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SIMULATION OF NUTRIENT LOADINGS IN SURFACE RUNOFF WITH THE NPS MODEL

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SIMULATION OF NUTRIENT LOADINGS IN SURFACE RUNOFF WITH THE NPS MODEL

by

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FOREWORD

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient analytical tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Technology Development and Applications Branch develops management or engineering tools to help pollution control officials achieve water quality goals through watershed management.

Techniques for estimating the contribution of various land use activities to nonpoint source pollution are essential to the development of water quality management plans for specific areas. The Nonpoint Source Model, which was developed to simulate pollutant contributions to stream channels for nonpoint sources, was expanded to include nutrients. This report documents the expanded effort and illustrates the additional testing given the model.

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ABSTRACT

The Nonpoint Source Pollutant Loading (NPS) Model was applied to one urban and two small agricultural watersheds to simulate nutrient loadings in surface runoff. Since the NPS Model simulates all nonpoint pollutants as a function of sediment loss, the key question was whether sediment is a reliable indicator of nutrients in surface runoff. Both the literature surveyed and the results of this work indicate Total nitrogen (N) and Total phosphorus (P) can be reasonably simulated in this manner. Also, organic components of N and P can be simulated since they are generally associated with sediment and comprise a major portion of the total nutrients in surface runoff.

Nitrate N (NO_3-N) and phosphate P (PO_4-P) are almost entirely contained in the soluble fraction of surface runoff and are not adequately simulated with the NPS Model. Ammonia N (NH_3-N) appears to be transported in significant amounts both in solution and attached to sediment; thus, the simulation results were inconclusive. Total Kjeldahl N (TKN) was simulated on the urban watershed which was large enough to provide a continuous baseflow. The simulated TKN values agreed reasonably well with recorded values except when baseflow TKN concentrations were high. Over 50% of the annual TKN loading was estimated to originate from the baseflow. Therefore, the NPS Model can simulate total nutrient loadings only in areas where subsurface contributions are minimal. This report was submitted in fulfillment of Grant No. R803315-01-2 by Hydrocomp Inc. under the sponsorship of the Environmental Protection Agency. The work was completed as of October 1976.

CONTENTS

FIGURES

TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS

Fe	-- iron
N	-- nitrogen
NH_3	-- ammonia
NH_3-N	-- nitrogen in the ammonia form
NO_3	-- nitrate
NO_3-N	-- nitrogen in the nitrate form
P	-- phosphorus
PO_4	-- phosphate or orthophosphorus
PO_4-P	-- phosphorus in the phosphate form
TKN	-- total Kjeldahl nitrogen, i.e. organic nitrogen and ammonia nitrogen

ABBREVIATIONS

cm	-- centimeters
cms	-- cubic meters per second
gm/ha	-- grams per hectare
ha	-- hectare
kg/ha	-- kilograms per hectare
m	-- meters
mg/l	-- milligrams per liter
mm	-- millimeters

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance and coordination provided by Mr. Lee A. Mulkey, Project Officer, of the EPA Environmental Research Laboratory in Athens, Georgia. Mr. David M. Cline and Mr. Charlie Smith of the Athens Laboratory were instrumental in supplying the needed data for testing purposes. Their assistance is sincerely appreciated.

At Hydrocomp, Dr. Norman H. Crawford was the principal investigator and Mr. Anthony S. Donigian, Jr. was the project manager. Mr. Harley H. Davis assisted in the literature search and analysis, nutrient data analysis, and model application. Drafting duties were ably performed by Mr. Guy Funabiki and the report was edited and typed by Ms. Donna D'Onofrio.

SECTION 1.0

CONCLUSIONS AND RECOMMENDATIONS

The Nonpoint Source Pollutant Loading (NPS) Model can be used to estimate total nutrient loadings from the land surface of urban and agricultural areas. Test results on a 433-hectare (ha) urban watershed (Third Fork Creek) in Durham N.C. show that simulated Total phosphorus (P) and iron (Fe) concentrations during a storm compare well with recorded values. Total annual loadings for 1972 were within 20% of the values estimated from regression analysis of the data. Simulated Total Kjeldahl nitrogen (TKN) concentrations and loadings were less accurate due to TKN concentrations in baseflow. Since in-stream processes and subsurface pollutant contributions occur in Third Fork Creek and are not simulated in the NPS Model, the size of the watershed approaches the upper limit of applicability of the model.

Where subsurface contributions are significant, the NPS Model should be modified to allow specification of average monthly pollutant concentrations in subsurface flow. If in-stream processes are major, the NPS Model should be interfaced with a stream water quality model. Both of these procedures would be required to simulate nonpoint pollution in large watersheds.

Nutrient concentrations and loadings were also simulated from two small agricultural watersheds (1.3 and 0.8 ha) in Watkinsville, Georgia and East Lansing, Michigan for the 1974 growing season. Total P and Total nitrogen (N) concentrations and loadings were adequately simulated because these nutrient forms are largely associated with the sediment fraction of surface runoff. Ammonia nitrogen (NH_3-N) values were not simulated as well as Total P and Total N since NH_3-N transport in solution was found to be significant. Nitrate nitrogen (NO_3-N) and phosphate phosphorus (PO_4-P) values were not adequately represented because they are transported almost entirely in solution form. Accordingly, the NPS Model should not be used to estimate loadings for these nutrient forms.

Just as Third Fork Creek approaches the upper size limit for the NPS Model, the agricultural watersheds were too small for accurate representation of the hydrologic and sediment characteristics. The NPS Model should only be applied to watersheds for which the 15-minute simulation interval is reasonable. The range of watershed sizes simulated in this study (0.8 to 433 hectares) provides estimates of the upper and lower bounds of applicability.

The nutrient simulation results were obtained by estimating the nutrient potency factors (i.e. nutrient loss/sediment loss x 100%) from observed data and then calibrating the values by comparing simulated and recorded concentrations. The goal was to evaluate the use of sediment loss, as simulated in the NPS Model, as an indicator of nutrient loadings in surface runoff. Further testing and verification should be conducted to see if the potency factors can be estimated, without calibration, as a function of fertilizer applications, management practices, soil characteristics, crop behavior, etc. Only in this way can the NPS Model be effectively applied in areas where little data is available.

The conclusions presented in this report do not mean that soluble nutrient forms are unimportant. In areas where subsurface flow is a major portion of total runoff, soluble nutrient forms may comprise much of the nutrient loading. The literature and results of this work indicate that total nutrient loads in surface runoff are associated largely with sediment. Until research can accurately represent the complex reactions and transformations of nutrient forms in all flow components, the NPS Model can be used to estimate total nutrient loads in surface runoff as a function of sediment loss.

SECTION 2.0

INTRODUCTION

This report presents the results of further testing of the NPS Model to specifically evaluate its applicability for simulating nutrient loadings from urban and agricultural watersheds. The NPS Model has been described in a previous EPA report (1). The reader is referred to the original report on the development and testing of the model which also provides guidelines for its use and application.

The NPS Model was developed to provide a tool to regional, state, and local planning agencies for the evaluation and analysis of nonpoint pollution problems. The model continuously simulates hydrologic processes, including snow accumulation and melt, pollutant accumulation, generation, and washoff from the land surface. Sediment and sediment-like material is used as the basic indicator of nonpoint pollutants. These erosion processes are simulated on both pervious and impervious areas. Pollutant loadings are determined by multiplying the resulting sediment discharge by "potency factors" i.e. pollutant mass/sediment mass x 100 percent, representing the pollutant strength of the sediment. The potency factors are specified for each pollutant by the user as single average values or 12 monthly values; the same potency factors are used throughout the simulation period.

The NPS Model is called a "pollutant loading" model because it simulates the total input or pollutant loading from the land surface to a stream channel or waterbody. Although the hydrologic algorithms simulate all runoff components (surface runoff, interflow, groundwater flow), the present version of the model evaluates only surface pollutant contributions. Subsurface, groundwater pollutants, and channel processes are not considered. For water quality simulation in watersheds where in-stream processes are significant, the NPS Model must be interfaced with a stream water quality model.

Since the NPS Model simulates all pollutants as a function of sediment washoff, the goal of this work was to evaluate how well this assumption works for various compounds of nitrogen (N) and phosphorus (P). A review of the literature has shown the majority of the Total N and Total P in surface runoff from agricultural lands is associated with the sediment fraction. Burwell, et al (2) estimate more than 96% of Total N and 95% of Total P losses in surface runoff from experimental plots [4.05 meters (m) x 22.13 m] in Minnesota were transported by sediment. These values pertain to plots managed as continuous fallow, continuous corn, and rotation corn. Plots managed as rotation hay produced little sediment loss with all of the runoff nutrients occurring in soluble form. However, the absolute value of soluble nutrient losses were low for all the experimental plots. Organic N on sediment was the predominant nitrogen form, except during snowmelt periods when nitrate nitrogen (NO_3-N) was prevalent. Ammonia nitrogen (NH_3-N) losses occurred both on sediment and in solution in almost equal proportions. Phosphorus losses were measured largely as Total P on sediment except for some Ortho-P (PO_4-P) and Total P in solution during snowmelt. In general, soluble nutrient losses occurred during the snowmelt period which produces most of the annual runoff.

Kissel, et al (3) noted similar results for nitrogen losses from duplicate 4-hectare (ha) watersheds in Texas. Runoff samples collected over a 4-year period indicate 85% and 77% of Total N was transported by sediment from the two watersheds planted on a rotation of grain sorghum, cotton, and oats. Johnson, et al (4) found that 80% of the Total P losses from a 330 km rural watershed in central New York were attached to the suspended solids measured in the stream. Most of the solid phase P was insoluble phosphate compounds and organic P. Using simulated rainfall on plots in Indiana, Romkens, et al (5) found high percentages of total nutrients in surface runoff were components of sediment under five different tillage systems. However, tillage practices that reduced sediment loss would also reduce sediment associated nutrient losses, but would increase the soluble nutrients in the surface runoff. An almost linear relationship (referred as "curvilinear") was established between sediment loss and sediment-associated N and P losses. On four watersheds (30 to 60.8 ha) in Southwestern Iowa, Schuman, et al (6) observed the percent of Total N losses associated with sediment was 92% for contour-planted corn watersheds and 51% for pasture watersheds. However, Total N losses from the pasture watershed was only 7.6% of the contour-planted watershed. Annual soluble N losses were low from all four watersheds during the 3-year study.

