL BRYAN COPENHAVER

Bachelor of Science

in Arts and Sciences

Oklahoma State University

Stillwater, Oklahoma

1988

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1991

EVALUATION OF NUTRIENT EXPORTS FROM THREE AGRICULTURAL WATERSHEDS IN THE BATTLE BRANCH SUBBASIN

Thesis Approved:

S. L. Burks

Thesis Adviser

L. G. Morrill

M. H. Bates

Norman N Durham

Dean of the Graduate College

ACKNOWLEDGMENTS

I wish to express heartfelt thanks and appreciation to Dr. S. L. "Bud" Burks whose patience, understanding, and advice throughout my graduate program kept me going. A graduate student could not have a finer mentor. A sincere thanks also go to Dr. Marcia Bates and Dr. Lawrence Morrill for serving on my graduate committee.

I extend sincere thanks to Ron Treat and the other Soil Conservation Service people that participated in getting the project off the ground. A special thanks go to the SCS district conservationist, Jerry Walker, who served as liaison with local landowners and assisted in the selection of study sites. I wish to also express my appreciation to the participating landowners for their full cooperation during the project.

Much love and gratitude go to my parents, E. L. and Bobba Copenhaver, for their moral guidance and support these many years. Special love and praise to my wife, Susie, who kept me believing in myself even on the cloudy days. Without her constant encouragement and support, this goal would not have been realized.

TABLE OF CONTENTS

Chapter Page

APPENDICES

LIST OF TABLES

LIST OF FIGURES

Figure Page

CHAPTER I

INTRODUCTION

Illinois River Basin

Covering a total drainage area of approximately 1.1 million acres, the Illinois River Basin (Water Resources Hydrologic Code 11110103) is located in northwest Arkansas and northeastern Oklahoma. The Oklahoma portion of the basin amounts to some 576,030 acres (SCS, 1989).

In recent years, water quality degradation of the Illinois River has been at the center of controversy between Arkansas and Oklahoma. Both states have conducted numerous studies of point source pollution such as municipal and industrial wastewater discharge, but only recently has the impact of nonpoint source pollution been considered.

The poultry industry in the Illinois River Basin has expanded rapidly in the last decade. Although a boon economically, it is suspected to be responsible for the increasing degradation of water quality in the Illinois River and consequently Tenkiller Ferry Lake (Gakstatter and Katko, 1986). Since it is designated as a scenic river by the Oklahoma Legislature for its esthetic quality and is also used for municipal and industrial water supplies, the Illinois River, along with Tenkiller Ferry lake, receives explicit protection from any degradation in water quality. It is therefore critical to develop accurate monitoring techniques and implement them throughout the basin to guard against any potential harm to the water supply.

With approximately 200 million chickens and turkeys being raised in the basin each year and producing over 800,000 tons of manure, the potential for nutrient loading from nonpoint sources into the Illinois River is formidable. Since most grasslands, which account for some 48% of the total area in the basin, are unsuitable for row crops, the preferred method of accumulated poultry litter disposal is surface spreading. This translates to over 11,000 tons of raw nitrogen and about 5,200 tons of phosphorus being spread over basin pastures each year (USDA, Forest Service and SCS, 1989).

In addition to the poultry industry, swine, dairy cattle, and unconfined beef cattle also contribute to the waste disposal problem. The total manure produced in the basin is estimated to be 2 million tons per year (USDA, Forest Service and SCS, 1989).

As previously stated, former studies within the basin have centered around point source pollution. There is now a clear necessity to formulate and implement plans, or Best Management Practices (BMP), to control nonpoint source pollutants, particularly nutrients.

One of the greatest challenges for managing water quality is the measurement and prediction of changes in nutrient concentrations in surface runoff. In order to evaluate the efficiency of BMP, it is therefore necessary to define the profile of a potential problem area of excessive nutrient loading and to then develop a database establishing water quality baselines.

Battle Branch Subbasin

Battle Branch subbasin contains nearly 6000 acres and is located in southern Delaware County on the northwest edge of the Illinois River Basin (Fig. 1). Consisting of approximately 2 miles of spring fed perennial flow over rock and gravel substrate, Battle Creek is a typical Northeast Oklahoma Ozarkian stream. Its point of confluence with Flint Creek is approximately 2 miles east of the town of Flint, Oklahoma.

The subbasin consists of extremely porous, thin, cherty soils of mostly Clarksville, Locust, Baxter-Locust, and Stigler silty loams (SCS, 1970). The relatively poor quality of the subbasin soil excludes row crops and renders them economically impracticable. Deprived of economic opportunity in field crop farming, local producers have focused their efforts on animal products. Consequently, this area, as does the rest of the basin, boasts a particularly high poultry population. SCS inventory of Aug. 1990 lists 29 poultry houses containing 435,000 broilers and 28,000 turkeys, as well as 415 dairy cows and some 4000 beef cattle.

Although Battle Branch contains over 3000 acres of grassland, or 51% of the subbasin, Cherokee Hills Resource Conservation and Development Project (1987) estimated that only 2,000 to 2,500 acres, or approximately 40%, is acceptable for manure spreading. These percentages closely compare to the 48% grassland of the entire Illinois River Basin. As with Battle Branch, a portion of the grassland in the Illinois River Basin is not available for manure application.

The Battle Branch subbasin is also geologically and agriculturally representative of others within the basin and contains no point source pollution hazards, thus providing a good model for investigation of nonpoint nutrient loading in the Illinois River Basin.

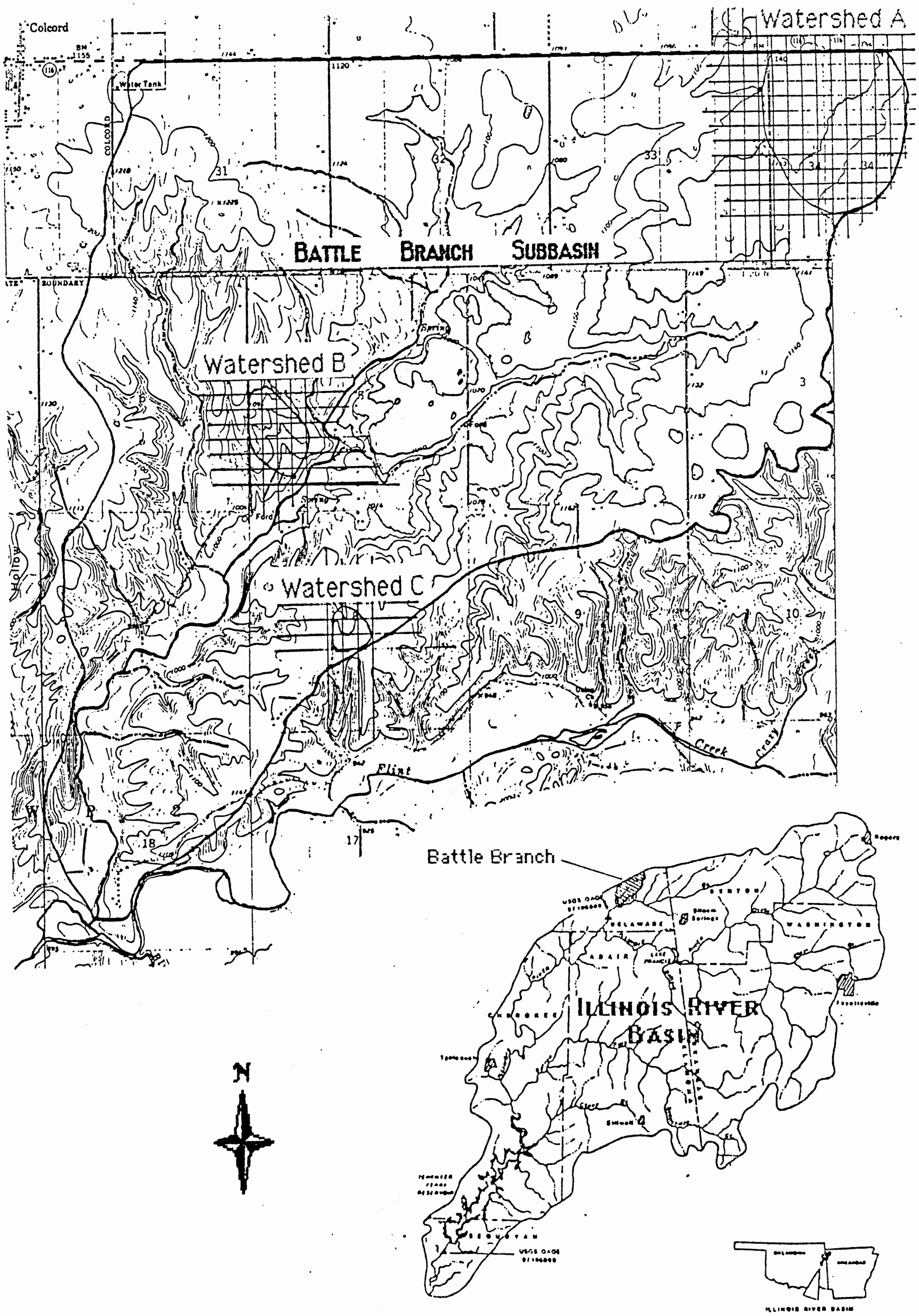


Figure 1. Battle Branch Subbasin with Selected Watersheds

CHAPTER II

LITERATURE REVIEW

Nonpoint Source Pollution

Within the last two decades, national and international communities have recognized the necessity to research and control nonpoint sources of pollution. Nonpoint defines those pollution sources related to human activity, such as agriculture and urbanization, and to the natural environmental processes (weathering and mineralization) commonly referred to as background pollution. Industrialized countries have previously committed all pollution abatement efforts to controlling only point source pollution. Generally, these discharges are visually identifiable and, therefore, easily dealt with through regulation and rapidly evolving engineering technologies.

In contrast to point source pollution, nonpoint source pollution is carried by diffuse surface water runoff from rural, as well as urban, hydrologically active areas (Novotny and Chesters, 1981). This fact makes it extremely difficult to determine the definitive origin, magnitude, or consequence of any suspected pollution loadings.

Not until the late 1960s did a few discrete areas of the United States begin to invest money and manpower into nonpoint pollution research. By 1982, six states had reported nonpoint sources as their primary cause of water degradation. In 1984, the Association of State and Interstate Water Pollution Control Administrators reported that nonpoint source pollution had significantly degraded 1.4 million acres of surface lake water within the previous decade (Dysart, 1985). Today, it is widely accepted that nonpoint source pollution is responsible for 50%, possibly more in agricultural areas, of our total water quality problems. Thus, in order to achieve and maintain the desired quality in our surface and ground waters, scientist should place a high priority on examining the total overall environment of any suspected pollution problem area.

Because of the diffuse and intermittent nature of surface runoff, nonpoint source pollution originates over diverse and often expansive areas of land (Novotny and Chesters, 1981). The pollutants may be transported over portions of the watershed or over the entire watershed before reaching surface waters. Since there is no point of origin and the overland transit makes determining the exact source extremely difficult, they cannot be monitored in the same manner as point sources.

Being dependent on the amount of runoff, the magnitude of nonpoint pollution is therefore a function of the quantity and intensity of climatic events. However, the magnitude of nonpoint pollution is also directly related to land use practices, land cover (Smart, et al., 1981; Omernik, 1977) and, to a lesser extent, geologic conditions (Dillon and Kirchner, 1975). The complex adjunct relationship of these parameters results in a governing environment that also differs, sometimes greatly, depending upon the season (Klausner, et al. 1976). Consequently, the elimination or control of nonpoint source pollution must be considered spatially and temporally site-specific.

The Soil Conservation Service defines appropriate conservation practices and land management techniques to control nonpoint pollution in agricultural areas as part of a program called Best Management Practices (BMP).

Nutrients and Eutrophication

While the biotic and abiotic components of a lake, pond, or stream may at first appear to constitute a unique microcosm, they are actually all components of a larger watershed ecosystem (Odum, 1983). The proportions of inflow and outflow of water and materials determine the ecosystem's function and stability with respect to the entire drainage basin. An absence of BMP for watersheds, such as applying more manure to the land than can be assimilated, may result in a net outflow of nutrients and subsequent "cultural" eutrophication of waters downstream from the watershed by greatly accelerating the trophic process (Reckhow et al., 1990).

Two different mechanisms account for non-productive nutrient removal from farmland. Leaching or percolation of soluble nutrients into ground water is dependent on the soil type and texture as well as the land gradient. Overland surface runoff, after a relatively heavy rain, carries not only dissolved nutrients, but also the top layer of soil. The transported soil particles are linked either chemically or adsorptively to varying amounts of nutrients (Vollenweider, 1968). Ephemeral runoff should be considered representative of near surface ground water.

Nitrogen and phosphorus are the nutrients of major concern, with respect to terrestrial loss, potential eutrophication of surface waters, and leaching into ground waters (Sharpley, et al., 1988; Vollenweider, 1968; Timmons, et al., 1973). Under usual aerobic conditions, the oxidized forms of nitrogen are water soluble and are readily transported during a runoff event. By contrast, phosphorus is quickly adsorbed to soil particles and is usually transported through soil erosion.

We can control soil erosion through appropriate conservation practices that restrict the flow of water, thus reducing phosphorus movement. Although restricting water flow may increase percolation of nitrate-N into groundwaters that eventually recharge streams, nitrogen levels may be reduced as runoff passes over grassed areas. More research into optimum nutrient levels that work in conjunction with well known conservation practices is needed to eliminate nutrient losses from our land and the subsequent eutrophication of our water (Wolff, 1985).

As explained by Wetzel (1983), eutrophication is a culmination to the natural successive aging process of any lake involving the biological dynamics of phytoplankton and macrophytes. When external nutrient enrichment accelerates this process blooms of nuisance algae and aquatic plants occur. Such an increase in productivity may, in turn, lead to increased hypolimnetic oxygen deficit, decreased water clarity, and changes in species composition (Dillon and Rigler, 1974).

Although greatly influenced by water volume and mean depth, Vollenweider (1968) fixed the threshold values at 0.3 mg L^{-1} for nitrate and 0.02 mg L^{-1} for soluble phosphate content. As a general rule, concentrations above these may be regarded as potentially eutrophic. However, Sharpley et al. (1985) found P levels in rainfall may exceed the critical values of 0.01 and 0.02 mg L^{-1} for soluble and total P, respectively, and can result in natural eutrophication. Consequently, the critical level approach should not be used as the sole criterion in quantifying permissible tolerance levels of P in surface runoff.

While serving as the vector for the excess nutrients, flowing waters commonly do not experience planktonic blooms. Due to the turbulence of currents and eddies, most lotic algae are members of the periphyton (attached) community. As with planktonic algae, they too flourish on the excess supplies of nutrients and are good indicator species in suspected nutrient loading problem areas in rivers and streams. They become dislodged when the periodic surge of a runoff event occurs and, like the soluble and sestonic nutrients, are transported into the receiving waters below the watershed to further contribute to the nutrient pool.

The trophic state of lentic waters is dependent on the amount of available nutrients, primarily nitrogen and phosphorus, and the rate at which they are recycled within the individual body of water. Microorganisms and macrophytes rapidly assimilate available forms of nitrogen and phosphorus. Consequently, soluble nutrient concentrations in clean natural water are usually low. Taylor et al. (1971) found the concentrations of nitrogen and phosphorus in runoff samples from undisturbed woodland watersheds to be .5-.9 mg L^{-1} and .01-.02 mg L^{-1}, respectively.

In addition to the soluble nutrient concentrations, it is also important to assess that which is bound to the exported soil particles. Nutrient concentrations contained in sediment, particularly phosphorus, play a crucial role in the nutrient cycle and thus the trophic state of a water body. As the sediment sinks into an anaerobic environment, phosphates may dissociate and recycle through the system in order to reach a new equilibrium.

It is therefore important, as pointed out by Timmons and associates (1973), to determine the quantities of both the sediment and water during the runoff event. This total discharge is the determining factor in the potential trophic effects a flowing stream will have on its receiving waters. High nutrient concentrations may contribute low total nutrient input (relative to the receiving body of water) if small volumes of water and sediment are being exported from the watershed.

A complex series of chemical, physical and biological interactions determine the limiting nutrient and thus, regulates the rate of production of organic matter. Vollenweider (1968) showed that nitrogen and phosphorus largely determine productivity and that phosphorus was predominant over nitrogen as a limiting factor. Odum (1983) suggested that this may be due to the relative scarcity of P in the environment.

Phosphorus. The transport of P in runoff from terrestrial to aquatic environments can occur as either soluble or particulate P (Sharpley and Syers, 1979). The term particulate P includes P sorbed by soil particles and organic matter eroded during runoff. Because P is strongly adsorbed to clay particles and organic matter contains relatively high levels of P, the major portion transported from agricultural land is usually in the particulate form (Burwell et al., 1977). The overland runoff during a storm scours and suspends colloidal particles from fields and ephemeral stream beds. Upon reaching a lake environment, large amounts of P may be released from these sediments and recycled in the orthophosphate form.

Since little erosion occurs on undisturbed grassland or forest soils, most P exported from these areas is in the soluble form (Burwell et al., 1975). Desorption from the soil must first take place, but even a runoff event of short duration can result in significant soluble P loading from grassland. Conducting lab experiments on different soils, Sharpley et al. (1981a) found it possible to desorb 75% of the P in the first 30 minutes of a 4 hour period.

The transformation between soluble and particulate P can occur any time during the transport process and is a function of the sorption capacity of the sediments. Under some conditions the sediment in the surface runoff may also act as a P sink (Sharpley, et al. 1981b)

<u>Nitrogen</u>. Forms of nitrogen dissolved in water include organic, ionized ammonia (NH_4^+), unionized ammonia (NH_3), nitrite (NO_2^-), and nitrate (NO_3^-) (Wetzel, 1983). Of these forms, nitrate and ionized ammonia are rapidly taken up by plants. However, since nitrate is stable at pH > 3 (Bohn, et al. 1985), it is the predominant form present in flowing streams.

Bacterial action and hydrolysis decomposes organic-N to form ammonia-N. <u>Nitrosomonas</u> (bacteria) oxidize ammonia-N to NO_2^- and the genus

Nitrobacter further oxidizes the resulting NO_2^- to NO_3^-. Although some reduction ($NO_3^- \rightarrow$ gaseous products) may also take place, algae and higher plants rapidly assimilate the NO_3^- and it is readily transported by water.

Although less than 1% of the total N in poultry litter is NO_3^--N, the organic-N in poultry litter is quickly mineralized to the more readily available inorganic form (Bitzer and Sims, 1988). When soil temperature is above 25° C, Sims (1986) found 30 to 60% of the organic-N would be mineralized within 90 days if moisture was not limiting. 5+0? The rapid mineralization of organic-N in the manure may result in significant leaching in coarse-textured soils and in overland transport of inorganic NO_3^-.

Kilmer et al. (1974) found that, during the heaviest runoff volume periods of the fall and spring months, NO_3^--N comprised approximately 80% of the total N lost from two watersheds. Total N losses ranged from 6-10% of that applied.

Precipitation exceeds evapotranspiration during winter months and the absence of plant uptake favors nitrate movement. The low temperatures of winter also limit assimilation by soil microorganisms and impede mineralization. In the absence of mineralization of soil organic matter, a small portion of the total N lost is thought to be residual in form (Kilmer et al., 1974).

Project Design and Objectives

The Battle Branch subbasin is an integral part of the Illinois River Basin. The subbasin will provide implicit knowledge in appraising the relative contribution of land use practices to the overall nutrient load exported from the basin. Therefore, the overall objective of this project was to evaluate the relative impact of nitrate and phosphorus from poultry-rearing and litter-spreading operations upon the total nutrient load in the drainage runoff waters of selected small watersheds in the Battle Branch subbasin. In addition to nitrate and phosphorus, the contribution of the conservative elements fluoride, chloride, and sulfate were evaluated. In an effort to correlate erosion losses with nutrient loads, particularly phosphorus, the turbidity of water samples from each runoff event was also measured.

A paired watershed design was chosen for the water quality monitoring technique (Spooner, et al., 1985; Clausen, 1985). The paired watershed design involves the simultaneous edge-of-field or downstream sampling of multiple similar watersheds in close physical proximity thereby permitting an evaluation of the quality of drainage associated with a shared meteorological event. This experimental design will allow evaluation and comparison between treated and untreated watersheds. In addition, it will supply an applicable database for the eventual research of the area once appropriate BMP have been implemented.

The eventual goal is to determine the potential problem areas of the Illinois River Basin and to evaluate the efficiency of BMP in controlling nutrient exports once those areas have been defined. It is therefore important to utilize all available resources and approaches in establishing a broad database from which to work.

