THE EFFICIENCY OF A 2.7 ACRE FARM POND IN REDUCING NUTRIENT AND SEDIMENT LOADING FROM A 68.2 ACRE WATERSHED

By

Michael J. Linskens

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Approved by the Graduate Committee of:

Dr. Byron H. Shaw, Committee Chairman
Professor of Soil and Water Science

Dr. N. Earl Spangenburg
Associate Professor of Water Science

Dr. Ronald F. Hensler
Associate Professor of Soils

Dr. James A. Bowles
Professor of Soils

Abstract

Significant amounts of sediment and nutrients from agricultural watersheds are removed from storm runoff by farm ponds. The purpose of this study was to determine the efficiency of a 2.7 acre farm pond in reducing sediment and nutrient loading from a 68.2 acre dairy farm watershed in northcentral Wisconsin for the period 1966-1979.

A gauging station was constructed at the pond inflow to monitor flow and water quality runoff data continuously in 1979. Fourteen years of overland flow to the pond was simulated with the Non-Point Source Pollution (NPS) model. Observed average sediment and nutrient concentrations for snowmelt and all other runoff in 1979 were used to calculate total sediment and nutrients input over the fourteen year life of the pond. Total sediment and nutrient trapped in the pond was quantified by analysis of sediment samples during the winter of 1980. Trapping efficiencies based on sediment sampling were found to be 100% for sediment, 12.4% for total phosphorus and 11.9% for total nitrogen. If calculated on an inflow/outflow basis, efficiencies decrease for sediment to 95.2% and increase for total phosphorus and total nitrogen to about 80% and 60%, respectively.

Average yearly sediment loading was found to be approximately 370 pounds per acre, well below the average gross erosion estimates for cropland for the Big Eau Pleine

River watershed of 4600 lbs/acre and somewhat below a 460 - 920 lbs/acre value that assumes a 10 - 20% delivery ratio. The use of grassed waterways and diversions on a major portion of the watershed probably contributed to reduced sediment loading.

Average yearly nutrient loading of 2.27 lbs/acre for total phosphorus and 10.2 lbs/acre for total nitrogen were greater by factors of 2.5 to 10 times reported values for the Big Eau Pleine watershed. These greater loadings were attributed to a greater density of animals. Dairying operations on the study area watershed are believed to contribute to overall high nutrient loading for the watershed.

Grab samples of runoff from barnyard or manured areas were found to contain greater than 100 times the concentration of sediment and nutrients as compared to cropland.

Systematic snow sampling on the watershed provided data that attributed high nutrient loading in snowmelt runoff to spreading of manure in the winter.

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INTRODUCTION

Congress has recognized that clean water is a desirable resource. Public Law 92-500 was created to assure navigable waters be maintained in a fishable and swimable condition. The law mandated point source pollution be controlled by 1983. Generally, this has been accomplished and surface water quality influenced by point source discharges is much improved. Yet, obnoxious algal blooms and excessive weed growth, often contributing to winter fish kills, still occur in many lakes and impoundments as a result of non-point agricultural pollution sources (Sullivan, 1977). Section 208 of the law calls for development and implimentation of areawide management plans for initial and long-term water quality control.

For many years the Soil Conservation Services (SCS) has promoted the use of soil management plans in reducing rural non-point source pollution. These plans include plowing on the contour, terracing, diversions, grassed waterways, manure storage areas, barnyard runoff pits and farm ponds. It has been shown that these techniques when properly applied reduce soil loss from managed areas and in the process reduce sediment and nutrient loading during runoff events (S.C.S., 1977; Highfill, 1982).

In particular, farm ponds have been constructed in natural waterways of small farm watersheds. Farm ponds are promoted by SCS because of their multi-use capability. In addition to being natural sediment and nutrient traps, they provide water for cattle during dry summer periods; recreation including boating, fishing and swimming; and flood control during runoff events.

OBJECTIVE AND STUDY APPROACH

The primary purpose of this study is to establish the efficiency of a 2.7 acre farm pond in reducing sediment and nutrient loading from a 68.2 acre watershed to the Big Eau Pleine River. For this study, nutrients shall be considered nitrogen (ammonia, nitrate-nitrite, and total Kjeldahl) and phosphorus (ortho and total) species and sediment as total suspended solids or pond sediment.

The efficiency of the pond in reducing sediment and nutrient loading can be expressed in two ways: one, as a physical trapping efficiency; and two, on an inflow/outflow basis. Although efficiency will be discussed on an inflow/outflow basis, the primary goal of this study was to obtain the pond's sediment and nutrient trapping efficiency. Both efficiencies can be described by the simple formulae:

$$\text{Trapping Efficiency (percent)} = \frac{\text{total trapped}}{\text{total input}} \times 100\%$$

$$\text{Inflow/Outflow Efficiency (percent)} = \frac{\text{inflow-outflow}}{\text{inflow}} \times 100\%$$

The total trapped equals the sediment and nutrients deposited in the pond since it was constructed in 1966 and was obtained using the following sequence of events:

- systematic random sampling of pond sediments,
- physical and chemical characterization of pond sediments; and,
- calculation of total sediment and nutrient trapped.

The total input equals the sediment and nutrients entering the pond through overland flow components and was obtained using the following sequence of field, laboratory, and computer methods:

Field

- Survey of study area,
- Construction of gauging station,
- Collection of model calibration data,
- Snow sampling,
- Sampling of runoff events,

Laboratory

- Chemical characterization of runoff events,
- Calculation of average sediment and nutrient runoff values,

Computer

- Selection of hydrologic model,
- Collection and preparation of meteorlogical data,
- Determination of model input parameter values,
- Model calibration; and,
- Final production run (simulation).

Efficiency on an inflow/outflow basis will be obtained by comparing observed data for the field study year of 1979.

A secondary objective of this study was to compare sediment and nutrient loading from selected managed segments of the watershed. The selected managed segments included:

- barnyard diversion,
- row crop grassed diversion,
- alfalfa grassed diversion,
- row crop,
- driveway diversion, and
- flume composite.

The data needed to compare sediment and nutrient loading was obtained using the following sequence of events:

- collection of grab samples during runoff events,
- chemical characterization, and
- comparison of results.

STUDY AREA

The study area is a 68.2 acre watershed located approximately two miles north of Stratford, Wisconsin in the southwestern portion of Marathon County (Figures 1 & 2). The watershed is in the north central portion of SEC. 13 T.27N, R.3E. It is composed of a gently rolling landscape with dairying and associated crop production as its land use. The watershed is oblong in shape with its axis in a north-south orientation. The watershed averages a width of approximately 1,000 feet and a length of approximately 3,000 feet. It gently slopes from south to north with an approximate rise in elevation of 85 feet.

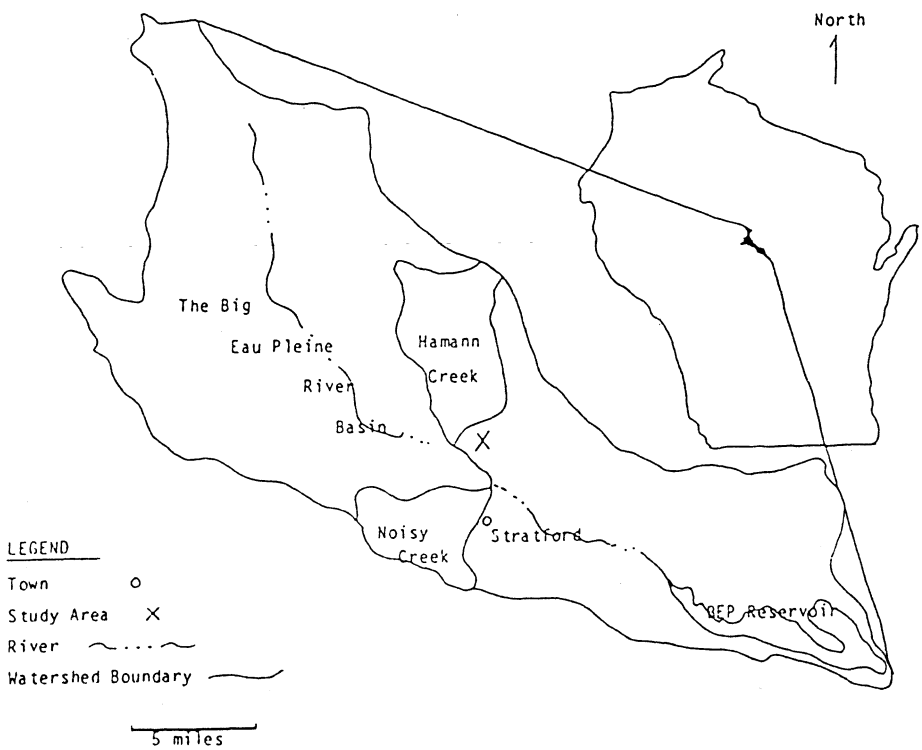
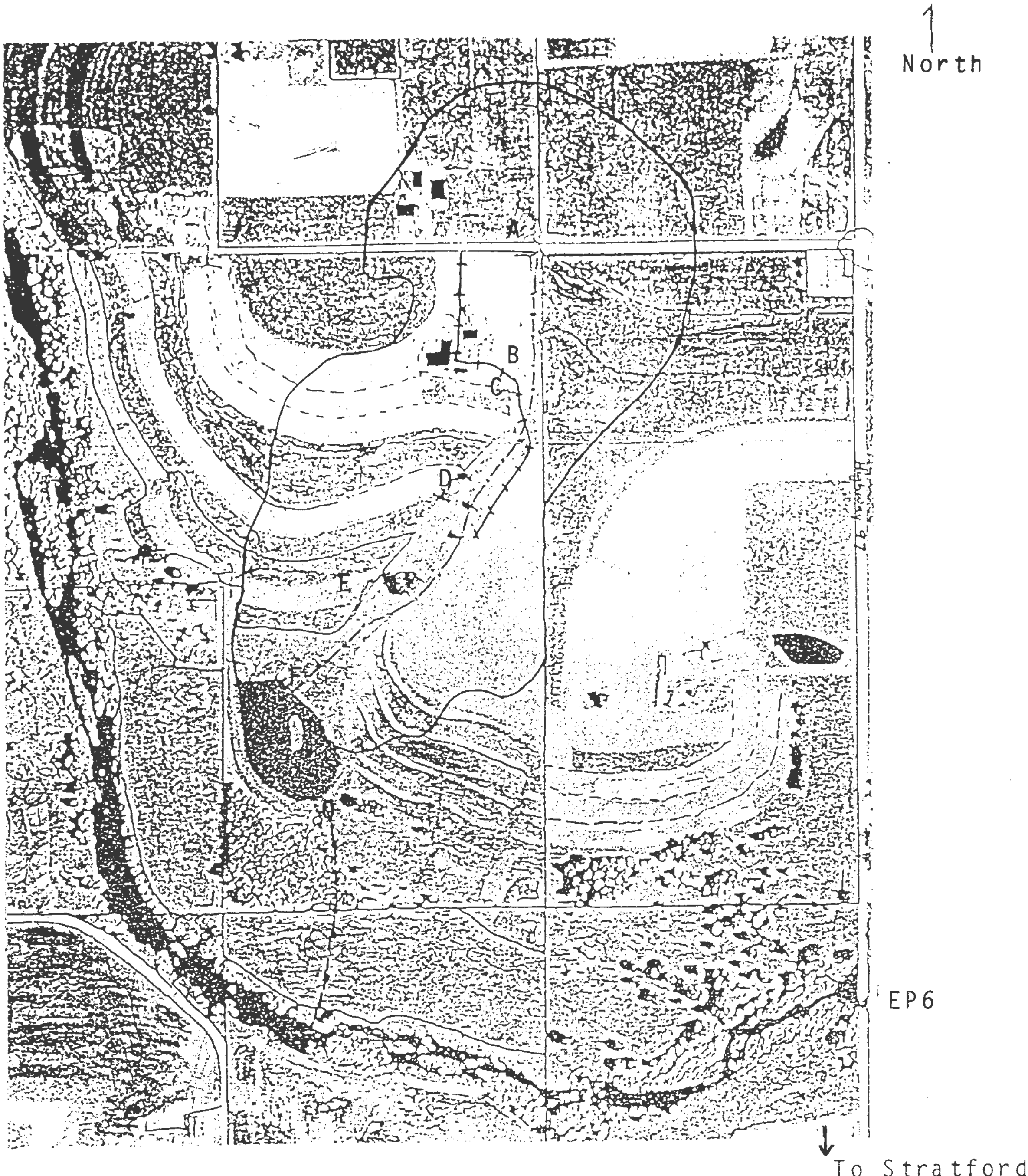


Figure 1: Location of the study area.



Legend

Road
Building
Driveway
Watershed Boundary
Intermittent Stream

660 ft

Sampling Points

Row Crop	A
Driveway Diversion	B
Barnyard	C
Alfalfa Diversion	D
Row Crop Diversion	E
Flume Composite	F
Outflow	O
USGS Gauging Station	EP6

Figure 2: Aerial photograph of the study area with designation of sampling points.

Portions of two dairy farms, one located in the northern quarter of the watershed, provide a contrast in soil conservation practices. The northern farm has been operated without any type of soil conservation program while the southern farm employs several SCS practices including plowing on the contour, diversions, grassed waterways, a manure storage area, and a 2.7 acre farm pond constructed in the spring of 1966.

During rainfall events, runoff from the northern quarter of the watershed reaches drainage ditches oriented east and west along a country road. Water pools and flows through a culvert onto a grassed waterway with a defined channel in some areas providing drainage of overland flow through the approximate middle of the southern part of the watershed to the pond. The 2.7 acre pond has an average depth of 7.5 feet and a turnover capacity of approximately 3.6 watershed inches.

A temperate climate provides a growing season of approximately 120 days with temperature averaging 14°F in January and 70°F in July. Average annual precipitation (water equivalent) is 32 inches. Snowfall has averaged 52 inches. Average estimated evapotranspiration is calculated at 21 inches leaving approximately 11 inches for overland flow or subsurface runoff components (Peterson and Barley, 1960).

The bedrock geology of the Marathon County area is predominantly granite and undifferentiated igneous and metamorphic rock with small areas consisting of gabbro and basalt. Depth to bedrock is generally not much greater than 5 to 8 feet (Hole, 1976). Exact bedrock geology of the study area is unknown, but probably quite similar.

Soils within the study area watershed are silt loams over glacial till averaging 2 feet in thickness. Two soils series are found: the Loyal (Typic Glossoboralf) and Withee (Typic Glossoboralf) silt loams. The Loyal and Withee series are the well-drained and somewhat poorly drained members of loamy soils over glacial till on uplands. Slow permeability of the soils limits groundwater recharge and causes the watershed to respond quickly to large rainfall events in the form of massive runoff (S.C.S., 1967, and Hole, et al 1968).

METHODS

A variety of field, laboratory, and computer techniques were used in collection and manipulation of data required for completion of this project.

Field Methods

Topographic Survey

A topographic survey of the watershed including the pond area was performed using conventional survey techniques. East to west transects were laid out at 75 yard intervals, and elevations were taken at 50 yard intervals along each transect. The concrete base of a flume was used as a benchmark (0.00). Measurements were taken of the length of principle waterways throughout the watershed. A contour map of the watershed was prepared (Figure 3).

Gauging Station

A stream flow gauging station was constructed at the inflow to the farm pond. An H-flume with a capacity for a 30 cubic foot per second (cfs) flow was constructed using United States Geological Survey (USGS) specifications (Ackers, etal, 1972). The flume was made of 1/8" plate steel, bolted securely to 4 by 4 wood beams that were sunk into the ground with a 4 foot deep concrete base. An approximate 10 foot section of channel upstream from the H-flume was prepared so that laminar flow would occur as

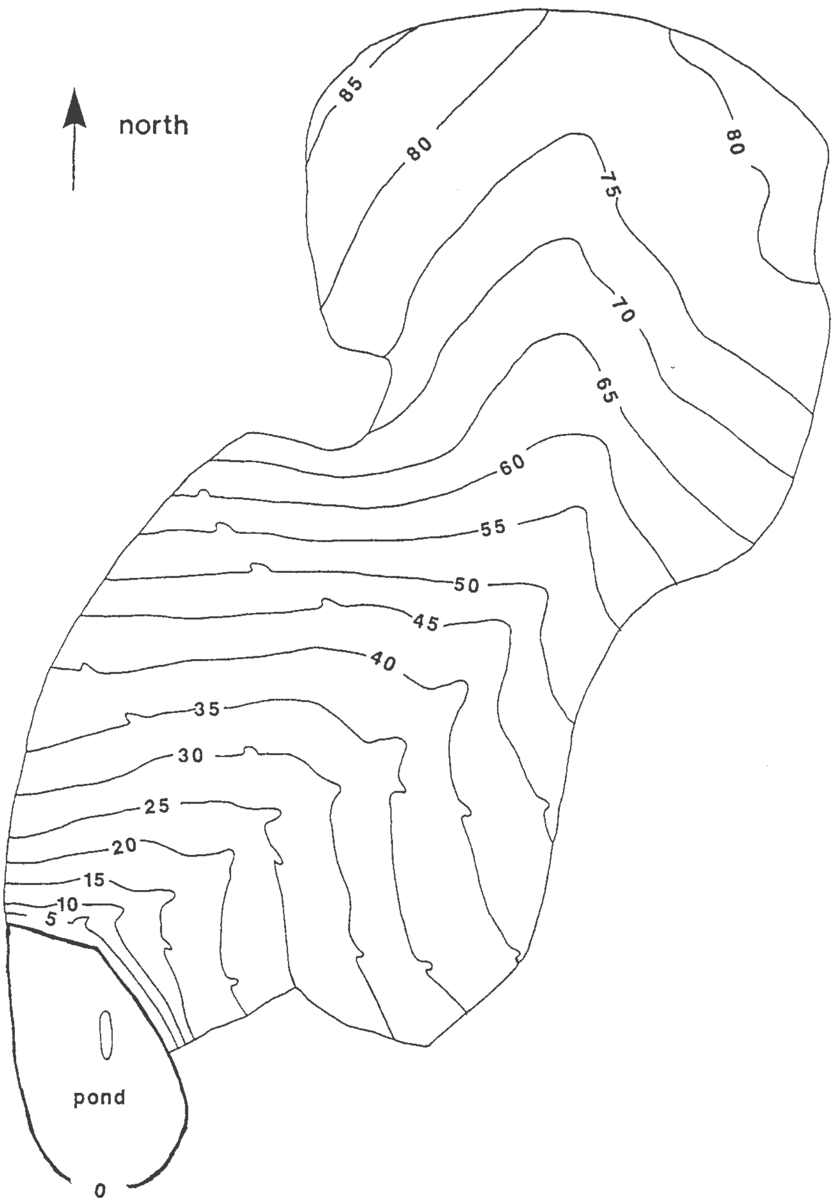


Figure 3: Topographic map of the 68.2 acre study area watershed.

water entered the measuring zone of the flume. A channel bank was created with a soil and rock retaining wall built up to the top of the flume level for approximately 20 feet upstream. A 3 inch galvanized pipe ran from the flume to a stilling well approximately 10 feet away on the stream bank. The stilling well was constructed from a 6 foot long piece of culvert, 18 inches in diameter. A Model F552 water level recorder (Weathermeasure Corporation, 1970) was used to monitor flume water levels from the stilling well continuously. A Model P601 tipping bucket rain gauge (Weathermeasure Corporation, 1972) was used to collect precipitation data continuously.

Water Quality Sampling

Water quality samples were collected at the gauging station during eight runoff events in the spring and summer of 1979 using an automatic sampler (ISCO Type). A conductivity bridge was installed in the stilling well to trigger the ISCO sampler to begin sampling after a one-inch rise (approximately .01 CFS) in flume water level. Samples were collected in 500 ml plastic bottles at half-hour intervals for up to 12 hours (24 samples).

Surface, inflow, and outflow pond water samples were collected at about two week intervals from the period of March to November, 1979.

Grab samples of runoff water (one per event) were collected at predetermined discharge points from five (5) differently managed segments of the watershed and at the flume as a watershed composite during four run-off events to compare water quality (see Figure 2). Samples were collected in one liter plastic bottles by pointing the bottle lengthwise upstream approximately 2 inches into the deepest area of running water. Care was taken not to disturb sediment while collecting the sample.

Row crop samples were collected in a bottom area where runoff collected from a relatively large (approximately 10 acres) cornfield on the upper unmanaged (in terms of soil conservation practices) portion of the watershed (Site A, Figure 2). Driveway diversion samples were collected at the discharge point of a grassed diversion leading from the driveway of the lower farming operation (Site B, Figure 2). Barnyard samples were collected from a diversion extending approximately 100 feet downhill from the barnyard (Site C, Figure 2). Past attempts at seeding the diversion have proven unsuccessful (Zuelke, 1979). Alfalfa diversion samples were collected at the discharge point of a grassed diversion draining a 3.3 acre alfalfa field (Site D, Figure 2). Row crop diversion samples were collected at the discharge point of a grassed diversion draining about a 1.1 acre corn field (Site E, Figure 2). Flume samples were collected at the outflow of the gauging station to provide a composite sample for the event to compare with samples collected from managed segments (Site F, Figure 2).

Snow Sampling

A composite snow sample was systematically collected on February 12, 1979 using a "Mount Rose" aluminum snow sampling device (Marano, 1979). Transects were laid out in a 75 yard grid covering the watershed to determine sampling points. A snow sample was collected at each point transects crossed. One sampler length of the snow column was collected and measured from each of 70 sampling points. After measurement, the sample was composited in a large plastic bag. The composite snow sample was melted, transferred to sample bottles and analyzed in the laboratory.

Seven separate snow grab samples were collected by compositing several lengths of the snow sampler from each of the following areas:

- clean area behind barn,
- piled snow from driveway,
- manured field,
- fall plowed field,
- fall grassed areas,
- field manured and turned in fall, and
- barnyard area.

Pond Sediment Sampling

Pond sediment samples were systematically collected on January 16, 1980. Transects were laid out in a 60 foot square grid on the pond ice surface. Thirty-five (35) six-inch holes were drilled through the ice with a power ice auger. A sediment sample was obtained at each location using a 3.4 cm diameter PVC coring device. The length of deposited sediment was measured in each core. The color of the deposited sediment was noted to be black, while the natural soil was brown, making measurement and separation of deposited sediment easy. The separated sediment was composited as a single sample in a stainless steel bucket.