Urban watersheds have not been as extensively monitored for the transport mechanisms of nutrient losses as have agricultural areas. In a study on nutrient loadings to a lake from urban residential land, Kluesener (7) and Kluesener and Lee (8) noted a striking similarity between the measured Total Solids concentrations and the Organic N and Total P concentrations during storm events. Sediment appeared to be the major transport mode for these constituents. Organic N was responsible for 77% of the Total N loading. Data presented by Cowen et al (9) for the same area showed Organic N was commonly associated with particulate matter. In a major study in Durham, N.C., Colston (10) extensively sampled solids, nutrients, organics, and metals from a mixed land-use urban watershed for an 18-month period. Colston's data showed a close correlation between Total Kjeldahl N (TKN), Total P, and the solids concentration. The more soluble nutrient forms (e.g. NO_3, PO_4, NH_3) were not analyzed so no indication of their relative importance was possible.

In summary, the literature appears to indicate sediment can be used as a reasonable indicator of nutrient loadings by surface runoff from agricultural and urban lands. However, soluble nutrient losses can be significant in watersheds where subsurface discharge is a major component of the runoff. Burwell, et al (11) found subsurface transport of soluble N accounted for 80% of the Total N loss from level-terraced and pasture watersheds. But looking only at the surface runoff from those same watersheds, 75-80% of the surface N losses occurred on the sediment. The intent of this investigation was to evaluate the use of sediment as an indicator of nutrient loadings in surface runoff as formulated in the NPS Model. Section 3.0 describes the three test watersheds and Section 4.0 presents the simulation results. Estimating nutrient potency factors is discussed in Section 6.0 and general value ranges are included. The appendices provide a description of the minor modifications to the NPS Model performed during this study, correction of errors noted in the NPS Model report, and a new listing of the NPS Model.

SECTION 3.0

TEST WATERSHEDS

Simulation of nutrient loadings with the NPS Model was performed on one urban watershed and two small agricultural watersheds. The urban watershed is the Third Fork Creek in Durham, N.C. and the agricultural watersheds are the P2 watershed in Watkinsville, Georgia and the P6 watershed in East Lansing, Michigan. These watersheds were chosen because of data availability and previous simulation work. Third Fork Creek was one of the test areas for the NPS Model development work and the P2 and P6 watersheds are test sites for continuing research work on the simulation of pesticides and nutrients on agricultural lands (12).

Third Fork Creek represents a typical urbanized area in the Piedmont region of the Southeastern United States. The basin encompasses a variety of land uses in the general categories of residential (60%), commercial (17%), industrial (13%), and open land (10%). Upper Third Fork Creek, simulated in this study, drains an area of 433 ha located within the city limits of Durham, North Carolina (Figure 1). The watershed contains approximately 30% impervious land and has been the subject of urban runoff studies by Colston (10) and Bryan (13). The NPS Model report (1) provides a complete description of Third Fork Creek and the data used in simulation.

P2 and P6 are small experimental agricultural watersheds on which recent data collection and analysis programs have been sponsored by the U.S. Environmental Protection Agency. In cooperative agreements with the USDA Southern Piedmont Conservation Research Center (Watkinsville, Georgia) and Michigan State University's Department of Crop and Soil Science and Department of Entomology, the Environmental Research Laboratory in Athens, Georgia directed these programs. Instrumentation was established for continuous monitoring of meteorologic conditions and continuous sampling of runoff and sediment from the experimental watersheds. The collected samples and periodic soil cores were analyzed for both pesticide and nutrient content. Field operations, chemical applications, and crop growth were monitored on four watersheds in Georgia and two watersheds in Michigan. The general goal is to provide extensive data for the development of simulation models for evaluating nonpoint pollution from agricultural lands and the impact of land management practices. These programs and model development are described in a report by Donigian and Crawford (12).

P2 (Figure 2) and P6 (Figure 3) are small natural watersheds draining 1.3 and 0.8 ha respectively. Both watersheds were planted to corn in 1974 with

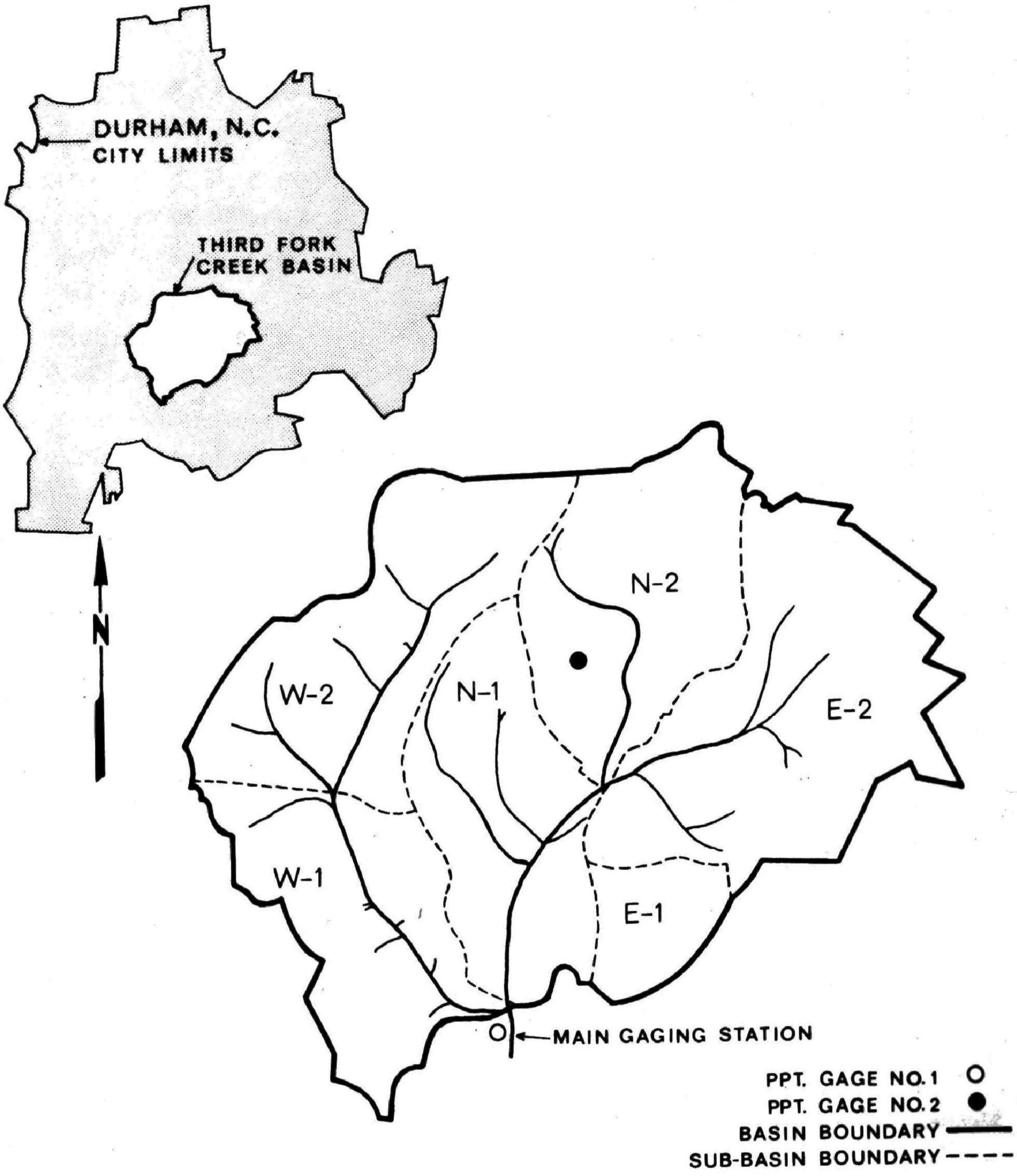

Figure 1. Third Fork Creek, Durham, North Carolina

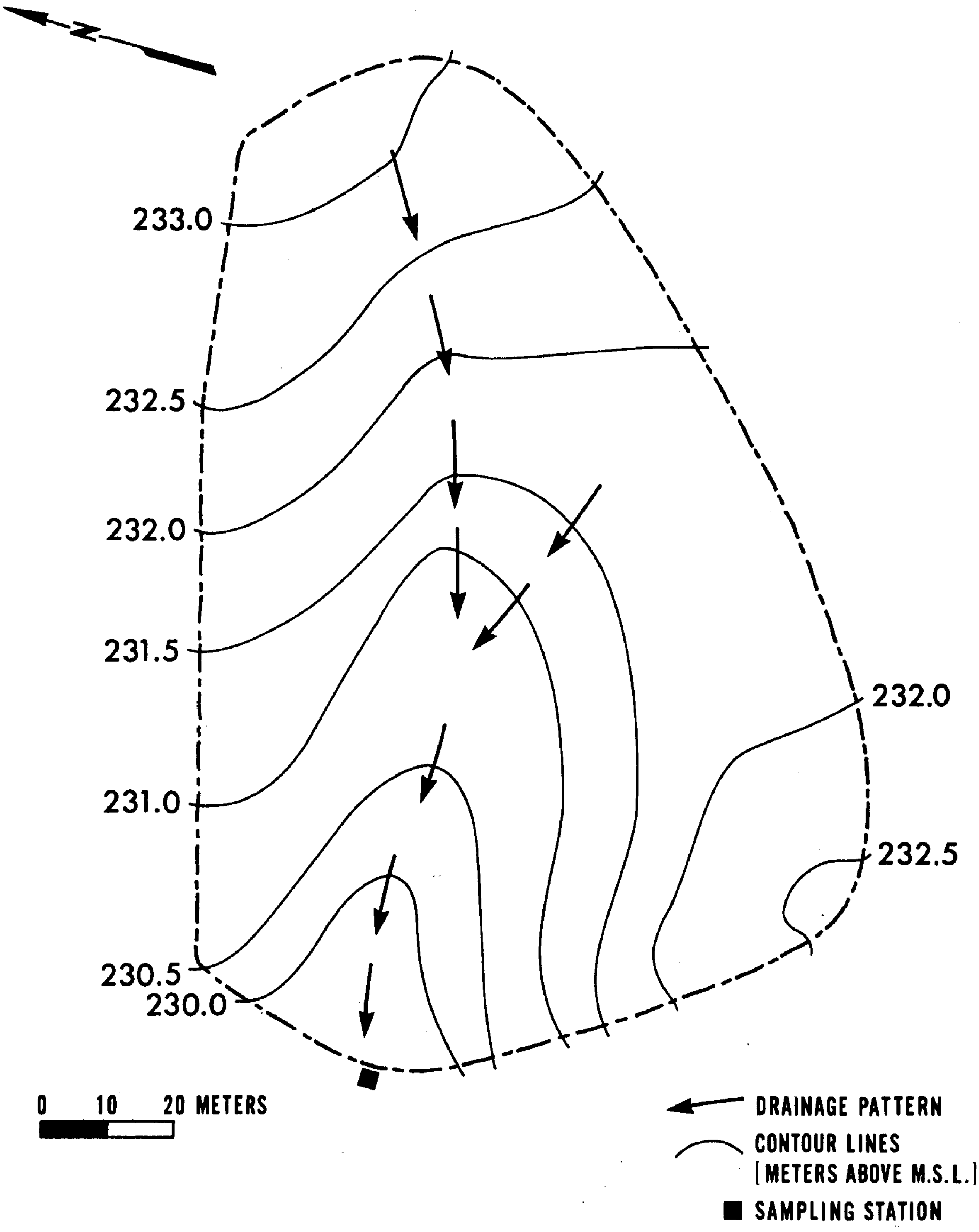

Figure 2. P2 Watershed, Watkinsville, Georgia (1.3 ha)