The Agricultural Non-Point-Source Pollution Model (AGNPS) is an available research tool that will provide an extra dimension to this project (Young et al., 1987). This event-based computer simulation model was designed to analyze nonpoint source pollution from agricultural watersheds. When supplied with proper input data, the model will predict: runoff volume and peak discharge rate; eroded and delivered sediment; nitrogen and phosphorus concentrations; and chemical oxygen demand (COD) for various runoff events.

The objective of this part of the project will be to evaluate any correlation between the observed data and that predicted by the AGNPS transport model. This should provide an important data base from which future research of the Illinois River Basin could begin. Furthermore, it will develop background information on the sensitivity of AGNPS.

The objectives are as follows:

1) To select three small watersheds in the Battle Branch subbasin

that have been thoroughly documented with respect to areas of land use practices (ie. poultry-rearing and/or waste-spreading operations), land cover, and population densities. The watersheds should be limited to specific landuse practices so that a meaningful correlation can be obtained between nutrients and landuse practices. In addition, a fourth control watershed with forest or undisturbed pasture land was selected to compare with the intensively managed areas.

2) To coordinate with the local SCS agent in order to: obtain data on the intensity of the poultry-rearing and relate operations in the watersheds; and to serve as liaison with local residents.

3) To set up automatic samplers at strategic discharge points for surface runoff and take measurements of the runoff channel so as to calculate discharge volume.

4) To perform analysis for the concentrations of nutrients and measure the turbidity per each water sample collected during a runoff event. The results will be plotted over time.

5) To optimize and define any correlation between actual nutrient losses and those predicted by the AGNPS computer model, thereby facilitating the examination of relationships between land use practices and nutrient runoff.

CHAPTER III

AGRICULTURAL NON-POINT SOURCE POLLUTION MODEL

Agricultural Non-Point Source model (AGNPS) is an event-based computer simulation model designed to analyze nonpoint source pollution from agricultural watersheds. Developed to assess water quality runoff from watersheds of up to 23,000 acres, it can be used to predict runoff volume and peak discharge rate, eroded and delivered sediment, and nitrogen, phosphorus, and chemical oxygen demand (COD) concentrations for all points in the watershed (Young et al., 1987). The input information necessary to build a watershed data file can be readily obtained through SCS records and surveys or by on-site visual inspections. The model is relatively easy to use and manipulate for varying single-event conditions and will run on any IBM-compatible personal computer. Untested, preliminary assessments of AGNPS have shown the potential for providing an accurate and uniform means by which to compare different watersheds or investigate possible Best Management Practices (BMP) prior to their implementation. Utilization of AGNPS to examine the watershed from its beginning to its outlet can depict specific problem areas and facilitate pollution abatement strategies.

Basic Model Structure

With the occurrence of a storm event, the resulting overland runoff picks up volume and energy as it meanders from the highest elevations to the discharge outlet of the watershed. In doing so, it transports and occasionally deposits sediment and nutrients in both soluble and particulate forms. As the energy and volume change from one distinct area to another, the transport load naturally fluctuates with additional erosion and deposition. AGNPS uses this same cascade principle in calculating the predicted exports.

As with many transport models, AGNPS operates on the basic cell design which divides the watershed into a uniform grid system. Proceeding from the top of the watershed to the outlet, the calculations are made in a stepwise cell-to-cell process. This method allows output analysis of the flow for any area (ie. cell) of the watershed.

From a detailed topographic map, the watershed boundaries are established and the section borders surrounding it are quartered into smaller cells. The appropriate cell size is dependent on the size of the watershed and the degree of sensitivity desired. For watersheds covering areas of less than 2000 acres, cells of 10 acres are suggested, while cells of 40 acres are recommended for larger basins (Young et al., 1987). The individual cells can further be quartered three successive times resulting in divisions 1/64 the size of the original cell. While effecting little variation in the overall results of the simulation, this feature allows for a more detailed characterization of specific problem cells within the watershed. Although requiring more labor and program run time, smaller cell size with more detailed input parameters will yield better accuracy.

Hydrology

Runoff Volume. Because of its widespread use and easily accessible numbers, the SCS curve number method is used to simulate overland runoff volume from each of the cells. The equation is as follows:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad [1]$$

where Q is runoff volume, P is rainfall, and S is a retention parameter. The retention parameter is determined as:

$$S = \frac{1000}{CN} - 10 \qquad [2]$$

where CN is the SCS curve number.

Peak Runoff Rate. The channelized flow is simulated using a peak flow equation developed for use in the Chemical, Runoff, and Erosion from Agricultural Management Systems model (CREAMS) as the basic framework. The coefficient values were developed using data from 304 storms that occurred on 56 watersheds located in 14 states (Bosch et al., 1983). The resulting equation is as follows:

$$Q_p = 3.79 A^{0.7} CS^{0.16} \left(\frac{RO}{25.4} \right)^{(0.903 A^{0.017})} LW^{-0.19} \qquad [3]$$

Q_p - peak flow rate in $m^3 s^{-1}$
A - drainage area in km^2
CS - channel slope in $m\ km^{-1}$
RO - runoff volume in mm
LW - watershed length-width ratio as calculated by the program as L^2/A, where L is the watershed length.

Sediment Transport

Erosion. In order to estimate upland erosion, the following modified version of the universal soil loss equation (Wischmeier and Smith, 1978; Walker, 1980) was employed.

$$SL = (EI)\ KLSCP\ (SSF) \qquad [4]$$

SL - soil loss
EI - product of the storm total kinetic energy and maximum 30-minute intensity
K - soil erodibility factor

LS = topographic factor
C = cover factor
P - land practice factor
SSF = factor to adjust for slope shape within the cell

As yields are calculated for each cell, it is further divided into 5 particle size classes: clay, silt, sand, small aggregates, and large aggregates. Stream-bank and gully erosion are also estimated during this phase.

Cell Routing. With runoff and erosion factors calculated, transport and deposition of the detached sediment is estimated by:

$$Q_s(x) = Q_s(o) + Q_{sl}\left(\frac{x}{L_r}\right) - \int_0^x (x) w dx \qquad [5]$$

$Q_s(x)$ = sediment discharge at the downstream end of the channel reach
$Q_s(o)$ = sediment discharge at the upstream end of the channel reach
Q_{sl} = lateral sediment inflow rate
x - downstream distance
L_r - reach length
w - channel width
D(x) - deposition rate -

$$D(x) = \left[\frac{V_{ss}}{q(x)}\right]\left[q_s(x) - g'_s(x)\right] \qquad [6]$$

V_{ss} - particle fall velocity
q(x) = discharge per unit width
$q_s(x)$ = sediment load per unit width

$g'_s(x)$ = effective transport capacity per unit width

The effective transport capacity ($g'_s(x)$) is solved by using a modified Bagnold stream power equation involving computations with Manning's roughness coefficient.

Sediment transport through each cell for each of the 5 particle sizes is thus culminated into the following basic routing equation:

$$Q_s(x) = \left[\frac{2q(x)}{2q(x) + \Delta x V_{ss}}\right]\left[Q_s(o) + Q_{sl}\frac{x}{L} - \frac{W\Delta x}{2}\left[\frac{V_{ss}}{q(o)}[q_s(o) - g'_s(o)] - \frac{V_{ss}}{q(x)}g'_s(x)\right]\right] \qquad [7]$$

Nutrient Transport

As with the peak runoff rate, the equation that simulates nitrogen and phosphorus transport through the watershed has been adapted from that used in CREAMS. With modifications to account for soil texture, it divides the transport into two fractions: soluble nutrients and that adsorbed to sediments. The sediment-attached nutrient load is calculated using the total sediment discharged from the cell. The equation is:

$$Nut_{sed} = (Nut_f)\,Q_s(x)\,E_R \qquad [8]$$

Nut_{sed} = N or P transported by sediment
Nut_f = N or P content in the field soil
$Q_s(x)$ = sediment yield

E_R = enrichment ratio =

$$E_R = 7.4\ Q_s(x)^{-0.2} T_f \qquad [9]$$

T_f = correction factor for soil texture

Soluble nutrients are considered with respect to rainfall, fertilization, and leaching. They are estimated by the equation:

$$Nut_{sol} = C_{nut}\, Nut_{ext}\, Q \qquad [10]$$

Nut_{sol} - concentration of soluble nutrient in runoff
C_{nut} - mean concentration of soluble N or P at the soil surface during runoff
Nut_{ext} - an extraction coefficient for movement into runoff
Q = total runoff

It should be pointed out that a more complete documentation of the AGNPS program may be found in the user's manual (Young et al., 1987), and that the aforesaid equations from Young and associates (1989) represent only the basics with a marginal explanation.

Parameters

Operator Input

The input variables needed to build a watershed data file are readily available from published material, appropriate public agencies, or on-site inspection. In addition, the model's user manual (Young et al., 1987) contains several tables listing standard variables and, if actual values are unknown, the program uses default settings for some of the parameters. If known, however, precise input values pertaining to the particular watershed in question will yield a more accurate simulation. Constituting a complete data file, the input parameters are divided into two categories: watershed data and cell data (Table 1). Watershed data is that which pertains to the entire watershed and the runoff event that is to be simulated. Cell data involves all aspects of the physical characteristics of each cell and the associated land use practices.

The cell data collection sheet (Figure 2) is used in initially documenting the watershed. When completed for each cell, the values are entered into the program spreadsheet to establish the watershed data file from which transport computations are made.

Integrated within the AGNPS model is a feedlot pollution model (Young et al., 1982). This subroutine treats animal wastes from a feedlot environment as a point source and routes the resulting concentrations and mass through the watershed with the nonpoint nutrients. Other point source inputs can likewise be accommodated by adding flow rates and concentrations in the appropriate cell.

TABLE 1

INPUT DATA FILE*

Watershed Parameters

Watershed Identification	Watershed B
Description	Turkey Litter
Area of each cell	2.5
Number of Cells	16
Precipitation	3.5
Energy-Intensity Value	280.0

Cell Parameters

A: Cell Number........	1	2	3
B: Cell Division......	000	000	000
C: Rec. Cell Number...	4	4	6
D: Rec. Cell Div......	000	000	000
E: SCS Curve Number...	60	60	60
F: Land Slope.........	4.0	4.0	2.0
G: Slope Shape........	2	2	1
H: Slope Length.......	330	330	330
I: Channel Slope......	2.0	2.0	1.0
J: Chan. Side Slope...	10.0	10.0	10.0
K: Mannings Coef......	0.08	0.08	0.08
L: K - Factor.........	0.28	0.28	0.28
M: C - Factor.........	0.03	0.03	0.03
N: P - Factor.........	1.00	1.00	1.00
O: Surf Cond Const....	0.29	0.29	0.29
P: Aspect.............	4	5	5
Q: Soil Texture #.....	2	2	2
R: Fert Level.........	0	0	0
S: Availability Fact..	0	0	0
T: Point Source Ind...	0	0	0
U: Gully Source Lev...	0	0	0
V: COD Factor.........	65	65	65
W: Impoundment Fact...	0	0	0
X: Channel Indicator..	0	0	0

*Taken from actual AGNPS input spreadsheet.

Watershed Data File

Sheet No.
Watershed Name

Cell No.	Rec Cell No.	SCS Curv No.	Land Slope %	Slope Shape Fact	Field Slope Lgth	Chnl Slope %	Chnl Side Slope	Man's Coefc	K Fact	C Fact	P Fact	Surf Cond Const	Aspt	Soil Text No.	Fert Lev	Avail Fact %	Point Srce Indic	Gully Srce	COD	Impd Fact	Chnl Indc

Figure 2. Cell Data Collection Sheet

Model Output

TABLE 2

WATERSHED SUMMARY OUTPUT

Watershed Summary	
Watershed Studied	Watershed B
The area of the watershed is	40 acres
The area of each cell is	2.50 acres
The characteristic storm precipitation is	3.50 inches
The storm energy-intensity value is	280
Values at the Watershed Outlet	
Cell number	15 000
Runoff volume	0.5 inches
Peak runoff rate	32 cfs
Total Nitrogen in sediment	12.29 lbs/acre
Total soluble Nitrogen in runoff	0.66 lbs/acre
Soluble Nitrogen concentration in runoff	5.55 ppm
Total Phosphorus in sediment	6.15 lbs/acre
Total soluble Phosphorus in runoff	0.12 lbs/acre
Soluble Phosphorus concentration in runoff	1.02 ppm
Total soluble chemical oxygen demand	7.29 lbs/acre

Tabular. Available in both summarized and detailed formats, AGNPS presents a variety of output options. Table 2 is the watershed export summary complete with its identifying preliminary data. A more detailed analysis is available for the entire watershed (Table 3) or on a cell-by-cell basis (Tables 4 and 5).

TABLE 3

DETAILED SEDIMENT ANALYSIS FOR ENTIRE WATERSHED

Sediment Analysis

Particle type	Area Weighted Erosion Upland (t/a)	Area Weighted Erosion Channel (t/a)	Delivery Ratio (%)	Enrichment Ratio	Mean Concentration (ppm)	Area Weighted Yield (t/a)	Yield (tons)
CLAY	0.81	0.00	99	3	13590.94	0.80	32.2
SILT	1.30	0.00	83	2	18271.09	1.08	43.2
SAGG	8.10	0.00	44	1	60028.24	3.55	142.1
LAGG	5.02	0.00	0	0	236.55	0.01	0.6
SAND	.97	0.00	0	0	43.89	0.00	0.1
TOTAL	16.20	0.00	34	1	92170.71	5.45	218.2

TABLE 4

EXAMPLE OF CELL BY CELL CHEMICAL ANALYSIS

Nutrient Analysis
PHOSPHORUS

Cell Num	Div	Drainage Area (acres)	Sediment Within Cell (lbs/a)	Sediment Cell Outlet (lbs/a)	Water Soluble Within Cell (lbs/a)	Water Soluble Cell Outlet (lbs/a)	Conc (ppm)
1	000	3	2.73	1.74	0.01	0.01	0
2	000	3	2.73	1.74	0.01	0.01	0
3	000	3	1.16	0.72	0.01	0.01	0
4	000	8	43.56	12.07	0.00	0.01	0
5	000	10	2.21	7.01	0.19	0.05	0
6	000	5	43.56	16.85	0.00	0.00	0

TABLE 5

HYDROLOGIC AND SEDIMENT DATA FOR THE FIRST 2 CELLS OF WATERSHED B

-HYDR- Cell Num	Div	Drainage Area (acres)	Overland Runoff (in.)	Upstream Runoff (in.)	Peak Flow Upstream (cfs)	Downstream Runoff (in.)	Peak Flow Downstream (cfs)
1	000	3	0.53	0.00	0	0.53	7
2	000	3	0.53	0.00	0	0.53	7

-SED- Cell Num	Div	Particle Type	Cell Erosion (t/a)	Above (tons)	Generated Within (tons)	Yield (tons)	Deposition (%)
1	000	CLAY	0.10	0.00	0.25	0.25	0
		SILT	0.16	0.00	0.40	0.38	4
		SAGG	0.99	0.00	2.47	2.02	18
		LAGG	0.61	0.00	1.53	0.15	90
		SAND	0.12	0.00	0.30	0.02	93
		TOTL	1.98	0.00	4.94	2.82	43
2	000	CLAY	0.10	0.00	0.25	0.25	0
		SILT	0.16	0.00	0.40	0.38	4
		SAGG	0.99	0.00	2.47	2.02	18
		LAGG	0.61	0.00	1.53	0.15	90
		SAND	0.12	0.00	0.30	0.02	93
		TOTL	1.98	0.00	4.94	2.82	43

Taken from my investigations, the above tables are actual readouts that help to illustrate the breadth of the AGNPS program. Hydrologic, sediment, and chemical (N, P, and COD) data are available for the watershed outlet point or for any cell. This gives the operator the ability to analyze the watershed as a whole and, if need be, select and examine potential or suspected problem areas for future management implementation.

Graphic. The Grafix Display utility of AGNPS allows simultaneous viewing of up to 14 variables with up to 5 conditions on each variable. For example, the operator might wish to highlight all cells (1 variable) containing impoundments (1 condition) exporting concentrations of more than 1 ppm P and more than 5 ppm N (2 conditions). The variable options include: whole watershed (Fig. 3); subwatershed; cell input and output conditions; path of cells to outlet; and feedlot parameters.

With variables kept to a minimum, graphic representations of the watershed data file are elementary and serve to give the operator an overall picture of the predominant existing conditions.

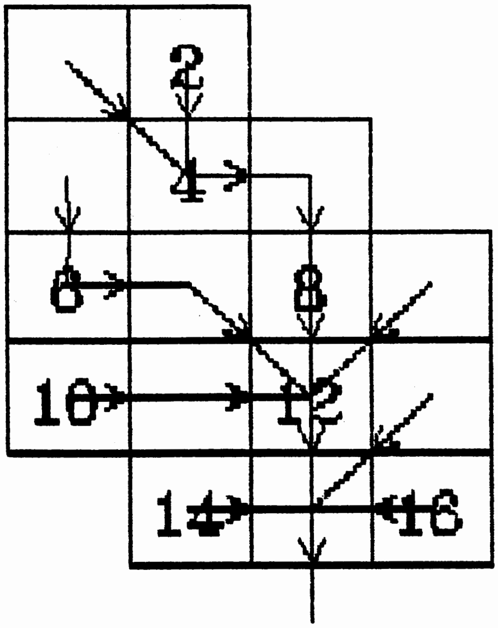


Figure 3. Watershed B with Grid, Numbered Cells, and Flow Vectors

CHAPTER IV

METHODS AND MATERIALS

Selection of Watersheds

Three small, individual watersheds within the Battle Branch subbasin were chosen for evaluation. Although not inside the Battle Branch subbasin, a fourth, forested watershed, was established as a control. All the selected watersheds contained only ephemeral stream channels, thereby allowing for sample collection only for the duration of each runoff event. Additionally, all vary slightly in size, land use, land cover, or steepness of slopes.

Watershed A. Consisting of 230 acres of tame pasture land, Watershed A contained 3 residence and 2 broiler houses with a maximum capacity of 30,000 birds. The majority land owner spreads poultry litter from the 2 houses, as well as litter and occasionally liquid swine manure obtained from local producers. He also grazed approximately 100 head of beef cattle. The soil types in order of relative abundance were: Captina silt loam, 1-3% slope; Stigler silt loam, 0-1% slope; Locust cherty silt loam, 1-3%

slope; and Staser silt loam, 0-1% slope.

Watershed B. Watershed B was 40 acres in size and contained 1 residence and 3 turkey houses. Vegetation in the watershed was approximately 65% grassland and 35% oak-hickory forest. Housing a minimum of 28,000 turkeys, the accumulated litter was spread over most of the the 26 acres of pasture where a few cattle are grazed. Even though the watershed was adjacent to Battle Creek, the drainage from the grassland appeared to enter the creek only through a well defined channel and discharge point. The soil types in order of relative abundance were: Sallisaw gravelly silt loam, 3-8% slope; Clarksville very cherty silt loam, 1-8% slope; and Clarksville stoney silt loam, 20-50% slope.

Watershed C. Watershed C occupied 20 acres of tame pasture land containing 1 residence, 1 broiler house with a minimum capacity of 15,000 birds, and a small dairy operation with approximately 60 cows. In addition to grazing the dairy cows, the land owner spread the accumulated litter and manure from the dairy holding pen over the entire watershed. The soil types in order of relative abundance were: Baxter-Locust complex, 3-5% slope; Locust cherty silt loam, 1-3% slope; and Clarksville stoney silt loam, 5-20% slope.

Watershed D. Used as the control, Watershed D covered 35 acres located outside the Battle Branch subbasin. It contained 2 residences and an otherwise undisturbed oak-hickory forest with a small, native grass meadow of approximately 2 acres. The aggregate soils in order of relative abundance are: Clarksville stoney silt loam, 20-50% slope; Locust cherty silt loam, 1-3% slope; and Clarksville very cherty silt loam, 1-8% slope.

AGNPS Parameters

Watershed Mapping

The first step in establishing a watershed data file for input into the AGNPS spreadsheet was to outline the boundaries of each watershed on USGS quadrangle maps, scale 1:24000 (Fig. 4a). The section boundaries surrounding the watershed were then divided into uniform cells by sequential quartering until the desired cell size was reached. Due to the small size of the study watersheds, they were divided into cells of 2.5 acres.

The cells were numbered consecutively beginning with the northwest corner and proceeding west to east while continuing southward (Fig. 4b). Only those cells with >50% of their area within the defined watershed boundary are numbered.