Laboratory

Runoff, pond, snow, and sediment samples collected were transported as soon as possible (the same day for most) to the Environmental Task Force Laboratory at the University of Wisconsin at Stevens Point, Wisconsin for chemical and physical characterization. Authoritative sources for laboratory methods were used to analyze water and sediment samples (Table 1).

All water samples were analyzed for:

- pH,
- specific conductance,
- total suspended solids (TSS),
- orthophosphate (PO_4-P),

Table 1: Analytical methods used for physical and chemical characterization of runoff, pond, snow, and sediment samples.

Water[1]	Procedure	Method Reference
Temperature	Thermometric	212
pH	Specific Ion Electrode	424
Specific Conductance	Wheatstone Bridge	205
Total Alkalinity	Titrimetric	403
Total Hardness	Titrimetric	309B
Biochemical Oxygen Demand (BOD_5)	Oxidation, Titrimetric	508
Chloride	Specific Ion Electrode	Orion
Orthophosphate	Colorimetric	425A,E
Total Phosphorus	Digestion, Colorimetric	425C,E
Ammonia Nitrogen	Distillation, Titrimetric	418A,D
Nitrate-nitrite Nitrogen	Cadmium Reduction, Autoanalyzer	419C
Total Kjeldahl Nitrogen	Digestion, Autoanalyzer	421
Total Suspended Solids	Gravimetric	208D

1. Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1976.

Table 1 (Continued): Analytical methods used for physical and chemical characterization of runoff, pond, snow and sediment samples.

Sediment[2]	Procedure	Page
Percent Moisture	Gravimetric	--
Percent Organic Matter	Volatilization, Gravimetric	1397
Total Phosphorus	Digestion, Colorimetric	1036
Total Kjeldahl Nitrogen	Digestion, Titrimetric	1171
Ammonia Nitrogen	Distillation, Titrimetric	1191
Nitrate-nitrite Nitrogen	Distillation, Titrimetric	1191

2. Black, C.A., et al, Methods of Soil Analysis, Part II, 1965.

- total phosphorus (TP),
- ammonia nitrogen (NH_4-N),
- nitrate-nitrite nitrogen (NO_3-N); and,
- total Kjeldahl nitrogen (TKN).

In addition to the above, pond water samples and grab runoff samples were also analyzed for:

- total alkalinity (alk),
- total hardness (hard),
- 5-day biochemical oxygen demand (BOD_5); and,
- chloride (Cl).

Five (5) subsamples of the composited pond sediment sample were analyzed for percent moisture, percent organic matter, TP, NH_4-N, NO_3-N, and TKN. The concentrations of TP and TKN were determined on twenty (20) replicate subsamples of the composite sample. All analyses of pond sediments were performed on a wet-weight basis and corrected to dry-weight concentrations after percent moisture determination.

Standard Good Laboratory Practices (GLP) were adhered to during analysis of the samples. Quality control consisted of the following items at a minimum:

- 5-point calibration curves, where applicable,
- one out of ten samples duplicated,
- one out of 20 samples spiked; and,
- a reagent blank every analytical run.

Computer

NPS Model

The non-point source pollutant (NPS) model developed by Hydrocomp Inc. (Donigian and Crawford, 1976) under a research grant from the United States Environmental Protection Agency was chosen to be used for this project for the following reasons:

- it was a state-of-the-art model developed in 1976,
- it had been extensively applied,

- it could continuously simulate hydrologic processes including snow accumulation and melt, and
- it could continuously simulate non-point pollutant processes of accumulation, generation, and transport from the land surface.

Initially, the project plan included simulating sediment and nutrient pollutant processes with the model. After several calibration runs, it was determined the model would not be acceptable to simulate the non-point pollutant processes occurring on this watershed and would only be used to simulate hydrologic processes. As a substitution, average sediment and nutrient concentrations were to be calculated from observed runoff data.

Input Data

The basic input meterological data set required for operation of the NPS model are:

- hourly precipitation,
- daily potential evapotranspiration (ET),
- daily maximum and minimum air temperature,
- daily solar radiation, and
- daily wind movement.

Daily precipitation totals for the watershed were obtained from the study area land owner who had daily records for the whole 14-year simulation period (Zuelke, 1979). Daily totals were transformed to hourly input data by comparison with hourly data from the Marshfield, Wisconsin weather station only nine miles away (National Climatic Center Publications, 1966-1978). On most days similar precipitation totals were noted. Marshfield storm duration data was used and then weighted to the watershed precipitation total. When totals differed significantly, a Marshfield storm from the same time of the year with a similar total precipitation was used and weighted to the actual watershed total. Precipitation data for the calibration period was continuously collected on-site with a tipping bucket rain gauge. Daily maximum and minimum air temperature and potential evapotranspiration were also obtained from records kept at the Marshfield weather station. Daily solar radiation totals were obtained from the National Climatic Center in Ashville, North Carolina (Hybrow, R.A. 1978). These data were collected in Madison, Wisconsin. Daily wind movement was obtained from National Climatic Center Publications for the Green Bay, Wisconsin weather station.

Input parameters required for operation of NPS include parameters related to model control, topography, soil characteristics, land surface conditions, hydrologic characteristics, and land use. The NPS user's manual

(Donigian and Crawford, 1976) describes each parameter individually and presents methods for evaluation, references, and other specific data sources.

Calibration

The NPS model was calibrated for a 15-month period from October 1, 1978 to December 31, 1979. The calibration process involves the adjustment of input parameters to improve agreement between recorded and simulated information. The general calibration procedure used for this study included the following steps:

1. Estimate initial input parameters,
2. Perform hydrologic calibration run,
3. Compare simulated monthly and annual runoff volumes with recorded data,
4. Adjust input parameters to improve agreement between simulated monthly and annual runoff volumes and observed values,
5. Repeat steps 2, 3, and 4 until satisfactory agreement is obtained,
6. Compare simulated runoff with recorded data for selected storms,
7. Adjust hydrologic calibration parameters to improve storm hydrograph simulation,
8. Perform additional calibration runs and repeat step 7 until satisfactory storm hydrograph

simulation is obtained while maintaining agreement in monthly and annual totals, and

9. Perform production run (simulation).

Twenty-one (21) computer calibration runs were performed before satisfactory agreement of observed and simulated data was obtained. Seventeen (17) calibration runs were performed to improve monthly and annual runoff volume agreement, and four (4) calibration runs were performed to improve storm hydrograph agreement.

Input Parameters

Three major catagories of input parameters are required for operation of the NPS model including:

- simulation control,
- hydrology, and
- snow accumulation and melt.

Simulation Control

The simulation control parameters specify the type of run (calibration or production), the type of measurement units (English or metric), specific run options, and the beginning and ending date of the simulation (Table 2). These input parameters remained constant from calibration run to calibration run until the type of simulation run desired changed from calibration to production.

Table 2: Simulation control input parameters for NPS model.

Input Parameter	Value Used	Description
HYCAL	1	Type of simulation run desired: (1) hydrologic calibration (HYCAL=1) (2) sediments and quality calibration (HYCAL=2) (3) production run--printer output only (HYCAL=3) (4) production run--printer and unit 4 output (HYCAL=4)
HYMIN	.04	Minimum flow for output during a time interval
NLAND	--	Number of land type uses within watershed (up to five)
NQUAL	--	Number of optional quality constituents simulated (up to five)
SNOW	1	Controls snowmelt simulation: (1) snowmelt performed (SNOW=1) (2) snowmelt not performed (SNOW=0)
UNIT	1	Specifies units of input and output: (1) English units (UNIT= -1) (2) metric units (UNIT=1)
PINT	1	Specifies type of input precipitation data: (1) 15-minute intervals (PINT=0) (2) hourly intervals (PINT=1)
MNVAR	--	Specifies type of input quality data: (1) mean monthly accumulation and removal data (MNVAR=1) (2) mean annual accumulation and removal rates (MNVAR=0)
BGNDAY BGNMON BGNYR	Oct. 1, 1978	Date simulation begins: day, month, year
ENDDAY ENDMON ENDYR	Dec. 31, 1979	Date simulation ends: day, month, year

Hydrology

The hydrology and snow input parameters provide the physical characteristics of the watershed that combine with observed meterological data to produce the simulated hydrologic response. Approximately one-half of the hydrology input parameters (Table 3) used in the calibration process remained unchanged throughout. Most were related to measureable physical characteristics of the watershed. These are indicated by an asterisk (Table 3). Many of these parameters were chosen on the basis of information obtained by the field survey of the study area.

Hydrology input parameters not asterisked were manipulated during the calibration process to improve agreement between observed and simulated results. The hydrologic calibration process was most affected by three input parameters:

- UZSN - nominal upper zone moisture storage,
- LZSN - nominal lower zone moisture storage, and
- INFIL - mean percolation rate.

Initial calibration values of UZSN (.40), LZSN (5.0), INFIL (.30) were chosen based on information provided in the NPS user's manual (Donigian and Crawford, 1976). Fifteen (15) attempts at manipulation of these parameters proved unsuccessful. Transfer of moisture from upper zone

Table 3: Hydrologic control input parameters for NPS model.

Input Parameter	Value Used	Description
UZSN	2.8	Nominal upper zone storage (inches)
LZSN	8.0	Nominal lower zone storage (inches)
INFIL	.06	Mean percolation rate (inches/hour)
INTER	.55	Interflow parameter, alters runoff timing
IRC	.05	Interflow recession rate
AREA	68.2 *	Watershed area (acres)
NN	.20 *	Manning's "n" for overland flow on pervious areas
SS	.03 *	Average slope of overland flow on pervious areas
L	1500 *	Length of overland pervious flow to channel (feet)
NNI	.13 *	Manning's "n" for overland flow on impervious areas
SSI	.07 *	Average slope of overland flow on impervious areas (ft/100 ft)
LI	420 *	Length of overland impervious flow to channel (feet)
K1	1.0 *	Ratio of spatial average rainfall to gauge rainfall
PETMUL	1.187*	Potential evapotranspiration data correction factors
K3	1.0 *	Index to actual evapotranspiration
EXPM	.10 *	Maximum interception storage
K24L	.95 *	Fraction of groundwater recharge percolating to deep groundwater
KK24	.001*	Ground recession rate
UZS	2.7	Initial upper zone storage (inches)
LZS	6.6	Initial lower zone storage (inches)
SGW	0.0 *	Initial groundwater storage (inches)

storage to lower zone storage and then on to deep groundwater storage was occurring too quickly. The model could not accurately simulate this watershed which had been under heavy agricultural use for over 30 years. Natural soil moisture movement processes had been greatly altered because of the development of a plowpan layer in an already tight soil (Pflug, D. and R. Schmidt, 1977). The NPS user's manual had hinted that agricultural watersheds may deviate significantly from normal soil moisture processes.

The problem of moisture transfer was corrected by changing an algorithm in the upper zone depletion section of the model. The constant in the algorithm presented below was changed from 0.1 to 0.001.

PERCB = 0.1* INFIL* UZSN* (DEEPL**3)

to PERCB = 0.001* INFIL* UZSN* (DEEPL**3)

where:

PERCB = upper zone depletion

INFIL = percolation rate

UZSN = upper zone storage

DEEPL = difference in upper and lower zone ratios

The change in the algorithm reduced transfer of moisture from upper to lower zone and ultimately deep groundwater storage.

Now, minor adjustments in UZSN, LZSN, and INTER over the next four (4) calibration runs provided satisfactory agreement between observed and simulated monthly and annual runoff totals to proceed with adjustment of hydrograph shape. Beginning upper (UZSN, 2.7) and lower zone (LZN, 6.6) storage values were also chosen at this time based on final values of UZSN and LZSN and the estimated moisture condition of the soil at the beginning (October 1, 1978) of the calibration process.

Hydrograph shape was altered through the use of the INTER and IRC input parameters. INTER is the interflow component that alters runoff timing, while IRC is the interflow parameter that alters the recession rate. The NPS manual suggests values of .5 to 5 for INTER with 2 to 3 (2.5 chosen) suggested for the Wisconsin area. A final value of .55 was needed for INTER. Lowering the value from 2.5 to .55 increased peak flows during the rising limb of the hydrograph and lowered flows during the falling limb. This process is illustrated in Figure 4 where a hypothetical hydrograph and how it changes with three (3) different INTER values is shown.

The IRC parameter should have been close to zero for a small watershed without base flow. The final value chosen of 0.05 is somewhat higher than expected because of the effect of the plowpan layer, which enhances the interflow process. The change made in the model reducing transfer of moisture from upper zone storage to lower zone storage increases interflow when the upper zone storage is at or near field moisture capacity.

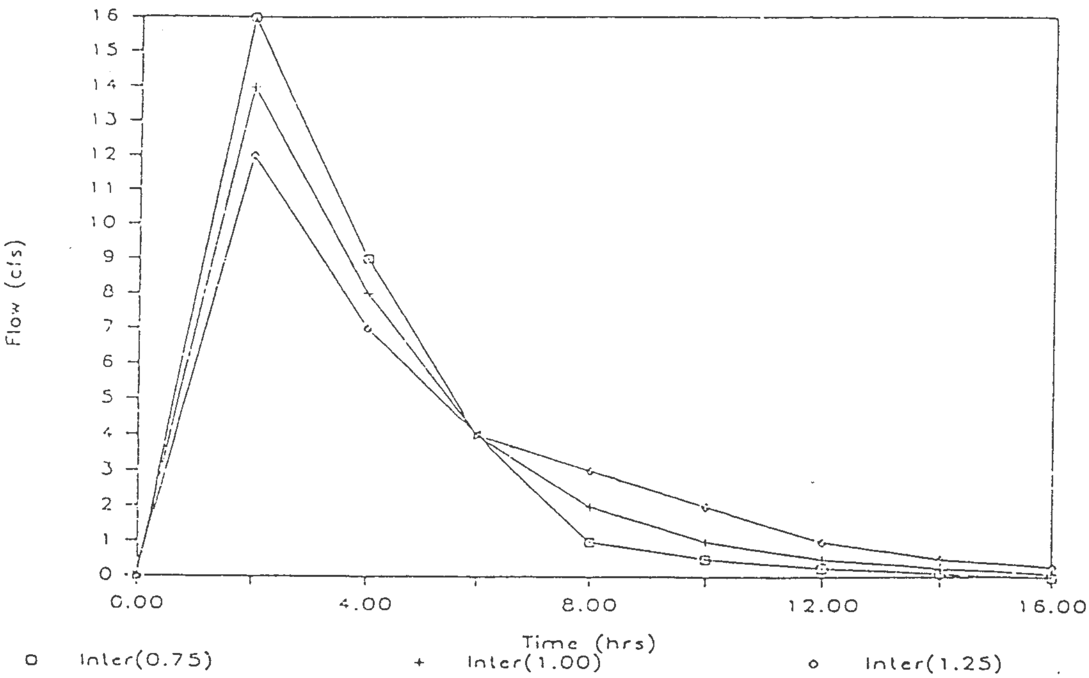


Figure 4: Example of the effect of changing the Inter Parameter on hydrograph shape.

Snow Accumulation and Melt

The calibration process for accumulation and snow melt was limited to the spring of 1979, the only period for which observed data were collected. A project was going on concurrently where snow relationships were being successfully modeled on the Big Eau Pleine watershed (Marano, 1979). All values for snow input parameters were initially chosen on the basis of Marano's research. Table 4 lists the input parameters with values used. Two input values were altered during the calibration process, RADCON and F. RADCON is the correction factor for radiation melt which is sensitive to watershed slopes and exposure, and F is the fraction of the watershed with complete forest growth. The study area had only a small stand of white spruce less than one-half acre in size, thus F was reduced from .5 to 0.005 for the initial calibration run.

After several calibration runs, it was apparent snow melt was occurring too rapidly. A small change in the RADCON parameter from .64 to .90 reducing melt from solar radiation was successful in slowing down the melt. The changes made for F and RADCON were related. A reduction in the watershed area that was forested through the use of the F parameter increased the watershed's susceptibility to radiation melt requiring the change in RADCON.

Table 4: Snow accumulation and melt input parameters for NPS model.

Input Parameter	Value Used	Description
RADCON	.90	Correction factor for radiation melt
CCFAC	1.0	Correction factor for condensation and convection melt
EVAPSN	.69	Correction factor for snow evaporation
MELEV	1200	Mean elevation of watershed (feet above sea level)
ELDIF	0.0	Elevation difference from temperature station to mean watershed elevation (feet)
TSNOW	33.5	Temperature below which precipitation occurs as snow (degrees F)
MPACK	1.0	Water equivalent of snowpack for complete watershed coverage
DGM	0.00	Daily groundmelt
WC	.05	Water content of snowpack by height
IDNS	.10	Initial density of new snow
SCF	1.1	Snow correction factor for raingauge catch deficiency
WMUL	1.0	Wind data correction factor
RMUL	.99	Radiation data correction factor
F	.005	Fraction of watershed with complete forest cover
KUGI	3.0	Index to forest density and undergrowth
PACK	1.0	Initial water equivalent of snowpack
DEPTH	0.0	Initial depth of snowpack (inches)

RESULTS AND DISCUSSION

This study is one of several non-point pollution studies performed on the Big Eau Pleine watershed as a result of a research grant from the United States Environmental Protection Agency. The results and discussion that follow present and compare data from the study area and from closely related studies performed on the Big Eau Pleine watershed as a result of the research grant.

Summary of Observed Results

Hydrologic Data

Continuous flow and precipitation data were to be collected from spring breakup to the last runoff event of the calendar year 1979. Generally, this collection was accomplished from March 15, 1979 to November 20, 1979. Flow data were obtained for 19 runoff events. Flow data gaps occurred during several periods including:

- May 24-May 31 - when the water level recorder ran out of chart paper.
- June 16-July 8 - when a 100-year storm washed out a portion of the gauging station.
- October 1-October 15 - when the pipe hydraulically connecting the flume and the stilling well became clogged with sediment.

A precipitation gap occurred during one period (October 21 - October 28). Daily rainfall totals for this period were obtained from the landowner (Zuelke, 1979).

Runoff Sampling

Sets of ISCO runoff samples were collected during 7 of the 19 runoff events. One additional set of ISCO runoff samples was collected on May 31, a flow data gap period. Flow and water quality data have been summarized in Tables 27 to 46 in Appendix A. The tables present observed and simulated flow data and corresponding observed sediment and nutrient concentrations (where available) for the nineteen (19) runoff events. Flow data will be discussed in depth later in this text when comparing observed and simulated results.

Figures 4 to 6 present observed flow and concentrations of TSS, TP, and TKN over time for three selected runoff events (May 1-3, June 9-10, and July 13th). Although the concentrations of TSS, TP, and TKN generally follow the shape of the selected hydrograph, with greatest concentrations occurring during greatest flow periods, no apparent statistical relationship is evident between storms. Kaminski (1977) found that the relationship between sediment yield and phosphorus forms for the Big Eau Pleine River watershed was highly inconsistent. Zanoni (1970) showed statistically that phosphate concentration could not be correlated with precipitation amount.

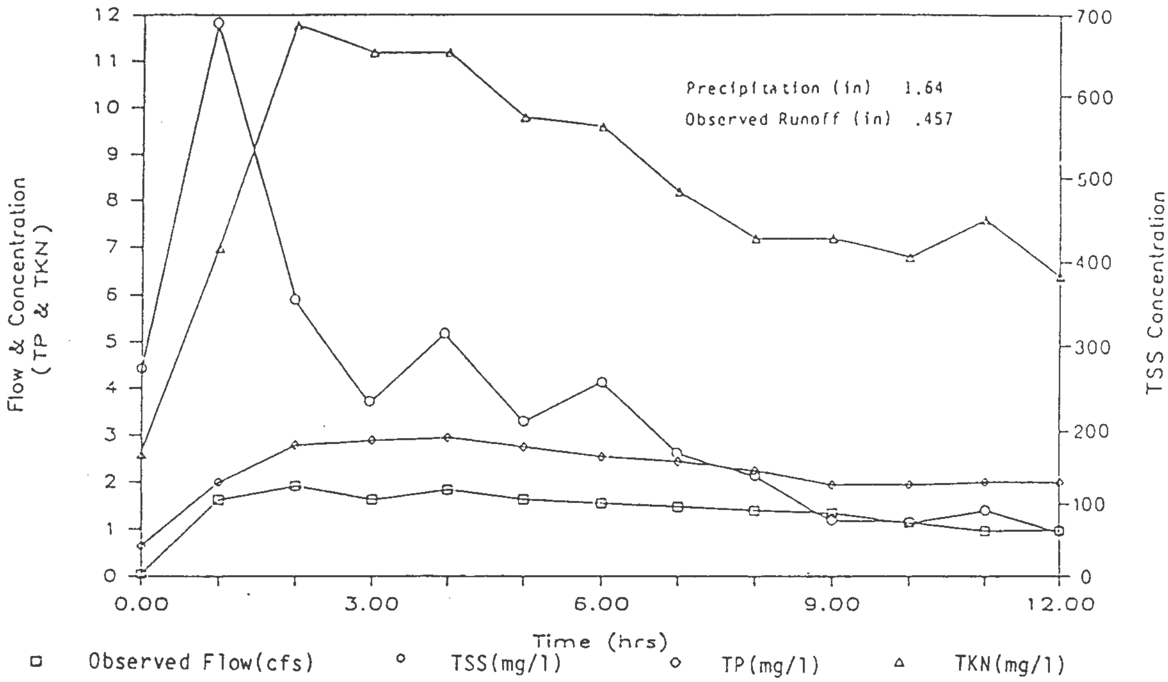


Figure 5: Observed flow from the study area watershed and concentrations of TSS, TP and TKN in runoff collected May 1, 1979.