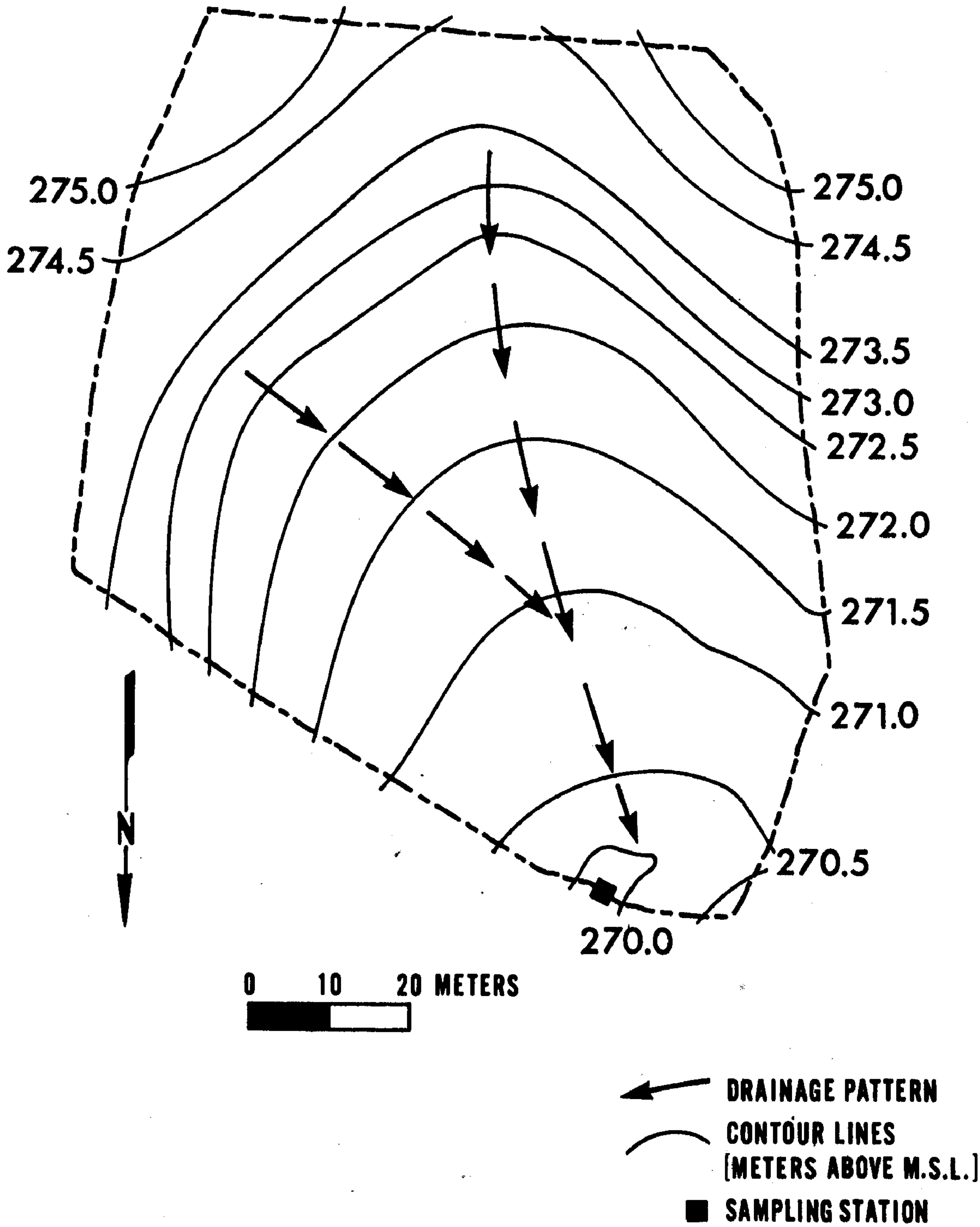

Figure 3. P6 Watershed, East Lansing, Michigan (0.8 ha)

fertilizer applications prior to planting and six weeks following. Table 1 lists the fertilizer application dates and amounts. The P2 watershed has an average slope of 2.5% and is comprised of Cecil sandy loam. The P6 watershed has a 6% slope with a variety of soil types including Spinks sandy loam and Travers, Hillsday, and Tuscola loam. Minimum tillage practices were followed on both watersheds with tillage operations performed only prior to planting.

TABLE 1. FERTILIZER APPLICATIONS ON THE P2 AND P6 WATERSHEDS IN 1974

Watershed	Date	N (kg/ha)	P (kg/ha)
P2 Watershed	4/29/74 (planting)	38	33
	6/11/74	112	-
P6 Watershed	5/20/74 (planting)	68	93
	7/8/74	130	-

SECTION 4.0

NUTRIENT SIMULATION RESULTS

The NPS Model was applied to each of the watersheds described in Section 3.0 for the period of available nutrient data. Monthly potency factors for various nutrient forms were calculated from the observed data. These initial values for the potency factors were adjusted slightly to improve agreement between simulated and observed nutrient washoff. The simulation results are discussed below for each watershed.

THIRD FORK CREEK, DURHAM, N.C.

Runoff, sediment, and nutrient loadings for Third Fork Creek were simulated for an 18-month period from October 1971 through March 1973. Simulated loadings of sediment (measured as Total Solids), TKN, Total P, and Fe are shown in Figure 4 and listed in Table 2. The hydrologic and sediment calibration was discussed in the NPS Model report and will not be repeated here. The variation in sediment and nutrient loadings shown in Figure 4 reflects the use of sediment as a pollutant indicator in the NPS Model. Since only selected storms were sampled on Third Fork Creek during the 18-month period, observed monthly loading values were not available for comparison with the simulation results. However, Colston (10) did estimate the 1972 pollutant loadings from regression equations developed from data on the 36 sampled storm events and extended to all 66 events that occurred on Third Fork Creek in 1972. The predicted loadings were then adjusted to correct a bias in the automatic sampling technique due to location of the equipment at the streambed. Because Third Fork Creek experiences a groundwater contribution, the pollutant loadings of the baseflow were estimated from analysis of periodic grab samples. Table 3 compares the NPS Model simulated pollutant loadings for 1972 with Colston's estimates. Since the NPS Model simulates only surface pollutant contributions, the simulated values should be compared with the storm runoff estimates. Except for TKN the simulated loadings are within 20% of Colston's estimates. This agreement is reasonably good considering the bias in the sampling technique, the regression method of estimation used by Colston, and the effects of in-stream processes and groundwater contributions neglected in the NPS Model. The over-simulated TKN loading is partially a result of calibrating the NPS Model potency factors with the storm-event data (discussed below). Over 50% of the total annual TKN loading originates from baseflow, according to Colston's estimates. Consequently, potency factors calibrated on storm events which include both surface runoff and groundwater would over-estimate the surface runoff contribution. Subsurface and groundwater flow paths appear to be significant for TKN