The direction of drainage flow from each cell (Fig. 4c) was determined by the topographical map lines and on-site inspections of each

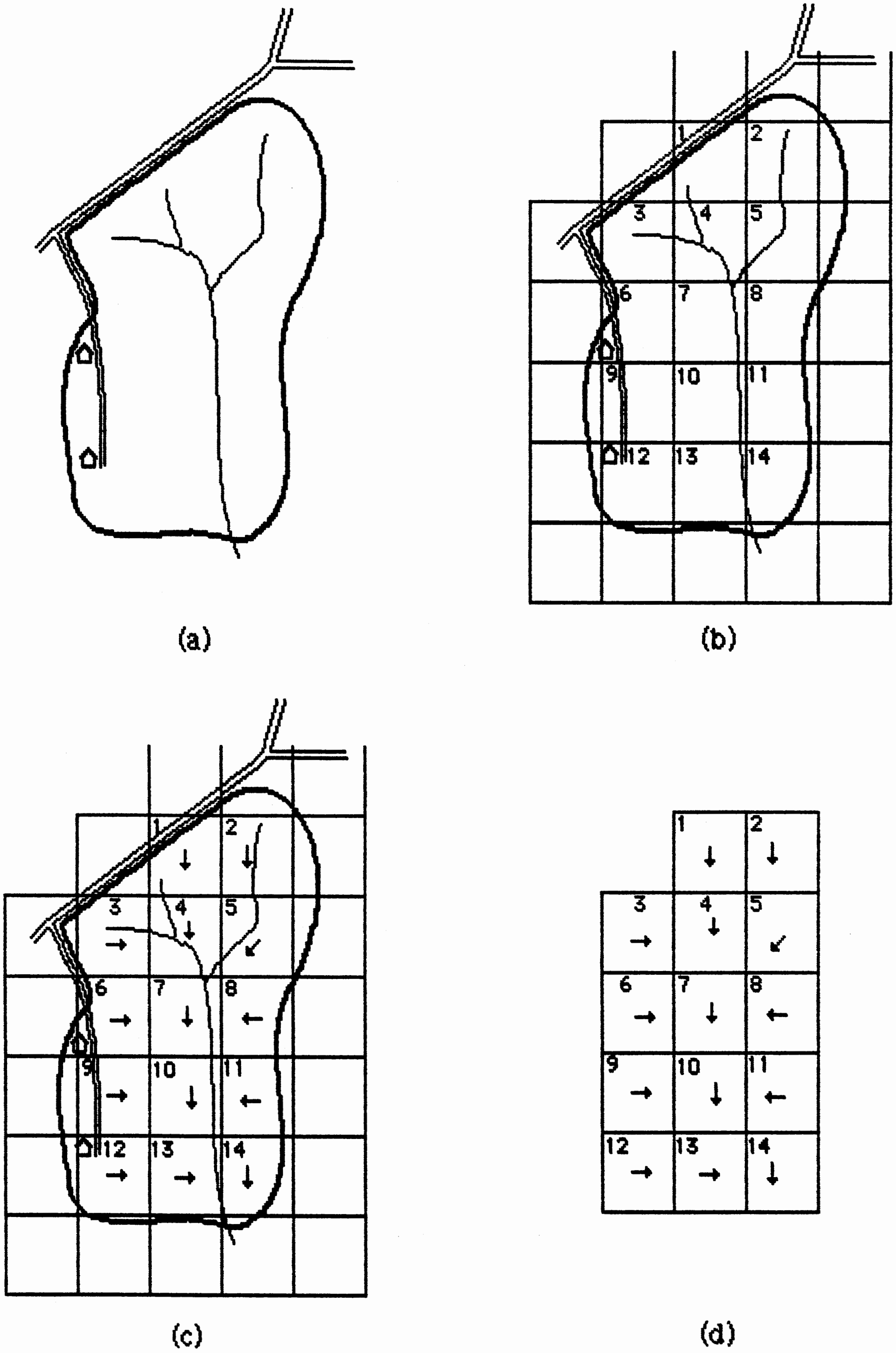


Figure 4. Watershed Mapping Steps

watershed. For input into the data file, AGNPS refers to the cell's flow direction as its aspect and assigns identification numbers 1 through 8 to correlate with the 8 possible directions. Figure 4d shows the mapped watershed as perceived by the AGNPS program.

After reducing to 1:20000 scale, transparent overlays of each mapped watershed was made. The overlays make it possible to discern the predominant soil type in each cell by merely placing the defined watershed transparency directly over the SCS soil survey maps (USDA, 1970). The soil type defines its hydrologic group which determines the SCS curve number for various land use practices. Land slopes for each cell are also given with soil identification.

Data File Input

The watershed data file, as seen in Chapter III (Fig. 2), can be established upon completion of the preliminary examination and mapping. A summary explanation of the parameters and methods of determining input is as follows:

Watershed Identification/Description. Consisted of 30 characters or less and identified the input and output files by the program.

Area of Each Cell. Size was dependent on operator discretion.

Number of Cells. Number of cells with >50% of their area within the watershed.

Precipitation. The amount, in inches, as determined by the particular runoff event to be simulated.

Energy-Intensity Value. This value was the rainfall erosion index (R) used in the universal soil loss equation (USLE) (Wischmeier and Smith, 1978) and was determined to be 280 for Delaware County from personal communication with the local SCS agent.

A: Cell Number. Identification number of the cell in question.

B: Cell Division. Indicates the level of division if any.

C: Rec. Cell Number. The number of the cell into which the majority runoff drained as determined by the aspect.

D: Rec. Cell Div. Indicated the level of receiving cell division if any.

E: SCS Curve Number. The runoff curve number as determined by preliminary mapping.

F: Land Slope. The major slope in percent of rise as determined by soil survey.

G: Slope Shape. An identification number indicating the dominant shape: 1, uniform; 2, convex; 3, concave (Young et al. 1987).

H: Slope Length. The field slope length, in feet, of the cell.

I: Channel Slope. The average slope of the channel if one existed. If not, assumed to be half of the land slope (Young et al. 1987).

J: Chan. Side Slope. The average side slope of the channel if one existed. If no value can be measured, assume 10% (Young et al. 1987).

K: Mannings Coef. Manning's roughness coefficient for the channel. If no channel, assumed a value appropriate to surface conditions (Young et al. 1987).

L: K-Factor. The soil erodibility factor used in the USLE and obtained from SCS soil data.

M: C-Factor. The cropping factor used in the USLE and obtained from SCS soil data.

N: P-Factor. The support practice factor used in the USLE. For worst case scenario assume 1.0 (Young et al. 1987).

O: Surf. Cond. Const. A constant (c) used to make adjustments for the time it takes for runoff to channelize (Young et al. 1987).

P: Aspect. Digital designation of runoff direction as determined by preliminary mapping (Young et al. 1987).

Q: Soil Texture #. Digital designation of the major soil texture classification: 0, water; 1, sand; 2, silt; 3, clay; 4, peat (Young et al. 1987).

<u>R: Fert. Level</u>. Digital designation of the fertilization level: 1, low; 2, med; 3, heavy. For manure-applied field assume 2 (Young et al. 1987).

<u>S: Availability Fact</u>. The percentage of fertilization in the top half inch of soil (ie. incorporated or not). 100% if spread (Young et al. 1987).

<u>T: Point Source Ind</u>. Digital designation of number of point sources within the cell.

<u>U: Gully Source Lev</u>. If excessive gully erosion occurred within the cell, this value was an estimate (tons) that would be added to the total amount of eroded sediment calculated.

<u>V: COD Factor</u>. Chemical oxygen demand (mg/L) based on land use (Young et al. 1987).

<u>W: Impoundment Fact</u>. Digital designation indicating the presence of an impoundment terrace system.

<u>X: Channel Indicator</u>. Digital designation indicating the presence of defined channel or channels.

Collection and Analysis Methods

Sample Collection

Three American Sigma, model 702, and one Isco, model 2900, automatic water samplers were installed at the discharge points of the selected watersheds. These models are discreet samplers with the capacity to collect a total of 24 individual samples. Using a 12 volt DC power system, the samplers can be programed to collect up to 500 ml (350 ml for the ISCO) per sample at any selected time or flow interval. Each sampler was equipped with a liquid level actuator in order to initiate collection upon the influx of water in the channel. Preliminary data from the Oklahoma Conservation Commission suggested that frequent initial samples should be taken approximately every 15 minutes. Collection intervals of this length would result in a 6 hour continuous sampling period, but could be extended by programing a longer time interval between the latter samples.

I inspected the automatic samplers approximately once a week and retrieved the samples within 12 hours of each runoff event. The samples were preserved under ice for transport and storage, and all analyses were performed within 12 hours of collection.

Hydrologic Measurements

So as to facilitate accurate assessments of real nutrient exports, hydrologic flow data must be determined for each watershed. In order to calculate total discharge from the watershed, correlated measurements of stage height, runoff velocity, and channel cross sectional area are necessary to create a stage-discharge rating table (Appendix A.). The instantaneous discharge will be calculated as the average velocity at a particular stage height times the cross sectional area at that stage height.

A stage-discharge calibration curve may then be established from the table to depict the relationship between the maximum height recorded and the amount of discharge during any runoff event. Determined by extrapolation, the estimated discharge (Q) can be used to indicate real nutrient exports during an event or, if the need arises, to calculate the amount of sediment transported.

Stage Height. Since automatic stage height recorders were unavailable, 1 inch diameter plastic tubes containing approximately 1 g of small cork particles recorded the maximum stage height during a runoff event for each location. The tubes were 36 inches in length (marked in quarter inch scale) with a strainer and trap assembly allowing for the transition of water while confining the cork particles within. As the water level rose and receded through the tube, the cork particles were left stuck to the sides at the maximum height attained during the event.

Runoff Velocity. A pygmy current meter was used to measure the average velocity of the flow at different times and heights during a particular runoff event. If water depth in the channel allows, the average velocity will be that derived from measurements taken at 0.2 depth and 0.8 depth. If the runoff was too shallow for the two point method of measuring, one reading at 0.6 depth was used. To develop an accurate stage-discharge curve, this process must be repeated for multiple events. Accordingly, on-site visits during some runoff events were conducted to manually record velocities and stage heights over time.

Cross Sectional Area Calculation. The channel cross sectional area at each sampling site was video taped for digitization with an image capture board for an IBM personal computer. Prior to taping each site, a metal "T" post was anchored at the deepest point in the channel. A PVC pipe with clearly marked increments of one foot was place over the post and a leveled measuring tape was run perpendicular from the opposing banks. While the post remained in the channel, the PVC and tape served only as scale markers for purposes of digitization and were removed after shooting the channel video. The stage height tube, liquid level actuator, and intake tubing screen were attached to the post. By digitizing the cross sectional area of each drainage channel, a height-area relationship was developed for estimating discharge after runoff events.

Sample Analysis

A Dionex model 12 Ion Chromatograph with an anion column was used to analyze for orthophosphates, soluble nitrates, chloride, fluoride and sulfates. Since analyses were for soluble forms, samples were injected through a $0.45\mu m$ filter.

The HACH analysis procedure was used to determine the total phosphate concentration of each sample and measurements of turbidity were made using the Hach Nephelometer.

CHAPTER V

RESULTS AND CONCLUSIONS

Runoff Samples

During the first 4 months of this research, less than 6 inches of rain fell in the project area. It was determined early on that a steady rain of at least 2 inches was necessary to start the ephemeral streams flowing. The first such rain, at times relatively intense, occurred in mid September and amounted to 5 inches. This produced a full suite of samples collected at Watershed A and Watershed B. However, due to the extreme dryness of the soil and vegetation, no runoff occurred at the Watershed C and Watershed D sites. Tables 6 and 7 present the chemical analysis of each of the 24 samples taken during this event.

The second event occurred in the first part of October and totaled almost 3 inches. This event failed to produce enough water in the channel at the B location to activate the sampler, but a second full set was taken at the A site (Table 8). As with Watershed B, there was insufficient runoff in the channels of Watershed C and Watershed D to initiate any sampling.

TABLE 6

SURFACE RUNOFF CONCENTRATIONS
FROM WATERSHED A
SEPT. 19,1990

Hours	Flouride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Phosphate (mg/L)	Total Phosphate (mg/L)	Turbidity (NTU's)
0.00	0.000	0.999	0.468	0.579	0.257	1.000	48
0.25	0.000	1.619	1.289	1.519	0.161	1.980	85
0.50	0.000	1.913	2.032	1.926	0.181	3.000	800
0.75	0.000	2.138	1.960	1.884	0.217	2.790	832
1.00	0.000	2.405	1.955	2.020	0.287	2.930	880
1.25	0.728	3.737	2.184	2.437	0.326	2.460	864
1.50	0.640	3.303	2.051	2.355	0.362	3.290	720
1.75	0.000	2.723	2.140	2.471	0.370	2.490	704
2.00	1.199	6.842	2.220	3.308	0.395	2.130	592
2.25	1.042	5.634	2.249	2.897	0.399	2.260	592
2.50	1.334	7.002	2.320	3.396	0.364	1.860	672
2.75	1.359	7.807	2.441	3.640	0.369	2.760	640
3.00	1.288	5.807	2.007	2.766	0.221	2.470	720
3.25	0.851	4.760	2.259	3.240	0.190	2.160	688
3.50	1.294	6.332	2.094	3.579	0.183	2.840	720
3.75	1.067	6.136	2.440	4.053	0.222	2.380	624
4.00	1.245	5.542	2.187	3.521	0.192	3.230	624
4.25	1.638	6.981	2.278	4.011	0.185	3.630	608
4.50	0.998	4.875	2.423	3.442	0.169	2.030	576
4.75	1.476	6.991	2.236	3.824	0.173	3.560	608
5.00	1.019	5.765	2.434	3.996	0.149	3.060	672
5.25	1.153	5.456	2.495	4.076	0.171	2.270	608
5.50	1.230	6.129	2.637	4.073	0.165	2.720	544
5.75	0.903	5.364	2.369	4.117	0.150	2.330	576

TABLE 7

SURFACE RUNOFF CONCENTRATIONS
FROM WATERSHED B
SEPT. 19,1990

Hours	Flouride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Phosphate (mg/L)	Total Phosphate (mg/L)	Turbidity (NTU's)
0.00	0.979	4.535	5.167	2.934	3.597	4.000	176
0.25	1.015	12.212	2.845	8.116	10.421	17.760	256
0.50	0.936	8.867	2.485	6.771	9.409	12.320	160
0.75	0.000	5.059	2.194	4.517	7.588	8.160	80
1.00	0.000	4.904	2.580	4.209	7.082	7.840	64
1.25	0.000	14.939	5.026	14.444	14.071	15.520	128
1.50	0.000	21.681	3.630	19.450	21.414	20.160	256
1.75	0.884	15.042	2.838	12.585	17.175	18.080	176
2.00	0.846	6.386	1.590	4.773	7.928	8.480	144
2.25	0.808	6.493	1.137	5.002	11.167	13.120	192
2.50	0.740	4.665	0.821	3.630	8.024	7.520	80
2.75	0.000	3.287	0.758	2.712	6.848	5.760	48
3.00	0.699	4.160	0.786	2.866	6.347	4.800	48
3.25	0.665	4.010	0.764	2.757	6.505	6.720	39
3.50	0.691	4.534	0.896	2.835	6.636	5.920	41
3.75	0.767	6.182	1.925	5.812	8.135	6.880	81
4.00	0.862	16.698	2.513	15.397	15.181	14.080	128
4.25	0.976	19.697	2.424	17.375	21.732	17.440	240
4.50	0.944	14.391	1.789	12.455	16.561	16.800	144
4.75	0.803	9.752	1.443	8.348	13.771	14.080	96
5.00	0.788	8.723	1.263	7.032	10.938	11.680	64
5.25	0.728	8.045	1.322	6.973	10.242	10.880	64
5.50	0.776	8.555	1.326	7.080	10.194	10.560	61
5.75	0.825	10.072	1.448	8.982	12.279	13.120	75

TABLE 8

SURFACE RUNOFF CONCENTRATIONS
FROM WATERSHED A
OCT. 9,1990

Hours	Flouride (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	Phosphate (mg/L)	Total Phosphate (mg/L)	Turbidity (NTU's)
0.00	0.626	2.720	0.890	2.357	0.427	2.490	688
0.25	0.658	3.557	1.363	2.923	0.382	1.830	624
0.50	0.725	3.549	1.488	2.739	0.342	1.930	656
0.75	0.949	4.869	1.770	3.127	0.313	1.650	624
1.00	0.781	4.891	1.010	4.130	0.541	2.200	1216
1.25	0.815	4.659	1.384	2.860	0.365	0.950	480
1.50	0.806	4.751	1.414	3.096	0.388	1.910	448
1.75	0.901	5.140	1.625	3.924	0.362	1.920	416
2.00	1.035	4.735	1.538	3.779	0.415	1.330	400
2.25	0.963	3.049	1.374	3.567	0.375	1.520	352
2.50	0.889	2.453	1.369	3.115	0.366	1.420	400
2.75	1.226	3.296	1.519	3.970	0.381	1.400	400
3.00	1.197	2.889	1.501	3.426	0.355	1.780	384
3.25	1.310	3.367	1.412	4.232	0.456	1.510	352
3.50	0.871	2.593	1.460	3.658	0.455	1.670	368
3.75	0.842	2.185	1.579	4.523	0.347	1.400	352
4.00	1.077	2.998	1.396	3.501	0.418	1.090	352
4.25	0.793	2.443	1.406	4.080	0.531	1.250	336
4.50	0.850	2.502	1.372	3.725	0.409	1.590	336
4.75	1.000	2.834	1.332	3.307	0.446	0.600	336
5.00	1.523	3.678	1.700	4.160	0.458	1.330	336
5.25	1.134	2.845	1.348	3.670	0.422	1.270	336
5.50	0.876	2.470	1.278	3.301	0.403	1.350	320
5.75	1.093	3.121	1.431	4.407	0.603	1.360	288

Unfortunately, both runoff events occurred during the evening and early morning hours which precluded hydrologic flow measurements. Consequently, a stage-discharge curve could not be established for this project.

Watershed A Analysis

Figure 5 graphically represents the nutrient runoff concentrations found for the Sept. 19th sample set. Nitrate concentrations ranged from 0.468 to 2.637 mg L^{-1}. Soluble phosphate and total phosphate varied from 0.399 to 1.5 mg L^{-1} and from 1.0 to 3.63 mg L^{-1} respectively.

The Oct. 9th data set is presented in Figure 6. Nitrate concentrations ranged from 0.89 to 1.77 mg L^{-1} while soluble phosphate and total phosphate ranged from 0.313 to 0.603 mg L^{-1} and 0.6 to 2.49 mg L^{-1} respectively.

When comparing the two runoff events, the September nutrient concentrations were found to be several times greater than those of October. This was also true of the sediment yields as reflected by the turbidity values (Fig. 7). Although this could reflect the variation in the intensity and duration of the two storms, one would expect the first runoff after a dry period to be higher in constituent concentrations. I later used the differences between these two events to calibrate the AGNPS model.