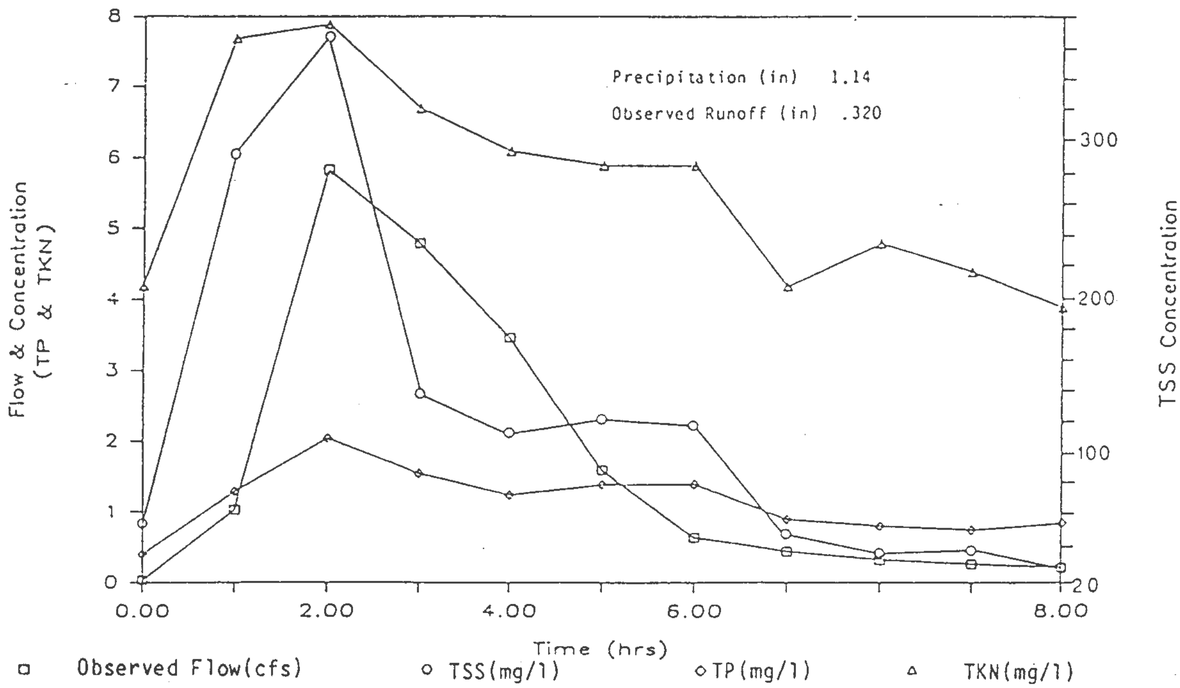


Figure 6: Observed flow from the study area watershed and concentrations of TSS, TP and TKN in runoff collected June 9, 1979.

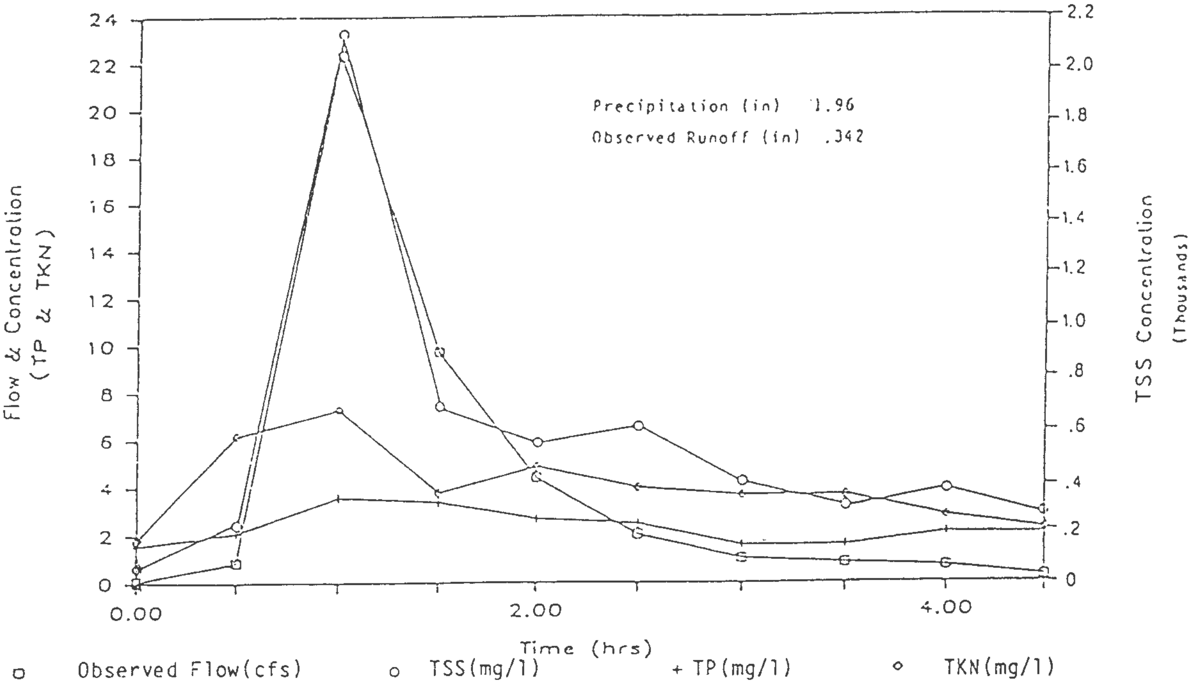


Figure 7: Observed flow from the study area watershed and concentrations of TSS, TP and TKN in runoff collected July 13, 1979.

Variability between storms in sediment and nutrient concentrations is expected for the study area and is generally related to the farming practices and rainfall intensity and duration on a storm basis.

Observed high concentrations of sediment and nutrients in runoff are presented in Table 5. The high value for TSS occurred after an intense thunderstorm which deposited 1.96 inches of rain in a one hour period. High TSS values are expected when energy from an intense storm increases soil detachment and transport processes (Donigian and Crawford, 1976). The high values for TP, TKN and NH_4-N occurred two days after the upper portion of the watershed had manure applied to it. Elbert (1977) also found high concentrations of nitrogen and phosphorus in runoff from Hamann and Noisy Creeks (Figure 1) to be related to spreading of manure. The high nitrate value may be related to fertilizing of crops with ammonium nitrate which is often incorporated in soil during the months of May and June. No particular significance is given for the greatest PO_4-P concentration.

Table 5: Observed high concentrations of total suspended solids and nutrients in runoff.

Parameter	Date	Concentration (mg/l)
TSS	July 13, 1979	2144
PO_4-P	August 26, 1979	2.2
TP	May 19, 1979	4.0
TKN	May 19, 1979	15.2
NH_4-N	May 19, 1979	3.4
NO_3-N	June 9, 1979	4.4

Snow Sampling

Snow sampling was performed on February 12, 1979. Snow characteristics were found to be:

- depth - 19.7 inches,
- density - .168, and
- snowpack equivalent - 3.31 inches of water.

NPS simulated values for February 12 compared reasonably well with:

- depth - 16.2 inches,
- density - .198, and
- snowpack equivalent - 3.2 inches of water.

Water quality results from seven snow samples collected from selected areas and one composite sample from 70 systematically collected subsamples are presented in Table 6. The expected contrast in concentrations of phosphorus and nitrogen for manure on snow, barnyard and driveway samples versus all other snow samples is noted. The results from the composite sample indicate that manuring of snow covered fields had increased the average concentrations of TSS, TP and TKN as compared to undisturbed snow (average of four non-manured areas) from 4, .15, and 2.2 mg/l to 11, .30, and 2.9 mg/l, respectively. The manure on snow field contained over 100 times the concentration of TSS, TP and TKN as compared to a non-manured field. Klausner (1976) found nutrient concentrations in runoff increased dramatically when manure was applied to snow field plots, but no increase when manure was applied to an early snowfall and later covered by new snow. From these data it is easy to see why winter spreading of manure is considered a problem source of nitrogen and phosphorus in spring runoff.

Table 6: Water quality results for snow samples collected February 12, 1979.

Sample of Location	pH	Cond	Concentration (mg/l) TSS	PO_4-P	TP	TKN	NH_4-N	NO_3-N	Approximate Acres/Area
Clean area behind barn	6.72	26	4	.09	.16	2.2	.94	.50	.2
Snow from driveway	7.23	118	20	1.45	1.90	12.5	2.60	.42	.8
Manured on snow	7.62	590	240	6.12	9.30	50.8	9.5	.04	1.1
Fall-plowed field	7.28	23	4	.11	.21	2.1	.62	.50	20.4
Fall-grassed field	6.43	23	2	.05	.14	1.9	1.00	.72	42.6
Manured and turned in fall	6.13	27	6	.03	.10	2.6	1.20	.92	2.8
Barnyard	7.52	420	180	2.10	2.90	18.4	3.40	1.50	.3
Watershed composite	7.12	80	11	.18	.30	2.9	1.02	.62	68.2

Pond Water Sampling

Water quality results for 13 surface water samples and ten pond outflow samples are presented in Tables 7 and 8, respectively. Surface water samples were collected four times indicated by an asterisk when no outflow was occurring. One outflow sample indicated by a double asterisk was collected without a surface water sample.

Table 7: Water quality results for pond surface samples.

			Pond Surface Concentration (mg/l)									
Date	pH	Cond	TSS	PO_4-P	TP	TKN	NH_4-N	NO_3-N	Alk	Hard	Cl	BOD_5
1/26/79*	7.05	275	7	.15	.28	2.34	-	<.02	82	91	31	4.9
3/10/79*	6.51	320	5	.13	.18	2.40	1.04	<.05	76	98	-	5.6
5/22/79	9.39	230	16	.08	.60	3.68	.17	<.05	58	70	38	16.0
6/4/79	9.22	230	12	.15	.47	3.20	.02	<.05	52	76	35	9.3
6/18/79	7.00	185	46	.22	.66	2.40	.42	.55	44	56	41	3.0
7/2/79	9.43	195	9	.15	.29	1.96	.05	<.05	34	64	30	8.0
7/17/79	9.83	205	12	.09	-	-	.08	<.05	50	62	28	11.9
7/30/79	8.30	198	1	.05	.21	2.14	.17	<.02	50	60	23	4.0
8/13/79	7.62	185	5	.02	.12	1.84	.08	.04	50	74	27	4.1
8/27/79	7.71	186	11	.04	.10	1.36	.22	.06	52	60	22	3.0
9/10/79*	8.09	190	3	.04	.10	1.64	.14	<.02	53	64	30	3.4
10/8/79*	7.43	201	4	.05	.12	1.40	.28	.16	54	62	22	2.0
10/29/79	7.33	200	5	.17	.23	1.56	.18	.78	46	62	28	1.4

* No outflow sample.

Table 8: Water quality results for pond outflow samples.

			Concentration (mg/l)									
Date	pH	Cond	TSS	PO_4-P	TP	TKN	NH_4-N	NO_3-N	Alk	Hard	Cl	BOD_5
3/30/79**	6.71	208	4	.47	.49	2.1	1.58	2.05	43	52	23	3.8
5/22/79	9.22	225	14	.10	.54	3.24	.18	<.05	58	70	35	15.0
6/4/79	8.56	235	10	.21	.50	3.00	.06	<.05	52	74	35	8.4
6/18/79	7.05	190	40	.13	.50	2.36	.40	.50	42	54	39	2.8
7/2/79	8.01	195	4	.25	.32	1.92	.21	.25	30	60	29	2.0
7/17/79	9.52	195	10	.14	-	-	.18	<.05	40	56	29	7.9
7/30/79	7.68	200	11	.18	.46	2.14	.14	<.02	54	60	28	4.4
8/13/79	7.90	190	11	.06	.12	1.68	.12	.04	56	62	28	3.3
8/27/79	8.04	185	10	.03	.12	1.52	.04	.06	50	62	22	3.0
10/29/79	6.80	215	2	.17	.23	1.48	.16	.80	48	64	29	2.0

** No pond sample.

Generally, pond surface and outflow data for the same day are similar. Outflow samples on several occasions are noted to have somewhat elevated concentrations of TSS and TP. Since the outflow is at the surface, increased TSS and TP may be a result of wave action stirring up sediments at the edge of the pond or skimming off of floating algae.

Pond surface and outflow concentrations of TSS and nutrients were low for all samples compared to inflow samples. Figures 8 to 10 represent observed average inflow and outflow concentrations of TSS, TP and TN over time (March - October, 1979). Concentrations of TSS and nutrients in pond water were constantly changing with peaks occurring after runoff events. Dramatic increases in concentrations of TSS, NH_4-N and NO_3-N were noted between the June 4 and June 18 sampling dates due to runoff from a 100-year storm that produced over 3.5 watershed inches of runoff in an 18 hour period.

Available nutrients in pond water contributed to substantial spring and summer diatom, algal and duckweed growth in 1978 and 1979. These have apparently never been excessive or obnoxious (Zuelke, 1979). The pond has been used for summer recreation (fishing and swimming).

Macrophyte growth had increased considerably during the years 1976-1979, especially near the inflow, and may have been a contributing factor to the pond's first fish kill in the winter of 1977-1978 (Zuelke, 1979).

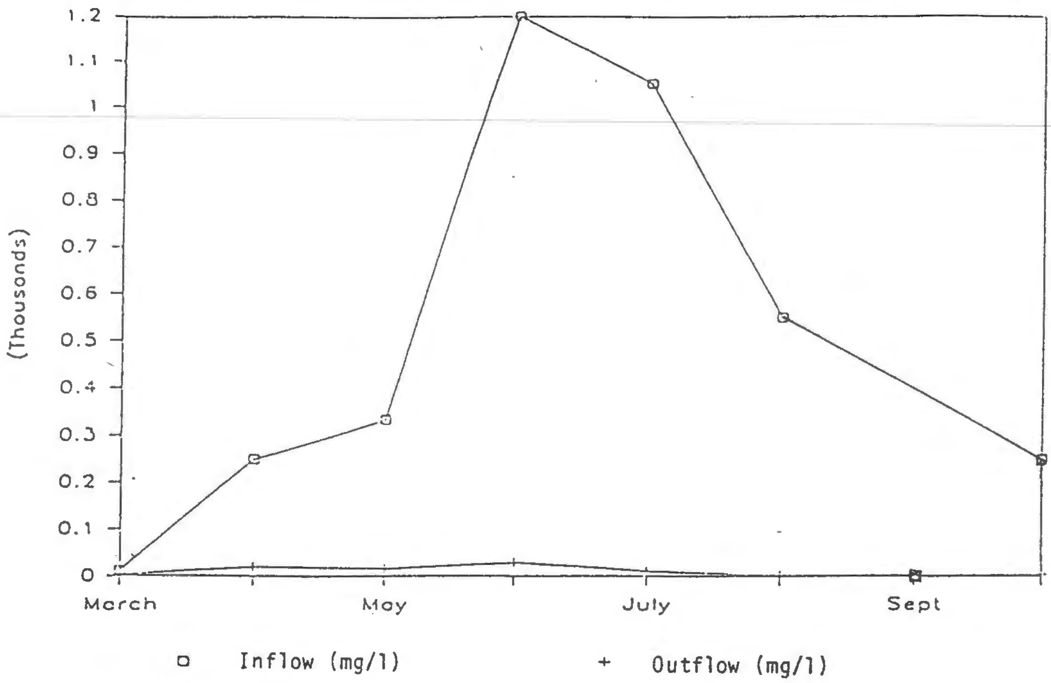


Figure 8: Average monthly concentration of total suspended solids for pond inflow and outflow samples, March-October, 1979.

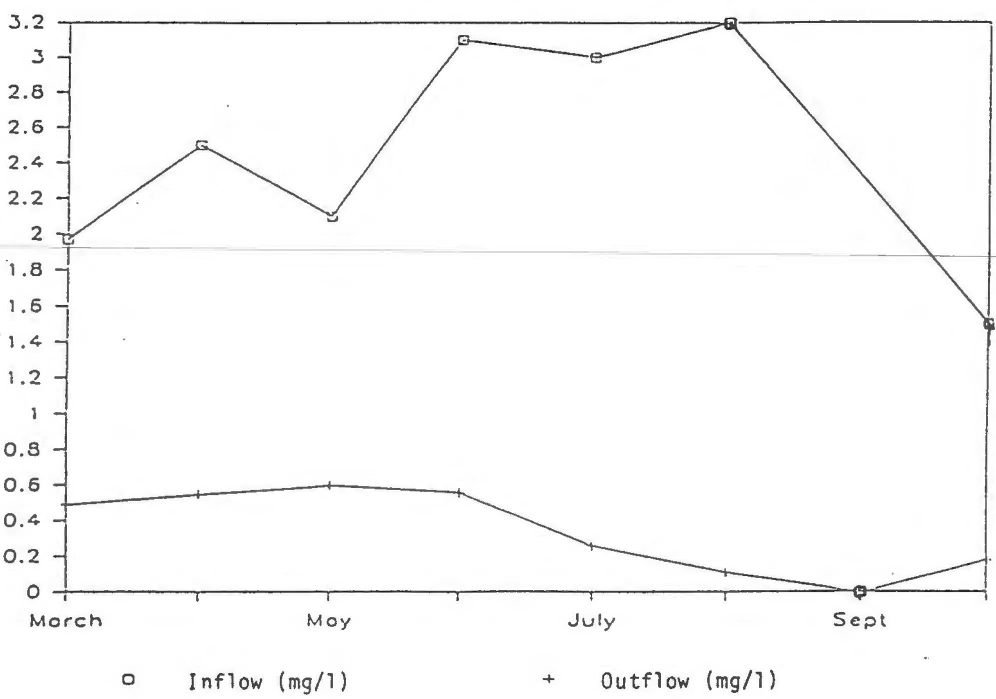


Figure 9: Average monthly concentrations of total phosphorus for pond inflow and outflow samples, March-October, 1979.

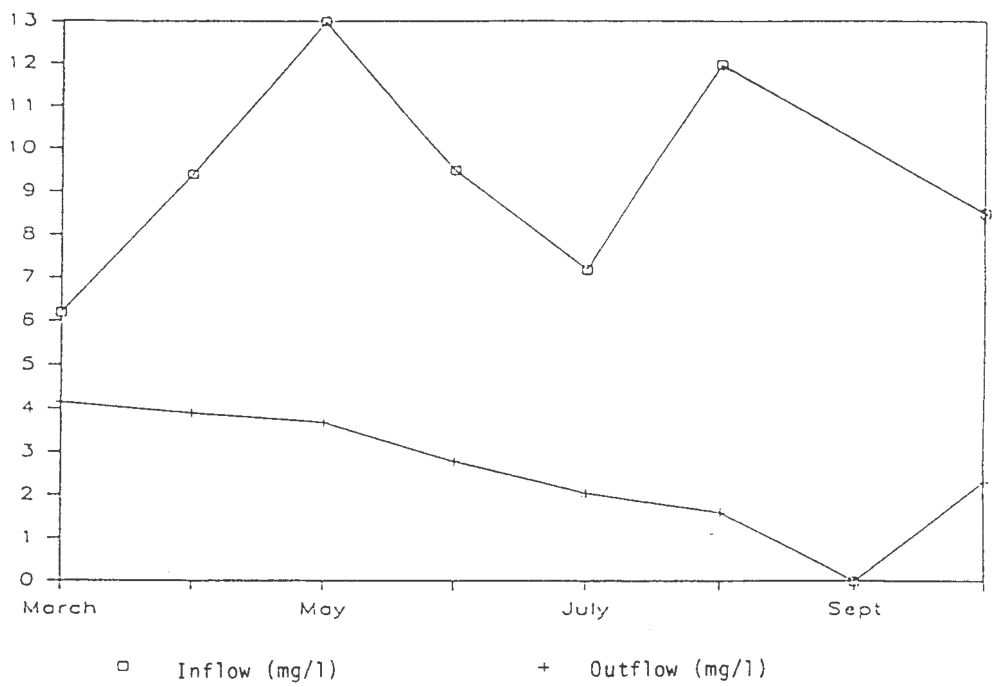


Figure 10: Average monthly concentrations of total nitrogen for pond inflow and outflow samples, March-October, 1979.

One snowmelt outflow sample was collected on March 30, 1979. High concentrations of PO_4-P, TP, NH_4-N and NO_3-N were noted. During the snowmelt season a flowthrough condition exists in the pond area. Runoff is channeled by remaining winter ice around the edges of the pond to the outflow. Much of the early spring runoff flows directly through the pond with very little mixing or retention.

Comparison of Water Quality Results From Managed Segments of the Watershed

Grab samples were collected from five (5) managed segments (see Figure 2) of the watershed and at the flume as a watershed composite sample during four (4) runoff events in 1979 (one sample from each area). Water quality results for the four sampling dates are presented in Tables 9 to 12. A summary of the data including high, low and average concentrations is presented in Table 13.

As expected, barnyard samples consistently had the poorest water quality and the alfalfa diversion samples had the best water quality. Row crop samples were (intended to represent an unmanaged segment) to be compared with row crop diversion samples (a managed segment of the watershed). The unmanaged area was expected to have consistently higher total suspended solids and nutrients. This was true, but the much higher concentrations noted may be more related to late spring manure spreading on the unmanaged area than actual soil conservation practices. Consistently higher conductivity, chloride, alkalinity and hardness in row crop samples reinforce this conclusion. Highfill (1983) reported vegetative diversions would reduce sediment concentrations in runoff from a cultivated field by 60-80%.

Harms, Dornbush and Anderson (1974) reported mean concentrations of TSS, TP, TKN and NO_3-N in runoff for three

Table 9: Water quality results for grab samples from managed segments of the watershed, March 30, 1979.

Managed Segment	pH	Cond	Concentration (mg/l) Alk	Hard	Cl	BOD_5	TSS	PO_4-P	TP	TKN	NH_4-N	NO_3-N
Barnyard	7.57	400	119	72	35	35	30	2.70	3.20	8.80	8.50	3.25
Row Crop Diversion						no sample						
Alfalfa Diversion	7.13	73	16	22	6	3.1	23	.15	.16	1.56	.02	.10
Row Crop						no sample						
Driveway Diversion						no sample						
Flume Composite	7.18	132	28	16	10	10	10	.78	.80	2.4	2.12	.50

Table 10: Water quality results for grab samples from managed segments of the watershed, June 7, 1979.

Managed Segment	pH	Cond	Concentration (mg/l) Alk	Hard	Cl	BOD_5	TSS	PO_4-P	TP	TKN	NH_4-N	NO_3-N
Barnyard	7.87	1030	266	186	135	74	3100	5.90	8.60	76	20	18
Row Crop Diversion	6.81	175	58	66	18	23	99	.58	1.00	4.6	.06	.05
Alfalfa Diversion	7.10	80	34	36	6	8	14	.16	.20	3.4	.06	.05
Row Crop	7.19	400	80	88	66	22	168	2.45	3.12	11.5	1.00	1.25
Driveway Diversion	7.10	220	32	80	22	6	40	.62	3.0	3.4	.22	<.05
Flume Composite	7.08	325	60	96	53	12	18	.75	1.12	6.2	.90	2.20

Table 11: Water quality results for grab samples from managed segments of the watershed, October 22, 1979.