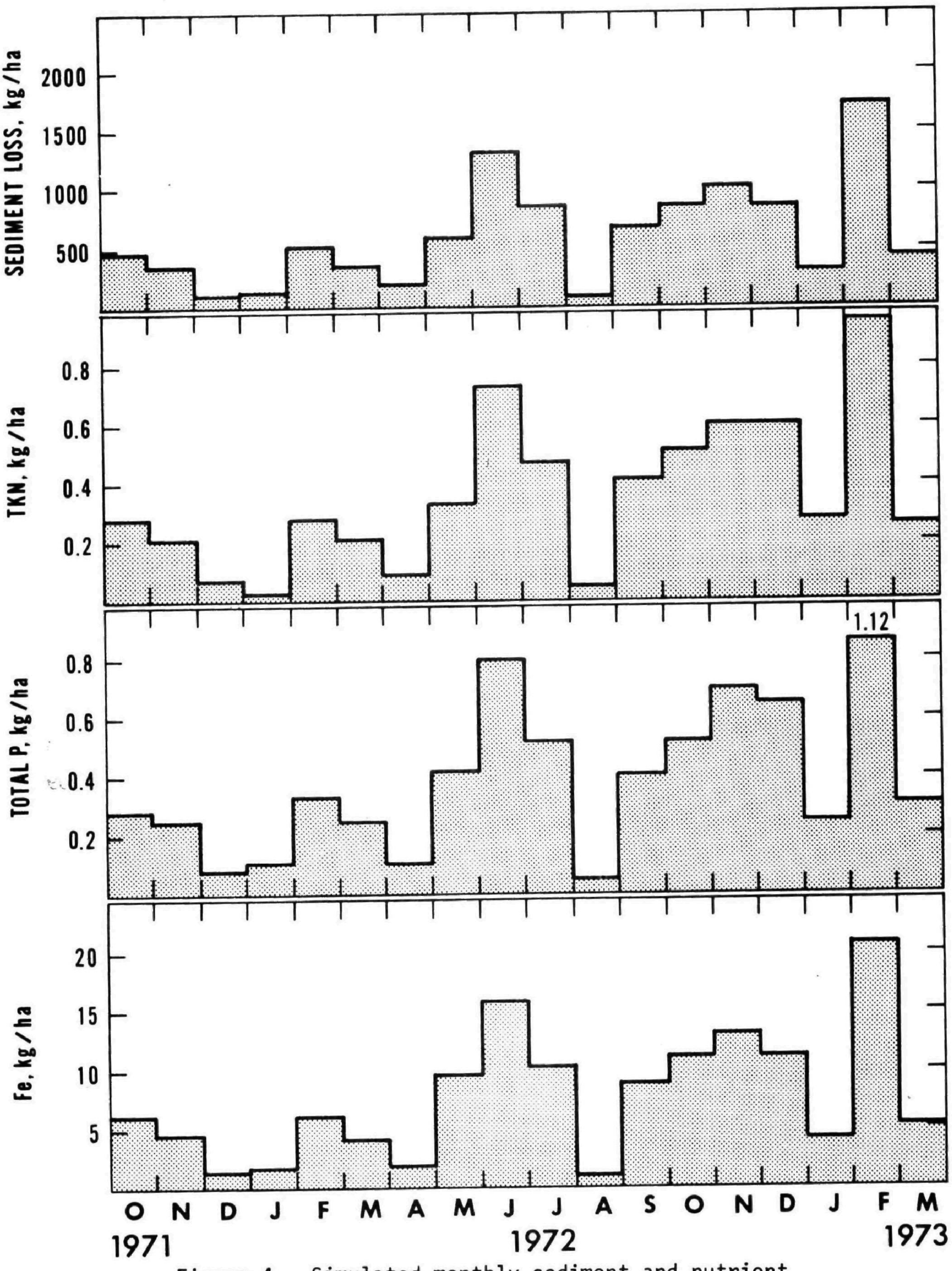

Figure 4. Simulated monthly sediment and nutrient loss from Third Fork Creek.

TABLE 2. SIMULATED MONTHLY SEDIMENT AND NUTRIENT LOSS FROM THIRD FORK CREEK

Month	Sediment kg/ha	TKN kg/ha	Total P kg/ha	Fe kg/ha
1971				
October	473	0.28	0.28	6.15
November	352	0.21	0.25	4.58
December	105	0.07	0.08	1.36
1972				
January	133	0.12	0.11	1.73
February	513	0.28	0.33	6.15
March	353	0.21	0.25	4.23
April	154	0.09	0.11	1.85
May	597	0.33	0.42	7.16
June	1326	0.73	0.80	15.91
July	861	0.47	0.52	10.33
August	90	0.05	0.05	1.09
September	686	0.41	0.41	8.91
October	858	0.51	0.52	11.15
November	1002	0.60	0.70	13.02
December	860	0.60	0.65	11.18
1973				
January	314	0.28	0.25	4.08
February	1730	0.95	1.12	20.76
March	439	0.26	0.31	5.26
Total	10846	6.45	7.16	134.90
Total for 1972	7433	4.40	4.87	92.71

loadings in Third Fork Creek; these contributions are not evaluated in the NPS Model.

TABLE 3. 1972 ANNUAL POLLUTANT LOADINGS IN URBAN RUNOFF FROM THIRD FORK CREEK (kg/ha)

	Estimated by Colston (10) Total	Base Flow	Storm Runoff	NPS Model Simulation Surface Runoff	% Difference[a]
Sediment	8624	672	7952	7433	-6.5
TKN	6.8	3.7	3.1	4.4	+41.9
Total P	5.3	1.0	4.3	4.9	+14.0
Fe	114.5	2.5	112	92.7	-17.2

[a] $\% \text{ Difference} = \frac{\text{NPS Model Simulation - Storm Runoff from Colston}}{\text{Storm Runoff from Colston}} \times 100\%$

Figures 5 through 14 present simulated and recorded data for five of the storms used in calibrating the nutrient potency factors on Third Fork Creek. Runoff and sediment loss for each storm are included in Figures 5, 7, 9, 11, and 13 to provide a basis for evaluating the nutrient simulation results. TKN, Total P, and Fe simulation results are shown in Figures 6, 8, 10, 12, and 14, except Fe was not measured in the storm of October 5, 1972 (Figure 14). Although the NPS Model simulates all streamflow components (surface runoff, interflow, groundwater), only surface pollutant loadings are evaluated. Also, in-stream processes are not considered in the model although such processes do occur in the Third Fork Creek watershed. (The possible impact of in-stream processes was discussed in the NPS Model report). These factors should be kept in mind when reviewing the simulation results.

Analysis of the results for Third Fork Creek indicate the following points:

(1) Total P and Fe concentrations are relatively close to recorded values for the majority of the storms. Also, the shape of the Total P and Fe curves is similar to the sediment curve indicating sediment as the significant transport medium.

(2) TKN concentrations show considerable variation from storm to storm. For the January 10 storm (Figure 6), the shape of the TKN curve is similar to the sediment curve (Figure 5) but the recorded values are twice the simulated TKN values. Since the same potency factor is used for all storms that occur in the same month, the remaining data for January did not warrant increasing the potency factor. Baseflow samples on January 5, January 19, and January 26 contained TKN concentrations of 1.2, 2.9, and 2.9 mg/l respectively. Also similar measurements during November and December 1971 produced TKN concentrations of up to 9.0 mg/l. These values are generally much higher than ones observed during storm events. Colston noted that the high TKN concentrations in two December 1971 storms were believed to

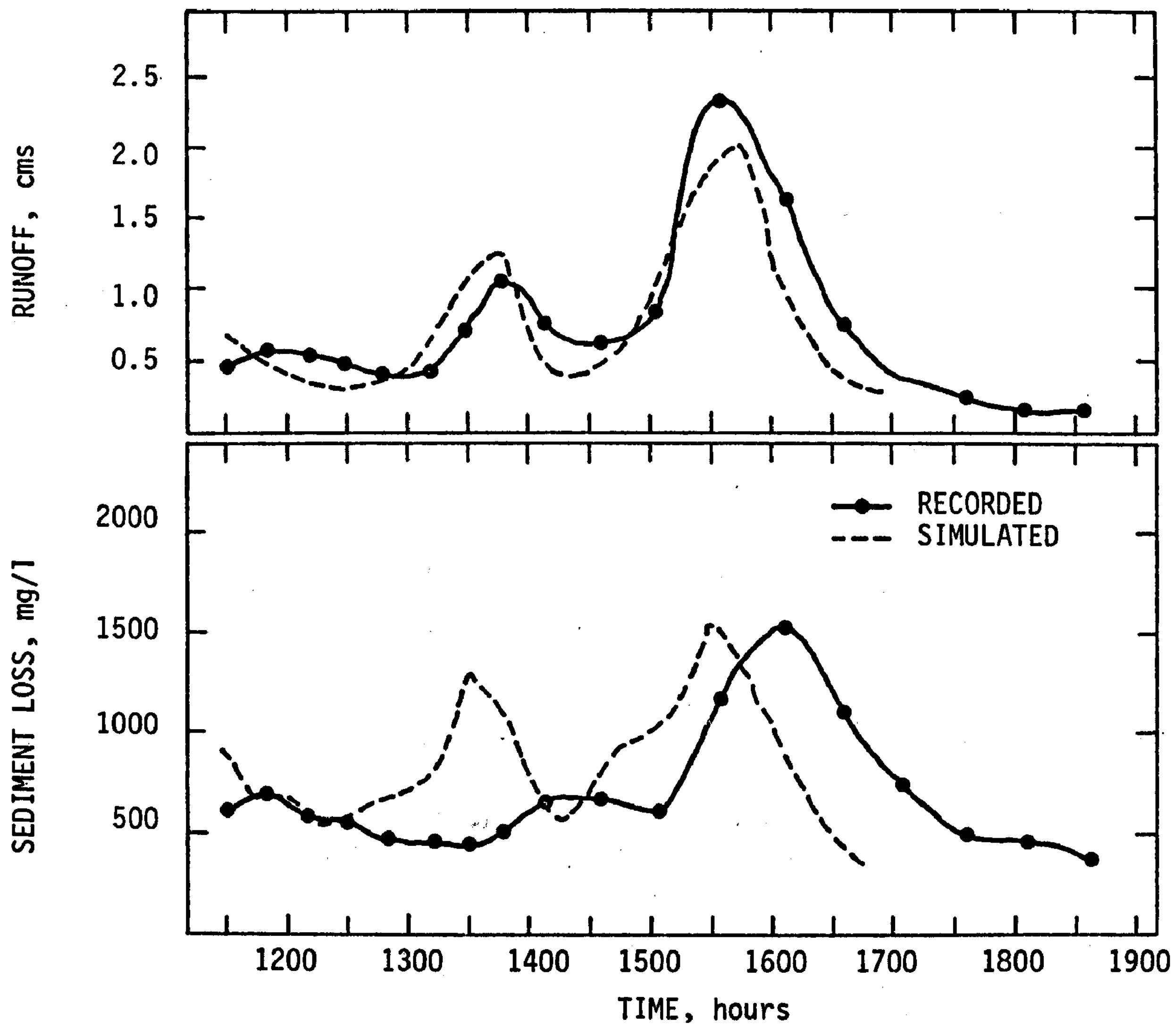

Figure 5. Runoff and sediment loss for Third Fork Creek for the storm of January 10, 1972.