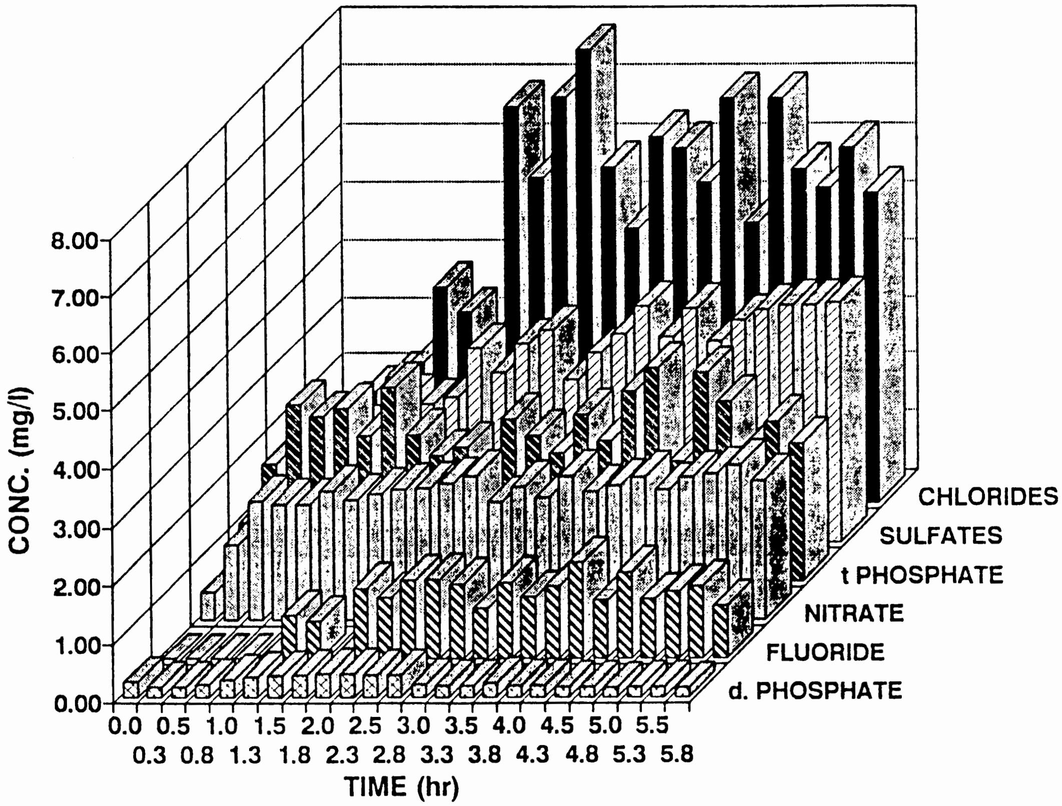


Figure 5. Concentrations of Chemicals in Runoff from Watershed A, Sept. 19, 1990

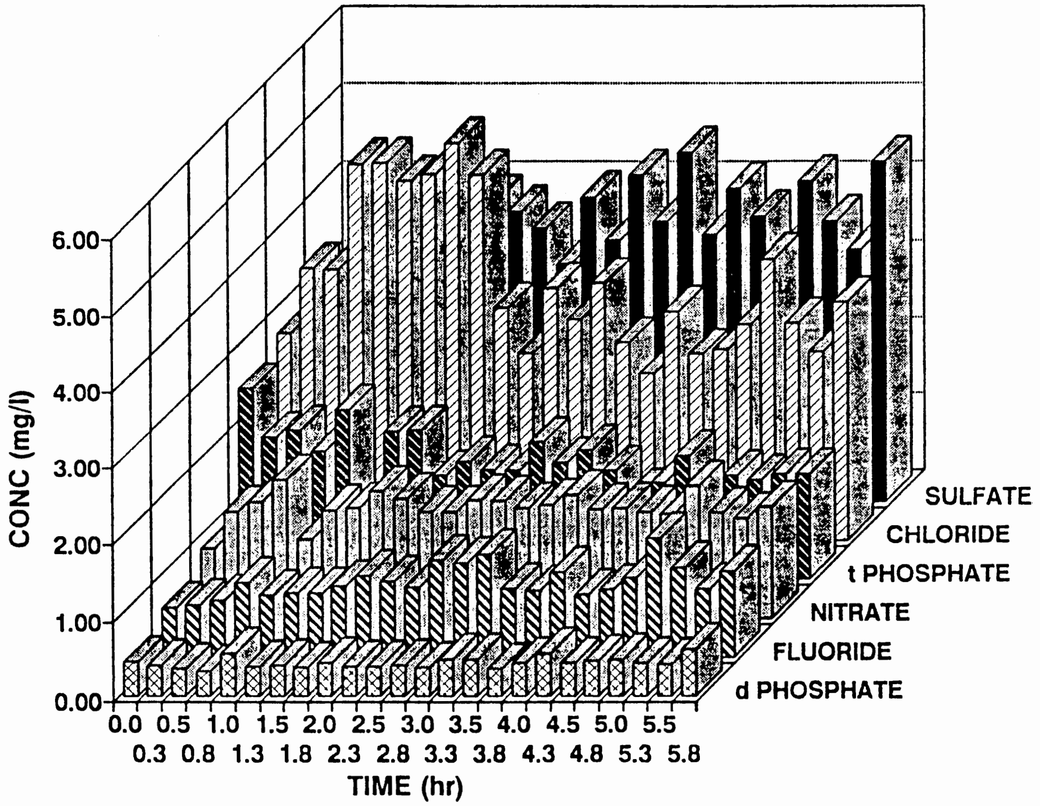


Figure 6. Concentrations of Chemicals in Runoff from Watershed A, Oct. 9, 1990

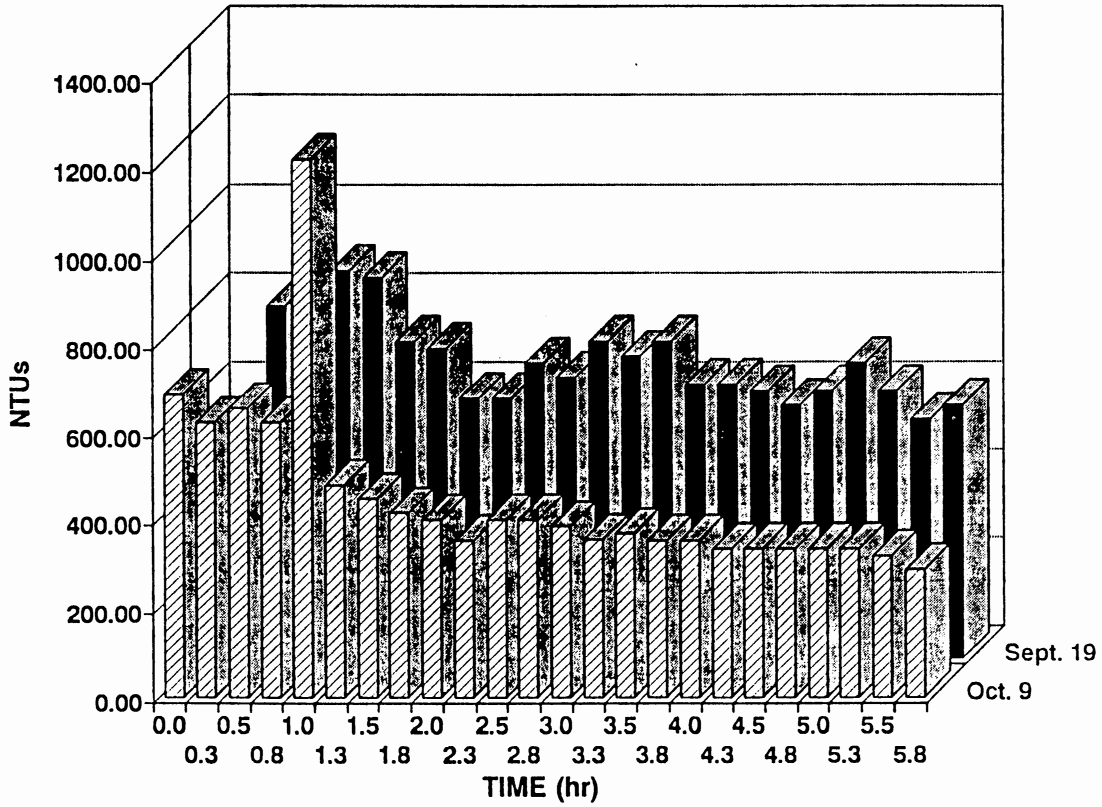


Figure 7. Turbidity of Runoff from Watershed A, Sept. 19 and Oct. 9, 1990

While the concentrations of nitrate and phosphate were well above the threshold values of 0.3 mg L^{-1} and 0.02 mg L^{-1} respectively, it was difficult to evaluate the real eutrophic threat this watershed poses to downstream waters. The ephemeral channel meanders more than 2 miles before reaching perennial stream flow, thus allowing substantial opportunity for leaching, adsorption, and dilution.

Watershed B Analysis

Figure 8, which depicts the Sept. 19th data set for this watershed, shows that two distinct surges occurred in the channel. The range of nitrate concentrations were 0.758 to 5.167 mg L^{-1}. Soluble phosphate and total phosphate ranged from 3.577 to 21.732 mg L^{-1} and 4.0 to 20.16 mg L^{-1} respectively.

The double peaks reflect the character of this watershed and give some insight as to why the runoff event of Oct. 9th failed to activate the sampler. With a duration of 10 to 12 hours, the 3 inch rain of Oct. was light and steady, permitting much of the runoff to infiltrate the soil. While of shorter duration, the 5 inch rain of Sept. 19th produced two intense downpours which resulted in more overland runoff and less percolation.

Even though only one data set was collected, the nutrient loading capabilities of this watershed give ample cause for concern. The excessively

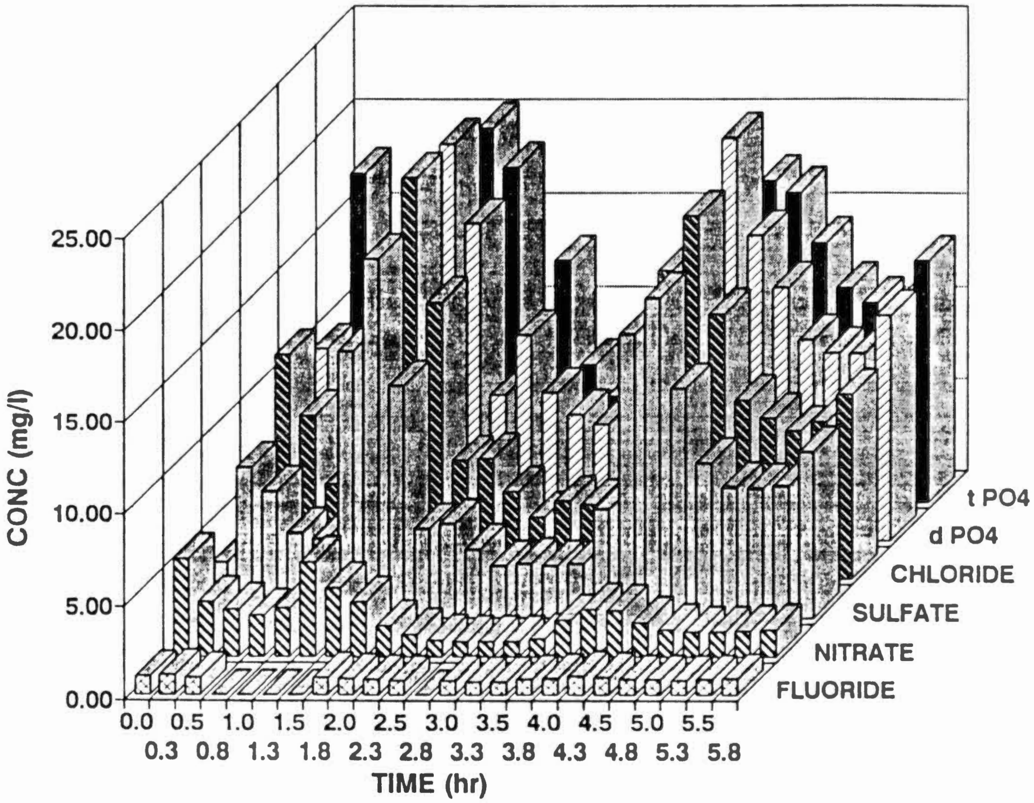


Figure 8. Concentrations of Chemicals in Runoff from Watershed B, Sept. 19, 1990

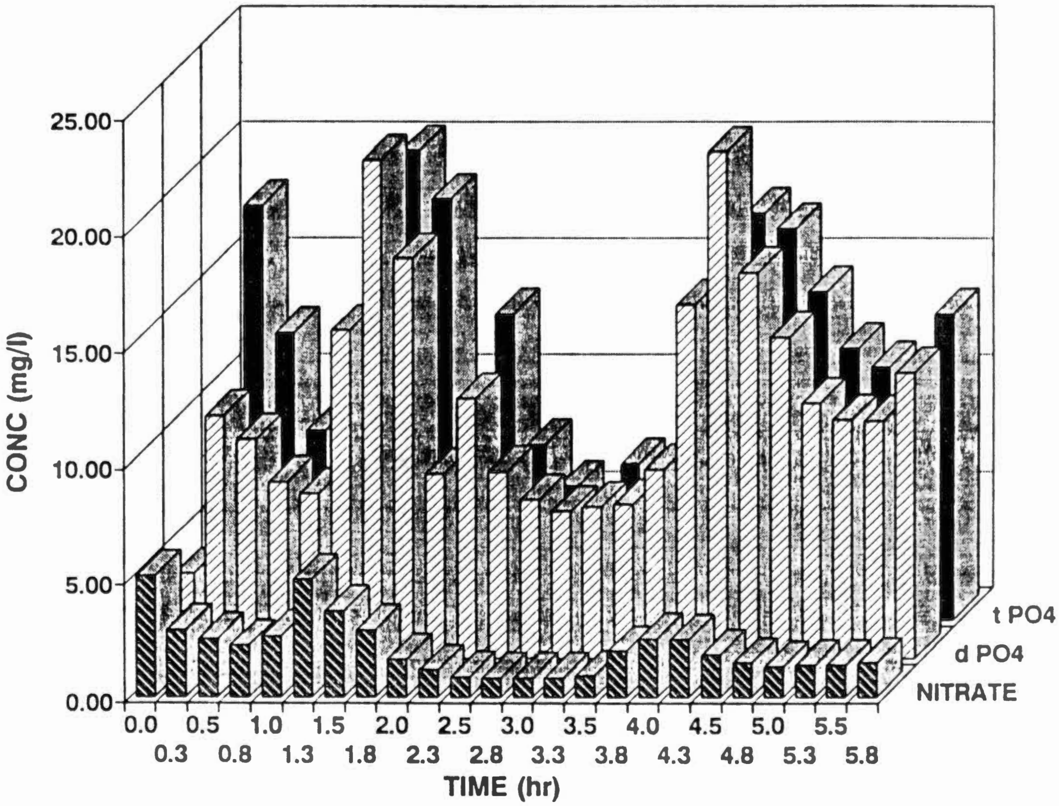


Figure 9. Concentrations of Nitrate and Phosphate in Runoff from Watershed B, Sept. 19, 1990

high concentrations of all nutrients, particularly phosphate and nitrate (Fig. 9), discharging directly into Battle Creek signal a real problem area.

It should be noted that there is little difference in concentrations between total phosphates and soluble phosphate (Fig. 10). This would indicate, unlike Watershed A, most of the phosphorus is entering the creek in the readily available soluble form at levels as high as 21 mg L^{-1}. The concentrations involved are far above eutrophic levels and abatement efforts should be implemented as soon as possible.

The overall high nutrient concentrations could be a consequence of two factors. First, only approximately 25 acres of the 40 are available to accommodate the litter generated by three turkey houses containing some 28,000 birds per year. Second, prior to spreading, the litter is stored uncovered on bare ground in a mound approximately 40 feet uphill from the watershed drainage channel.

While the available acreage appears to be insufficient for the amount of litter generated, the storage mound is most probable cause for the elevated levels of nutrients found, particularly the extremely high dissolved phosphate and nitrate concentrations. The close proximity and steep grade across bare ground to the channel allows little if any infiltration of nutrients as they are solubilized from the exposed manure. An intense rain, such as those occurring in the spring, would cause a pulse of soluble nutri-

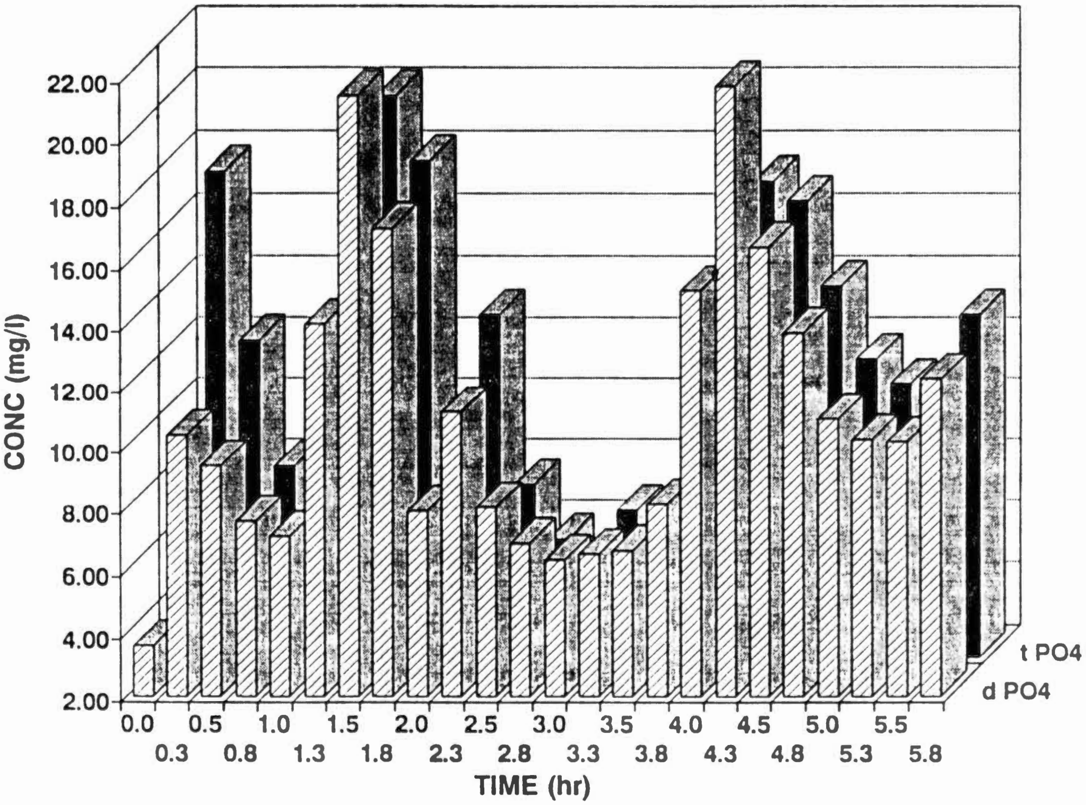


Figure 10. Concentrations of Soluble and Total Phosphate in Runoff from Watershed B, Sept. 19, 1990

ents, with little time for infiltration or adsorption to take place, to directly enter Battle Creek. The most important factor determining the concentration of soluble P in runoff is the length of time that soil components are exposed to the P (Sharpley and Syers, 1979).

Further evidence of the lack of adsorption to sediments is reflected by the relatively low turbidity levels (Fig. 11). Like the nutrients, the turbidity values reflect the double peaks of two separate surges. However, when compared to Watershed A data of the same date, they are 4 to 7 times lower while soluble phosphate levels are 24 to 55 times greater (Fig. 12).

AGNPS Collation

While known cell parameters such as SCS curve number, soil type, slope, and land use factors remain constant for their respective watersheds, the two parameters that most effect the predicted concentrations must be determined with the help of the land owner or from direct observation of his practices. As the land owners were hesitant to commit themselves, determining the fertility level (ie. the amount of N and P applied; 1 implying low, 2 implying medium, and 3 implying high) and the availability factor (the percent of that applied that is available for transport) was a matter of personal observation or conviction.