Managed Segment	pH	Cond	Concentration (mg/l) Alk	Hard	Cl	BOD_5	TSS	PO_4-P	TP	TKN	NH_4-N	NO_3-N
Barnyard	7.76	560	222	138	68	74	158	4.00	13.0	22.0	2.80	1.80
Row Crop Diversion	6.94	170	58	54	14	19	33	1.75	1.86	7.2	.48	.35
Alfalfa Diversion	6.94	75	38	32	8	7.0	19	.17	.33	1.72	.08	.02
Row Crop	7.47	410	86	64	58	16	47	3.75	4.90	6.40	.80	1.40
Driveway Diversion	7.10	210	35	84	48	2.8	48	.58	3.22	1.70	.02	.10
Flume Composite	7.30	300	60	84	34	6.5	55	.98	2.68	4.56	1.40	.40

Table 12: Water quality results for grab samples from managed segments of the watershed, November 5, 1979.

Managed Segment	pH	Cond	Concentration (mg/l) Alk	Hard	Cl	BOD_5	TSS	PO_4-P	TP	TKN	NH_4-N	NO_3-N
Barnyard	8.07	800	224	260	93	120	120	6.80	9.20	27.6	5.60	5.20
Row Crop Diversion	7.27	190	60	46	16	20	40	1.68	1.93	7.20	.46	.25
Alfalfa Diversion	7.19	60	16	17	5	14	69	.58	.93	1.52	<.04	.12
Row Crop	7.64	440	89	126	46	24	86	3.45	4.05	7.40	1.60	2.40
Driveway Diversion	7.47	170	47	62	14	4	43	.73	2.20	2.80	.20	1.00
Flume Composite	7.45	230	46	70	52	14	53	1.38	1.82	3.90	.72	1.60

Table 13: Range and mean concentration of water quality results for grab samples from managed segments of the watershed.

Parameter	Barnyard	Row Crop Diversion	Alfalfa Diversion	Row Crop	Driveway Diversion	Flume Composite
pH /Mean	7.57-8.07 /7.82	6.81-7.27 /7.01	6.94-7.19 /7.09	7.19-7.64 /7.43	7.10-7.47 /7.22	7.08-7.45 /7.25
Cond /Mean	400-1030 /700	170-190 /180	60-80 /72	400-440 /420	170-220 /200	132-325 /247
Alk /Mean	119-266 /258	58-60 /59	16-38 /25	80-89 /85	32-47 /38	28-60 /48
Hard /Mean	72-260 /164	46-66 /55	17-36 /27	64-126 /93	62-84 /75	16-96 /66
Cl /Mean	35-135 /83	14-18 /16	5-8 /6	46-66 /57	14-48 /28	10-53 /37
BOD_5 /Mean	35-120 /76	19-23 /21	3.1-14 /8.0	16-24 /21	2.8-6.0 /4.3	6.5-14 /11
TSS /Mean	30-3100 /850	33-99 /57	14-69 /31	47-168 /100	40-48 /44	5.3-55 /34
PO_4-P /Mean	2.7-6.8 /4.8	.58-1.75 /1.34	.15-.68 /.26	2.45-3.75 /3.22	.58-.73 /.64	.75-1.38 /.97
TP /Mean	3.2-13 /8.5	1.00-1.93 /1.60	.16-.93 /.40	3.12-4.90 /4.02	2.20-3.20 /2.81	.80-2.68 /1.60
TKN /Mean	8.8-76 /34	4.6-7.2 /6.3	1.52-3.40 /2.05	6.4-11.5 /8.4	1.20-3.40 /2.97	2.4-6.2 /4.26
NH_4-N /Mean	2.8-20 /9.2	.06-.48 /.33	<.04-.08 /.04	.80-1.60 /1.13	.02-.22 /.14	.72-2.12 /1.28
NO_3-N /Mean	1.8-18 /7.1	.05-.35 /.22	.02-.10 /.07	1.25-2.90 /1.68	<.05-1.00 /.37	.40-2.20 /1.18
Acres /Area	.3	1.1	3.3	10.0	.8	68.2

(3) land uses; cultivated, pasture and alfalfa. They found row crop samples to contain average concentrations of TSS, TP, TKN and NO_3-N of 1021, 1.05, 2.6, and 1.5 mg/l, respectively. Pasture and alfalfa samples had much lower concentrations of TSS (38 and 40 mg/l), of TP (0.49 and 0.35 mg/l), of TKN (1.7 and 0.8 mg/l) and of NO_3-N (0.4 and 0.3 mg/l).

Comparison of Observed and Simulated Results

Seasonal and Yearly Runoff Totals

Seasonal and yearly simulated totals for the study area were within 20% of observed totals. Total observed and simulated runoff in watershed inches for eighteen (June 16 storm has been eliminated from total of nineteen) comparison storms in 1979 were 6.06 and 6.41, respectively. These included observed and simulated seasonal runoff totals of 3.42 and 3.92 inches for snowmelt, of 1.41 and 1.33 inches for spring, of .52 and .62 inches for summer, and of .72 and .58 inches for fall, respectively.

Seasonal and yearly runoff totals for the fourteen (14) year simulation period presented in Table 14 can be compared to seasonal and yearly runoff totals for the Big Eau Pleine River Watershed presented in Table 15. The Big Eau Pleine data was collected at a U.S.G.S. gauging station at Stratford, Wisconsin, less than one (1) mile from the study area.

Table 14: Simulated seasonal and yearly overland flow totals in watershed inches for the study area watershed for the 14 year period.

	Watershed Inches				
Year	Snowmelt[1]	Spring[2]	Summer[3]	Fall[4]	Year
1966		.137	.060	.032	.229
1967	.675	1.300	.428	.079	2.482
1968	.234	4.428	1.580	.322	6.564
1969	3.618	3.497	.530	.132	7.777
1970	1.334	3.646	.193	.416	5.589
1971	6.487	.930	.420	.391	8.228
1972	4.153	1.288	1.529	1.112	8.082
1973	7.470	5.870	.092	.048	13.480
1974	.161	.563	.060	.034	.818
1975	.072	1.371	.083	.057	1.583
1976	2.405	1.091	.043	.001	3.540
1977	.098	.060	.039	.046	.242
1978	.131	.281	1.462	.089	1.963
1979	3.683	11.134	1.677	1.238	17.732
Total	30.521	39.596	8.196	3.996	78.309
Average	2.348	2.828	.585	.285	6.046
Percent	38.8	46.8	9.7	4.7	100.0

1. January, February and March
2. April, May and June
3. July, August and September
4. October, November and December

Table 15: Observed seasonal and yearly overland flow totals in watershed inches for the Big Eau Pleine River at Stratford, Wisconsin for the 14 year period.

	Watershed Inches				
Year	Snowmelt[1]	Spring[2]	Summer[3]	Fall[4]	Year
1966		3.47	.32	.41	4.20
1967	4.98	6.11	1.00	.22	12.31
1968	1.14	9.44	3.42	.84	14.84
1969	1.69	8.52	.40	.27	10.88
1970	.74	6.24	.51	2.58	10.07
1971	.61	7.63	.42	1.64	10.30
1972	.98	7.58	2.86	2.90	14.32
1973	5.96	9.32	.18	.23	15.69
1974	1.37	4.91	.10	.18	6.56
1975	.41	5.60	.83	1.97	8.81
1976	6.48	3.23	.07	.07	9.85
1977	.86	.89	1.06	2.06	4.87
1978	1.53	4.35	7.16	.86	13.90
1979	4.21	7.69	.38	2.99	15.27
Total	30.96	84.98	18.71	17.22	151.87
Average	2.38	6.07	1.34	1.23	11.02
Percent	21.6	55.1	12.2	11.1	100.0

1. January, February and March
2. April, May and June
3. July, August and September
4. October, November and December

Average yearly runoff totals for the study area and runoff plus baseflow totals for the Big Eau Pleine watershed were 5.76 and 11.02 inches, respectively. The difference in the totals is expected for three reasons. First, the Big Eau Pleine River has a relatively large base flow component compared to none for the watershed, especially in the spring where an average of 3.25 inches greater than the study area was observed. Second, because of its soil conservation practices such as diversions and grassed waterways, the study area reduces water runoff volumes (Highfill, 1983). Third, because of its intensive farming practices, the study area probably has a higher average annual evapotranspiration than the average for the Big Eau Pleine watershed.

Linear regression analysis was performed using simulated yearly runoff totals from the study area and observed yearly runoff totals for the Big Eau Pleine River. An r^2 value of .697 (r = .835), a slope of 1.058 and an intercept of -6.01 were found. The fact that the slope of the linear regression is near 1.0 and the intercept is -6.0 support the interpretation of the differences in yearly totals.

Storm Totals and Hydrographs

A summary of storm runoff data for nineteen (19) observed and simulated events for the study area for 1979 is presented in Table 16. Linear regression

Table 16: Observed precipitation and corresponding observed and simulated runoff totals.

Date	Precipitation (Inches)	Runoff (Inches) Observed	Runoff (Inches) Simulated
3/18-24/79	2.81 (ROS)*	3.42	3.92
4/6-7/79	.35	.056	.060
4/20-21/79	.21 (ROS)*	.052	.020
5/1-3/79	1.64	.457	.451
5/10-11/79	.48	.112	.118
5/19-20/79	.81	.232	.165
6/7-8/79	1.25	.183	.175
6/9-10/79	1.14	.320	.339
6/16/79	5.16	1.998	2.641
7/13/86	1.96	.342	.273
8/9/79	1.75	.013	.056
8/13/79	.93	.042	.067
8/19/86	.64	.023	.072
8/22/79	.36	.020	.031
8/26-27/79	.73	.044	.085
8/28/79	.35	.031	.041
10/22-24/79	2.48	.399	.263
10/31-11/1/79	.31	.037	.050
11/5-6/79	1.00	.282	.228

*ROS = Rain on Snow

analyses were performed using observed and simulated runoff totals in watershed inches with and without outliers and produced excellent agreement. Correlation (r^2), slope and intercept with outliers were .994, 1.066 and -.021, respectively. Correlation (r^2), slope and intercept without outliers were .957, .987 and .024, respectively.

Simulated runoff totals greater than .100 watershed inches were within 20% agreement of observed data except for one storm on October 22-23, 1979.

Simulated runoff totals less than .100 watershed inches were within 20% of the observed total for only one of nine events.

Storm hydrograph comparisons for the 19 observed runoff events are presented in Figures 14 to 32 in Appendix B. Observed and simulated hydrographs for the snowmelt event (March 18-24, 1979) compared reasonably well (Figure 11). The actual melt process occurred over seven (7) days for both simulated and observed results. Simulated results were found to contain daily peaks and valleys because of the way the snowmelt algorithms calculate runoff. The algorithms use hourly temperature data created from a single input of maximum and minimum daily temperature by using a sinusoidal curve. This type of snowmelt algorithm produces maximum runoff during an assumed high temperature portion of the day and minimum runoff during an assumed low temperature for the day.

Comparison of observed versus simulated hydrographs for all other runoff events was also generally very good. Initial runoff and peak flow timing were excellent. Simulated hydrographs often had recession tails that extended many hours beyond the observed. However, the extended recession flow for these events did not significantly affect the total runoff for the storm.

Hydrograph comparison was poor for only one storm, October 22-24, 1979. The observed hydrograph (Figure 12) appears to be a result of three short duration, intense rainfall events that occurred over a 48 hour period. The simulated hydrograph appears to be a result of a longer duration, less intense rainfall event that occurred over the same period. The problem seems to be an error in input data. This storm occurred during the time gap when continuous precipitation data was not collected at the study area. Storm totals were available from the land owner (Zuelke, 1979) and were transformed to hourly data based on a weighted comparison to Marshfield precipitation data for the same 48 hour period. The poor comparison to observed data shows the need for accurate input data when modeling.

Snow Accumulation and Melt

Snowmelt runoff processes were simulated using values for NPS input parameters based on Marano's (1979) successful snow modeling research conducted on the Big Eau Pleine

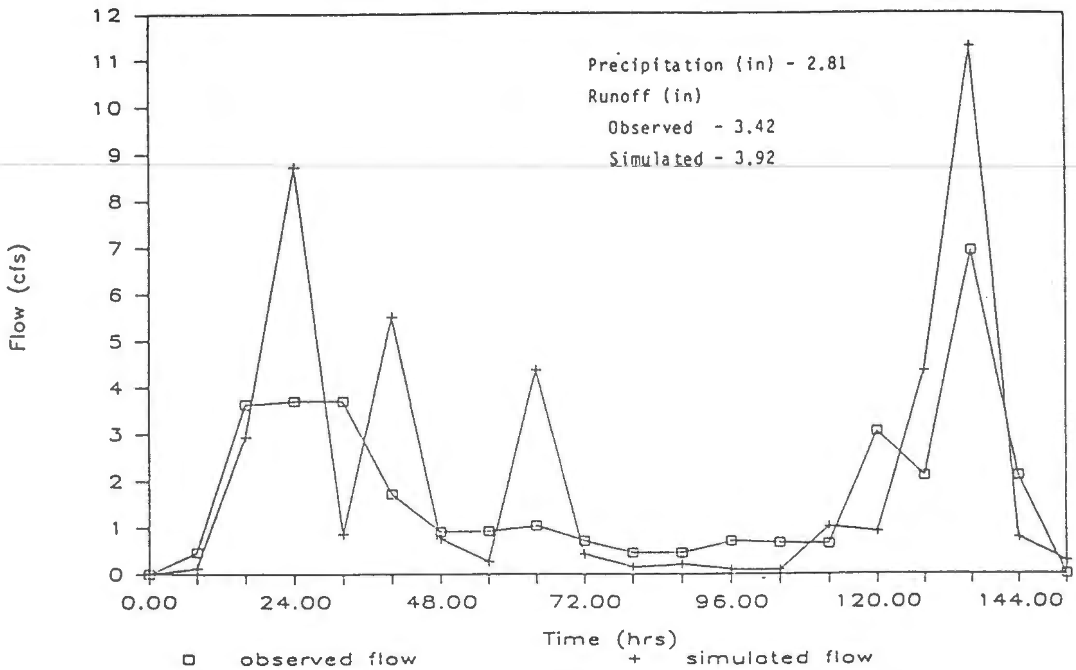


Figure 11: Observed and simulated hydrographs for the snowmelt period, March 18-24, 1979.

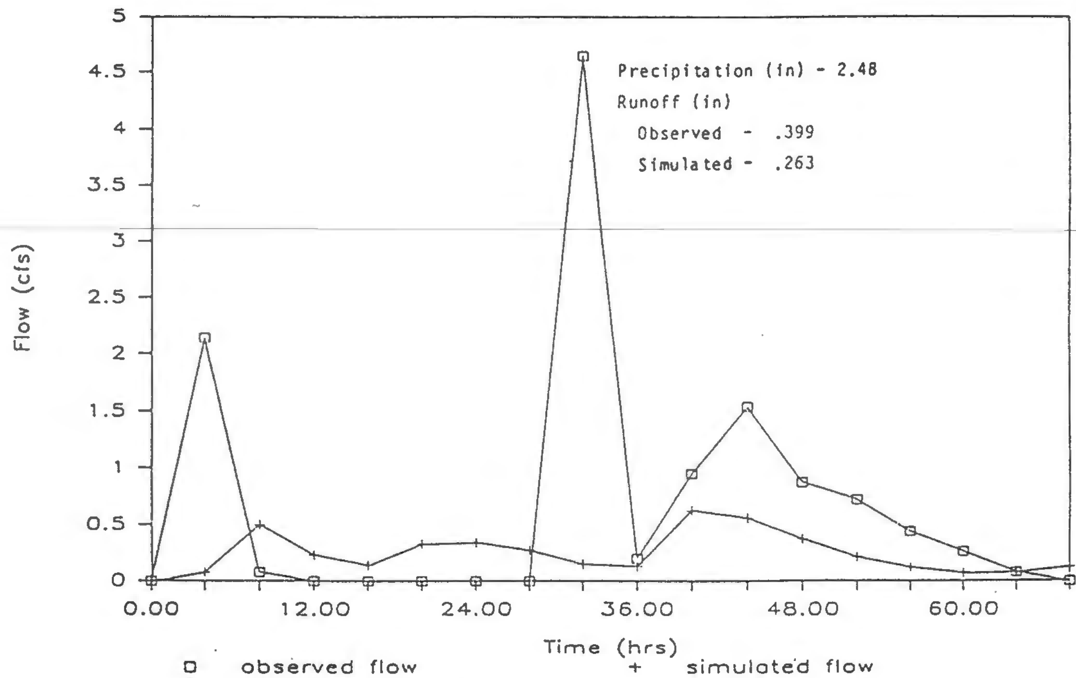


Figure 12: Observed and simulated hydrographs for October 22-24, 1979.

watershed. The snowmelt period for this study is assumed to be January, February and March. The only observed study area data for the snowmelt runoff process was collected in 1979. Snowmelt occurred quickly in 1979, during the seven day period March 18 to March 24. A potential water equivalent snowpack of 4.95 inches combined with 2.81 inches of rain on snow contributed to a total observed runoff of 3.42 inches while NPS simulated 3.92 inches.

Overland flow from snowmelt for eight (8) tributaries to Hamann and Noisy Creeks ranged from 0.25 to 0.82 inches in 1975 and 1.29 to 2.09 inches in 1976 (Elbert, 1978). Simulated values using NPS for the study area for the same periods were 0.072 and 2.10 inches, respectively. Elbert also reported snowmelt occurred slowly over a two week period without rainfall ending on March 28 in 1975 and rapidly over several days with rainfall ending on March 27 in 1976. NPS did not accurately simulate the timing of the 1975 snowmelt but did well in 1976 when the snowmelt process was complete by March 30th. The majority of the simulated snowmelt for 1975 occurred during the fourth week of April.

Average snowmelt runoff for the fourteen year simulation period was found to be 2.35 inches as simulated by NPS (Table 18) and 2.38 inches as observed for the Big Eau Pleine River watershed (Table 19). Although averages for the fourteen year period compared well, year-to-year observed versus simulated snowmelt totals did not correlate well (r^2 = .331). The correlation was improved (r^2 = .762) when adding the snowmelt and spring runoff seasons together indicating the difficulty in simulating the timing of spring snow melt.

Sediment Loading

Table 17 presents total and average simulated sediment loss through overland flow, by season and by year. Since simulated totals were obtained by multiplying simulated flow by observed average concentrations for 1979, no comparison to observed data for the study area can be made.

The average simulated soil loss through overland flow was 370 lbs/acre. This value is low if compared to reported data. Hansen (1979) reported average gross soil loss for the Big Eau Pleine watershed to be 4600 lbs/acre for cropland. The gross erosion value can be adjusted to 460 to 920 lbs/acre by estimated sediment delivery ratios (SDR) of 10 - 20% for a small watershed (SCS, 1966). An actual SDR of 8% for the watershed is found by dividing simulated soil loss by gross erosion. The 8% value is closer to 6 - 8% values reported for large watersheds (SCS, 1966). The use of terraces and grassed waterways on the study area watershed reduces the sediment delivery ratio by physical entrapment because of reduced slopes.

Nitrogen Loading

Tables 18, 19 and 20 present total and average simulated nitrogen (total nitrogen, total Kjeldahl nitrogen

Table 17: Simulated total sediment[5] loss through overland flow in lbs/acre for the 14 year study period.

	pounds/acre				
Year	Snowmelt[1]	Spring[2]	Summer[3]	Fall[4]	Total
1966		14.6	6.4	3.3	24.3
1967	2.3	137.6	45.2	8.4	193.5
1968	.8	468.7	167.0	34.2	670.7
1969	12.5	370.2	56.0	13.9	452.6
1970	4.6	385.8	20.5	44.1	455.0
1971	22.3	98.3	44.5	41.4	206.5
1972	14.3	136.2	161.8	117.4	429.7
1973	25.8	621.3	9.7	5.1	661.9
1974	.5	59.5	6.4	3.5	69.9
1975	.3	145.4	8.8	5.9	160.4
1976	8.3	115.5	4.6	.2	128.6
1977	.3	6.4	4.2	4.9	15.8
1978	.5	29.8	154.8	9.5	194.6
1979	12.7	1178.4	176.5	131.0	1498.6
Total	105.2	3767.7	866.4	422.8	5162.1
Average	8.1	269.1	61.9	30.2	369.3
Percentage	2.2	72.9	16.8	8.1	100.0

1 January, February and March
2 April, May and June
3 July, August and September
4 October, November and December
5 Sediment = total suspended solids

Table 18: Simulated total nitrogen[5] loss through overland flow in lbs/acre for the 14 year study period.

	pounds/acre				
Year	Snowmelt[1]	Spring[2]	Summer[3]	Fall[4]	Total
1966		.28	.14	.05	.47
1967	.92	2.72	.90	.17	4.71
1968	.32	9.28	3.31	.67	13.59
1969	4.89	7.34	1.12	.28	13.63
1970	1.80	7.63	.40	.86	10.69
1971	8.77	1.94	.87	.81	12.40
1972	5.61	2.69	3.19	2.33	13.82
1973	10.07	12.30	.19	.11	22.67
1974	.22	1.18	.14	.09	1.63
1975	.10	2.83	.17	.12	3.22
1976	3.26	2.30	.09	<.01	5.65
1977	.13	.14	.09	.09	.44
1978	.17	.59	3.05	.19	4.00
1979	4.97	23.31	3.51	2.60	34.39
Total	41.23	74.53	17.17	8.37	141.32
Average	3.17	5.32	1.22	.60	10.21
Percentage	29.2	52.8	12.1	5.9	100.0

1 January, February and March
2 April, May and June
3 July, August and September
4 October, November and December
5 TKN + NO_3

Table 19: Simulated total Kjeldahl nitrogen loss through overland flow in lbs/acre for the 14 year study period.

	pounds/acre				
Year	Snowmelt[1]	Spring[2]	Summer[3]	Fall[4]	Total
1966		.22	.11	.04	.37
1967	.62	2.14	.71	.13	3.60
1968	.22	7.30	2.60	.53	10.65
1969	3.28	5.78	.88	.22	10.16
1970	1.21	6.00	.31	.68	8.20
1971	5.89	1.52	.68	.64	8.73
1972	3.77	2.12	2.51	1.83	10.23
1973	6.75	9.68	.15	.09	16.67
1974	.15	.93	.11	.07	1.26
1975	.07	2.23	.13	.09	2.52
1976	2.18	1.81	.07	<.01	4.06
1977	.09	.11	.07	.07	.33
1978	.11	.46	2.40	.15	3.12
1979	3.33	18.34	2.76	2.05	26.48
Total	27.67	58.64	13.49	6.59	106.39
Average	2.13	4.19	.96	.47	7.75
Percentage	26.0	55.1	12.7	6.2	100.0

1 January, February and March
2 April, May and June
3 July, August and September
4 October, November and December

Table 20: Simulated total nitrate-nitrite nitrogen loss through overland flow in lbs/acre for the 14 year study period.

	pounds/acre				
Year	Snowmelt[1]	Spring[2]	Summer[3]	Fall[4]	Total
1966		.06	.03	.01	.10
1967	.30	.58	.19	.04	1.11
1968	.10	1.98	.71	.14	2.94
1969	1.61	1.56	.24	.06	3.47
1970	.59	1.63	.09	.18	2.49
1971	2.88	.42	.19	.17	3.67
1972	1.84	.57	.68	.50	3.59
1973	3.32	2.62	.04	.02	6.00
1974	.07	.25	.03	.02	.37
1975	.03	.60	.04	.03	.70
1976	1.08	.49	.02	<.01	1.59
1977	.04	.03	.02	.02	.11
1978	.06	.13	.65	.04	.88
1979	1.64	4.97	.75	.55	7.91
Total	13.56	15.89	3.68	1.78	34.93
Average	1.04	1.13	.26	.13	2.56
Percentage	38.8	45.6	10.5	5.1	100.0

1 January, February and March
2 April, May and June
3 July, August and September
4 October, November and December

and nitrate nitrogen, respectively) loss through overland flow by season and by year for the study area watershed. Simulated nitrogen totals were also obtained by multiplying simulated flow by observed average concentrations for 1979 and, therefore, cannot be compared to observed data for the study area.