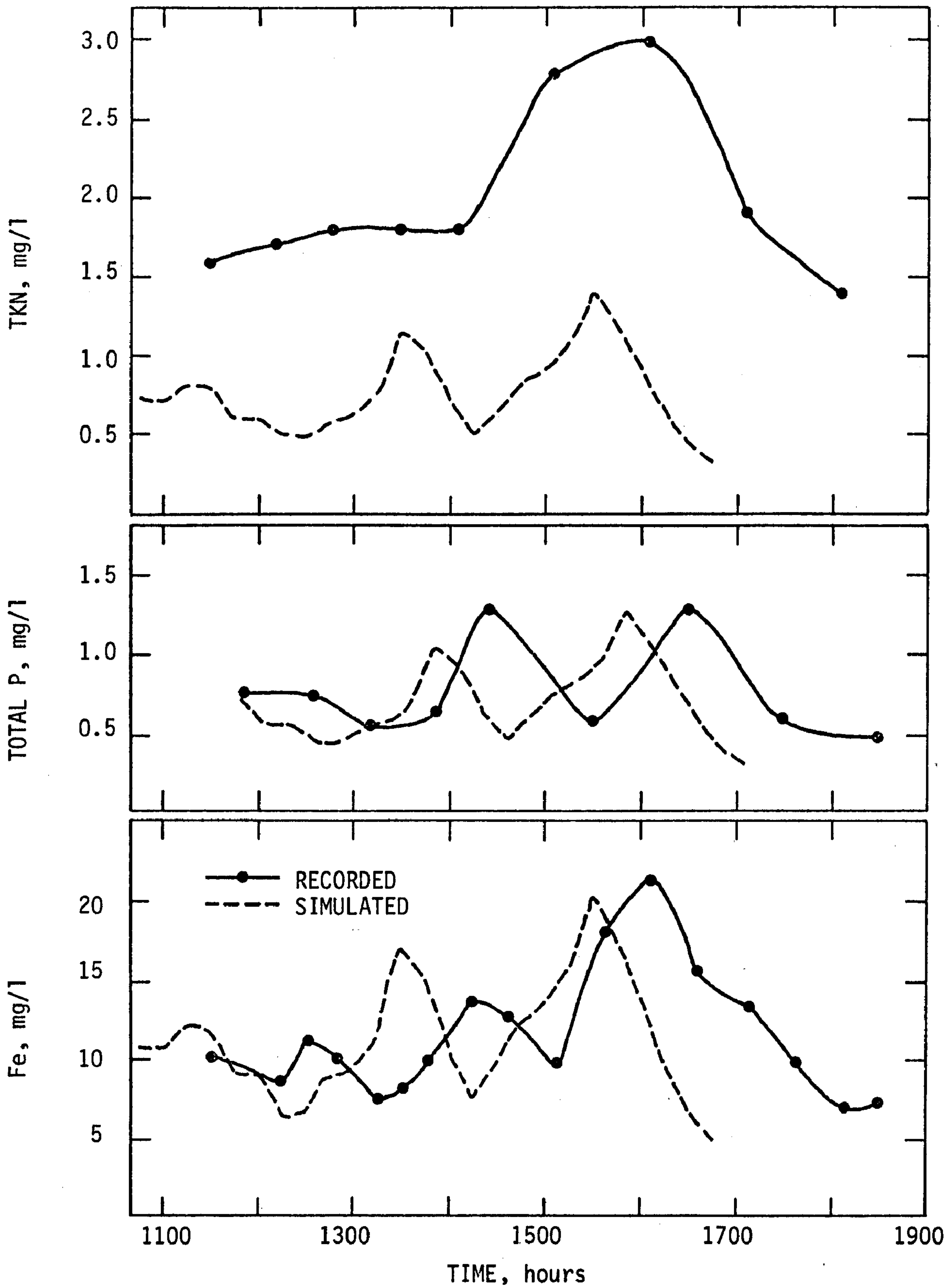

Figure 6. TKN, Total P, and Fe concentrations for Third Fork Creek for the storm of January 10, 1972.

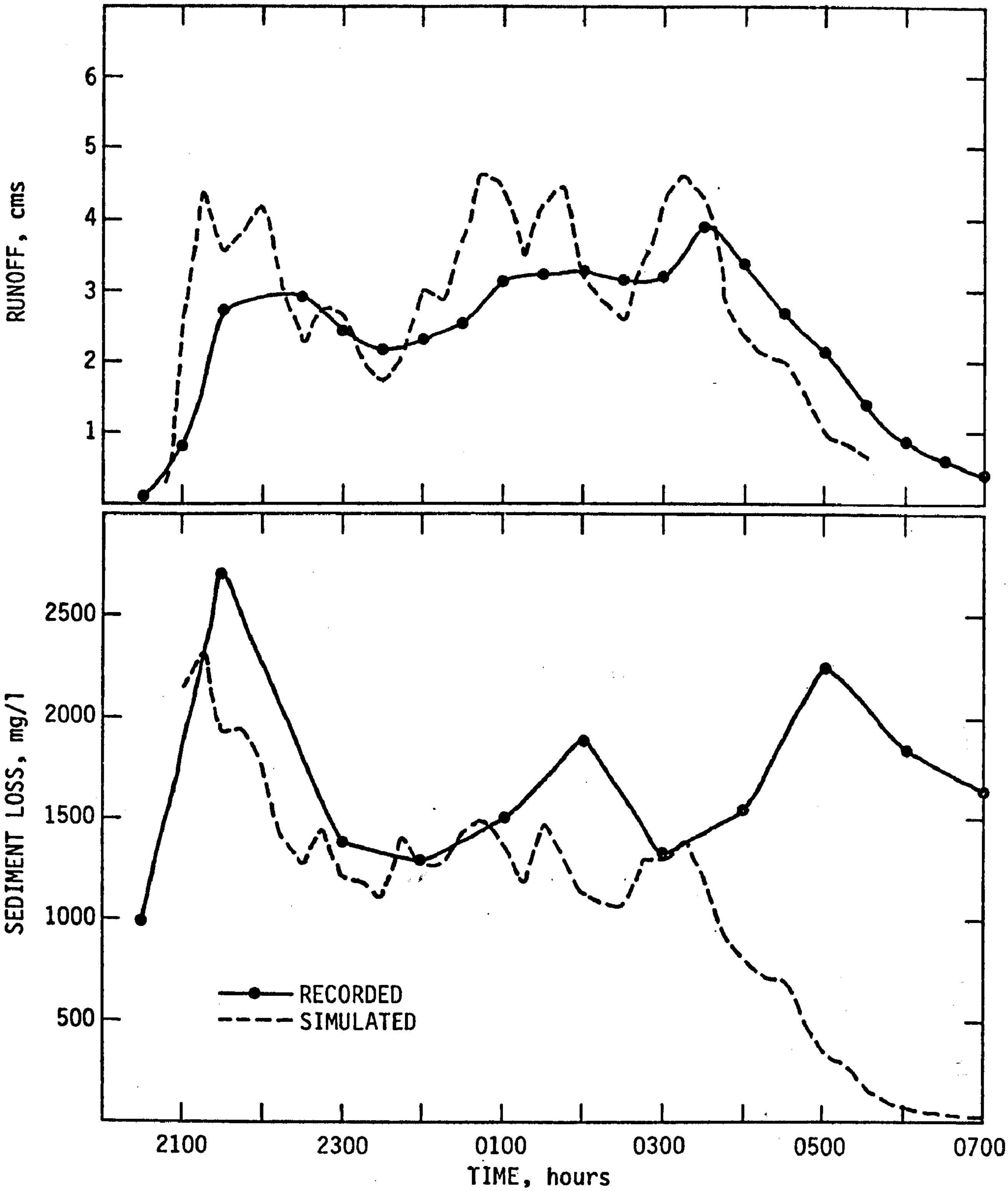

Figure 7. Runoff and sediment loss for Third Fork Creek for the storm of February 1, 1972.

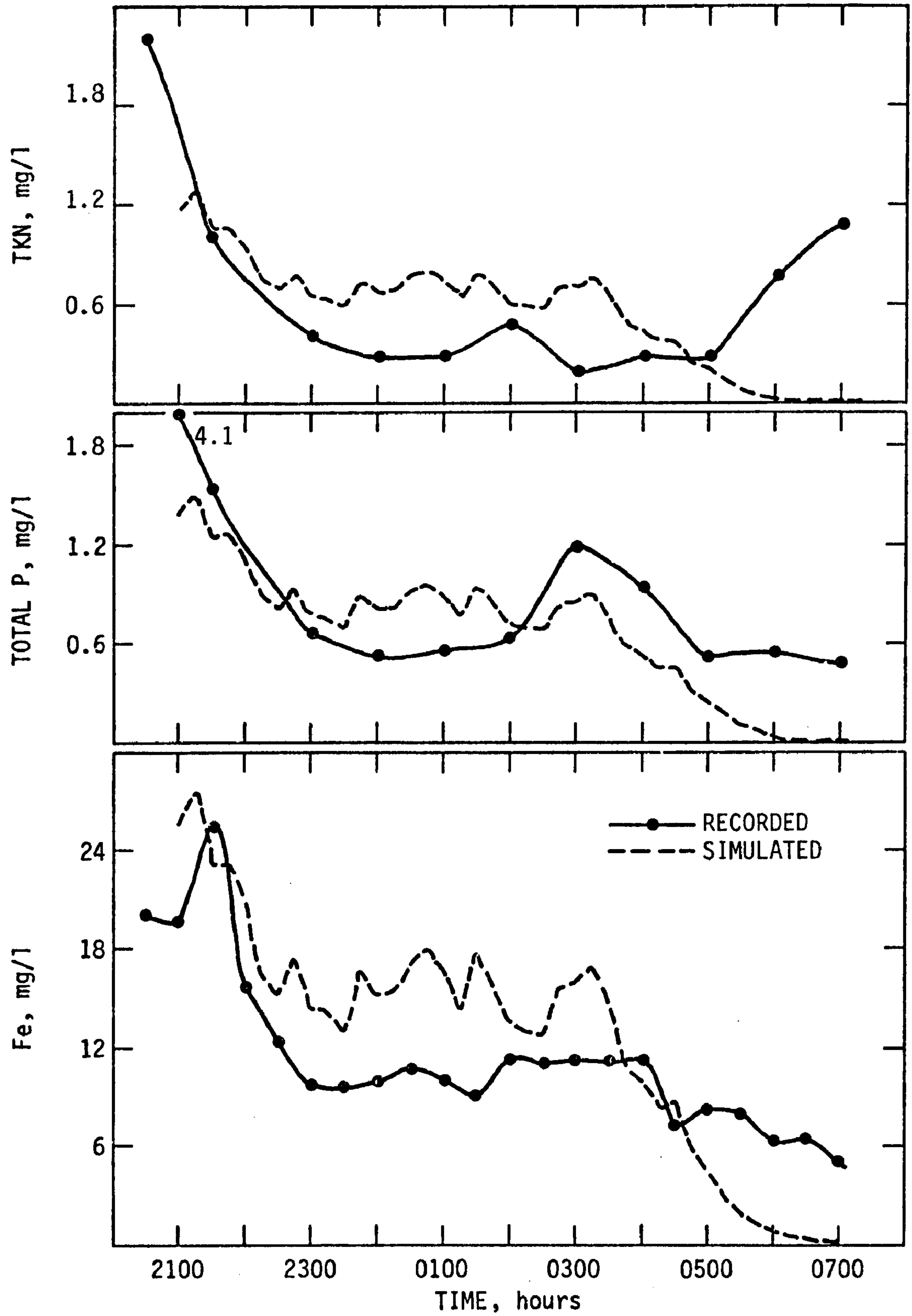

Figure 8. TKN, Total P, and Fe concentrations for Third Fork Creek for the storm of February 1, 1972.