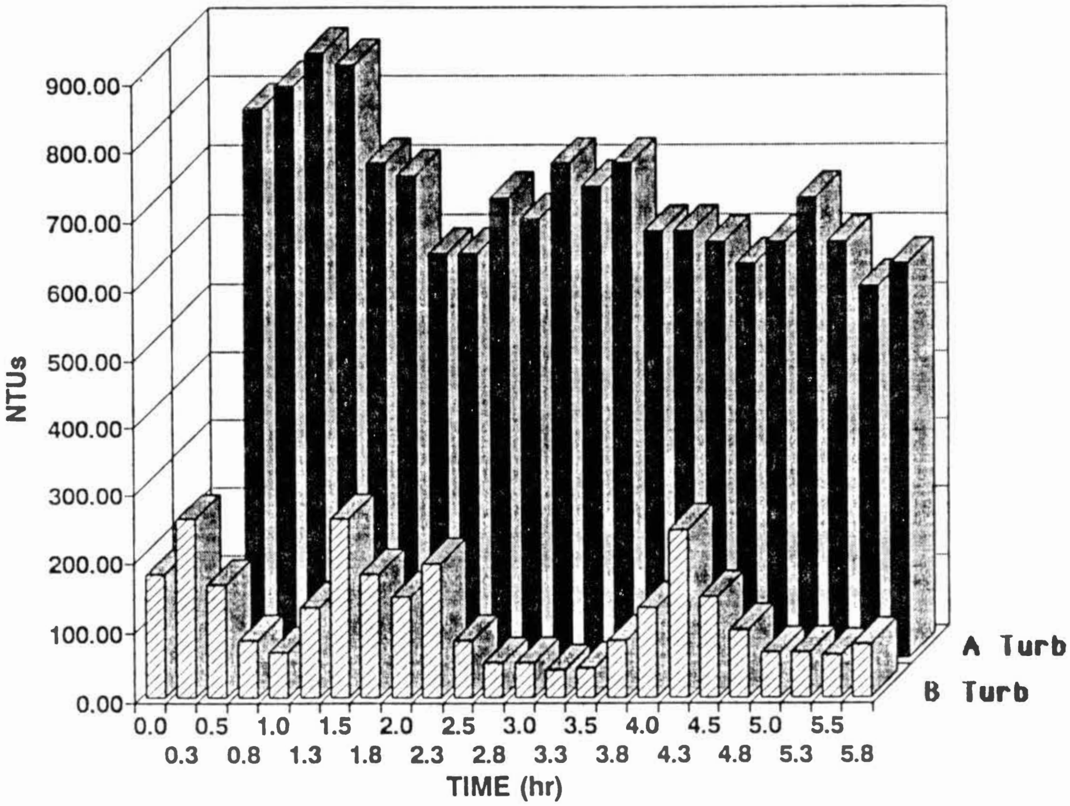


Figure 11. Turbidity of Runoff from Watersheds A and B, Sept. 19, 1990

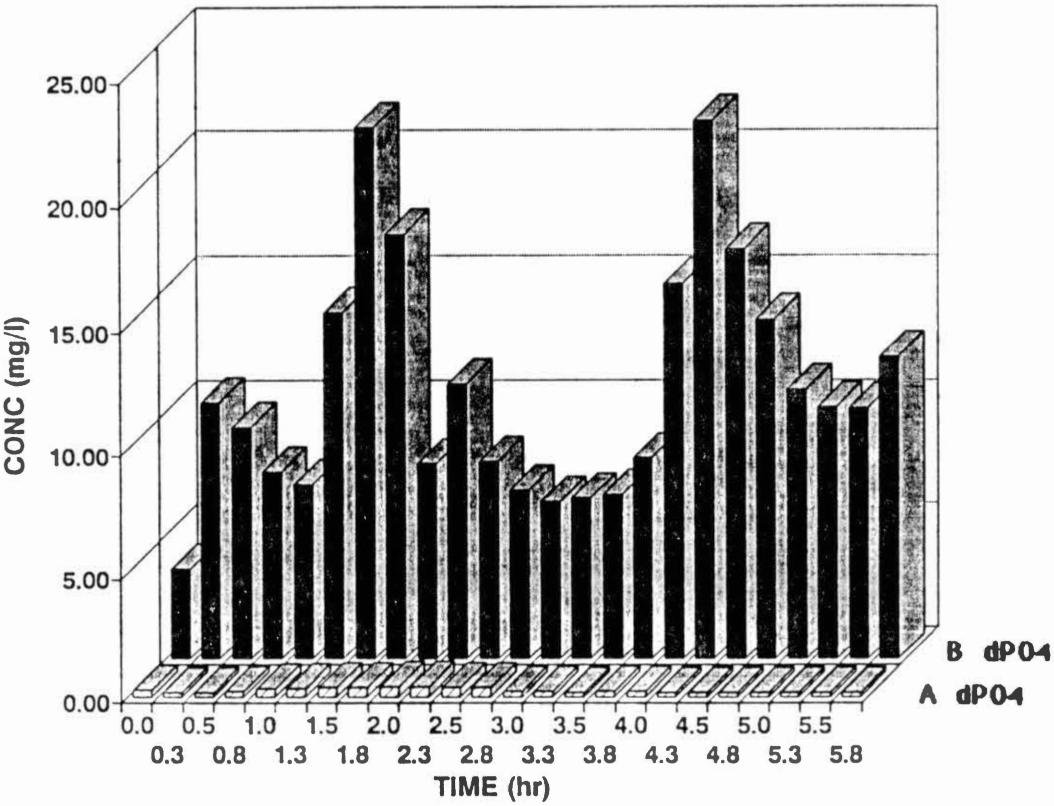


Figure 12. Soluble Phosphate in Runoff from Watersheds A and B, Sept. 19, 1990

The two data sets for Watershed A provided the basis from which the sensitivity of the AGNPS model could be analyzed. Considering the size of the watershed in relation to the amounts of N and P being applied, a "low" fertility level was used for the modeling process.

The availability factor was estimated with several variables in mind. Among them: Vollenweider (1968) predicts losses from runoff to be 10 to 25% for N and 1 to 5% for P; at least 20% of the N would be expected to be taken up by plants (Magette, et al., 1987); much of the P would also be quickly taken up by plants or adsorbed to soil particles; and the straw content of the litter would likewise sorb much of the nutrients. Table 9 presents the comparison modeling results using a 30% availability factor.

The observed concentrations in Table 9 are an average of the soluble nutrients analyzed from the 24 samples collected during each runoff event. The averages of the observed and predicted concentrations for both events were found to be within 0.063 mg L^{-1} and 0.07 mg L^{-1} for phosphorus and nitrogen respectively. Since computer models characteristically predict long-term averages as opposed to individual events, the negligible differences lend credence to the AGNPS correlation.

Watershed B presents a difficult correlation problem due to the aforementioned litter storage system. Attempts to represent the mound as either a feedlot or as a point source failed to yield satisfactory results from

TABLE 9

COMPARISON OF OBSERVED SOLUBLE NUTRIENTS RUNOFF FROM WATERSHED A TO THAT PREDICTED BY AGNPS

	Precip (in)	Obs Conc (mg/L)	Pred Conc (mg/L)	Avg Obs Conc (mg/L)	Avg Pred Conc (mg/L)	Comparison Obs to Pred (+or- mg/L)
Phosphorus	3	0.414	0.35	-	-	-
	5	0.242	0.18	-	-	-
				0.328	0.265	0.063
Nitrogen	3	1.41	2.27	-	-	-
	5	2.12	1.39	-	-	-
				1.76	1.83	0.07

the model (Young, et al., 1982). If calculated as a point source, an analysis of the litter to determine the exact N and P content and the rate of discharge from the mound to the channel were necessary. Since this information was unknown and the mound is in various degrees of depletion during different times of the year, it was excluded from the modeling process. It may be assumed that, if the mound were removed, the concentrations predicted by AGNPS would be accurate.

Even without observed data for watersheds C and D, the same degree of confidence can be achieved by emulating the process, as followed with Watershed A, and altering only the fertility level and availability factor as

TABLE 10

AGNPS PREDICTED EXPORTS

Watershed	Inches Precip	Runoff Volume (in)	Peak Runoff Rate (cfs)	Tot N Sediment (lbs/acre)	Tot Sol N Runoff (lbs/acre)	N Conc Runoff (ppm)	Tot P Sediment (lbs/acre)	Tot Sol P Runoff (lbs/acre)	P Conc Runoff (ppm)
A	2	0.2	35	0.19	0.18	3.71	0.10	0.03	0.62
	2.5	0.4	62	0.26	0.25	2.82	0.13	0.04	0.45
	3	0.6	93	0.31	0.32	2.27	0.16	0.05	0.35
	3.5	0.9	128	0.36	0.38	1.92	0.18	0.06	0.28
	4	1.2	166	0.41	0.44	1.68	0.20	0.06	0.23
	4.5	1.5	205	0.45	0.51	1.51	0.23	0.07	0.20
	5	1.8	246	0.49	0.57	1.39	0.25	0.07	0.18
	5.5	2.2	289	0.53	0.63	1.29	0.27	0.08	0.16
	6	2.5	332	0.57	0.70	1.22	0.28	0.08	0.14
B	2	0.1	5	0.03	0.09	6.71	0.01	0.02	1.22
	2.5	0.2	12	0.04	0.16	4.25	0.02	0.03	0.73
	3	0.3	21	0.06	0.22	2.98	0.03	0.04	0.48
	3.5	0.5	32	0.07	0.27	2.26	0.04	0.04	0.34
	4	0.7	44	0.09	0.31	1.82	0.04	0.04	0.26
	4.5	1.0	56	0.10	0.35	1.54	0.05	0.05	0.20
	5	1.3	70	0.11	0.39	1.35	0.06	0.05	0.16
	5.5	1.6	84	0.12	0.44	1.22	0.06	0.05	0.14
	6	1.9	98	0.13	0.49	1.13	0.07	0.05	0.12

TABLE 10 (Continued)

Watershed	Inches Precip	Runoff Volume (in)	Peak Runoff Rate (cfs)	Tot N Sediment (lbs/acre)	Tot Sol N Runoff (lbs/acre)	N Conc Runoff (ppm)	Tot P Sediment (lbs/acre)	Tot Sol P Runoff (lbs/acre)	P Conc Runoff (ppm)
C	2	0.2	8	0.05	0.81	20.25	0.02	0.16	3.99
	2.5	0.4	14	0.07	1.10	13.85	0.03	0.22	2.72
	3	0.6	21	0.08	1.29	10.01	0.04	0.25	1.96
	3.5	0.8	29	0.10	1.41	7.58	0.05	0.28	1.48
	4	1.1	37	0.11	1.49	5.96	0.06	0.29	1.16
	4.5	1.4	46	0.13	1.55	4.84	0.06	0.30	0.94
	5	1.7	55	0.14	1.60	4.04	0.07	0.31	0.78
	5.5	2.1	64	0.15	1.63	3.45	0.07	0.31	0.66
	6	2.4	73	0.16	1.67	3.01	0.08	0.31	0.56
D	2	0.1	7	11.24	0.02	0.92	5.62	0.00	0.05
	2.5	0.3	15	14.18	0.05	0.89	7.09	0.00	0.05
	3	0.4	24	16.20	0.09	0.87	8.10	0.01	0.05
	3.5	0.7	34	17.62	0.13	0.86	8.81	0.01	0.05
	4	0.9	45	18.67	0.18	0.85	9.33	0.01	0.05
	4.5	1.2	57	19.46	0.23	0.84	9.73	0.01	0.05
	5	1.5	70	20.09	0.29	0.84	10.04	0.02	0.05
	5.5	1.8	83	20.06	0.35	0.83	10.30	0.02	0.05
	6	2.2	96	21.03	0.41	0.83	10.51	0.02	0.05

applicable for each.

The completed input data file, as entered into the model, for each watershed may be found in Appendix A. Table 10 lists the exports for each watershed as predicted by AGNPS with selected graphs of the information found in Appendix B.

AGNPS Evaluation

The objectives of each individual project determine the detail of data to be entered into the program. For large projects dealing with thousands of acres, the program operator must decide whether the increased degree of accuracy merits increased data input. Since the project involved minimum-sized watersheds, it was not deemed necessary to divide each cell into smaller units. Without exception, all cells represented 2.5 acres.

Most input variables are base values that represent the unchanging characteristics of the cell. These include such variables as: SCS curve number, land slope, soil texture, etc. Base values do indeed affect output results to some degree. For example, land slope, soil erodibility factor (K), SCS curve number, and cropping factor (C) affect sediment yield and sediment-associated nutrient yields. However, they are seasonally consistent, making it inappropriate to modify the data file unless the land is physically altered.

Once the base values have been determined, the input variables to reevaluate for possible revision to reflect actual or experimental conditions are: rainfall, energy intensity value, fertilization level, and fertilizer availability factor. Precipitation values, in increments of inches, should be entered for a 24-hour period. The energy intensity value, which is the rainfall erosion index (R) used in the universal soil loss equation, affects the sediment yields. For modeling actual runoff events, the energy intensity value in foot-tons per acre-inch should be calculated for each storm. However, since the simulations were predictions of possible long-term exports, the SCS designated value of 280 was used for all runs. This should allowed a uniform comparison among watersheds, thus providing credible "averages" for this project.

The accuracy of the simulations would improve if it were possible to enter the definite amounts of N and P into the program. The digital designations for low, medium, and high manure applications lack precision. As previously stated, the fertilization level is a single-digit designation of the amount of fertilization in the cell. As such, it affects the soluble and total sediment-associated nutrient yields. For a manure-applied field, the program authors suggest low (ie. "1") for an average application and medium (ie. "2") for a heavy application. The concept of determining an unspecified amount applied to a given area is purely subjective and may not have any basis in truth. Since N to P ratios differ slightly among animal manures, modeling manure-applied fields would be better served if actual or experimental values in lbs per acre could be entered into the program.

The fertilizer availability factor is defined as the percentage of fertilizer left in the top half-inch of soil at the time of the storm. It significantly affects the total soluble amounts and concentrations of nutrients in the runoff. From my observations, it has no affect on the sediment-associated nutrients and is more conjecture than fact. Although the land-applied litter is not incorporated into the soil, is the availability factor 100% as suggested for unincorporated fertilizers? A percentage of nutrients, particularly phosphorus, are adsorbed to the organic material and are thus unavailable. Additionally, time and weather conditions will affect the percentage of nutrients that may volatilize and/or leach beneath the straw and soil.

The cover and management factor (C) provides the means by which a temporal element may be expressed by the model. The C-factor is the ratio of soil loss from cropped land to loss from continuous fallow land corresponding to the appropriate period of the growing season. The appropriate C-factor requires knowledge of how the erosive rainfall in a given locale is likely to be distributed throughout the year and how much erosion control protection the growing plants, plant residues, and selected management practices will provide at the time when erosive rains are most likely to occur (Wischmeier and Smith, 1978). Revisions of the C-factor should theoretically reflect differing seasonal conditions. This parameter can be fine tuned for cultivated soil, but we are concerned with litter-applied pasture, not commercially fertilized cropland. How can the C-factor be manipulated to better define applications during different times of the year?

Although designed primarily for commercial inorganic fertilizer, the land-use management implications for AGNPS are great. The aforementioned flaws are minor and still provide relevant "averages". Once data bases for individual subbasins are established, nutrient exports for the entire Illinois River Basin can be determined.

Extrapolation to the Battle Branch Subbasin

Because land use remains relatively constant in the region, it is possible to predict total nutrient exports for the entire subbasin from those predicted for the study areas. Since there exists no litter production audit of the area, the exact tonnage of land-applied litter each year is a near impossible task to determine. Land owners maintain few if any records and each litter may contain differing ratios of straw to manure thus affecting the overall weight as well as the availability of nutrients. As an accurate land use inventory is retained by SCS, it is feasible to project the total nutrients produced in the subbasin. From these production rates, exports can be determined.

A valid estimate of the amount of litter applied to the land within the subbasin is assumed to be nearly equal to the amount produced. Poultry houses can be considered occupied and producing N and P year round. Although individual groups of birds remain in the houses only 7 to 8 weeks, a new brood replaces the old resulting in 5 to 6 turnovers per year. As it is economically desirable, most, if not all, of the N and P is spread within the same area in which it is produced.

TABLE 11

ANIMAL NUTRIENT PRODUCTION

	Tot P	Tot N
	(lbs/yr/animal)	
Broiler[a]	0.198	0.859
Turkey[a]	0.859	1.85
Dairy Cow[b]	55.125	83.79
Beef[b]	28.60	116.80

[a] (Omernik, 1977)

[b] (Novotny and Chesters, 1981)

Table 11 denotes total P and N produced by full growth individual domestic animal species contained within the subbasin. Multiplying the appropriate number of animals, as previously stated in Chapter I and Chapter IV, by the given values will yield an overall nutrient production per year for each watershed and the entire subbasin (Table 12).

TABLE 12

TOTAL NUTRIENT PRODUCTION

Watershed	Animals	Tot N (Ton/yr)	Tot P (Ton/yr)
A	30,000 broilers	12.89	2.97
	100 Beef	5.8	1.4
B	28,000 turkeys	25.9	12.02
C	15,000 broilers	6.44	1.48
	60 dairy cows	2.51	1.65
TOTAL		53.54	19.52
Battle Branch			
	435,000 broilers	186.83	43.6
	28,000 turkeys	25.9	12.02
	415 dairy cows	17.38	11.43
	4000 beef	233.6	57.2
TOTAL		463.71	124.25

The study areas, totaling 275 acres of the approximately 2250 acres of applicable land in the subbasin, receives 53.54 tons N and 19.52 tons P per year. In other words, 12.2% of the land receives 11.5% of the N and 15.6% of the P produced in the subbasin. The percentages indicate a relatively uniform and equable rate of application within the subbasin. Accordingly, the percentage exported from the study areas should be representative of that exported from the subbasin.

As a general rule, depending on the conditions (slopes, distances, soils, etc.), Vollenweider (1968) establishes export percentages due to overland runoff to be from 10 to 25% for N and 1 to 5% for P. A worst-case scenario, therefore, would indicate 115.9 tons yr^{-1} N and 6.2 tons yr^{-1} P are entering Flint Creek from the Battle Branch subbasin. It should be noted, however, that the Vollenweider percentages were established in reference to commercial fertilizer not animal manure.

To further refine these figures while utilizing AGNPS's sensitivity to the unique conditions of the area and because estimates of "average" rates of P loss should be calculated only over long periods of time (Kunishi et al. 1972), the yearly precipitation for the region was needed to establish a long-term monthly rainfall pattern (Table 13). The 10 year average monthly rainfall was determined to be 4 inches.

Referring to Table 10 (page 60), the total N and P exported monthly

TABLE 13

YEARLY RAINFALL FOR BATTLE BRANCH REGION*

Year	Inches
1980	25.86
1981	53.96
1982	43.12
1983	39.40
1984	62.25
1985	74.13
1986	57.68
1987	50.80
1988	37.30
1989	34.46
TOTAL	478.96

*(Springer, D. O., 1991)

TABLE 14

STUDY AREA PREDICTED TOTAL MONTHLY NUTRIENT EXPORTS

Watershed	Size (acres)	Tot N Sed (lbs/a)	Tot Sol N Runoff (lbs/a)	Tot N Exported (lbs/mo)	Tot P Sed (lbs/a)	Tot Sol P Runoff (lbs/a)	Tot P Exported (lbs/mo)
A	230	0.41	0.44	195.5	0.2	0.06	59.8
B	40	0.09	0.31	16	0.04	0.04	3.2
C	20	0.11	1.49	32	0.06	0.29	7
Total				243.5			70

12 month total = 2922 lbs N and 840 lbs P

from each watershed is estimated by combining the amounts in the sediment and the soluble amounts in the runoff during a 4 inch rain. Table 14 summarizes the amounts into total monthly exports. Simple calculations disclose 1.46 tons N yr^{-1} and 0.42 tons P yr^{-1}, or 2.8% and 2.2% respectively, are exported from the project area. If the export percentages are expected to remain similar, total yearly output for the Battle Branch subbasin is 12.98 tons N and 2.73 tons P.

While the 2.2% estimate for P exports validates the Vollenweider range of 1-5%, the 2.8% figure for N falls short of the suggested range of 10-25%. However, studies have shown base water flow (ie. low flow conditions fed by groundwaters) from fertilized agricultural lands to contain 3% of the applied N and 2% of the applied P (Loehr, 1974). The export estimates are thus credible and imply a need for additional monitoring throughout the Battle Branch subbasin. The estimates are far in excess of the critical specific loading levels above which eutrophication may occur in a flowing stream. Vollenweider (1968) puts the critical levels at 0.002-0.005 lbs $acre^{-1}$ P and 0.05-0.09 lbs $acre^{-1}$ N.

Oklahoma Conservation Commission Report

In 1986, the Oklahoma Conservation Commission began a water quality monitoring project for Battle Creek. The study focused on the perennial flow conditions during normal and high flow periods. The OCC installed automatic samplers at the upper end, middle, and lower end of the creek to collect samples during high flow events. They also used grab samples at the three locations and groundwater monitoring wells for normal or low flow analysis. During the 4 years since the study, the land use practices and management have remained relatively constant while waste production has increased.

The "upper" location was a spring constituting the upper limit of perennial flow. This site is approximately 2 miles below Watershed A and is the entry point for the watershed's runoff. The "middle" site was located adjacent to the drainage point from Watershed B. In order to monitor the entire subbasin, the "lower" station was situated above the confluence with Flint Creek.

As previously stated, the distance from Watershed A to perennial flow makes it difficult to evaluate the watershed's effect upon the stream. As illustrated with the nitrate concentrations shown on Table 15, it is reasonable to expect higher nutrient concentrations at Watershed A than those at the upper site. The lower concentration values at the drainage entry point reflect the leaching, adsorption, and dilution possibilities of the 2 mile journey. The phosphorus concentrations, however, tell a different story. Unexpectedly, ortho-phosphorus concentrations are dramatically higher at the upper site than they are at Watershed A. Since the distance gives ample opportunity for sorption to occur, Watershed A could not be responsible for the elevated concentrations. An examination of watersheds adjacent to the spring should give an indication of the responsible area.

TABLE 15

MEAN CONCENTRATIONS OF PERENNIAL FLOW* AND EPHEMERAL RUNOFF (mg/L)

	Upper		Middle		Lower	
Date	NO_3	$O\text{-}PO_4$	NO_3	$O\text{-}PO_4$	NO_3	$O\text{-}PO_4$
Feb-Sept 1986	1.29	2.02	1.17	1.94	1.87	0.93
	Watershed A		Watershed B			
Sept 19, 1990	2.13	0.24	2.04	10.96		
Oct 9, 1990	1.41	0.41	-	-		

*(Oklahoma Conservation Commission, 1987)

High concentrations of nitrate and phosphorus are rapidly diluted and adsorbed upon entering a larger volume of perennial flow. Thus, the concentration trends observed from Watershed B to the middle site are to be expected. It should be noted, however, that the average phosphorus concentrations at the middle site were very similar to those found at the upper site while the lower site showed a reduction. Since the distance between upper and middle sites is more than a mile, the concentrations could be artificially inflated by runoff from Watershed B.

Overall, OCC reports observed nitrate concentrations remained relatively constant during high and normal flow conditions, as well as from the upper end to the lower end of the watershed. By contrast, ortho-phosphorus levels show a steady decline from the upper end to the lower end and fluctuated during high and normal conditions. Although concentrations are high, this overall trend is to be expected.