The average simulated loss for total nitrogen, TKN and NO_3-N were 10.21, 7.75 and 2.56 lbs/acre/yr, respectively. Elbert (1979) found total nitrogen losses to be 2.88 and 4.99 lbs/acre/yr, TKN losses 1.96 and 2.45 lbs/acre/yr and NO_3-N .92 and 2.76 lbs/acre/yr for Hamann and Noisy Creeks. Greater losses simulated from the study area are attributed to a greater animal density. Elbert reported animal densities of .17 to .30 per acre. The study area averaged about 1.0 per acre (Zuelke, 1979). Loehr (1974) reported total nitrogen values for cropland drainage in the United States of .33 to 15.1 lbs/acre/year and for pasture and manure disposal land of 4.25 to 490 lbs/acre/yr, respectively.

Phosphorus Loading

Table 21 presents total and average simulated phosphorus loss through overland flow by season and by year. Simulated totals for total phosphorus were also obtained by multiplying simulated flow by observed average concentrations for 1979 and, therefore, cannot be compared to observed data for the study area.

Table 21: Simulated total phosphorus loss through overland flow in lbs/acre for the 14 year study period.

Year	Snowmelt[1]	Spring[2]	Summer[3]	Fall[4]	Total
	pounds/acre				
1966		.07	.02	.02	.11
1967	.13	.71	.22	.05	1.11
1968	.04	2.38	.86	.18	3.46
1969	.66	1.87	.29	.07	2.89
1970	.24	1.96	.11	.22	2.53
1971	1.21	.51	.22	.22	2.16
1972	.77	.68	.82	.60	2.87
1973	1.39	3.15	.05	.02	4.61
1974	.03	.33	.02	.03	.41
1975	.03	.73	.05	.02	.83
1976	.44	.57	.02	<.01	1.03
1977	.03	.03	.02	.02	.10
1978	.03	.15	.78	.05	1.01
1979	.68	5.97	.93	.66	8.24
Total	5.68	19.11	4.41	2.15	31.35
Average	.44	1.37	.31	.15	2.27
Percentage	18.1	60.9	14.1	6.9	100.0

1 January, February and March
2 April, May and June
3 July, August and September
4 October, November and December

The average simulated loss for phosphorus was 2.27 lbs/acre/yr. Elbert (1979) found TP losses for 1975 and 1976 to be .27 and 1.00 lbs/acre/yr for Hamann and Noisy Creeks. Greater losses from the study area are again attributed to a greater animal density. Loehr (1974) reported TP losses for cropland drainage in the United States of 0.01 - 0.29 lbs/acre/year and for pasture and manure disposal land of .67 - 145 lbs/acre/year, respectively.

Total Sediment and Nutrients Trapped

Pond sediments were sampled to determine the total sediment and nutrients trapped. A contour map showing the areal distribution of the deposited sediment is presented in Figure 14. Average depth of the sediment was found to be 3.43 cm with a maximum of 15.2 cm and a minimum of .5 cm. As expected sediment depths were greatest at the inflow to the pond and decreased with distance from the inflow.

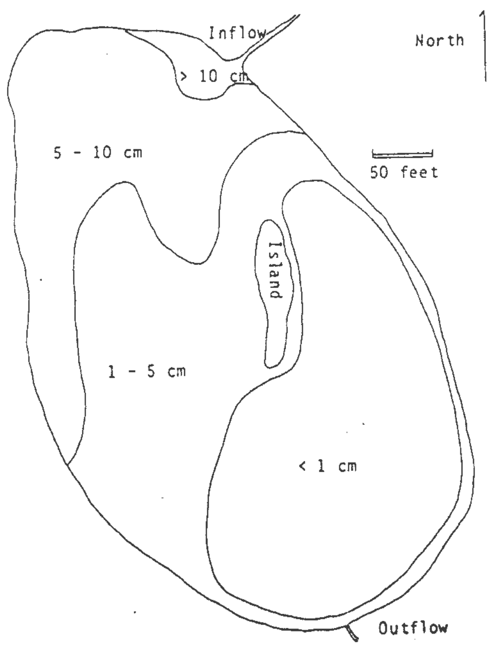


Figure 13: Areal distribution of pond sediments.

Results of pond sediment analyses are presented in Table 22.

Table 22: Results of physical and chemical characterization of pond sediment.

Parameter (# of Replicates)	Average	Standard Deviation
Total Phosphorus (20)	750 mg/kg	26.6
Total Kjeldahl Nitrogen (20)	3,230 mg/kg	228.6
Nitrate-nitrite Nitrogen (5)	12.8 mg/kg	1.0
Ammonia Nitrogen (5)	52.0 mg/kg	4.1
Percent Organic Matter (5)	7.0 percent	.06
Bulk Density (5)	.433 g/cc	.031

The total mass of the sediment was calculated as presented below:

- Dry weight density = .433 g/cc
- Area = 2.67 acres = 10,805 m^2 = 1.0805×10^8 cm^2
- Average depth of sediment = 3.43 cm
- Mass of sediment = area x depth x dry weight density
- Mass of sediment = 1.6048×10^8 g = 1.6048×10^5 kg

The total mass (1.6048×10^5 kg) is the total sediment trapped in the pond. Multiplying mass of sediment trapped times the average nutrient concentration from Table 22 gives total nutrients trapped as presented in Table 23.

Table 23: Total sediment and nutrient trapped.

Parameter	Total Trapped
Total Phosphorus	120 kg
Total Kjeldahl Nitrogen	519 kg
Ammonia Nitrogen	8.3 kg
Nitrate-Nitrite Nitrogen	30 kg
Sediment	1.605×10^5 kg

Average Sediment and Nutrients Input

Early in the model calibration process it was determined sediment and nutrient runoff processes could not adequately be simulated by NPS to obtain the total input to the pond. Instead snowmelt and hydrologic processes were modeled to simulate a total overland flow which could be multiplied by an average observed sediment and nutrient concentration to obtain the total input.

Observed concentrations of sediment and nutrients showed a marked difference for snowmelt versus other runoff events. Average concentrations were calculated for each of the runoff processes.

Snowmelt

Table 24 presents water quality results for ten (10) grab samples collected during snowmelt of 1979. Average concentrations for sediment and nutrients have been calculated.

Table 24: Results of chemical analyses of ten snowmelt grab runoff samples.

		Concentration (mg/l)					
Date	Time	TSS	PO_4-P	TP	TKN	NH_4-N	NO_3-N
3/18/79	10:00	15	.80	1.20	4.88	1.86	1.65
3/18/79	12:00	9	.93	1.33	4.76	1.90	1.92
3/18/79	14:00	21	.76	.96	3.84	.66	1.90
3/19/79	12:00	17	.97	1.17	5.36	1.44	2.14
3/20/79	10:00	13	.79	1.14	4.96	1.64	1.84
3/20/79	11:00	21	.20	.26	2.96	.96	2.14
3/22/79	12:00	16	.20	.27	2.84	.80	1.96
3/23/79	14:00	12	.84	1.01	3.50	1.20	1.80
3/23/79	15:00	20	.16	.28	2.68	1.04	2.10
3/23/79	16:00	8	.26	.60	4.24	1.00	2.15
Average		15.2	.59	.82	4.00	1.25	1.96

Average sediment and nutrient concentrations are generally higher than those found by Elbert (1977) during snowmelt on tributaries to Hamann and Noisy Creeks in 1975 and 1976. He found average TP concentrations to range from .197 to .497 mg/l; TKN to range from 1.68 to 3.84 mg/l, NH_4-N to range from .07 to 1.35 mg/l and NO_3-N to range from .42 to 1.34 mg/l for eight (8) sampling points. Higher concentrations of nutrients from specific sampling locations on Hammen and Noisy Creeks were found to be related to dairying operations and winter spreading of manure. Although nutrient concentrations were similar between years for the same sampling locations, he noted

TSS concentrations were much higher in 1976 than in 1975; 8 to 185 mg/l and 4 to 11.5 mg/l, respectively.

Snowmelt water quality data was collected from seven (7) small watersheds (7.18-18.68 acres) in eastern South Dakota with similar soils (sandy clay loams) and topography (rolling hills)(Harms, Dornbush and Anderson, 1974). Data was presented from three ground cover types, cultivated land, pasture and alfalfa or grass. Average concentrations noted were: TP - 0.44, 1.05 and 0.67 mg/l; NO_3-N - 1.0, 0.9 and 0.8 mg/l; TKN - 2.1, 3.3 and 2.8 mg/l; and TSS - 51, 18 and 42 mg/l, respectively.

All Other Runoff

Table 25 presents average TSS, TP, TKN, and NO_3-N concentrations calculated from observed data for 122 ISCO samples collected during eight other runoff events.

Table 25: Average sediment and nutrient concentrations based on 122 samples from eight runoff events.

Parameter	Total (g)	Average Concentration(mg/l)
Total Flow	1.0578×10^4	--
Total Suspended Solids	4.944×10^6	467.0
Total Phosphorus	2.504×10^4	2.37
Total Kjeldahl Nitrogen	7.687×10^4	7.27
Nitrate-nitrite Nitrogen	2.080×10^4	1.97

Total flow in cfs was converted to average flow in cubic meters for each observed time interval. Since grams per cubic meter is equal to parts per million, total grams of TSS, TP, TKN and NO_3-N could be calculated for each time interval by multiplying the average part per million value times the total flow in cubic meters. Total flow and total grams were then found by summing the subtotals for the intervals. Average concentrations were calculated by dividing total grams by cubic meters.

Average sediment and nutrient concentrations are again higher than those found by Elbert (1977) for tributaries to Hamann and Noisy Creeks. His data averages concentrations for all stream flow, which include runoff events and base flow. He found average TSS concentrations to range from 4 - 71 mg/l, TP to range from .014 - .249 mg/l, TKN to range from .39 - 2.2 mg/l and NO_3-N to range from .01 - 1.57 mg/l for eight (8) sampling points.

Harms, Dornbush and Anderson (1974) reported more comparable values for runoff collected in eastern South Dakota. They found average concentrations for 32 runoff events for TSS to range from 38 - 1,021 mg/l, for TP to range from .35 - 1.05 mg/l, for TKN to range from .8 - 2.6 mg/l and for NO_3-N to range from .3 - 1.5 mg/l.

Efficiency Considerations

Pond Trapping Efficiency

The trapping efficiency of the farm pond is expressed as total trapped in pond sediment as measured by sediment coring and analysis, divided by total input through overland flow (simulated) times 100%. Table 26 presents the total nutrient and sediment trapped, the total sediment and nutrient input and the corresponding observed trapping efficiencies.

Table 26: Sediment and nutrient trapping efficiency.

	Total Trapped (kg)	Total Input (kg)	Trapping Efficiency (percent)
Sediment	160,480	159,800	100.4
Total Phosphorus	120	969	12.4
Total Kjeldahl Nitrogen	519	3,292	15.8
Total Nitrate Nitrogen	2.0	1,079	.2
Total Nitrogen	521	4,371	11.9

Trapping efficiencies of 100.4% for sediment, 12.4% for phosphorus and 11.9% for total nitrogen (15.8% for TKN and .2% for NO_3-N) are reasonable. The trapping efficiency for sediment should be very high because of the pond's relatively large retention capacity (approximately 3.6 watershed inches).

Sediment trapping efficiencies ranging from 77 to 100% have been reported in the literature (Dendy and Cooper, 1984; Amandes, 1980; Rausch and Schreiber, 1981; and Johnston, et al, 1984). Lower efficiencies reported were related to smaller structures in terms of relative retention capacity or to watersheds with clayey soils.

Trapping efficiencies for TP and TN are reasonable because observed concentrations in pond sediment (Table 22) are within the range of concentrations reported for TP (580-7000 mg/kg) and TN (2200-21,000 mg/kg) in sediments from Wisconsin lakes (Williams, et al, 1971). Observed concentrations on the low end of reported ranges are expected because of the relatively low observed organic matter content of the pond sediment of 7%.

Rausch and Schreiber (1981) reported trapping efficiencies of 49% for TP and 37% for inorganic N for a small flood detention reservoir with a capacity of only .6 inches of runoff. McCuen (1980) observed trapping efficiencies from 6 to 22% for TP and 63 to 92% for inorganic N for a 5.7 acre storm water management basin.

Efficiency Based on Inflow/Outflow

The efficiency of the farm pond in reducing sediment and nutrient loading can also be calculated based on an inflow/outflow basis for 1979. During snowmelt it was noted that a flowthrough situation existed because of remaining ice and that the trapping efficiency is probably low. If it is assumed that all sediment and nutrients flow directly through the pond for the snowmelt period, trapping efficiencies of 98% for sediment, 81.9% for TP and 70.8% for TN are still possible. Using the greatest observed outflow concentrations (see Table 8) for TSS, TP and total nitrogen (sum of TKN and NO_3) of 40, .54 and

3.24 mg/l, respectively, and average inflow concentrations of 497, 2.37 and 9.24 mg/l, respectively, the inflow/outflow trapping efficiency is still relatively good at 90.1% for TSS, 62.8% for TP and 46.0% for TN. If the relatively high value of 40 mg/l for TSS, which occurred after the 100-year storm in June of 1979, is thrown out and the next highest observed TSS value of 14 mg/l is used, sediment trapping efficiency becomes 95.2%. Probable efficiencies based on inflow/outflow considerations are near 80% for TP and 60% for TN.

The efficiency of the farm pond in reducing inorganic nitrogen is excellent. Based on average inflow concentrations (see Table 24 and 25) and outflow concentrations (see Table 8) over 90% is dissipated. Bouldin (1974) found the primary loss of nitrogen from six different ponds was through volatilization for ammonia and through denitrification for nitrate. He found losses of up to 38% per day for ammonia and 15% per day for nitrate. McCuen (1980) found the volatilization efficiency of ammonia to range from 63-92% on a storm-by-storm basis. Brye (1970) reported 30% of the nitrogen which entered two large Tennessee Valley Authority reservoirs could not be accounted for in the outflow. Hassler (1963) reported that about 80% of the inorganic nitrogen which entered Lake Mendota in 1949 was not accounted for in the outflow.

Biological transformations occur which help account for the higher inflow/outflow efficiencies for phosphorus and nitrogen. The pond is a thriving ecosystem which requires continuous nutrient input. Phosphorus and nitrogen are used by algae as basic building blocks of the pond's food chain. Zooplankton, invertebrates and fish are the receptors of the algal primary production. When invertebrates hatch or fish are removed from the system, loss of phosphorus and nitrogen occur.

Comparison of Trapping and Inflow/Outflow Efficiencies

Trapping efficiencies of the pond for sediment, TP and TN were found to be approximately 95%, 80% and 60%, respectively on an inflow/outflow basis and 100%, 12.4% and 11.9%, respectively, based on measurement of accumulated sediment in the pond. The efficiency on an inflow/outflow basis is the true efficiency in reducing sediment and nutrient loading from the study area. The efficiency based on measurement of accumulated sediment is the trapping efficiency. When taking into account nitrogen and phosphorus transformations, because of the pond's relatively long retention capacity, the two efficiencies compare well.

CONCLUSIONS

The Non Point Source (NPS) Model did an excellent job of simulating overland flow. Correlations (r^2) of .994 for all data and .957 with outliers removed were found for observed versus simulated runoff totals. Simulated runoff timing for snowmelt was observed to be only fair in one of the three years for which observed data was available and very good for the other two years.

Significant amounts of sediment and nutrients from agricultural watersheds are removed from storm runoff by farm ponds. The immediate impact of this farm pond is to reduce nutrient and sediment loading to the Big Eau Pleine River and ultimately the Big Eau Pleine Reservoir.

Efficiency of the farm pond in trapping sediment and nutrients for the fourteen year simulation was found to be 100% for sediment, 12.4% for total phosphorus, 15.8% for total Kjeldahl nitrogen, .2% for nitrate-nitrogen and 11.9% for total nitrogen, based on measurement of accumulated sediment in the pond. If calculated on an inflow/outflow basis using observed data for 1979, efficiency decreases for sediment to 95.2% and increases for total phosphorus and total nitrogen to about 80% and 60%, respectively. Efficiency on an inflow/outflow basis is considered the true efficiency in reducing sediment and nutrient loading from the watershed. Physical and biological transformation of nitrogen and phosphorus from the pond account for large differences in nitrogen and phosphorus efficiencies for the two methods.

Average yearly simulated sediment loading to the pond was found to be approximately 370 lbs/acre, well below the average reported gross soil loss for the Big Eau Pleine watershed of 4600 lbs/acre for cropland (Hansen, 1979). The 8% sediment delivery ratio is well below reported SCS values of 10 - 20% for small watersheds but is close to SCS reported values of 6 - 8% for large watersheds. The use of terraces and grassed waterways on the study area watershed probably contributes to reduced sediment losses.

Average yearly simulated nitrogen and phosphorus losses from the study area were 10.2 and 2.27 lbs/acre, respectively. These averages were greater than reported values for the Big Eau Pleine watershed by factors of 2.5 to 10 times (Elbert, 1979). Greater losses were attributed to the dairy operation and a greater density of animals.

Grab samples collected from managed segments of the watershed indicate that areas of high animal density, such as barnyard and pasture, contribute to greater nitrogen and phosphorus concentrations in runoff.

Systematic snow sampling on the watershed provided data that attributed high nutrient loading in snowmelt runoff to spreading of manure in the winter. Relatively small areas with manure on snow increased nutrient concentrations in a composite snow sample two-fold, as compared to samples collected from non-manured areas of the watershed. A manured snow field contained over 100 times the concentration of sediment and nutrients as compared to a non-manured field.

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APPENDIX A

Observed Flow and Runoff Data

Table 27: Summary of observed and simulated flow data for March 18-24, 1979.

Date	Time	Flow (CFS) Observed	Flow (CFS) Simulated
3/18/79	0.00	.01	.02
	4.00	.04	.04
	8.00	.48	.13
	12.00	3.31	1.74
	16.00	3.64	2.95
	20.00	2.93	.83
3/19/79	0.00	3.72	8.75
	4.00	4.72	1.03
	8.00	3.72	.87
	12.00	2.33	3.16
	16.00	1.73	5.53
	20.00	1.21	2.29
3/20/79	0.00	.92	.76
	4.00	.80	.44
	8.00	.93	.27
	12.00	1.09	3.40
	16.00	1.05	4.39
	20.00	.90	.76
3/21/79	0.00	.73	.44
	4.00	.59	.26
	8.00	.47	.16
	12.00	.34	.09
	16.00	.47	.22
	20.00	.58	.19
3/22/79	0.00	.72	.11
	4.00	.70	.10
	8.00	.68	.10
	12.00	.59	.79
	16.00	.66	1.03
	20.00	.95	.59
3/23/79	0.00	3.06	.92
	4.00	2.60	6.16
	8.00	2.12	4.36
	12.00	5.51	2.93
	16.00	6.93	11.30
	20.00	4.47	1.35
3/24/79	0.00	2.12	.79
	4.00	.07	.47
	8.00	.01	.29
	12.00	--	.17
	16.00	--	.16
	20.00	--	.02

Precipitation = 2.81 inches (rain on snow)
Total Observed = 3.42 watershed inches
Total Simulated = 3.92 watershed inches

Table 28: Summary of observed and simulated flow data for April 6-7, 1979.

Date	Time	Flow (CFS) Observed	Flow (CFS) Simulated
4/6/79	14.00	.04	.06
	16.00	.34	.63
	18.00	.54	.35
	20.00	.86	.26
	22.00	.32	.20
	24.00	.12	.15
4/7/79	2.00	.05	.12
	4.00	.03	.09
	6.00	.01	.07
	8.00	--	.05
	10.00	--	.03
	12.00	--	.01

Precipitation = .35 inches
Total Observed = .056 watershed inches
Total Simulated = .060 watershed inches

Table 29: Summary of observed and simulated flow data for April 20-21, 1979.

Date	Time	Flow (CFS)	
		Observed	Simulated
4/20/79	19.00	.03	.02
	20.00	.13	.18
	21.00	.34	.17
	22.00	.43	.14
	23.00	.45	.12
4/21/79	4.00	.39	.07
	8.00	.16	.04
	12.00	.10	--

Precipitation = .21 inches (rain on snow)
Total Observed = 0.052 watershed inches
Total Simulated = 0.020 watershed inches

Table 30: Summary of observed and simulated flow and water quality data for May 1-3, 1979.