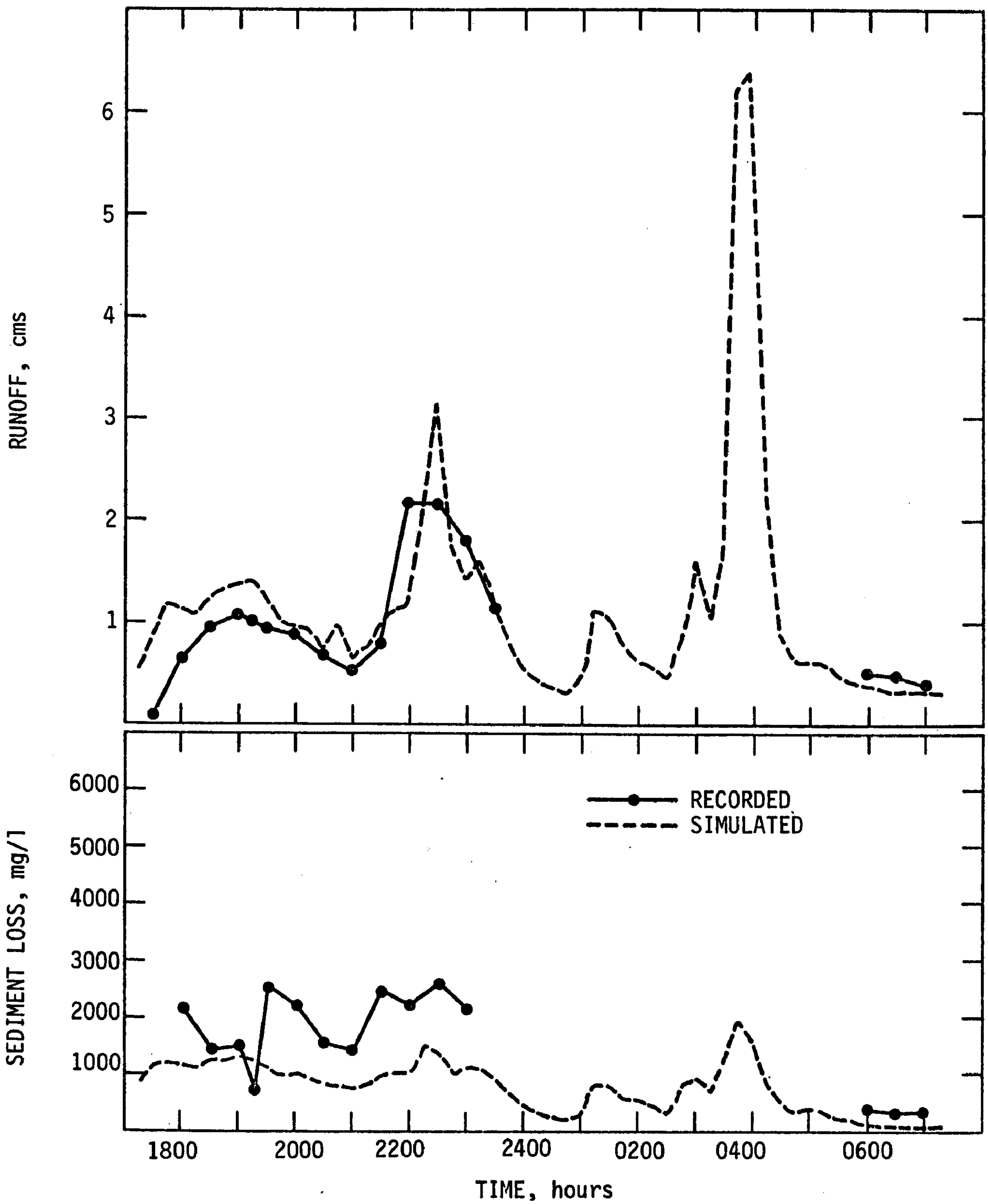

Figure 9. Runoff and sediment loss for Third Fork Creek for the storm of February 12, 1972.

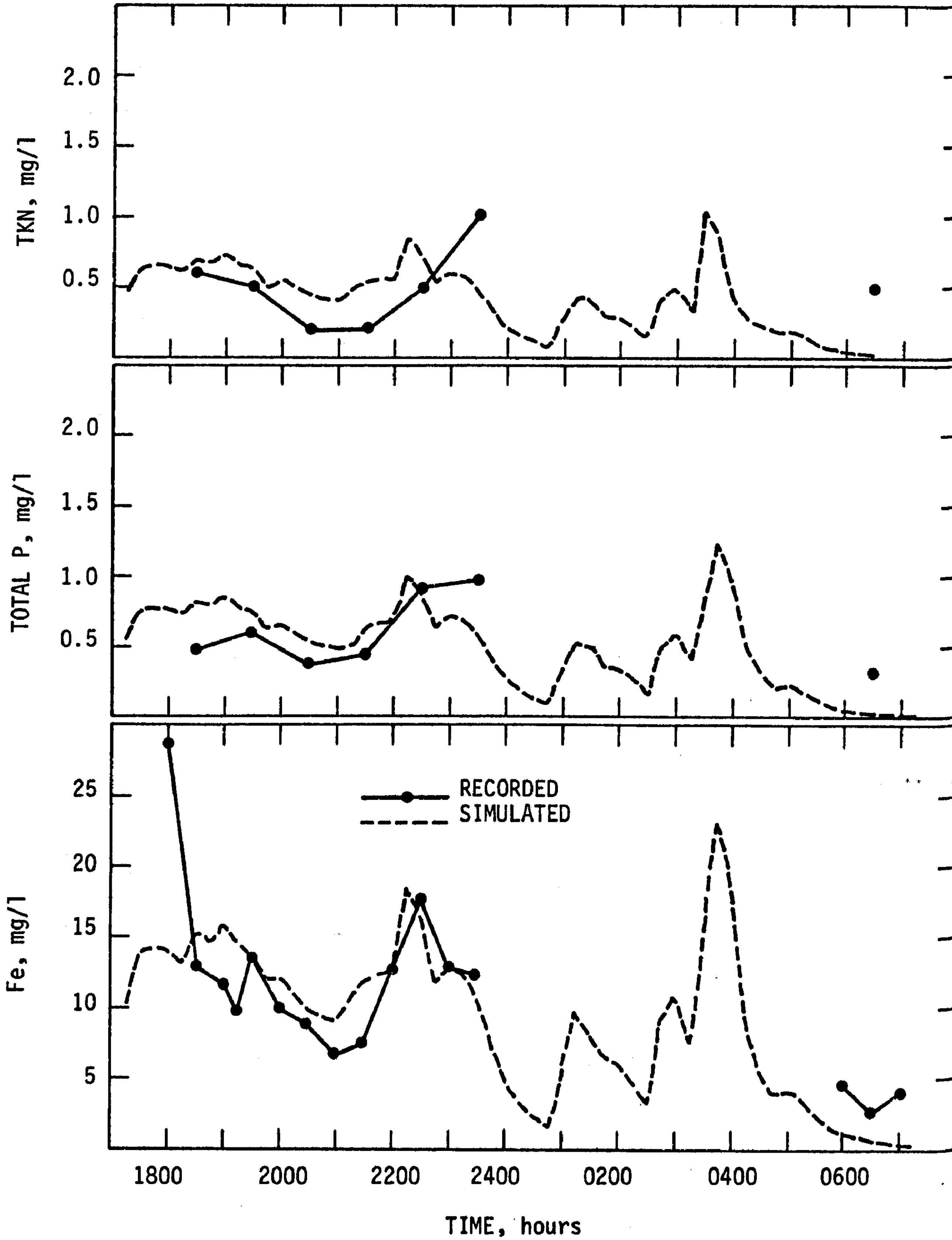

Figure 10. TKN, Total P, and Fe concentrations for Third Fork Creek for the storm of February 12, 1972.