Although the high flow conditions last only 24 to 48 hours, nutrient concentrations during this period exceed eutrophic threshold values. In addition, the normal flow concentrations of 2 to 3 mg L^{-1} for nitrate and 0.1 to 0.5 mg L^{-1} for ortho-phosphorus (OCC, 1987) are also excessive. Even though the threshold values are always exceeded, OCC indicates that algal growth does not conform to the expected growth rates. They suggest that this may be due to an unknown limiting micronutrient and that much of the nitrate and phosphorus is being transported downstream.

Observed nutrient concentrations in the perennial flow and in the ephemeral runoff indicate the subbasin has a definite nutrient exportation problem. From a public health view point, nitrate concentrations remain below the EPA standard of 10 mg L^{-1}. However, both nitrate and phosphorus concentrations remain above the eutrophic thresholds with phosphorus consistently above the EPA limit of 0.1 mg L^{-1} for flowing streams.

Considering the diverse nature of poultry litter and its complex reactions with water and soil, it is a challenge to predict safe amounts. The 1987 OCC report suggests there is twice as much litter applied to the land in Battle Branch than can be assimilated. However, if only 20% of the yearly N exports in runoff (ie. 12.98 tons) is nitrate (McLeod and Hegg, 1981), 2.59 tons of NO_3-N enters Flint Creek from the subbasin. A simple ratio computation using known concentrations (Fig. 13) suggests an application reduction factor of 6.2. In other words, land-applied litter in the

$$\frac{1.87\ \text{mg L}^{-1}}{2.59\ \text{tons NO}_3\text{-N}} = \frac{0.3\ \text{mg L}^{-1}}{X\ \text{tons NO}_3\text{-N}} \qquad \frac{2.59\ \text{tons NO}_3\text{-N}}{.415\ \text{tons NO}_3\text{-N}} = 6.2$$

$$X = .415\ \text{tons NO}_3\text{-N}$$

2.59 tons NO_3-N = amount nitrate lost in runoff
1.87 mg L^{-1} = nitrate conc. at Battle Branch confluence w/ Flint Creek
0.3 mg L^{-1} = eutrophication threshold for nitrate

Figure 13. Predicted Nutrient Reduction Factor

Battle Branch Subbasin should be reduced by a factor somewhere between 2 to 6 times.

Recommendations

1. Monitoring of selected watersheds, particularly Watershed B, should continue from spring thru fall. The Oklahoma Conservation Commission project on Battle Creek should be reimplemented and continued throughout the year.

2. Poultry litter should not be stored uncovered on bare ground. The best storage would be an open-sided roof with concrete slab surrounded by vegetative filter strips.

3. Although records need be no more a calendar with the number of applied spreader loads written on it, local agents should encourage land-owners to keep accurate records, when possible. This should also include any litter moved off site and its destination.

4. Land-owners should be encouraged to spread during dry months when grass is in full growth and precipitation has decreased. Litter should not be applied immediately before or after rain or snow.

5. The AGNPS model should be utilized and refined to represent conditions in other local watersheds which would eventually serve as reference points for making similar estimates for the Illinois River Basin.

6. Analysis of the local poultry litter and the litter-applied soils should be conducted to determine their constituents. This would facilitate an understanding of the maximum safe loads for the region.

7. As it is apparent litter production is overwhelming the area, thought must be given to removing it, possibly as a commercial fertilizer product.

BIBLIOGRAPHY

Bitzer, C. C. and J. T. Sims, 1988. Estimating the Availability of Nitrogen in Poultry Manure Through Laboratory and Field Studies. Journal of Environmental Quality 17(1):47-54.

Bohn, H. L., B. L. McNeal, and G. A. O'Connor, 1985. Soil Chemistry, 2nd ed. John Wiley & Sons, Inc., New York, NY. 325 pp.

Bosch, D. D., C. A. Onstad, and R. A. Young, 1983. A Procedure for Prioritizing Water Quality Problem Areas. Presented at the 1983 Summer meeting of American Society of Agricultural Engineers, June 26-29, 1983. Montana State University, Boseman, Montana.

Burwell, R. E., D. R. Timmons, and R. F. Holt, 1975. Nutrient Transport in Surface Runoff as Influence by Soil Cover and Seasonal Periods. Soil Science Society of America Proceedings 39:523-528.

Burwell, R. E., G. E. Schuman, H. G. Heinemann, and Spomer, 1977. Nitrogen and Phosphorus Movement from Agricultural Watersheds. Journal of Soil and Water Conservation 32:226-230.

Cherokee Hill Resource Conservation and Development Project, 1987. Battle Branch Project Plan: Water Quality in the Illinois River Basin. U. S. Department of Agriculture and Soil Conservation Service, Stillwater, Oklahoma.

Clausen, J. C., 1985. The St. Albans Bay Watershed RCWP: A Case Study of Monitoring and Assessment. Perspectives on Nonpoint Source Pollution: Proceedings of a National Conference, Kansas City, Missouri, May 19-22, 1985. EPA 440/5-85-001, United States Environmental Protection Agency, Washington, D. C.

Dillon, P. J. and F. H. Rigler, 1974. The Phosphorus-Chlorophyll Relationship in Lakes. Limnology and Oceanography 19(5):767-773

Dillon, P. J. and W. B. Kirchner, 1975. The Effects of Geology and Land Use on the Export of Phosphorus from Watersheds. Water Research 9:135-148.

Dysart, B. C., 1985. Perspectives on Nonpoint Source Pollution Control, A Conservation View. Perspectives on Nonpoint Source Pollution: Proceedings of a National Conference, Kansas City, Missouri, May 19-22, 1985. EPA 440/5-85-001, United States Environmental Protection Agency, Washington, D. C.

Gakstatter, J. H. and A. Katko, 1986. An Intensive Survey of the Illinois River (Ark. & Ok.) in August 1985. EPA 600/3-87-040, United States Environmental Protection Agency, Duluth, Mn.

Kilmer, V. J., J. W. Gilliam, J. F. Lutz, R. T. Joyce, and C. D. Eklund, 1974. Nutrient Losses from Fertilized Grassed Watersheds in Western North Carolina. Journal of Environmental Quality 3(3):214-219.

Klausner, S. D., P. J. Zwerman, and D. F. Ellis, 1976. Nitrogen and Phosphorus Losses from Winter Disposal of Dairy Manure. Journal of Environmental Quality 5(1):47-49.

Kunishi, H. M., A. W. Taylor, W. R. Heald, W. J. Gburek, and R. N. Weaver, 1972. Phosphate Movement from an Agricultural Watershed During Two Rainfall Periods. Journal of Agricultural Food Chemistry 20(4):900-905.

Loehr, R. C., 1974. Characteristics and Comparative Magnitude of Non-Point Sources. Journal of Water Pollution Control Federation 46(8):1849-1872.

Magette, W. L., R. B. Brinsfield, R. E. Palmer, and J. D. Wood, 1987. Nitrogen Movement to Ground Water and Surface Water from Poultry Litter. American Society of Agricultural Engineers Microfiche Collection, St. Joseph, Mich.

McLeod, R. V. and R. O. Hegg, 1981. Pasture Runoff Water Quality from Application of Ammonium Nitrate, Dairy Manure, Poultry Manure, and Municipal Sludge. Amercan Society of Agricultural Engineers, 1981. Winter Meeting, no. 81-2583.

Novotny, V. and G. Chesters, 1981. Handbook of Nonpoint Pollution Sources and Management. Van Nostrand Reinhold Co., New York, NY. 535 pp.

Odum, E. P., 1983. Basic Ecology. Saunders College Publishing, New York, NY. 555 pp.

Oklahoma Conservation Commission, 1987. Battle Creek Nonpoint Source Study Interim Report. Oklahoma Conservation Commission, Sept. 1987.

Omernik, J. M., 1977. Nonpoint Source - Stream Nutrient Level Relationships: A Nationwide Study. EPA-600/3-77-105. Environmental Research Laboratory, Office of Research and Development, U. S. Environmental Protection Agency, Corvallis, Oregon.

Reckhow, K. H., S. W. Coffey, and C. Stow, 1990. Technical Release: Managing the Trophic State of Water Bodies. Soil Conservation Service, USDA, Washington, D. C. Draft Copy 74 pp.

Sharpley, A. N., and J. K. Syers, 1979. Phosphorus Inputs Into a Stream Draining an Agricultural Watershed. Water, Air, and Soil Pollution. 11:417-428.

Sharpley, A. N., L. R. Ahuja, M. Yamamoto, and R. G. Menzel, 1981a. The Kinetics of Phosphorus Desorption from Soil. Soil Science Society of America Journal 45:493-496.

Sharpley, A. N., R. G. Menzel, S. J. Smith, E. D. Rhoades, and A. E. Olness, 1981b. The Sorption of Soluble Phosphorus by Soil Material during Transport in Runoff from Cropped and Grassed Watersheds. Journal of Environmental Quality 10(2)211-215.

Sharpley, A. N., S. J. Smith, and J. R. Williams, 1988. Nonpoint Source Pollution Impacts of Agricultural Land Use. Lake and Reservoir Management 4(1):41-49.

Sharpley, A. N., S. J. Smith, R. G. Menzel, and R. L. Westerman, 1985. The Chemical Composition of Rainfall in the Southern Plains and its Impact on Soil and Water Quality. Agricultural Experiment Station Technical Bulletin # T-162, Oklahoma State University Division of Agriculture, 44 pp.

Sims, J. T., 1986. Nitrogen Transformation in a Poultry Manure Amended Soil: Temperature and Moisture Effects. Journal of Environmental Quality 15(1)59-63.

Smart, M. M., T. W. Barney, and J. R. Jones, 1981. Watershed Impact on Stream Water Quality: A Technique for Regional Assessment. Journal of Soil and Water Conservation, Sept.-Oct. 297-300.

Spooner, J., R. P. Maas, S. A. Dressing, M. D. Smolen, and F. J. Humenik, 1985. Appropriate Designs for Documenting Water Quality Improvements from Agricultural NPS Control Programs. Perspectives on Nonpoint Source Pollution: Proceedings of a National Conference, Kansas City, Missouri, May 19-22, 1985. EPA 440/5-85-001, United States Environmental Protection Agency, Washington, D. C.

Springer, D. O., 1991. Personal communication. Colcord, Oklahoma, Feb. 22, 1991.

Taylor, A. W., W. M. Edwards, and E. C. Simpson, 1971. Nutrients in Streams Draining Woodland and Farmland Near Coshocton, Ohio. Water Resources Research 7(1):81-89.

Timmons, D. R., R. E. Burwell, and R. F. Holt, 1973. Nitrogen and Phosphorus Losses in Surface Runoff from Agricultural Land as Influenced by Placement of Broadcast Fertilizer. Water Resources Research 9(3):658-667.

U. S. Department of Agriculture Forest Service and Soil Conservation Service (Ark. & Ok.), 1989. Illinois River Cooperative River Basin Study Plan of Work. U. S. Department of Agriculture, 22 pp.

U. S. Department of Agriculture Soil Conservation Service, 1970. Soil Survey: Cherokee and Delaware Counties Oklahoma. Soil Conservation Service, USDA, Washington, D. C.

U. S. Department of Agriculture Soil Conservation Service, 1989. Illinois River Basin Report, Arkansas and Oklahoma. Soil Conservation Service

Vollenweider, R. A., 1968. Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters, with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication. Organization for Economic Co-operation and Development Directorate for Scientific Affairs, Paris.

Walker, R. D., 1980. Universal Soil Loss Equation: A Quick Way to Estimate Your Soil Erosion Losses. Crops and Soils, Oct.:10-13.

Wetzel, R. G., 1983. Limnology, 2nd ed. Saunders College Publishing, a division of Holt, Rinehart & Winston, Inc., Orlando, Fl. 750 pp.

Wischmeier, W. H., and D. D. Smith, 1978. Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. U. S. Department of Agriculture, Agriculture Handbook no. 537, USDA, Washington, D. C., 56 pp.

Wolff, G. S., 1985. Nonpoint Source Pollution: Managing Nutrients A Key to Control. Perspectives on Nonpoint Source Pollution: Proceedings of a National Conference, Kansas City, Missouri, May 19-22, 1985. EPA 440/5-85-001, United States Environmental Protection Agency, Washington, D. C.

Young, R. A., C. A. Onstad, D. D. Bosch, and W. P. Anderson, 1987. AGNPS, Agricultural Nonpoint Source Pollution Model: A Watershed Analysis Tool. Conservation Research Report 35. Agricultural Research Service, USDA, Washington, D. C. 77pp.

Young, R. A., C. A. Onstad, D. D. Bosch, and W. P. Anderson, 1989. AGNPS: A Nonpoint Source Pollution Model for Evaluating Agricultural Watersheds. Journal of Soil and Water Conservation 44(2):168-173.

Young, R. A., M. A. Otterby, and A. Roos, 1982. A Technique for Evaluating Feedlot Pollution Potential. Journal of Soil and Water Conservation 37(1):21-23.

APPENDIXES

APPENDIX A

AGNPS INPUT

Stage-Discharge Table

A

Time	Height	Velocity	Area	Discharge

B

Time	Height	Velocity	Area	Discharge

C

Time	Height	Velocity	Area	Discharge

D

Time	Height	Velocity	Area	Discharge

Watershed Data File

Sheet No. 1
Watershed Name Watershed A

Cell No.	Rec Cell No.	SCS Curv No.	Land Slope %	Slope Shape Fact	Field Slope Lgth	Chnel Slope %	Chnel Side Slope	Man's Coefc	K Fact	C Fact	P Fact	Surf Cond Const	Aspt	Soil Text No.	Fert Lev	Avail Fact %	Point Srce Indic	Gully Srce	COD	Impd Fact	Chn Ind
1	10	74	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
2	10	74	2	1	330	1	1	0.08	0.43	0	1	0.22	6	2	1	30	0	0	60	0	0
3	12	61	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
4	13	61	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
5	14	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	5	2	1	30	0	0	60	0	0
6	15	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	5	2	1	30	0	0	60	0	0
7	16	61	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
8	17	74	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
9	19	61	2	1	330	1	1	0.048	0.43	0	1	0.22	5	2	1	30	0	0	60	0	1
10	20	74	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
11	20	74	2	1	330	1	1	0.08	0.43	0	1	0.22	6	2	1	30	0	0	60	0	0
12	22	74	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
13	22	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	6	2	1	30	0	0	60	0	0
14	13	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	7	2	1	30	0	0	60	0	0
15	14	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	7	2	1	30	0	0	60	0	0
16	26	61	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
17	27	74	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
18	28	74	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
19	93	66	1	1	330	0.5	1	0.048	0.42	0	1	0.22	7	2	1	30	0	0	65	0	1
20	19	61	1	1	330	0.5	1	0.08	0.42	0	1	0.22	7	2	1	30	0	0	60	0	0
21	20	61	2	1	330	1	1	0.08	0.42	0	1	0.22	7	2	1	30	0	0	60	0	0
22	21	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
23	22	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	7	2	1	30	0	0	60	0	0
24	23	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	7	2	1	30	0	0	60	0	0
25	24	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	7	2	1	30	0	0	60	0	0

Watershed Data File

Sheet No. 2
Watershed Name Watershed A

Cell No.	Rec Cell No.	SCS Curv No.	Land Slope %	Slope Shape Fact	Field Slope Lgth	Chnel Slope %	Chnel Side Slope	Man's Coefc	K Fact	C Fact	P Fact	Surf Cond Const	Aspt	Soil Text No.	Fert Level	Avail Fact %	Point Srce Indic	Gully Srce	COD	Impd Fact	Chn Ind
26	25	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
27	37	61	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
28	38	61	2	1	330	1	1	0.08	0.43	0	1	0.22	5	2	1	30	0	0	60	0	0
29	19	77	2	1	330	1	1	0.048	0.43	0	1	0.22	1	2	1	30	0	0	65	0	1
30	20	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
31	20	61	2	1	330	1	1	0.08	0.43	0	1	0.22	8	2	1	30	0	0	60	0	0
32	21	61	2	1	330	1	1	0.08	0.43	0	1	0.22	8	2	1	30	0	0	60	0	0
33	22	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	8	2	1	30	0	0	60	0	0
34	33	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
35	34	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
36	35	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
37	36	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
38	37	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
39	29	66	2	1	330	1	1	0.048	0.43	0	1	0.22	1	2	1	30	0	0	65	0	1
40	41	74	2	1	330	1	1	0.08	0.43	0	1	0.22	3	2	1	30	0	0	60	0	0
41	31	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
42	41	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
43	42	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
44	43	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	7	2	1	30	0	0	60	0	0
45	44	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
46	45	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
47	36	61	2	1	330	1	1	0.08	0.43	0	1	0.22	8	2	1	30	0	0	60	0	0
48	47	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
49	39	61	2	1	330	1	1	0.048	0.43	0	1	0.22	1	2	1	30	0	0	65	0	1
50	51	61	2	1	330	1	1	0.08	0.43	0	1	0.22	3	2	1	30	0	0	60	0	0

Watershed Data File

Sheet No. 3
Watershed Name Watershed A

Cell No.	Rec Cell No.	SCS Curv No.	Land Slope %	Slope Shape Fact	Field Slope Lgth	Chnel Slope %	Chnel Side Slope	Man's Coefc	K Fact	C Fact	P Fact	Surf Cond Const	Aspt	Soil Text No.	Fert Level	Avail Fact %	Point Srce Indic	Gully Srce	COD	Impd Fact	Chn Ind
51	41	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
52	51	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
53	52	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
54	53	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
55	54	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
56	46	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
57	46	61	2	1	330	1	1	0.08	0.43	0	1	0.22	8	2	1	30	0	0	60	0	0
58	48	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
59	51	61	2	1	330	1	1	0.08	0.43	0	1	0.22	2	2	1	30	0	0	60	0	0
60	51	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
61	51	61	2	1	330	1	1	0.08	0.43	0	1	0.22	8	2	1	30	0	0	60	0	0
62	53	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
63	62	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
64	54	61	2	1	330	1	1	0.08	0.43	0	1	0.22	8	2	1	30	0	0	60	0	0
65	56	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
66	57	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
67	58	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
68	59	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
69	60	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	1	2	1	30	0	0	60	0	0
70	61	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	1	2	1	30	0	0	60	0	0
71	62	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	1	2	1	30	0	0	60	0	0
72	63	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
73	63	61	2	1	330	1	1	0.08	0.43	0	1	0.22	8	2	1	30	0	0	60	0	0
74	65	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
75	66	74	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0

Watershed Data File

Sheet No. 4
Watershed Name Watershed A

Cell No.	Rec Cell No.	SCS Curv No.	Land Slope %	Slope Shape Fact	Field Slope Lgth	Chnel Slope %	Chnel Side Slope	Man's Coefc	K Fact	C Fact	P Fact	Surf Cond Const	Aspt	Soil Text No.	Fert Level	Avail Fact %	Point Srce Indic	Gully Srce	COD	Impd Fact	Chn Ind
76	67	74	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
77	69	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	1	2	1	30	0	0	60	0	0
78	70	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	1	2	1	30	0	0	60	0	0
79	71	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	1	2	1	30	0	0	60	0	0
80	71	61	2	1	330	1	1	0.08	0.43	0	1	0.22	8	2	1	30	0	0	60	0	0
81	73	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
82	74	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
83	75	74	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
84	78	80	1	1	330	0.5	1	0.08	0.49	0	1	0.22	1	2	1	30	0	0	60	0	0
85	79	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
86	79	61	2	1	330	1	1	0.08	0.43	0	1	0.22	8	2	1	30	0	0	60	0	0
87	81	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
88	82	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
89	83	74	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
90	85	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0
91	90	61	2	1	330	1	1	0.08	0.43	0	1	0.22	7	2	1	30	0	0	60	0	0
92	87	61	2	1	330	1	1	0.08	0.43	0	1	0.22	1	2	1	30	0	0	60	0	0