		Flow (CFS)		Chemistry Results (mg/l)					
Date	Time	Observed	Simulated	TSS	PO_4	TP	TKN	NH_4	NO_3
5/1/79	21.00	.05	.18	258	.14	.65	2.60	.08	.55
	22.00	1.63	.71	693	.75	2.00	7.00	.63	1.10
	23.00	1.92	3.77	347	1.35	2.80	11.80	1.74	1.55
	24.00	1.63	2.68	219	1.50	2.90	11.20	2.08	1.80
5/2/79	1.00	1.84	1.61	308	1.65	2.95	11.20	1.90	1.85
	2.00	1.63	2.79	196	1.65	2.75	9.80	1.78	2.00
	3.00	1.56	3.70	244	1.55	2.55	9.60	1.86	2.25
	4.00	1.48	2.92	158	1.60	2.45	8.20	1.78	2.65
	5.00	1.40	2.56	130	1.55	2.25	7.20	1.52	2.90
	6.00	1.35	.77	76	1.45	1.95	7.20	1.96	3.15
	7.00	1.14	.93	70	1.40	1.95	6.80	1.52	3.25
	8.00	.97	1.01	85	1.45	2.00	7.60	2.20	3.35
	9.00	.97	.88	62	1.40	2.00	6.40	1.76	3.35
	10.00	.97	.72	56	1.35	1.90	6.20	1.40	3.45
	11.00	.97	.63	55	1.30	1.80	6.00	1.60	3.50
	12.00	.66	.55	49	1.30	1.65	5.60	1.64	3.55
	13.00	.66	.48	43	1.25	1.70	6.40	1.78	3.55
	16.00	.54	.32						
	20.00	.57	.25						
	24.00	.45	.15						
5/3/79	4.00	.39	.09						
	8.00	.28	.05						
	12.00	.22	.04						
	16.00	.04	--						
	20.00	.01	--						

Precipitation = 1.64 inches
Total Observed = .457 watershed inches
Total Simulated = .451 watershed inches

Table 31: Summary of observed and simulated flow data for May 10-11, 1979.

		Flow (CFS)	
Date	Time	Observed	Simulated
5/10/79	10.00	.07	.08
	11.00	1.12	2.37
	12.00	.77	2.84
	13.00	.61	.56
	14.00	.51	.36
	15.00	.41	.31
	16.00	.35	.27
	20.00	.29	.14
	24.00	.21	.08
5/11/79	4.00	.17	.05
	8.00	.06	--

Precipitation = .48 inches
Total Observed = .112 watershed inches
Total Simulated = .118 watershed inches

Table 32: Summary of observed and simulated flow and water quality data for May 19-20, 1979.

	Flow (CFS)			Chemistry Results (mg/l)					
Date	Time	Observed	Simulated	TSS	PO_4	TP	TKN	NH_4	NO_3
5/19/79	10.00	.04	.04						
	10.30	.10	.09	104	.16	.55	2.8	.12	.60
	11.00	.17	.14	124	.20	.65	3.0	.22	.55
	11.30	.49	.27	112	.27	.80	3.4	.22	.40
	12.00	1.24	.47	105	1.30	1.35	5.4	2.70	.75
	12.30	1.92	1.73	196	1.25	4.00	13.8	2.40	.70
	13.00	2.53	2.88	145	1.25	2.75	10.6	2.60	.70
	14.00	2.57	3.52						
	15.00	2.30	2.26						
	16.00	1.59	1.03	94	1.85	3.95	15.0	3.35	.65
	17.00	1.02	.51						
	18.00	.74	.44	71	1.65	3.75	15.2	3.40	.60
	19.00	.57	.39						
	20.00	.53	.33	46	1.45	3.00	12.4	2.80	.65
	24.00	.41	.20						
5/20/79	4.00	.14	.12						
	8.00	.05	.07						

Precipitation = .81 inches
Total Observed = .232 watershed inches
Total Simulated = .165 watershed inches

Table 33: Summary of observed and simulated flow and water quality data for May 31, 1979.

	Flow (CFS)			Chemistry Results (mg/l)					
Date	Time	Observed	Simulated	TSS	PO_4	TP	TKN	NH_4	NO_3
5/31/79	1.30	--	.05	80	.18	.25	2.5	.95	4.40
	2.00	--	.15	136	.15	.35	7.6	1.80	3.00
	2.30	--	1.86	481	.55	2.00	--	1.20	1.10
	3.00	--	2.33	743	.53	2.30	7.8	1.90	.80
	3.30	--	.36	458	1.30	--	8.5	2.50	1.00
	4.00	--	.22	313	1.56	--	8.2	2.00	1.60
	4.30	--	.20	192	1.76	--	7.5	2.10	1.80
	5.00	--	.21	142	1.67	--	7.3	2.00	2.10
	5.30	--	.20	108	1.56	2.25	6.6	1.90	2.20
	6.00	--	.20	88	1.48	2.10	6.1	1.70	2.10
	6.30	--	.18	70	1.35	1.85	5.6	1.60	2.40
	7.00	--	.17	59	1.26	1.80	5.4	1.70	2.30
	7.30	--	.16	36	1.21	1.55	5.2	1.20	2.20
	8.00	--	.14	42	1.09	1.50	5.5	1.20	2.10
	8.30	--	.13	35	1.06	1.40	5.5	1.30	2.00
	9.00	--	.12	28	1.05	1.40	5.5	1.20	2.00
	9.30	--	.11	26	1.02	1.32	4.4	1.10	2.00
	10.00	--	.11	28	1.00	1.38	5.0	1.20	2.00
	10.30	--	.10	27	.98	1.32	5.4	1.20	2.00
	11.00	--	.09	27	.97	1.30	5.3	1.10	2.00
	11.30	--	.09	40	.92	1.35	5.4	1.20	1.90
	12.00	--	.07	47	.90	1.25	4.8	1.20	1.90
	12.30	--	.06	28	.88	1.22	5.2	1.10	1.80
	13.00	--	.05	26	.85	1.18	4.7	1.30	1.80
	13.30	--	.05	24	.83	1.18	5.9	1.10	1.80
	14.00	--	.04	18	.80	1.15	4.6	1.00	1.60
	14.30	--	.16	38	.80	1.18	5.3	.98	1.60
	15.00	--	1.12	77	.57	1.25	9.1	1.80	1.80

Table 34: Summary of observed and simulated flow and water quality data for June 7-8, 1979.

		Flow (CFS)		Chemistry Results (mg/l)					
Date	Time	Observed	Simulated	TSS	PO_4	TP	TKN	NH_4	NO_3
6/7/79	7.00	.07	.04						
	7.30	1.20	1.07						
	8.00	2.67	3.17	374	.05	1.60	4.70	.80	3.00
	8.30	4.47	5.00	417	.10	1.35	4.60	.80	3.00
	9.00	2.61	2.69	378	.19	1.47	5.70	1.00	1.75
	9.30	1.40	1.90	260	.35	1.28	5.10	.80	1.25
	10.00	1.20	.70	260	1.05	2.60	7.00	1.70	1.25
	10.30	.65	.37	247	1.33	3.00	5.80	1.10	2.75
	11.00	.40	.34	196	1.28	2.05	5.70	1.40	3.25
	11.30	.45	.42	160	1.25	2.30	6.70	1.20	3.25
	12.00	.56	.37	90	1.18	1.95	5.90	.90	3.25
	12.30	.59	.35	88	1.08	1.80	7.00	.90	3.50
	13.00	.69	.42	44	.69	1.65	5.90	.40	3.50
	13.30	1.36	1.20	48	1.02	1.95	6.30	.50	3.00
	14.00	1.14	1.02	51	1.02	1.80	6.20	.70	2.75
	16.00	.55	.46	52	1.08	1.40	5.90	.80	2.25
	18.00	.20	.32	52	.64	1.15	6.40	1.10	1.25
	20.00	.13	.19	52	.51	.95	5.80	1.00	.75
	22.00	.08	.11						
	24.00	.06	.07						
6/8/79	2.00	.04	.04						

Precipitation = 1.25 inches
Total Observed = .183 watershed inches
Total Simulated = .175 watershed inches

Table 35: Summary of observed and simulated flow and water quality data for June 9-10, 1979.

Flow (CFS)				Chemistry Results (mg/l)					
Date	Time	Observed	Simulated	TSS	PO_4	TP	TKN	NH_4	NO_3
6/9/79	19.30	.03	--	56	.07	.40	4.20	1.70	1.50
	20.00	.18	.43						
	20.30	1.04	2.44	278	.15	1.30	7.70	2.20	.75
	21.00	3.37	5.93						
	21.30	5.84	7.05	349	.55	2.05	7.90	1.60	1.00
	22.00	5.60	7.46						
	22.30	4.80	7.97	134	.74	1.55	6.70	1.80	3.25
	23.00	4.61	3.56						
	23.30	3.47	1.50	110	.65	1.25	6.10	1.50	4.00
	24.00	2.26	.64						
6/10/79	.30	1.60	.43	119	.49	1.40	5.90	1.30	3.75
	1.00	1.13	.40						
	1.30	.64	.37	115	.50	1.40	5.90	1.50	4.25
	2.30	.44	.32	48	.54	.90	4.20	1.20	4.75
	3.30	.32	.28	38	.51	.80	4.80	1.20	4.50
	4.30	.26	.25	40	.48	.75	4.40	1.20	4.25
	5.30	.21	.22	28	.45	.85	3.90	1.10	3.75
	8.00	.22	.25						
	10.00	.22	.18						
	12.00	.15	.14						
	14.00	.08	.10						
	16.00	.03	.08						

Precipitation = 1.14 inches
Total Observed = .320 watershed inches
Total Simulated = .339 watershed inches

Table 36: Summary of runoff data for June 16, 1979.

Date	Time	Flow (CFS) Observed	Flow (CFS) Simulated
6/16/79	3.30	.02	.10
	4.00	.84	3.82
	4.30	6.00	7.00
	5.00	3.56	3.43
	5.30	1.81	1.58
	6.00	.90	.34
	6.30	2.43	2.20
	7.00	12.07	8.73
	7.30	10.97	10.52
	8.00	7.75	8.70
	8.30	4.72	6.27
	9.00	3.37	5.10
	9.30	2.73	2.32
	10.00	2.26	1.00
	10.30	3.16	23.70
	11.00	30.00+	55.50
	12.00	13.00+	5.70
	13.00	6.38+	1.21
	14.00	3.51+	.71
	15.00	2.57+	.62
	16.00	2.14+	.55
	17.00	1.92+	.47
	18.00	1.32+	.42
	19.00	7.37+	29.17
	19.30	22.37+	50.58
	20.00	15.41+	40.49
	21.00	6.11+	6.47
	22.00	2.69+	1.41
	23.00	1.63+	.70
	24.00	1.11+	.61
6/17/79	4.00	.65+	.36
	8.00	.45+	.21
	12.00	.39+	.13
	16.00	.31+	.08
	20.00	.17+	.04

Precipitation = 5.16 inches
Total Observed = 1.989+ watershed inches
Total Simulated = 2.641 watershed inches

Table 37: Summary of observed and simulated flow and water quality data for July 13, 1979.

Flow (CFS)				Chemistry Results (mg/l)					
Date	Time	Observed	Simulated	TSS	PO_4	TP	TKN	NH_4	NO_3
7/13/79	7.00	.10	.12	72	--	1.58	1.80	--	--
	7.30	.88	.36	225	--	2.12	6.20	--	--
	8.00	22.37	19.96	2144	--	3.60	7.30	--	--
	8.30	9.73	5.03	677	--	3.40	3.80	--	--
	9.00	4.42	1.23	540	--	2.70	4.90	--	--
	9.30	2.03	.39	612	--	2.50	4.00	--	--
	10.00	1.04	.29	396	--	1.60	3.70	--	--
	10.30	.84	.27	294	--	1.60	3.70	--	--
	11.00	.69	.25	362	--	2.12	2.80	--	--
	11.30	.29	.23	262	--	2.10	2.30	--	--
	12.00	.15	.21						
	12.30	.10	.17						
	13.00	.10	.13						
	14.00	.02	.11						

Precipitation = 1.96 inches
Total Observed = .342 watershed inches
Total Simulated = .273 watershed inches

Table 38: Summary of observed and simulated flow and water quality data for August 9, 1979.

	Flow (CFS)			Chemistry Results (mg/l)					
Date	Time	Observed	Simulated	TSS	PO_4	TP	TKN	NH_4	NO_3
8/9/79	8.30	.07	.10	1705	.19	1.80	14.00	.64	1.52
	9.00	.04	.72	752	.26	2.80	11.00	.96	1.96
	9.30	.27	.56	736	.64	3.30	10.00	1.08	1.62
	10.00	.55	.80	68	1.30	1.95	5.40	.94	1.14
	10.30	.32	.15						
	11.00	.17	.15						
	12.00	.06	.16						
	13.00	.02	.16						
	16.00	--	.11						
	20.00	--	.19						
	24.00	--	.10						

Precipitation = 1.75 inches
Total Observed = .013 watershed inches
Total Simulated = .056 watershed inches

Table 39: Summary of observed and simulated flow data for August 13, 1979.

Date	Time	Flow (CFS) Observed	Flow (CFS) Simulated
8/13/79	.30	.01	.06
	1.00	.16	1.05
	1.30	.40	1.94
	2.00	1.26	2.89
	2.30	1.61	.63
	3.00	.94	.20
	4.00	.32	.17
	5.00	.12	.15
	6.00	.06	.13

Precipitation = .93 inches
Total Observed = .042 watershed inches
Total Simulated = .067 watershed inches

Table 40: Summary of observed and simulated flow data for August 19, 1979.

		Flow (CFS)	
Date	Time	Observed	Simulated
8/19/79	11.00	.03	.57
	12.00	1.01	1.19
	13.00	6.02	5.19
	14.00	.56	3.42
	15.00	.16	.56
	16.00	.04	.21
	17.00	--	.15
	18.00	--	.11
	19.00	--	.08
	20.00	--	.05

Precipitation = .64 inches
Total Observed = .023 watershed inches
Total Simulated = .072 watershed inches

Table 41: Summary of observed and simulated flow data for August 22, 1979.

Date	Time	Flow (CFS) Observed	Flow (CFS) Simulated
8/22/79	4.00	.05	.04
	5.00	.63	1.34
	6.00	.41	.19
	7.00	.08	.14
	8.00	.02	.11
	9.00	--	.14
	10.00	--	.09
	11.00	--	.07
	12.00	--	.05

Precipitation = .36 inches
Total Observed = .020 watershed inches
Total Simulated = .031 watershed inches

Table 42: Summary of observed and simulated flow and water quality data for August 26-27, 1979.

Flow (CFS)				Chemistry Results (mg/l)					
Date	Time	Observed	Simulated	TSS	PO_4	TP	TKN	NH_4	NO_3
8/26/79	21.30	.02	.09						
	22.00	.04	.11	10	.12	.35	1.40	.18	4.40
	22.30	.20	.31	38	.25	.60	2.60	1.32	1.20
	23.00	.54	.87	128	.30	1.30	4.20	1.40	1.22
	23.30	.46	.80	74	.98	1.70	5.20	1.62	1.26
	24.00	.58	.76	83	1.03	2.45	7.00	1.20	1.04
8/27/79	.30	.92	.97	66	1.72	3.20	6.00	2.20	1.20
	1.00	.64	1.15	39	1.30	2.50	4.80	1.28	2.00
	1.30	.43	.58	46	1.80	3.20	5.60	1.12	2.20
	2.00	.40	.40	35	1.75	2.10	3.40	.80	2.50
	2.30	.34	.37	36	2.20	2.20	4.20	1.24	2.04
	3.00	.30	.35	35	1.90	2.25	4.20	1.30	1.84
	3.30	.24	.32	36	1.85	2.15	6.00	1.18	1.84
	4.00	.20	.30	36	1.80	2.15	4.00	1.08	1.80
	4.30	.18	.28	29	1.70	2.10	5.60	1.00	1.84
	5.00	.12	.26	28	1.70	2.00	5.80	.40	1.90
	5.30	.12	.24	22	1.60	2.05	4.20	.76	1.80
	6.00	.10	.22	20	1.70	1.75	4.20	.76	1.80
	6.30	.08	.22						
	7.00	.04	.22						
	8.00	.02	.20						
	10.00	--	.15						
	12.00	--	.12						
	16.00	--	.07						
	20.00	--	.03						

Precipitation = .73 inches
Total Observed = .044 watershed inches
Total Simulated = .085 watershed inches

Table 43: Summary of observed and simulated flow data for August 28, 1979.

Date	Time	Flow (CFS)	
		Observed	Simulated
8/28/79	9.00	.05	.03
	10.00	.96	2.20
	11.00	.92	.32
	12.00	.16	.18
	13.00	.04	.16
	14.00	--	.14
	16.00	--	.10
	18.00	--	.07
	20.00	--	.04

Precipitation = .35 inches
Total Observed = .031 watershed inches
Total Simulated = .041 watershed inches

Table 44: Summary of observed and simulated flow data for October 22-24, 1979.

Date	Time	Flow (CFS) Observed	Flow (CFS) Simulated
10/22/79	.00	.00	.00
	2.00	2.14	.08
	4.00	.19	.16
	6.00	.08	.50
	8.00	.02	.30
	10.00	--	.23
	12.00	--	.18
	14.00	--	.14
	16.00	--	.21
	18.00	--	.33
	20.00	--	.32
	22.00	--	.34
	24.00	--	.35
10/23/79	2.00	--	.27
	4.00	.01	.20
	6.00	4.65	.15
	8.00	.60	.11
	10.00	.20	.13
	12.00	.54	.63
	14.00	.95	.63
	16.00	.85	.61
	18.00	1.54	.56
	20.00	1.87	.48
	22.00	.87	.37
	24.00	.94	.28
10/24/79	2.00	.72	.21
	4.00	.45	.16
	6.00	.44	.12
	8.00	.32	.10
	10.00	.26	.07
	12.00	.22	.06
	14.00	.08	.08
	16.00	.04	.13
	18.00	--	.13
	20.00	--	.10
	22.00	--	.07
	24.00	--	.02

Precipitation = 2.48 inches
Total Observed = .399 watershed inches
Total Simulated = .263 watershed inches

Table 45: Summary of observed and simulated flow data for October 31 - November 1, 1979.

Date	Time	Flow (CFS) Observed	Flow (CFS) Simulated
10/31/79	16.00	.01	.05
	17.00	.16	2.21
	18.00	1.21	.28
	19.00	.68	.22
	20.00	.12	.19
	22.00	.04	.14
	24.00	--	.11
11/1/79	2.00	--	.08
	4.00	--	.06
	6.00	--	.05
	8.00	--	.02

Precipitation = .31 inches
Total Observed = .037 watershed inches
Total Simulated = .050 watershed inches

Table 46: Summary of observed and simulated flow data for November 5-6, 1979.

Date	Time	Flow (CFS) Observed	Flow (CFS) Simulated
11/5/79	7.00	.01	.07
	8.00	.16	.10
	9.00	1.60	.18
	10.00	2.22	.38
	11.00	2.23	1.20
	12.00	1.76	2.14
	13.00	1.54	1.11
	14.00	1.27	.80
	15.00	1.00	1.22
	16.00	.89	1.06
	17.00	.80	1.02
	18.00	.65	.77
	19.00	.50	.68
	20.00	.40	.61
	21.00	.39	.54
	22.00	.42	.47
	23.00	.51	.41
	24.00	.57	.36
11/6/79	2.00	.49	.28
	4.00	.33	.21
	6.00	.22	.16
	8.00	.14	.13
	10.00	.11	.10
	12.00	.07	.09
	14.00	.07	.09
	16.00	.06	.09
	20.00	.04	.05
	24.00	.02	.02

Precipitation = 1.00 inches
Total Observed = .282 watershed inches
Total Simulated = .228 watershed inches

APPENDIX B

Comparison of
Observed vs. Simulated Hydrographs

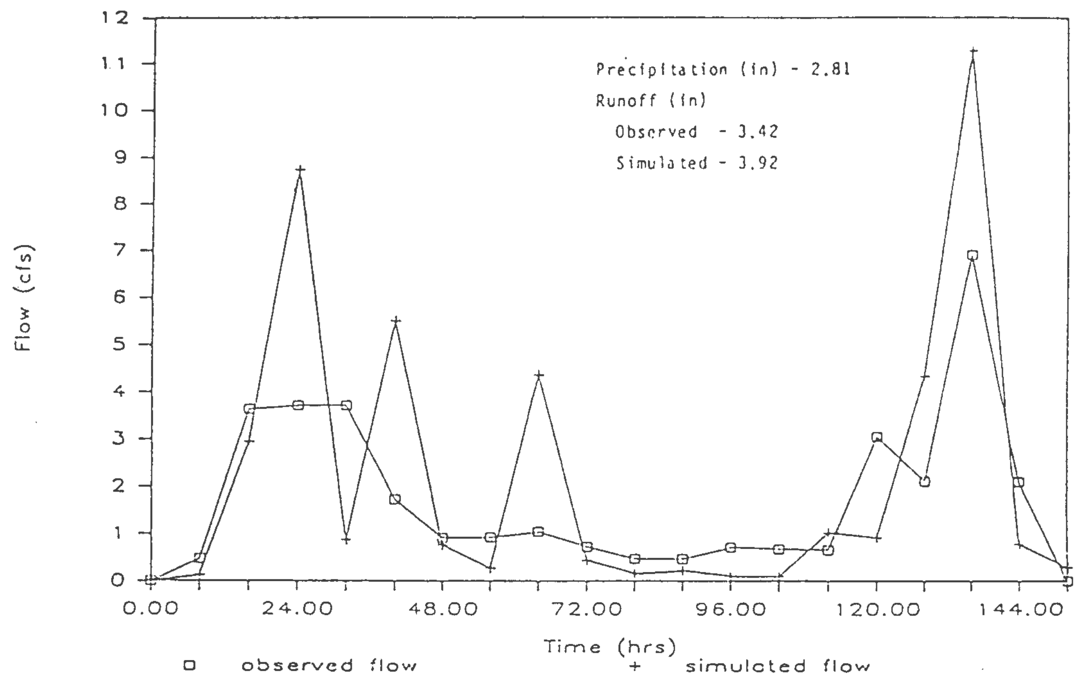

Figure 14: Observed and simulated hydrographs for the snowmelt period, March 18-24, 1979.