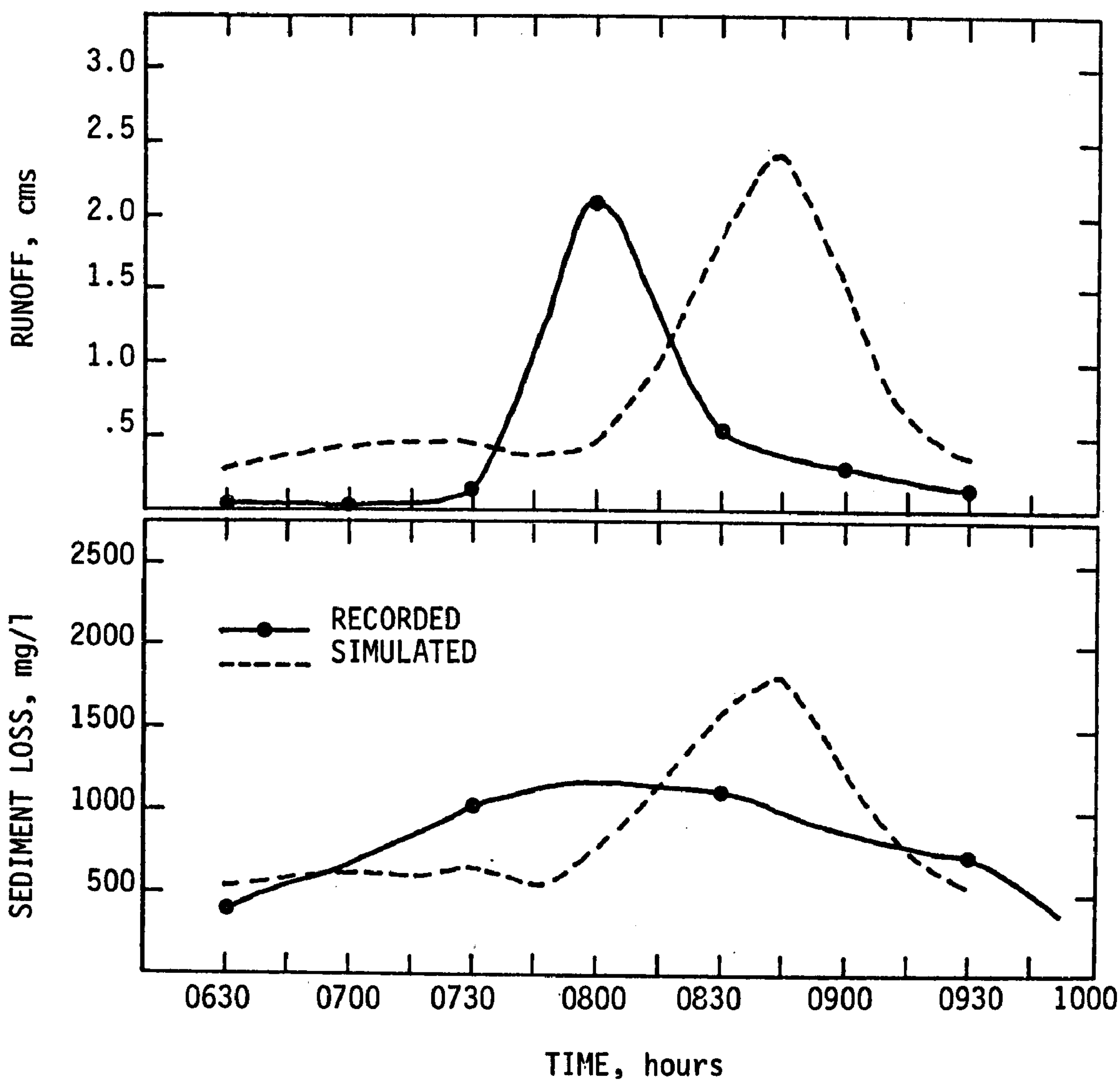

Figure 11. Runoff and sediment loss from Third Fork Creek for the storm of June 20, 1972.

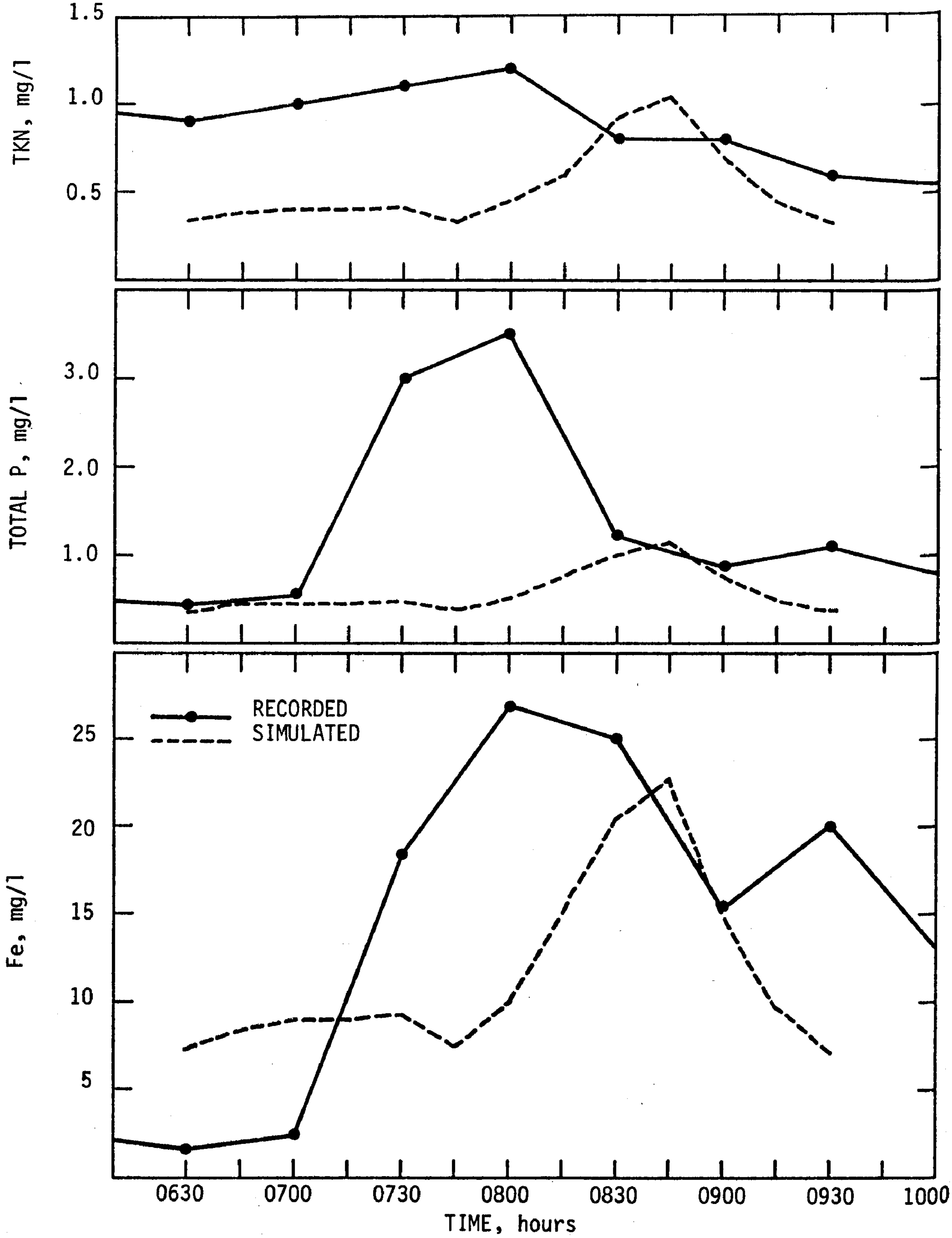

Figure 12. TKN, Total P, and Fe concentrations for Third Fork Creek for the storm of June 20, 1972.

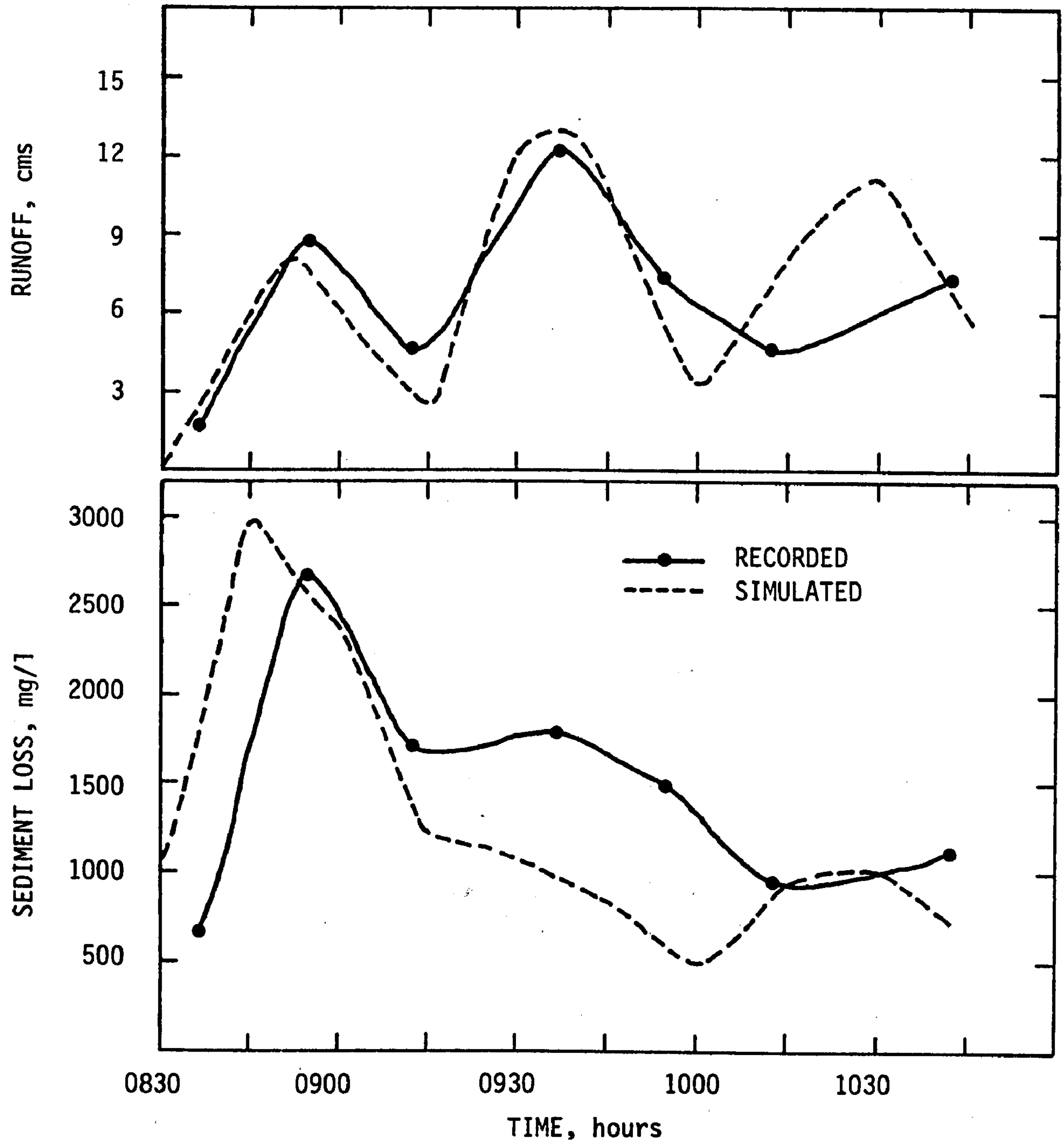

Figure 13. Runoff and sediment loss for Third Fork Creek for the storm of October 5, 1972.