Watershed Data File

Sheet No. 1
Watershed Name Watershed B

Cell No.	Rec Cell No.	SCS Curv No.	Land Slope %	Slope Shape Fact	Field Slope Lgth	Chnel Slope %	Chnel Side Slope	Man's Coefc	K Fact	C Fact	P Fact	Surf Cond Const	Aspt	Soil Text No.	Fert Lev	Avail Fact %	Point Srce Indic	Gully Srce	COD	Impd Fact	Chn Ind
1	4	60	4	2	165	2	2	0.08	0.28	0	1	0.29	4	2	0	0	0	0	65	0	0
2	4	60	4	2	165	2	2	0.08	0.28	0	1	0.29	5	2	0	0	0	0	65	0	0
3	6	60	2	1	330	1	1	0.08	0.28	0	1	0.29	5	2	0	0	0	0	65	0	0
4	5	55	35	2	165	17.5	17.5	0.08	0.28	0	1	0.59	3	2	0	0	0	0	65	0	0
5	8	61	4	1	330	2	2	0.08	0.28	0	1	0.22	5	2	3	30	0	0	60	0	0
6	7	55	35	2	165	17.5	17.5	0.08	0.28	0	1	0.59	3	2	0	0	0	0	65	0	0
7	12	61	35	2	165	17.5	17.5	0.08	0.28	0	1	0.22	4	2	3	30	0	0	60	0	0
8	12	61	5	1	330	2.5	10	0.048	0.24	0	1	0.22	5	2	3	30	0	0	60	0	1
9	12	61	4	1	330	2	2	0.08	0.28	0	1	0.22	6	2	3	30	0	0	60	0	0
10	11	55	35	1	330	17.5	17.5	0.08	0.28	0	1	0.59	3	2	0	0	0	0	65	0	0
11	12	61	5	1	330	2.5	2.5	0.08	0.24	0	1	0.22	3	2	3	30	0	0	60	0	0
12	15	61	5	1	330	2.5	2.5	0.048	0.24	0	1	0.22	5	2	3	30	0	0	60	0	0
13	15	61	5	1	330	2.5	2.5	0.08	0.24	0	1	0.22	6	2	3	30	0	0	60	0	0
14	15	61	5	1	330	2.5	2.5	0.08	0.24	0	1	0.22	3	2	3	30	0	0	60	0	0
15	17	61	5	1	330	2.5	10	0.048	0.24	0	1	0.22	5	2	3	30	0	0	60	0	1
16	15	61	5	1	330	2.5	2.5	0.08	0.24	0	1	0.22	7	2	3	30	0	0	60	0	0

Watershed Data File

Sheet No. 1
Watershed Name Watershed C

Cel No.	Rec Cell No.	SCS Curv No.	Land Slope %	Slope Shape Fact	Field Slope Lgth	Chnel Slope %	Chnel Side Slope	Man's Coefc	K Fact	C Fact	P Fact	Surf Cond Const	Aspt	Soil Text No.	Fert Lev	Avail Fact %	Point Srce Indic	Gully Srce	COD	Impd Fact	Chn Ind
1	9	61	4	2	165	2	45	0.048	0.32	0	1	0.22	1	2	3	60	0	0	60	0	1
2	1	61	10	2	165	5	5	0.08	0.28	0	1	0.22	7	2	3	60	0	0	60	0	0
3	4	61	4	1	330	2	2	0.08	0.32	0	1	0.22	3	2	3	60	0	0	60	0	0
4	2	61	4	1	330	2	45	0.048	0.32	0	1	0.22	1	2	3	60	0	0	60	0	1
5	4	61	4	1	330	2	2	0.08	0.32	0	1	0.22	7	2	3	60	0	0	60	0	0
6	7	74	2	1	330	1	1	0.08	0.43	0	1	0.22	3	2	3	60	0	0	60	0	0
7	4	74	2	1	330	1	45	0.048	0.43	0	1	0.22	1	2	3	60	0	0	60	0	1
8	4	74	2	1	330	1	1	0.08	0.43	0	1	0.22	8	2	3	60	0	0	60	0	0

Watershed Data File

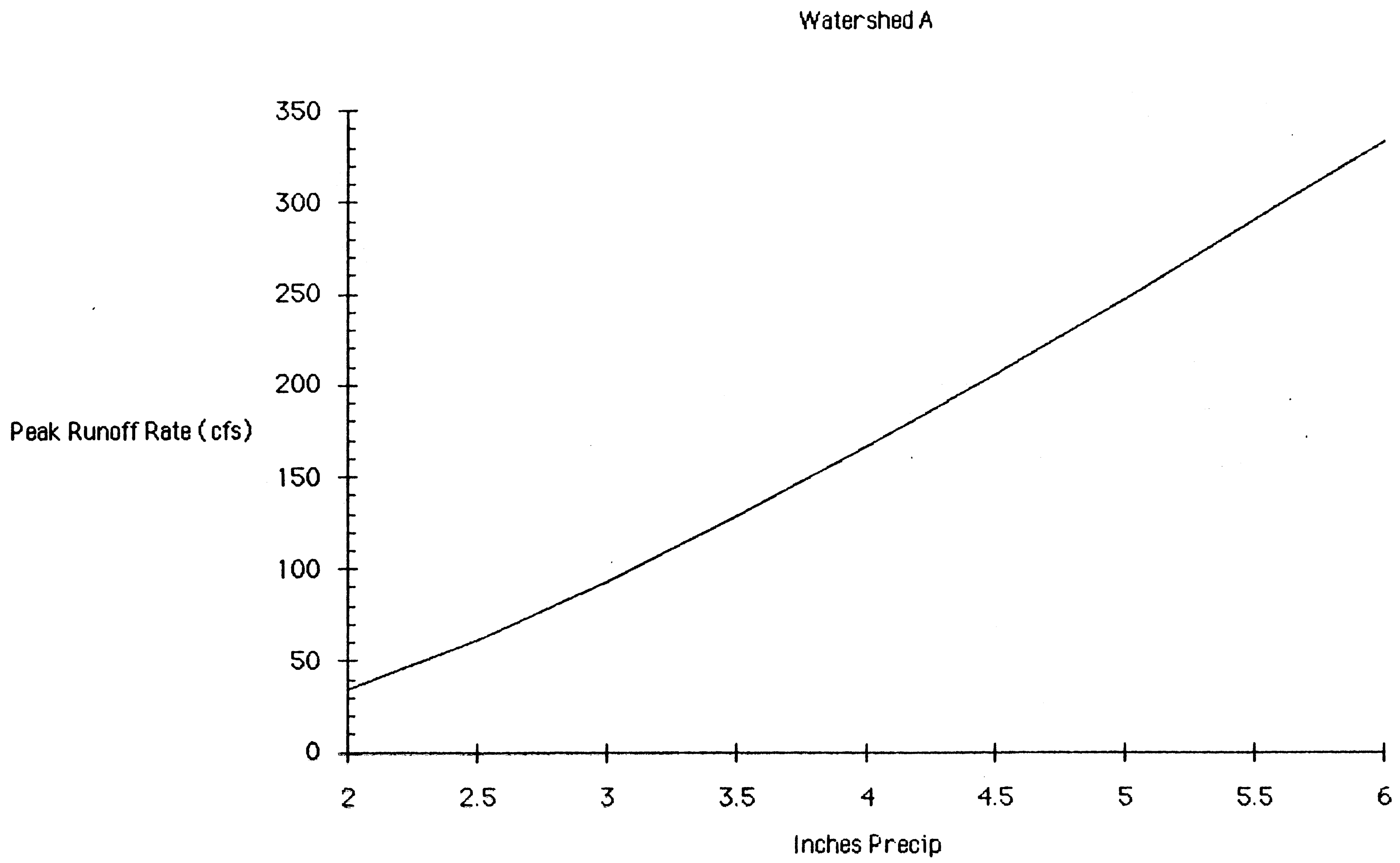
Sheet No. 1

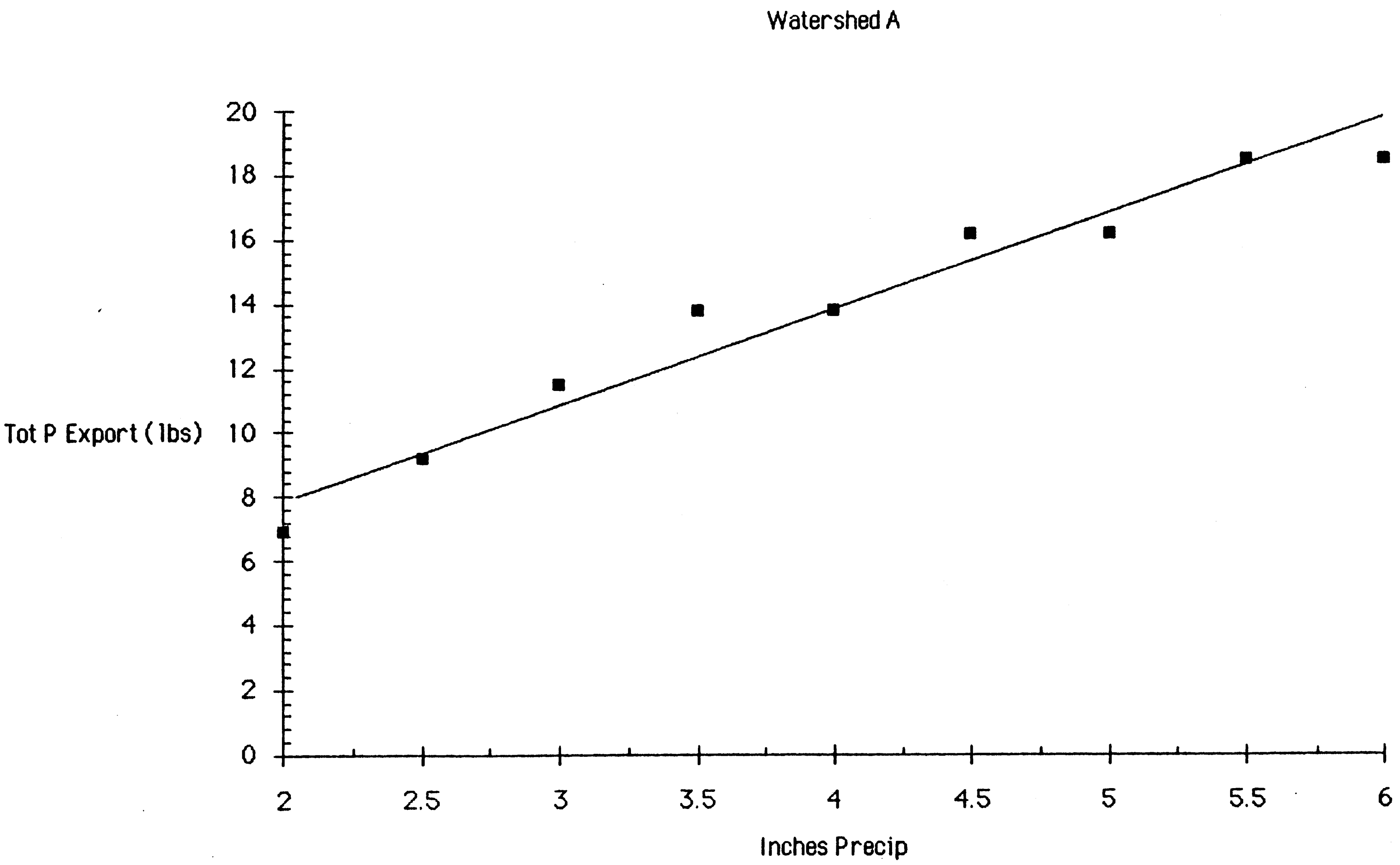
Watershed Name Watershed D (control)

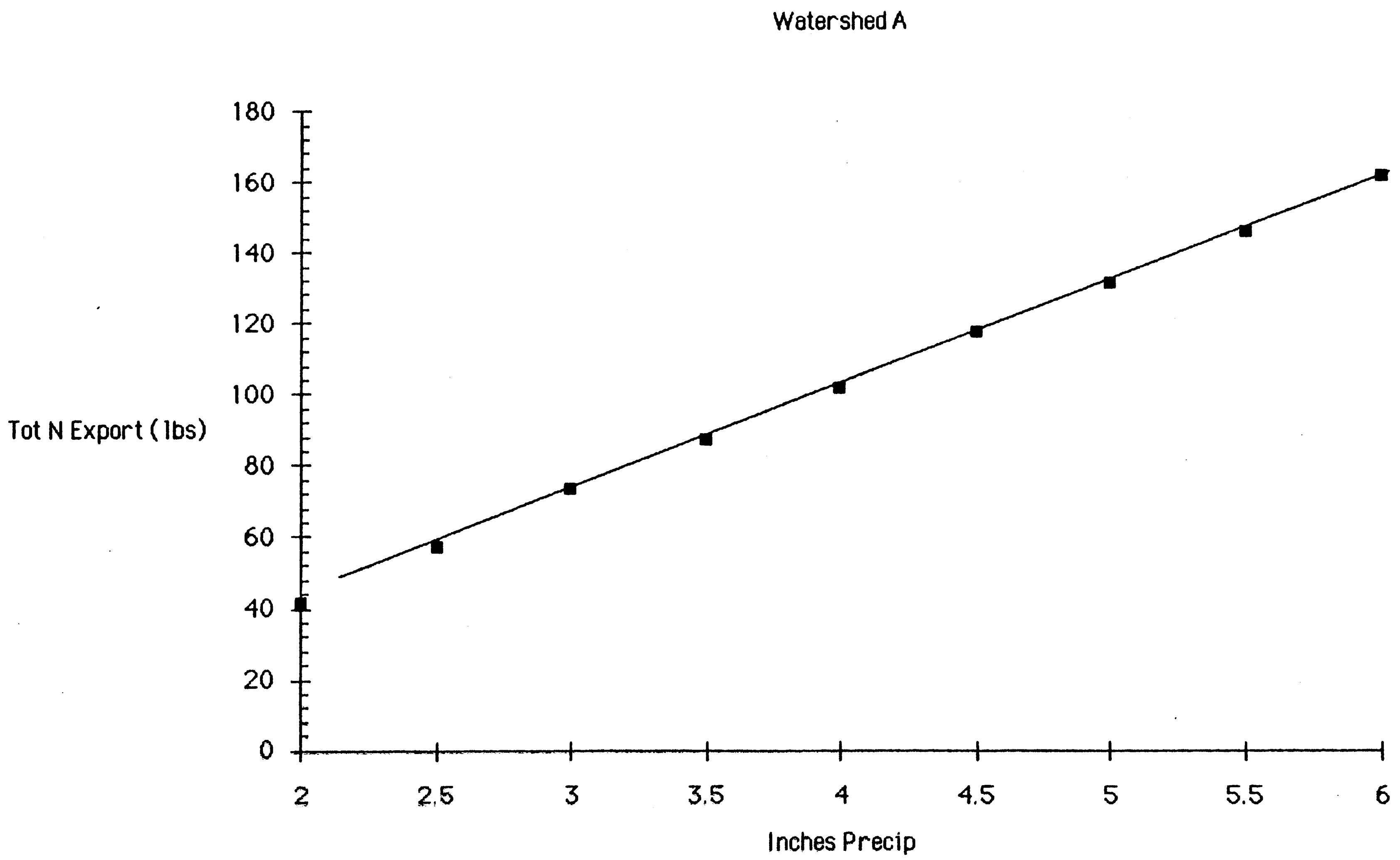
Cel No.	Rec Cell No.	SCS Curv No.	Land Slope %	Slope Shape Fact	Field Slope Lgth	Chnel Slope %	Chnel Side Slope	Man's Coefc	K Fact	C Fact	P Fact	Surf Cond Const	Aspt	Soil Text No.	Fert Lev	Avail Fact %	Point Srce Indic	Gully Srce	COD	Impd Fact	Chn Ind
1	4	70	2	1	330	1	10	0.048	0.43	0	1	0.59	5	2	0	0	0	0	65	0	0
2	5	55	20	2	165	20	45	0.048	0.28	0	1	0.59	5	2	0	0	0	0	65	0	1
3	4	55	20	2	165	20	45	0.048	0.28	0	1	0.59	3	2	0	0	0	0	65	0	1
4	7	55	35	1	330	35	45	0.048	0.28	0	1	0.59	5	2	0	0	0	0	65	0	2
5	7	66	35	1	330	35	45	0.048	0.28	0	1	0.29	6	2	0	0	0	0	65	0	1
6	7	66	20	3	165	10	10	0.048	0.28	0	1	0.29	3	2	0	0	0	0	65	0	0
7	10	66	20	3	165	2	10	0.048	0.28	0	1	0.29	5	2	0	0	0	0	65	0	1
8	7	58	20	2	165	10	10	0.048	0.28	0	1	0.59	7	2	0	0	0	0	65	0	0
9	10	66	20	1	330	10	10	0.048	0.28	0	1	0.29	3	2	0	0	0	0	65	0	0
10	13	66	20	3	165	2	10	0.048	0.28	0	1	0.29	5	2	0	0	0	0	65	0	1
11	10	66	35	1	330	17.5	10	0.048	0.28	0	1	0.29	7	2	0	0	0	0	65	0	0
12	13	58	20	1	330	10	10	0.048	0.28	0	1	0.59	3	2	0	0	0	0	65	0	0
13	14	66	20	1	330	10	10	0.048	0.28	0	1	0.29	3	2	0	0	0	0	65	0	1
14	15	66	20	1	330	2	45	0.048	0.28	0	1	0.29	5	2	0	0	0	0	65	0	1