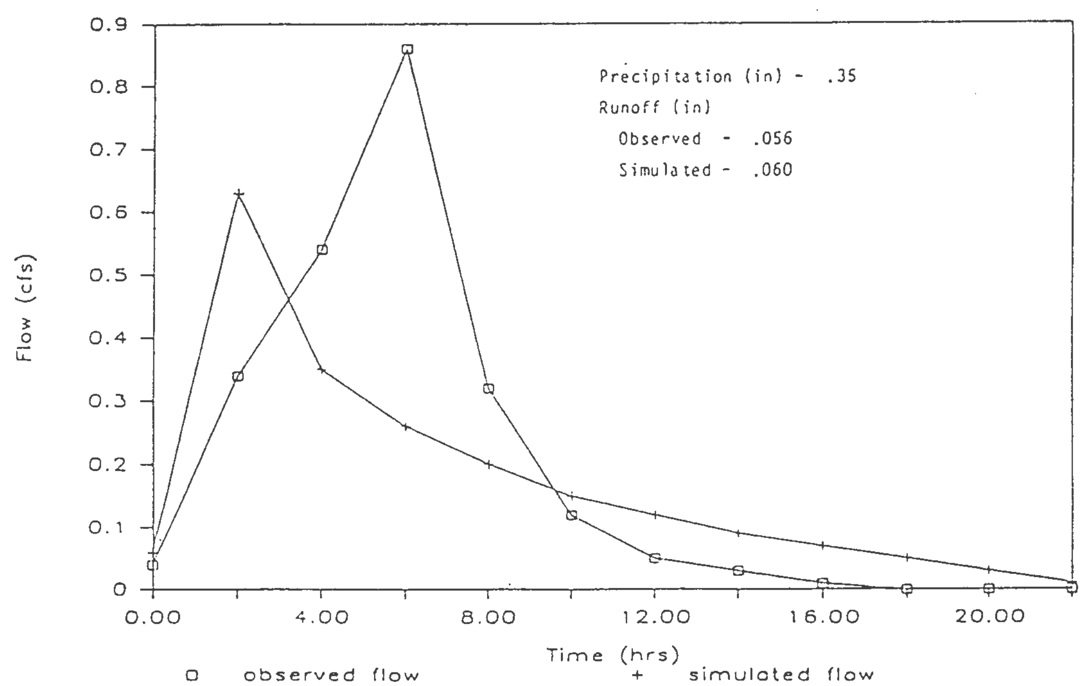

Figure 15: Observed and simulated hydrographs for April 6-7, 1979.

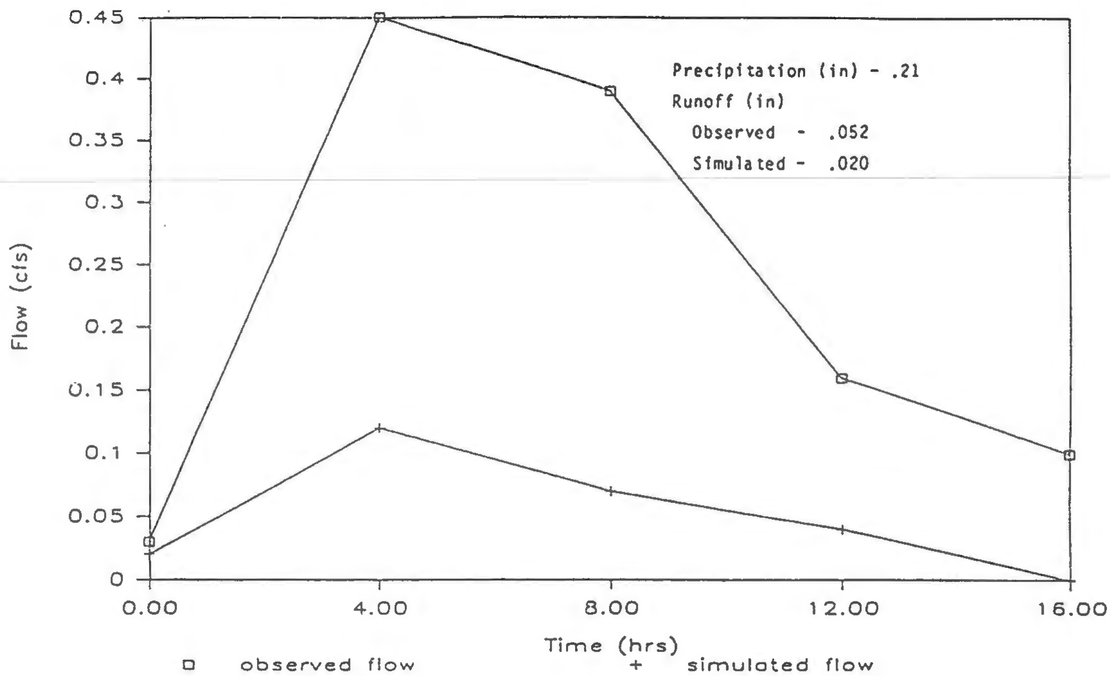

Figure 16: Observed and simulated hydrographs for April 20-21, 1979.

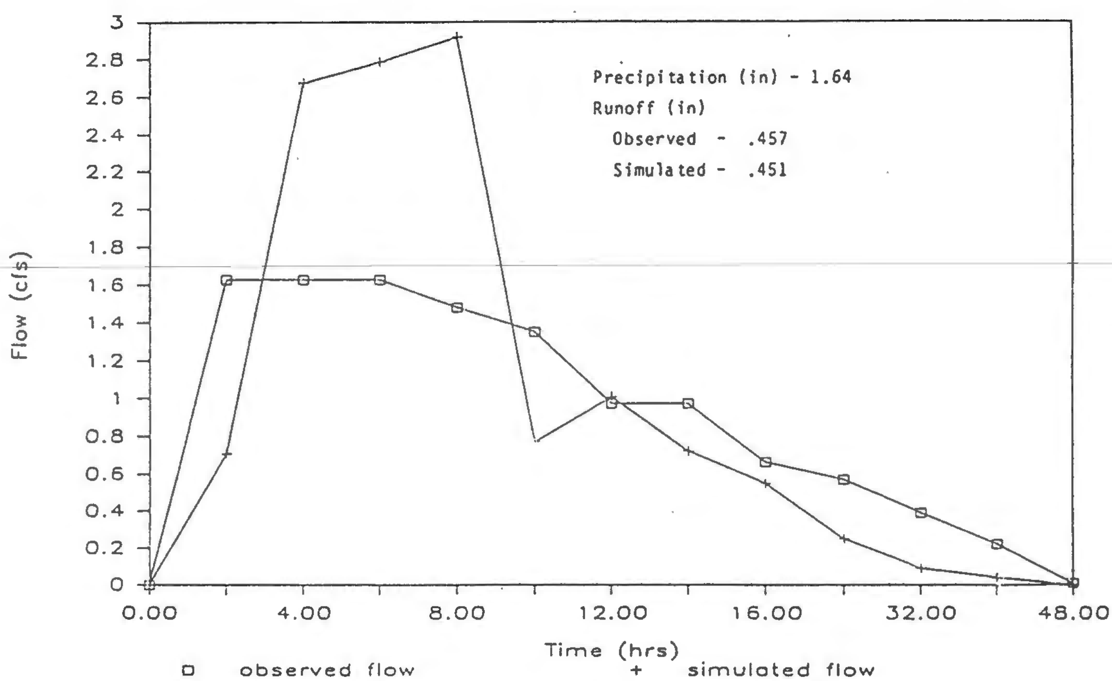

Figure 17: Observed and simulated hydrographs for May 1-3, 1979.

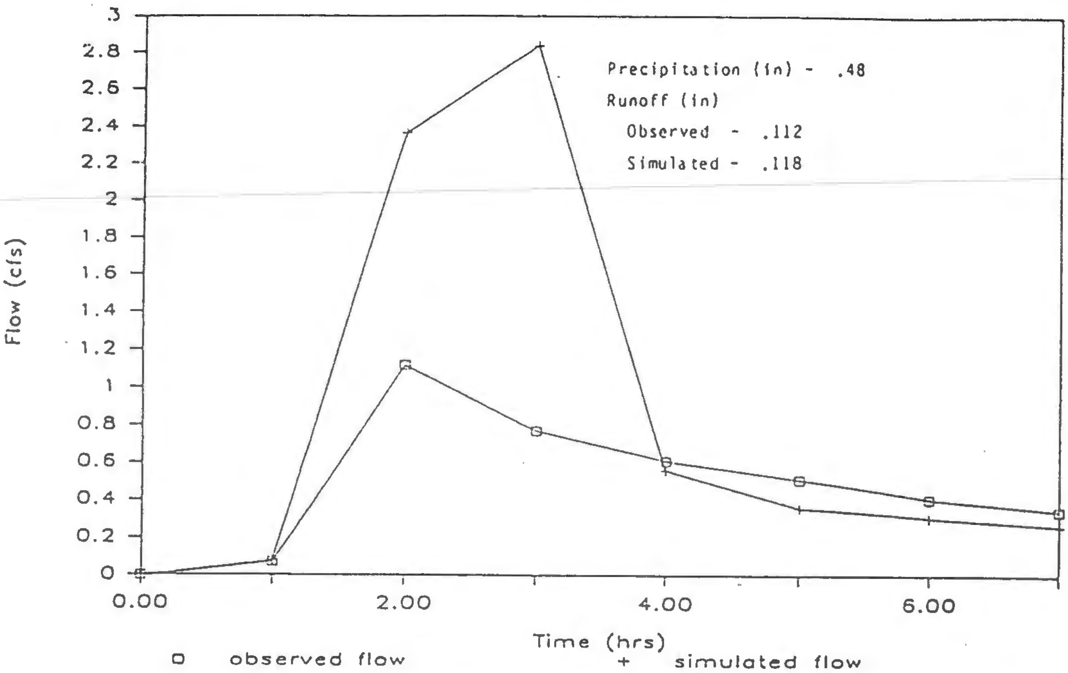

Figure 18: Observed and simulated hydrographs for May 10-11, 1979.

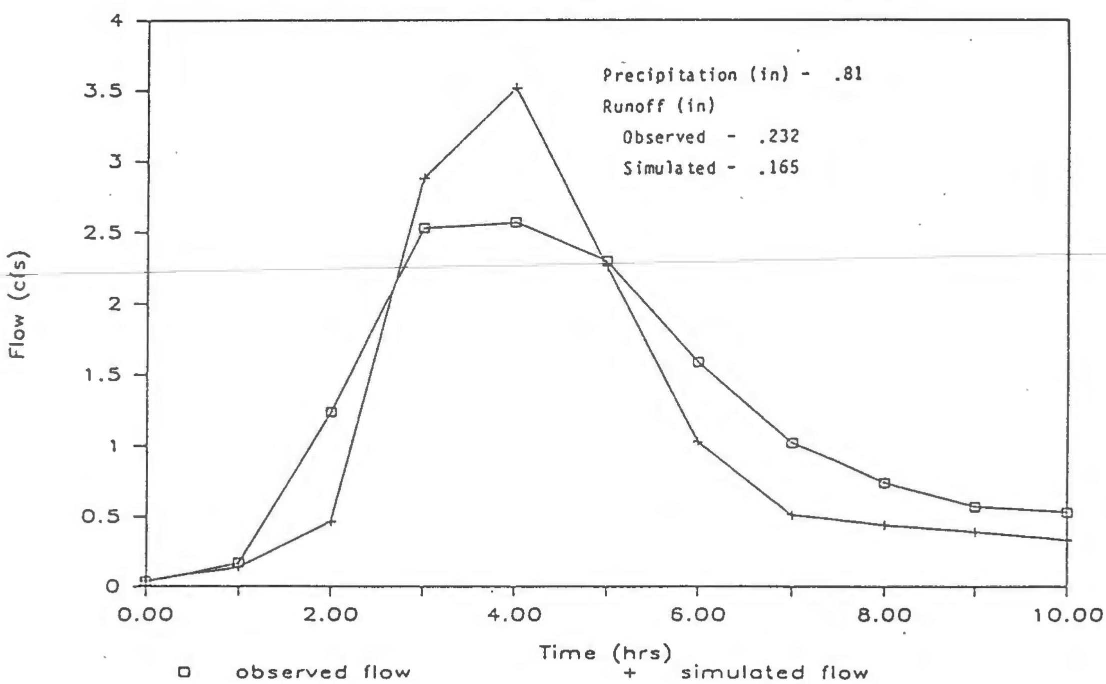

Figure 19: Observed and simulated hydrographs for May 19-20, 1979.

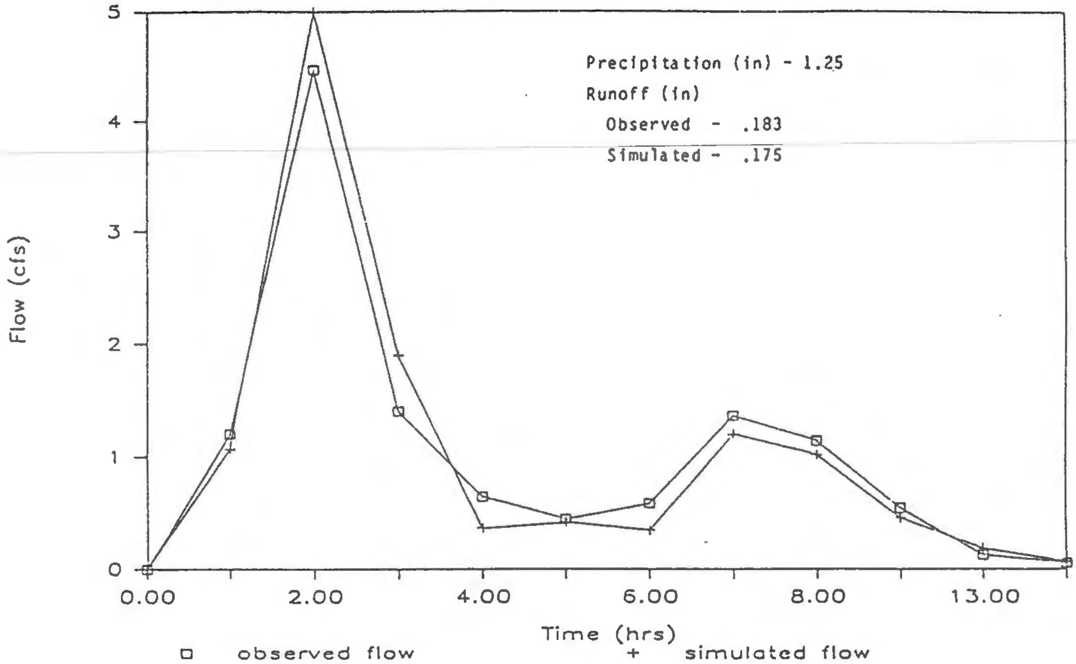

Figure 20: Observed and simulated hydrographs for June 7-8, 1979.

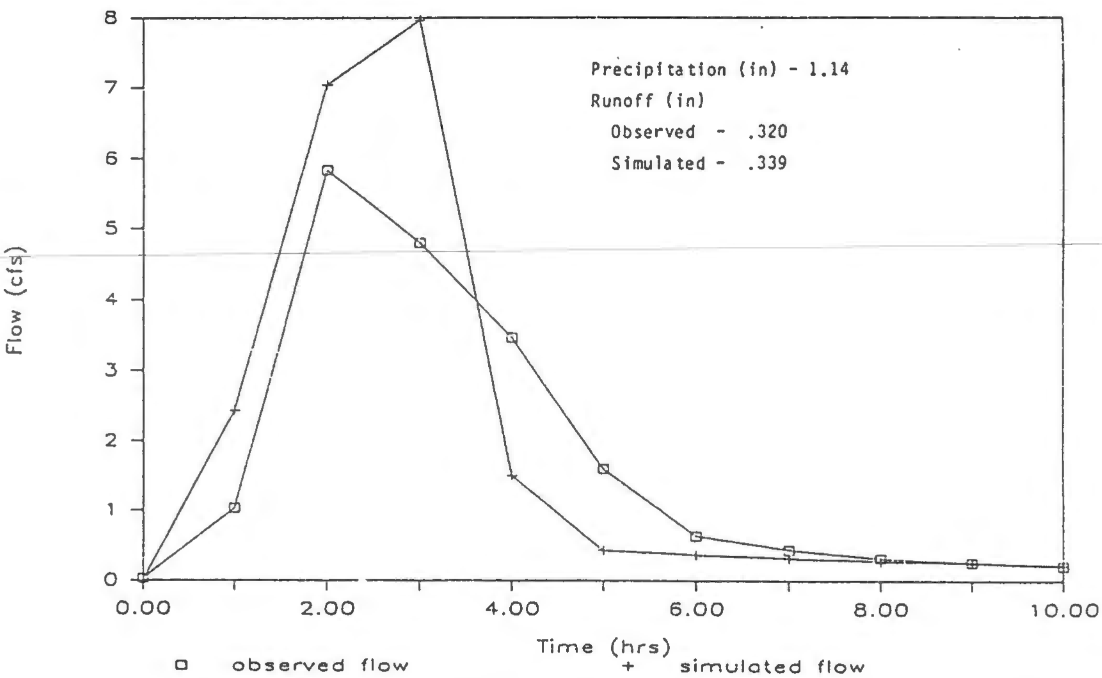

Figure 21: Observed and simulated hydrographs for June 9-10, 1979.

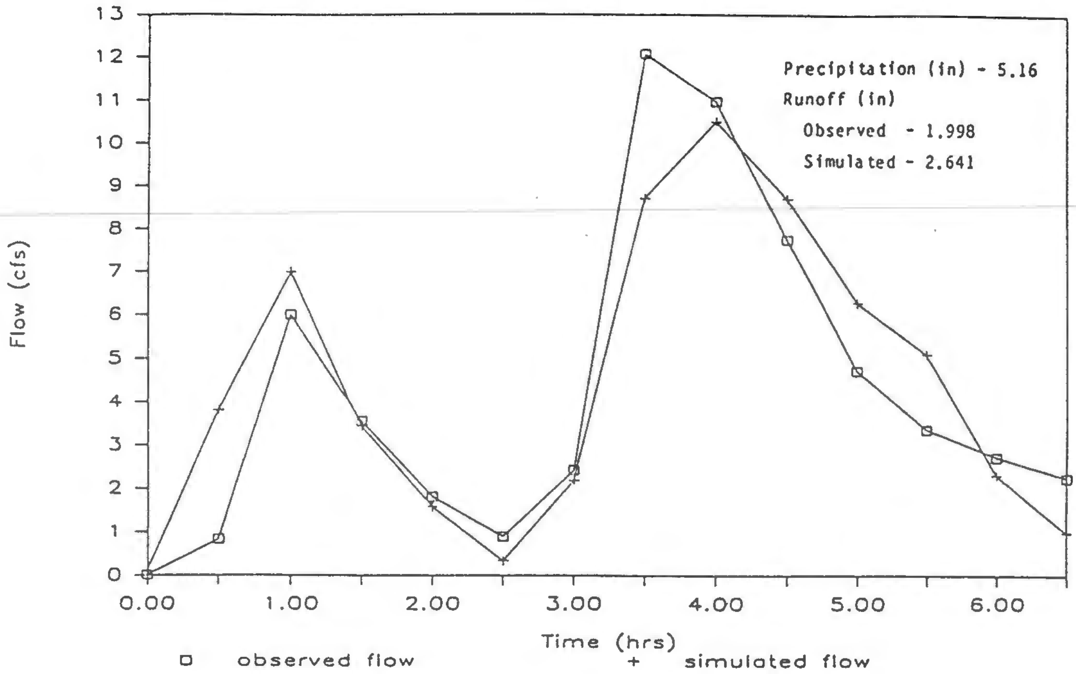

Figure 22: Observed and simulated hydrographs for June 16, 1979.

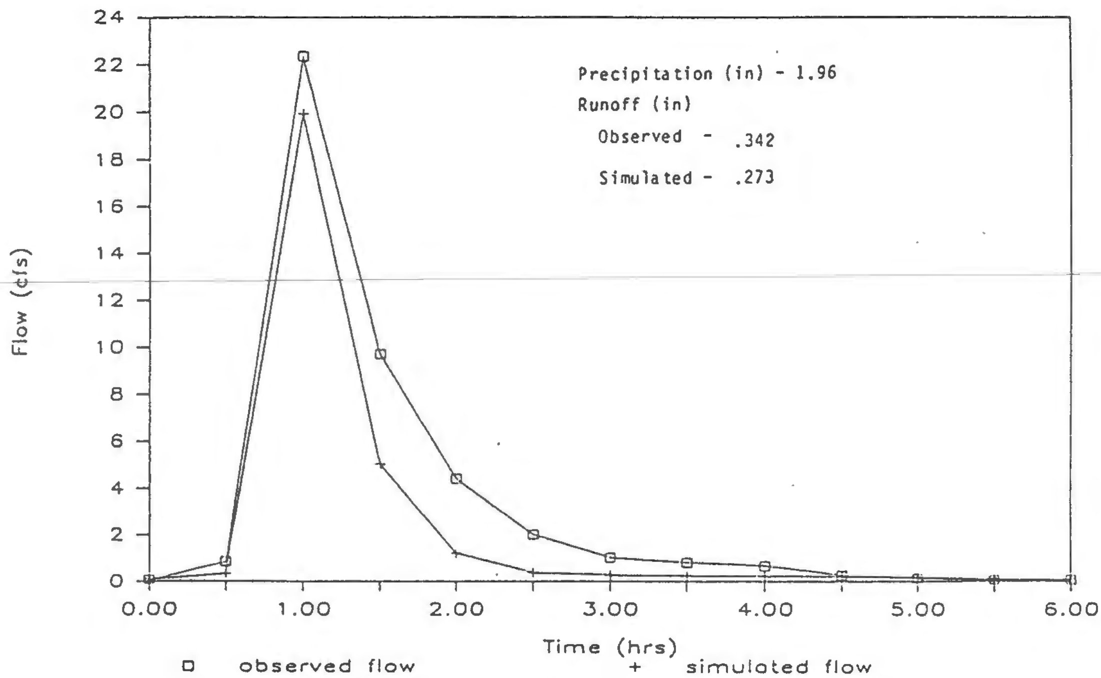

Figure 23: Observed and simulated hydrographs for July 13, 1979.