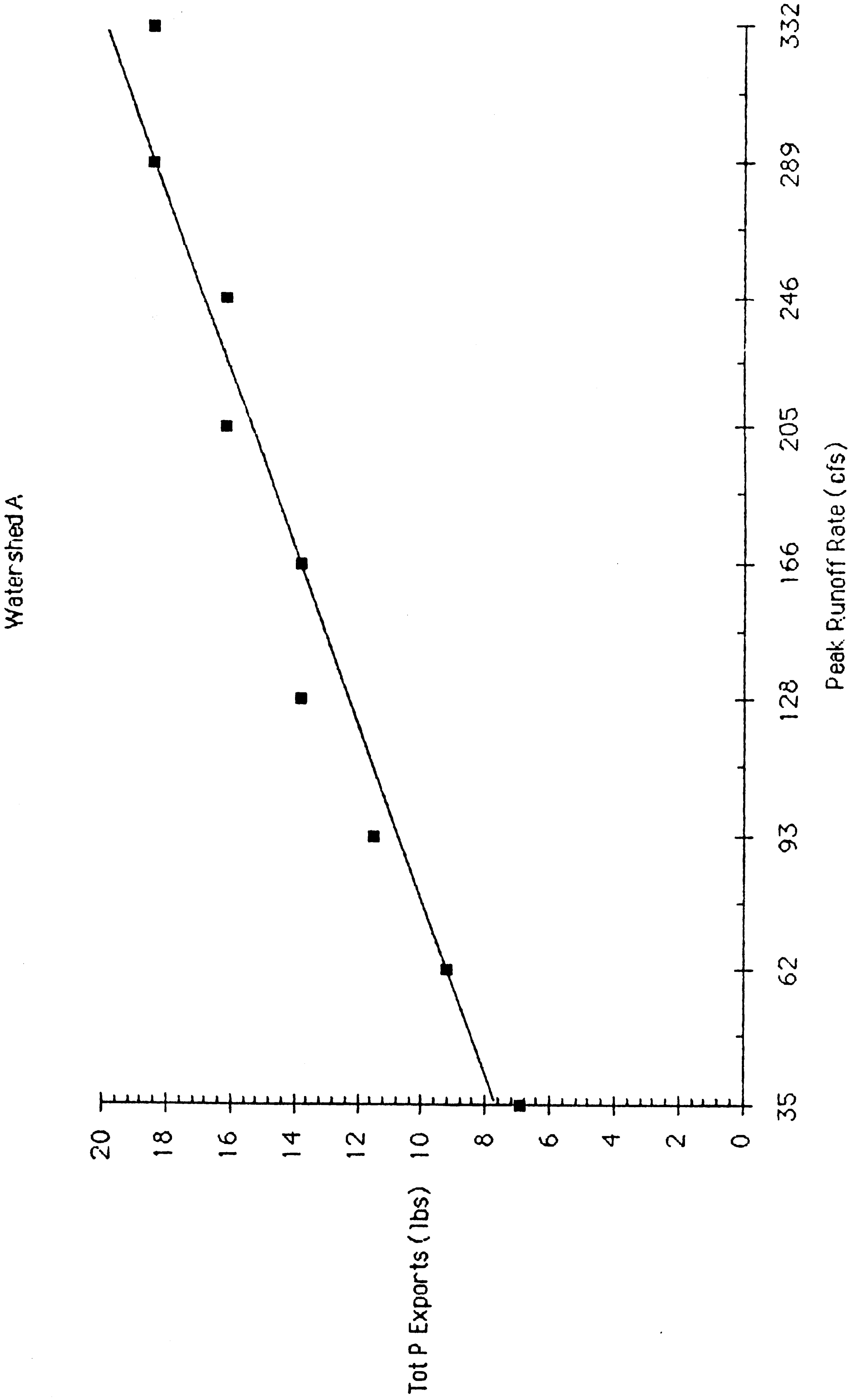
APPENDIX B

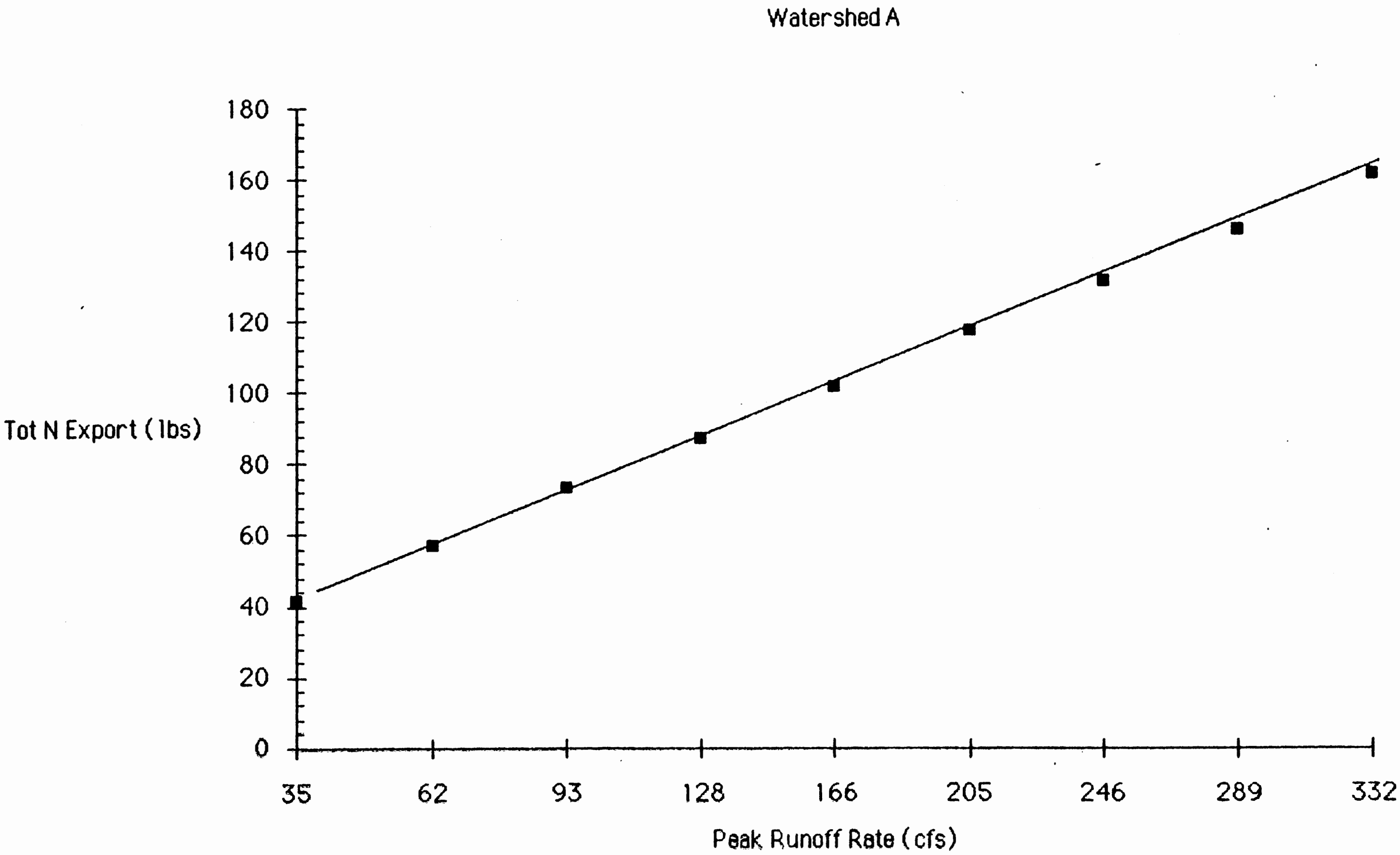
AGNPS OUTPUT

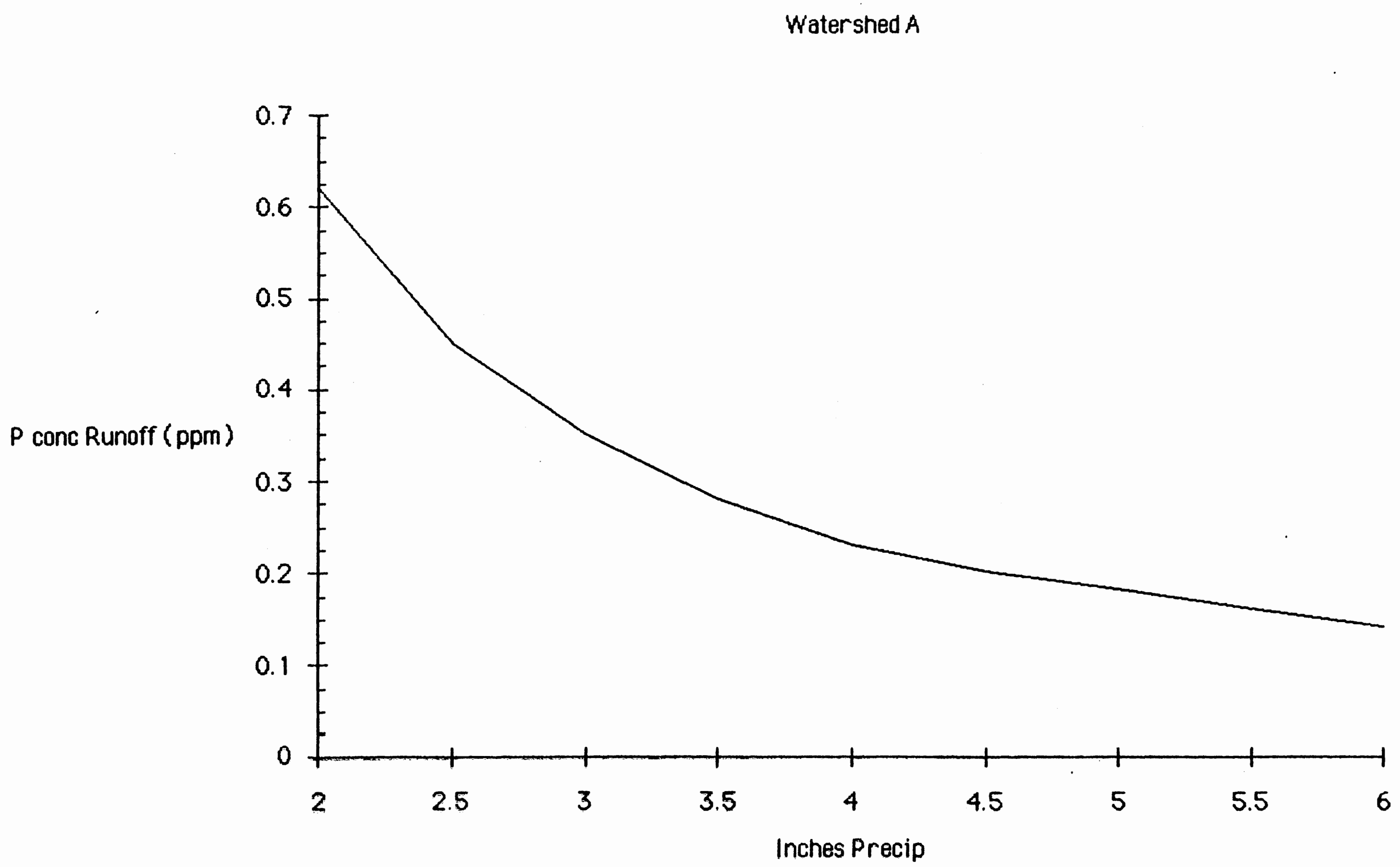

Watershed A
Peak Runoff Rate (cfs)
350
300
250
200
150
100
50
0
2
2.5
3
3.5
4
4.5
5
5.5
6
Inches Precip

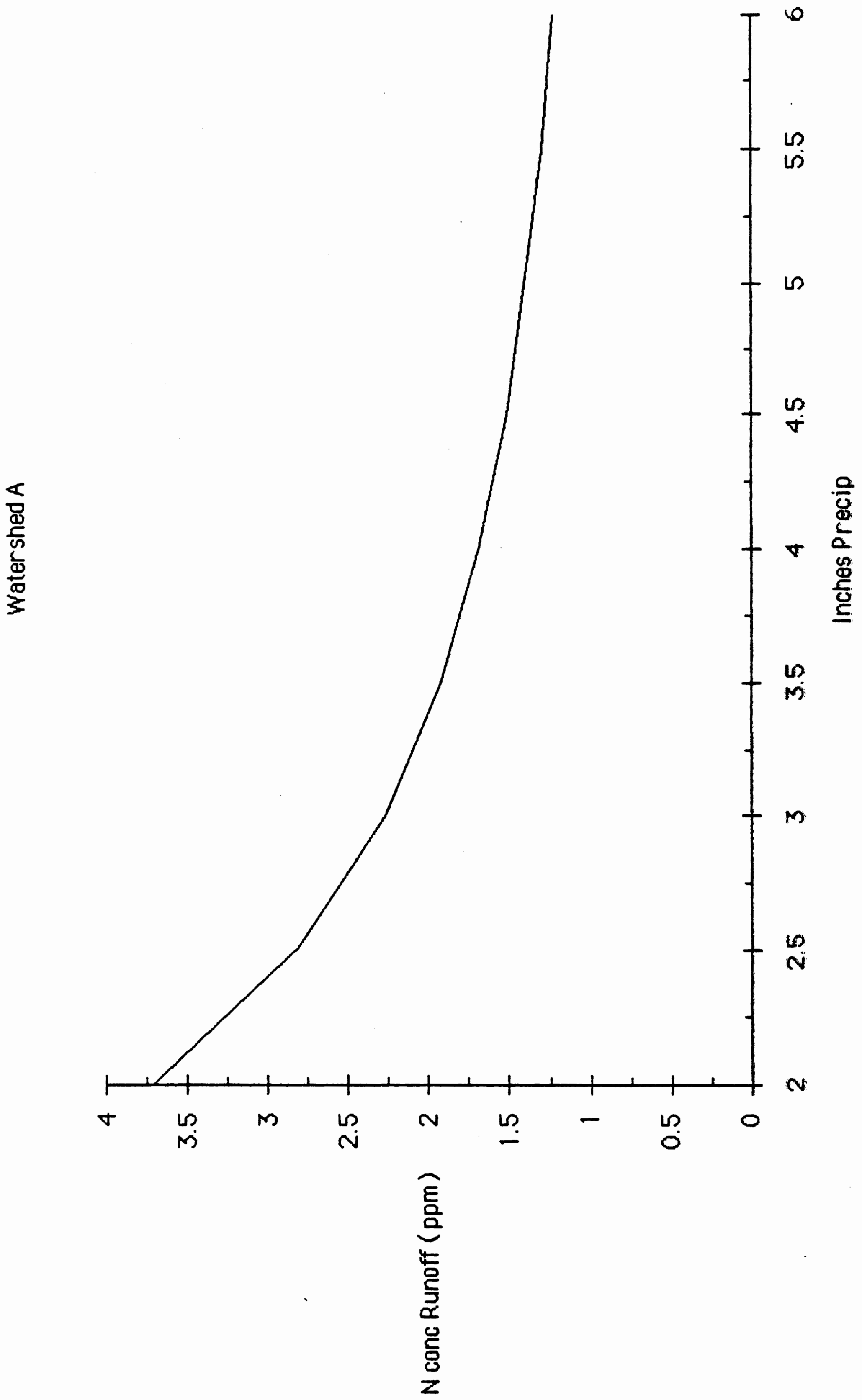

Watershed A
Tot P Export (lbs)
20
18
16
14
12
10
8
6
4
2
0
2
2.5
3
3.5
4
4.5
5
5.5
6
Inches Precip

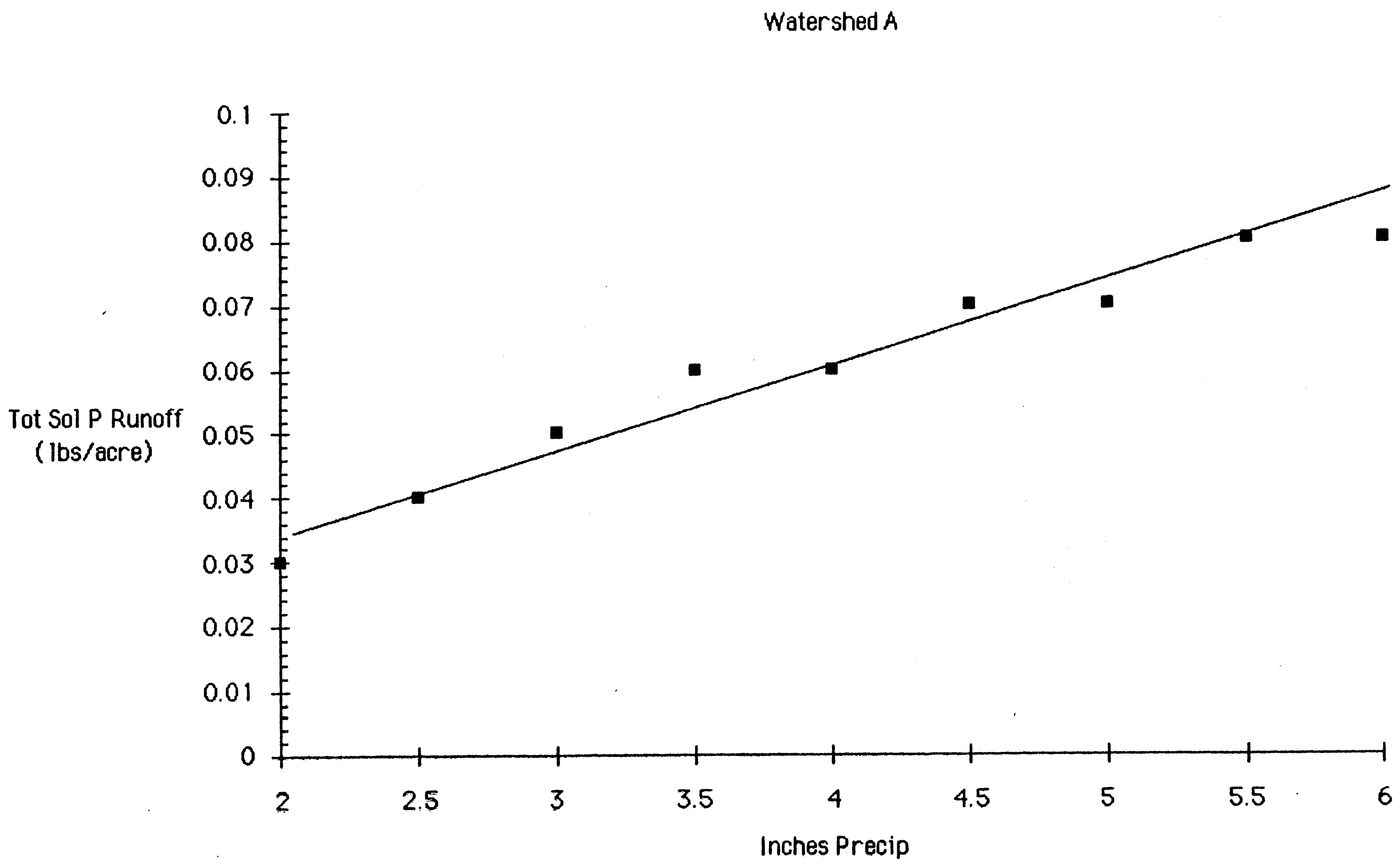

Watershed A
Tot N Export (lbs)
180
160
140
120
100
80
60
40
20
0
2
2.5
3
3.5
4
4.5
5
5.5
6
Inches Precip

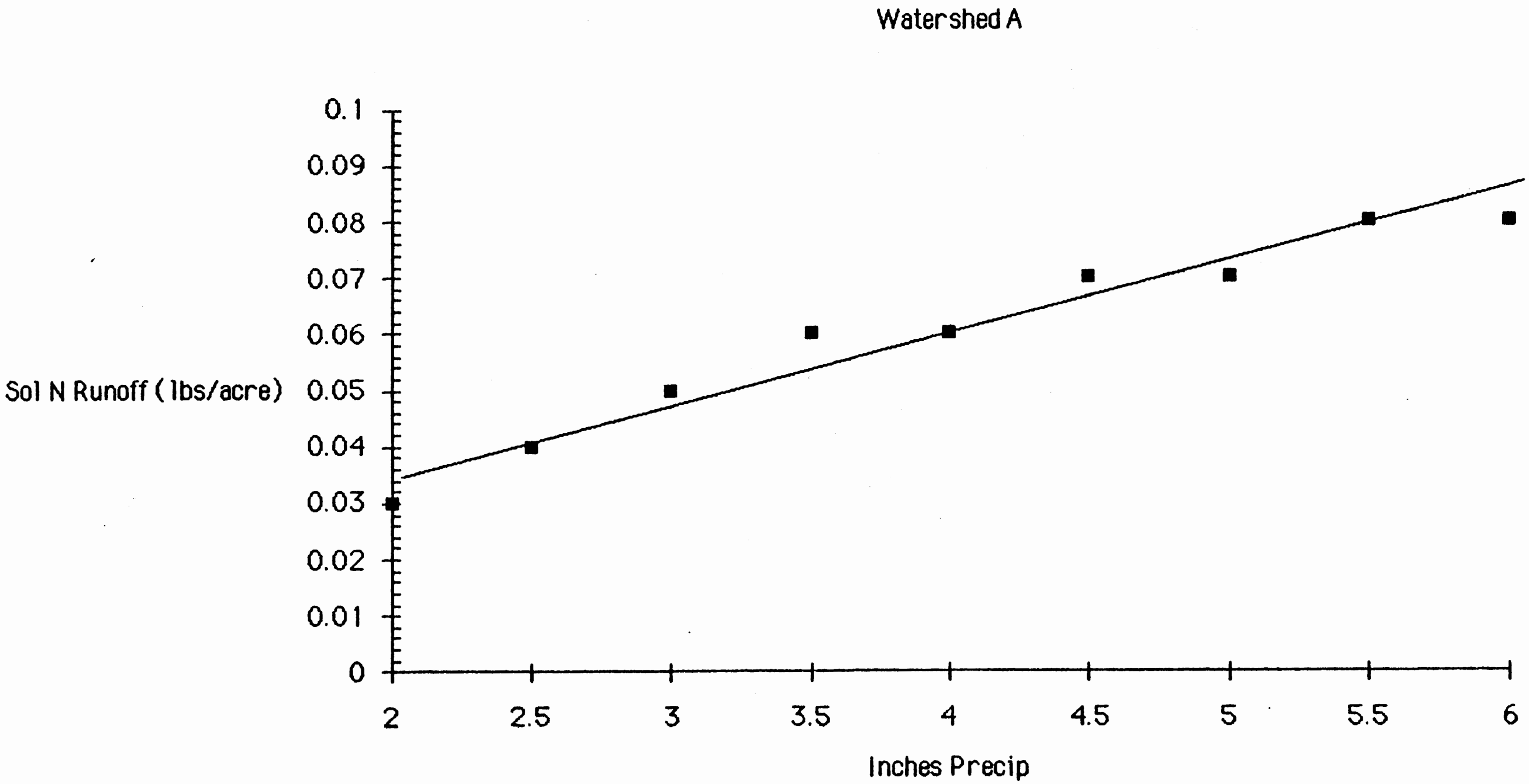

Watershed A
Tot P Exports (lbs)
20
18
16
14
12
10
8
6
4
2
0
35
62
93
128
166
205
246
289
332
Peak Runoff Rate (cfs)


Watershed A
Tot N Export (lbs)
0
20
40
60
80
100
120
140
160
180
35
62
93
128
166
205
246
289
332
Peak Runoff Rate (cfs)


Watershed A
P conc Runoff (ppm)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2
2.5
3
3.5
4
4.5
5
5.5
6
Inches Precip


Watershed A
N conc Runoff (ppm)
0
0.5
1
1.5
2
2.5
3
3.5
4
2
2.5
3
3.5
4
4.5
5
5.5
6
Inches Precip


Watershed A
Tot Sol P Runoff
(lbs/acre)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
2
2.5
3
3.5
4
4.5
5
5.5
6
Inches Precip


Watershed A
Sol N Runoff (lbs/acre)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
2
2.5
3
3.5
4
4.5
5
5.5
6
Inches Precip

VITA

Micheal B. Copenhaver

Candidate for the Degree of

Master of Science

Thesis: EVALUATION OF NUTRIENT EXPORTS FROM THREE AGRICULTURAL WATERSHEDS IN THE BATTLE BRANCH SUBBASIN

Major Field: Environmental Science

Biographical:

Personal Data: Born in Muskogee, Oklahoma, June 21, 1947, the son of E. L. and Bobba Copenhaver.

Education: Graduated from Sulphur Senior High School, Sulphur, Oklahoma, in January 1965; received Bachelor of Science Degree in Botany from Oklahoma State University in May, 1988; completed requirements for the Master of Science degree at Oklahoma State University in July, 1991.

Professional Experience: Research Assistant, Department of Zoology, Oklahoma State University, January, 1990 to July, 1991.