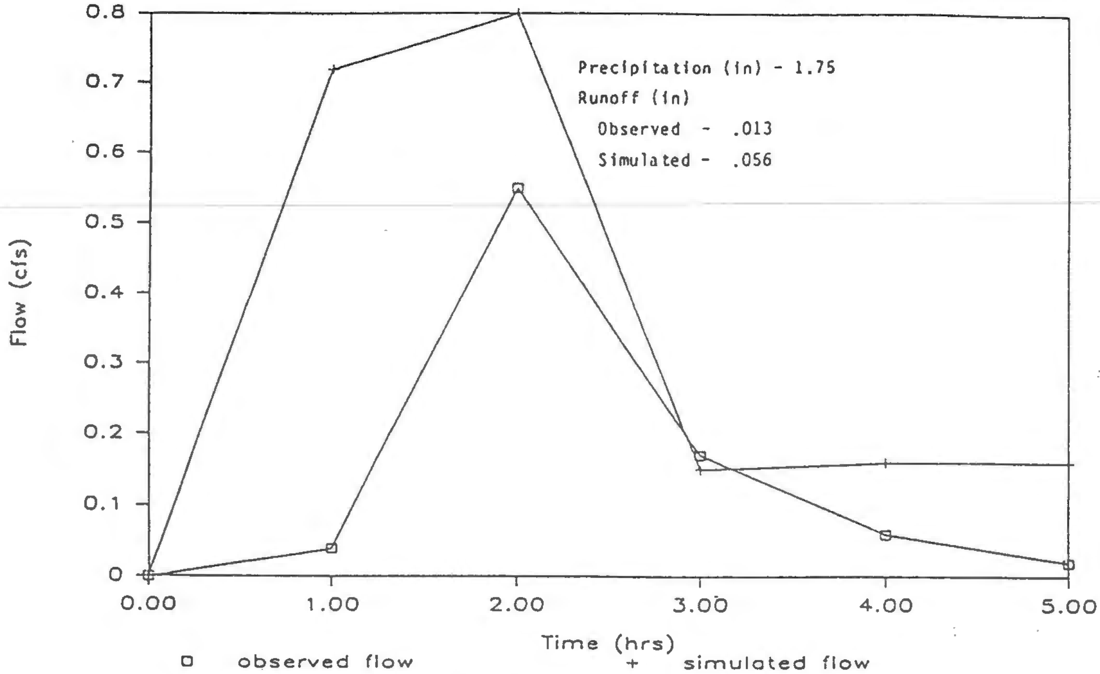

Figure 24: Observed and simulated hydrographs for August 9, 1979.

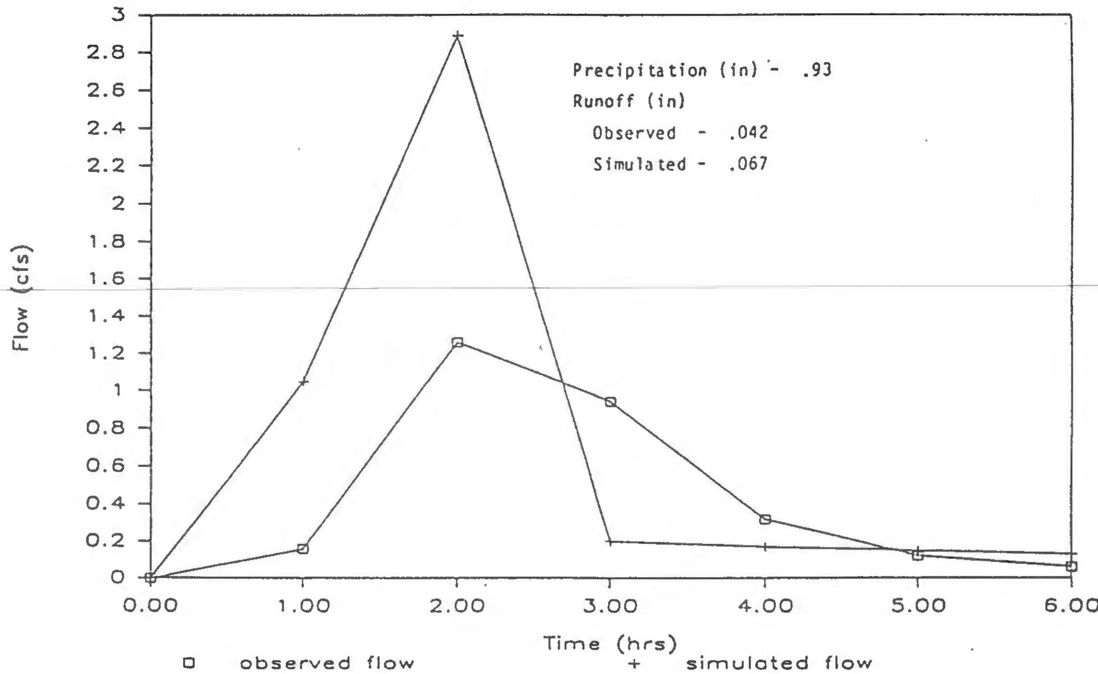

Figure 25: Observed and simulated hydrographs for August 13, 1979.

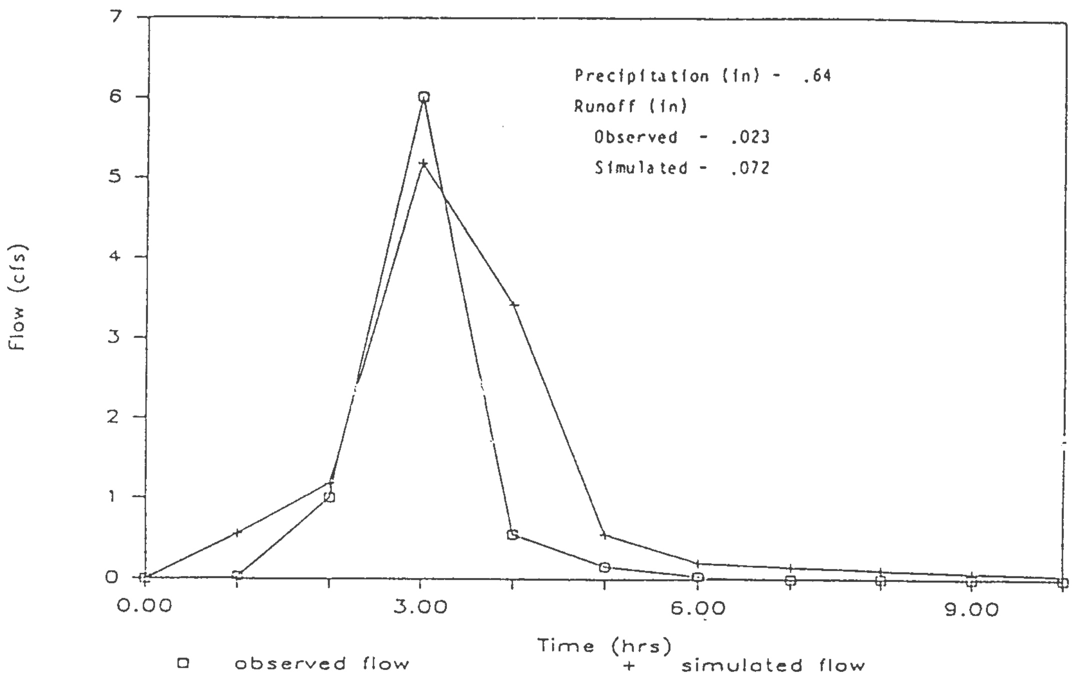

Figure 26: Observed and simulated hydrographs for August 19, 1979.

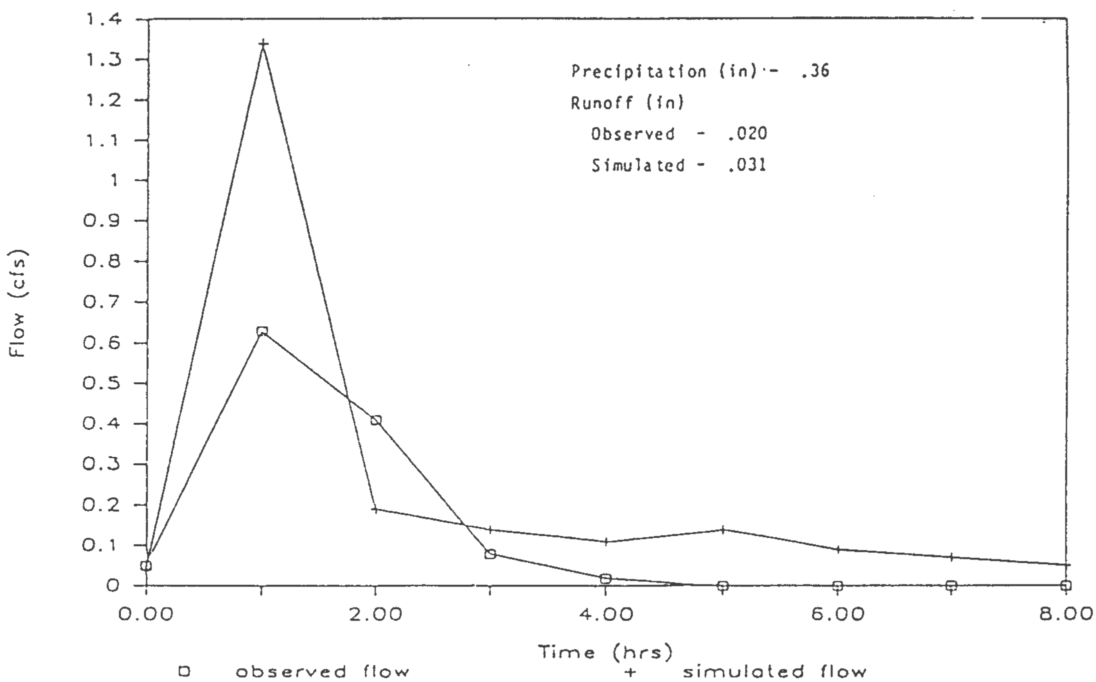

Figure 27: Observed and simulated hydrographs for August 22, 1979.

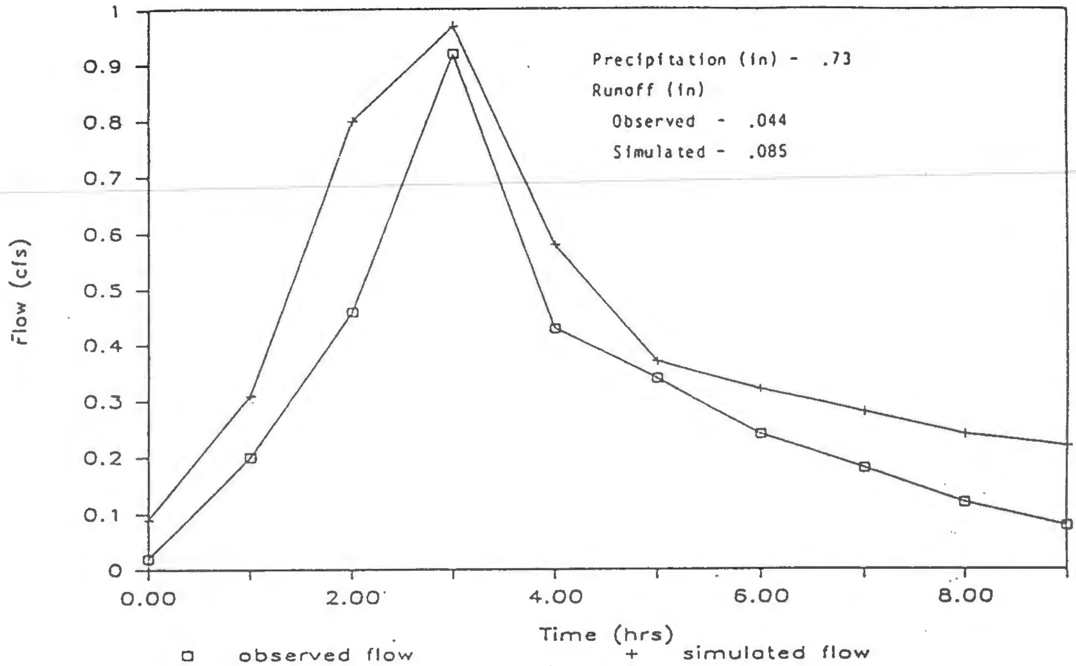

Figure 28: Observed and simulated hydrographs for August 26-27, 1979.

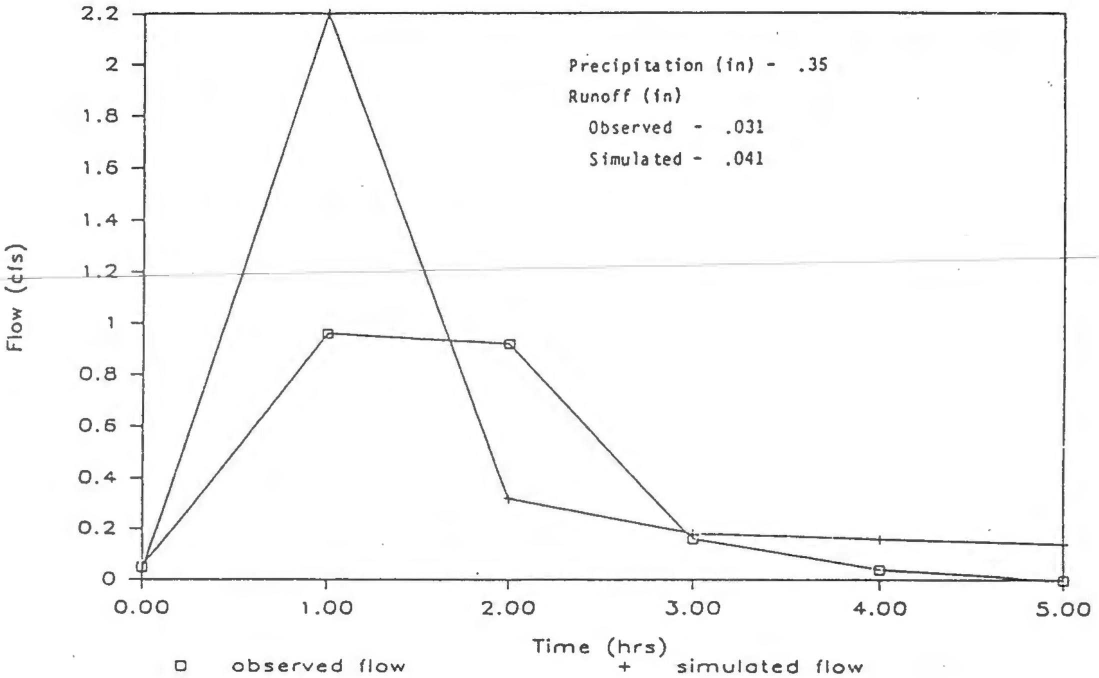

Figure 29: Observed and simulated hydrographs for August 28, 1979.

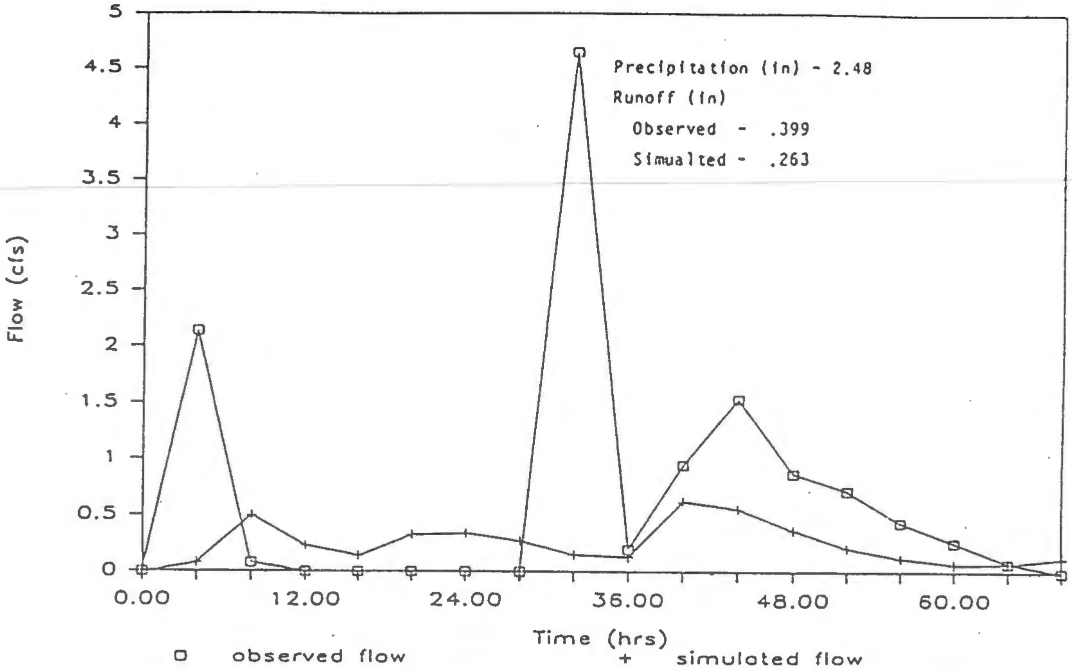

Figure 30: Observed and simulated hydrographs for October 22-24, 1979.

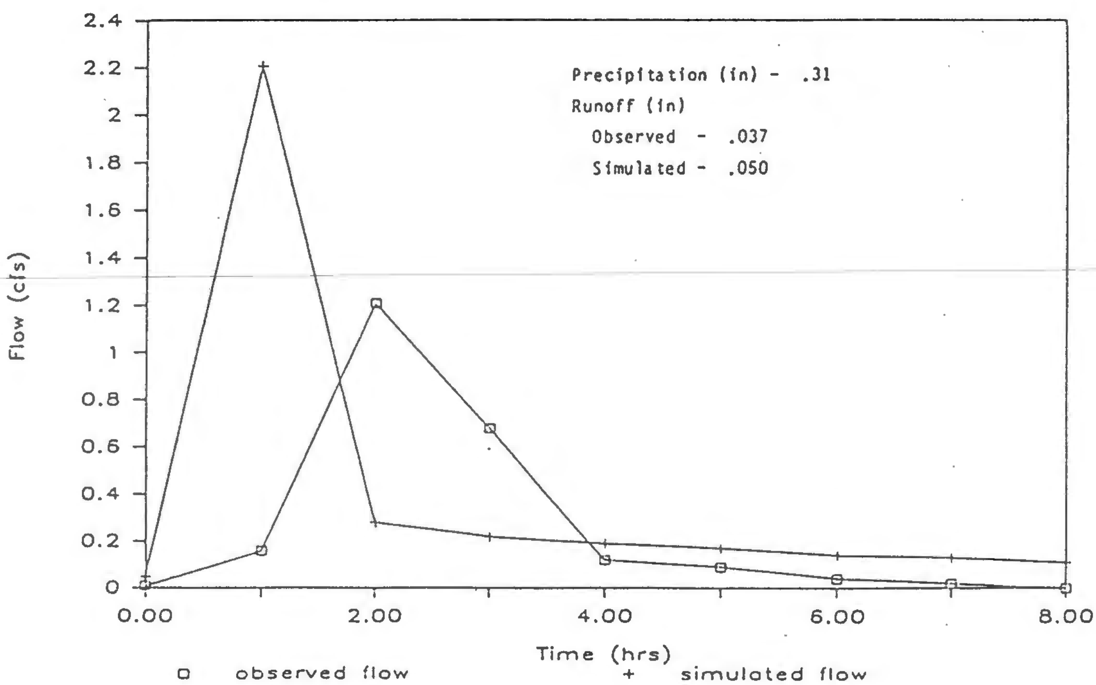

Figure 31: Observed and simulated hydrographs for November 1, 1979.

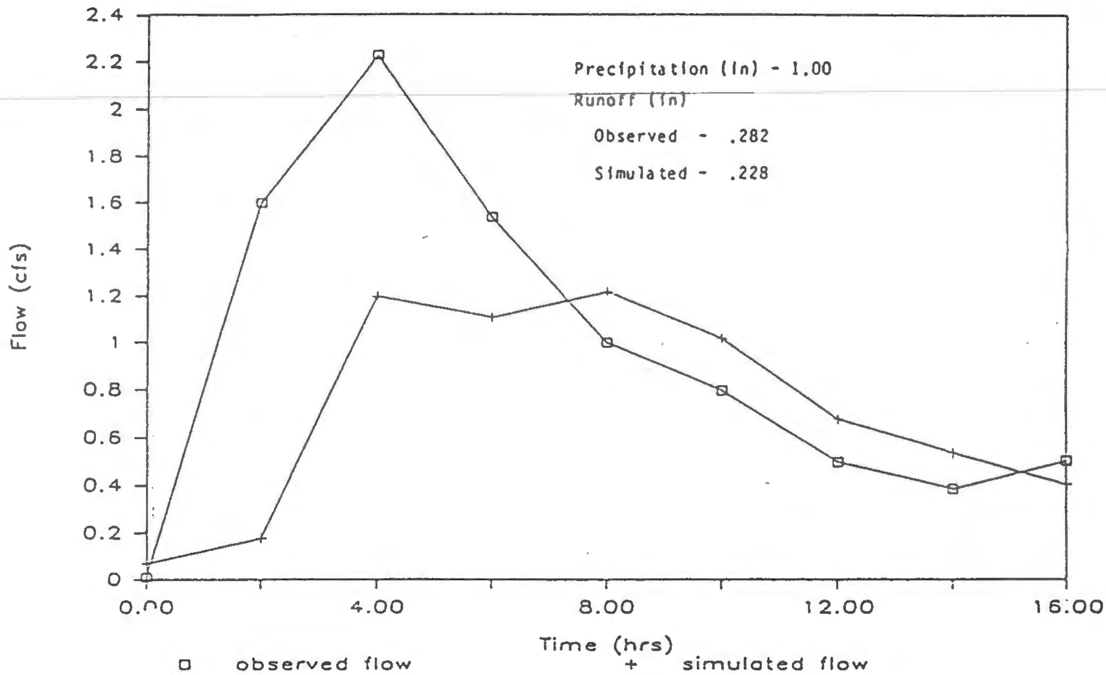

Figure 32: Observed and simulated hydrographs for November 5-6, 1979.