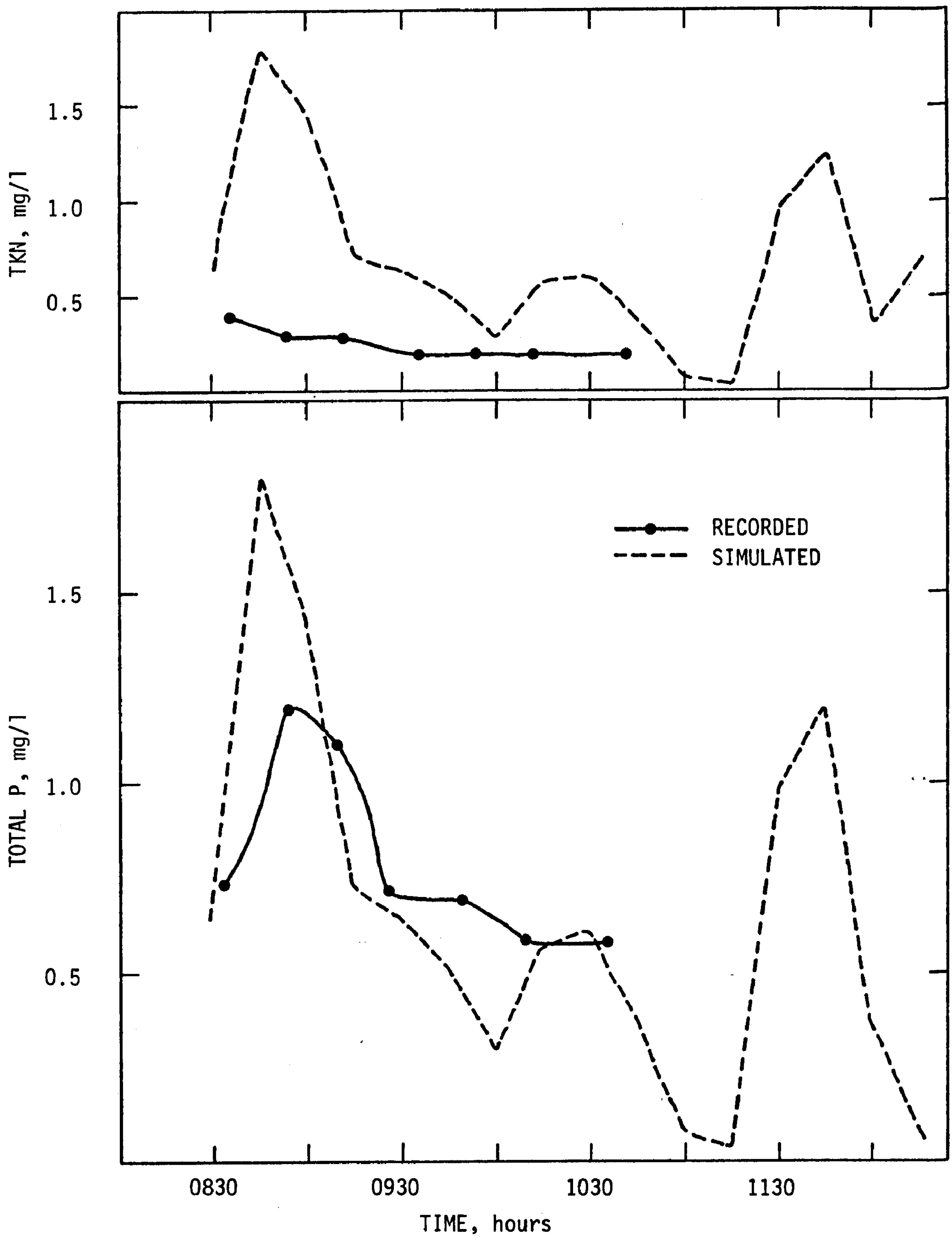

Figure 14. TKN and Total P concentrations for Third Fork Creek for the storm of October 5, 1972.

be erroneous. Thus, the high recorded values for January 10 could be due to unusual conditions and/or sampling/analysis errors.

(3) The TKN concentrations during February storms (Figures 8 and 10) are well represented by the simulation. Since the storms occur in the same month, the same potency factor for TKN was used. On the other hand, the October 5 storm (Figure 14) produced TKN concentrations reminiscent of baseflow; very little variation was recorded throughout the storm. Consequently, the simulated and recorded TKN concentrations for the October storm differ considerably with no apparent explanation.

(4) The February 1 storm (Figure 8) shows the impact of baseflow pollutant contributions. High TKN concentrations occurred at the beginning and end of the storm when flow was minimal and likely originating from subsurface and groundwater sources. Since baseflow TKN concentrations were high during this period (1.0 to 3.0 mg/l), the effect of the storm runoff was to dilute the baseflow contribution.

(5) The simulation results for the June 20 storm (Figures 11 and 12) demonstrate a number of problems that should be noted when comparing simulated and observed values. The runoff volume and peak flow are reasonably close except for a 1½ hour discrepancy in the timing of the peak. Unless such differences occur consistently throughout the simulation period, they can usually be assigned to errors in the recorded time of either the input precipitation or the observed streamflow. Although the recorded sediment data does not closely correspond to the simulated values, the major reason for this is the lack of observed data points between 7:30 and 8:30 when the peak flow occurred. Total P, Fe, and suspended solids (not shown) had peak concentrations at 8:00; therefore, one would expect the sediment to behave in a similar fashion. A peak sediment concentration at 8:00 would have improved agreement between simulated and recorded values, although the timing error remains.

    The nutrient simulation results for June 20 are similar to the results for the other storms except for greater differences between simulated and recorded values. Total P and Fe closely correspond to the "expected" sediment curves. The unusually high Total P concentrations are not substantiated in other summer storms; thus, the simulated values are low. The TKN concentrations show little variation with flow or sediment resulting in differences between the simulated and recorded values.

The simulation results for Third Fork Creek indicate the NPS Model, using sediment as a pollutant indicator, can reasonably represent Total P and Fe loadings from the land surface. Other constituents (e.g. micronutrients, heavy metals) behaving in a similar fashion would likely show similar accuracy. The TKN concentrations were not represented as well as Total P and Fe due in part to TKN concentrations in baseflow. Since pollutant concentrations in baseflow are less variable than in surface runoff, the NPS Model could be modified to allow input of monthly values for pollutant concentrations occurring in the baseflow. Such a modification would likely improve simulation results in watersheds where a groundwater flow component is present.

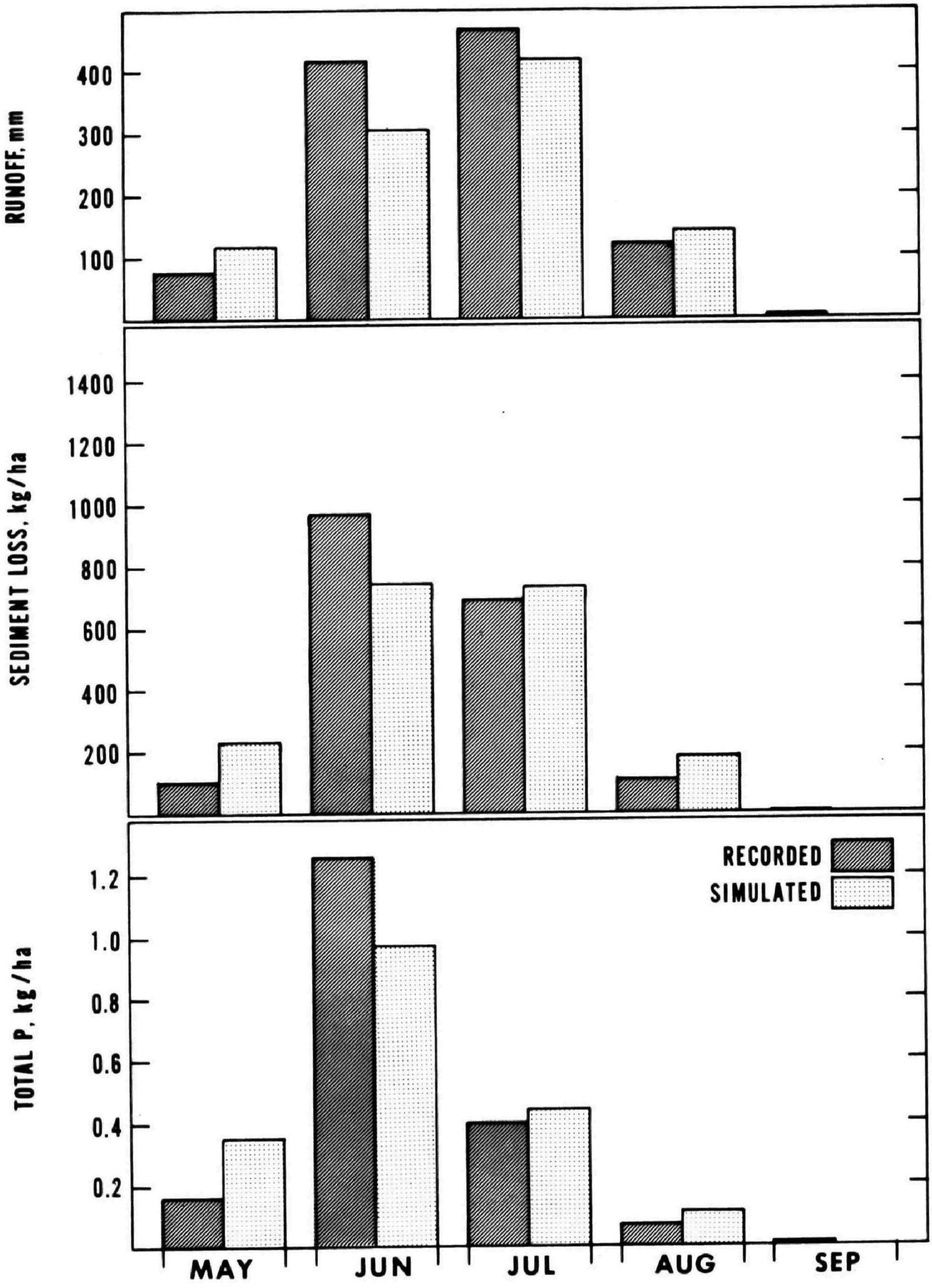

Figure 15. Monthly runoff, sediment and Total P loss from the P2 watershed (May-September 1974).

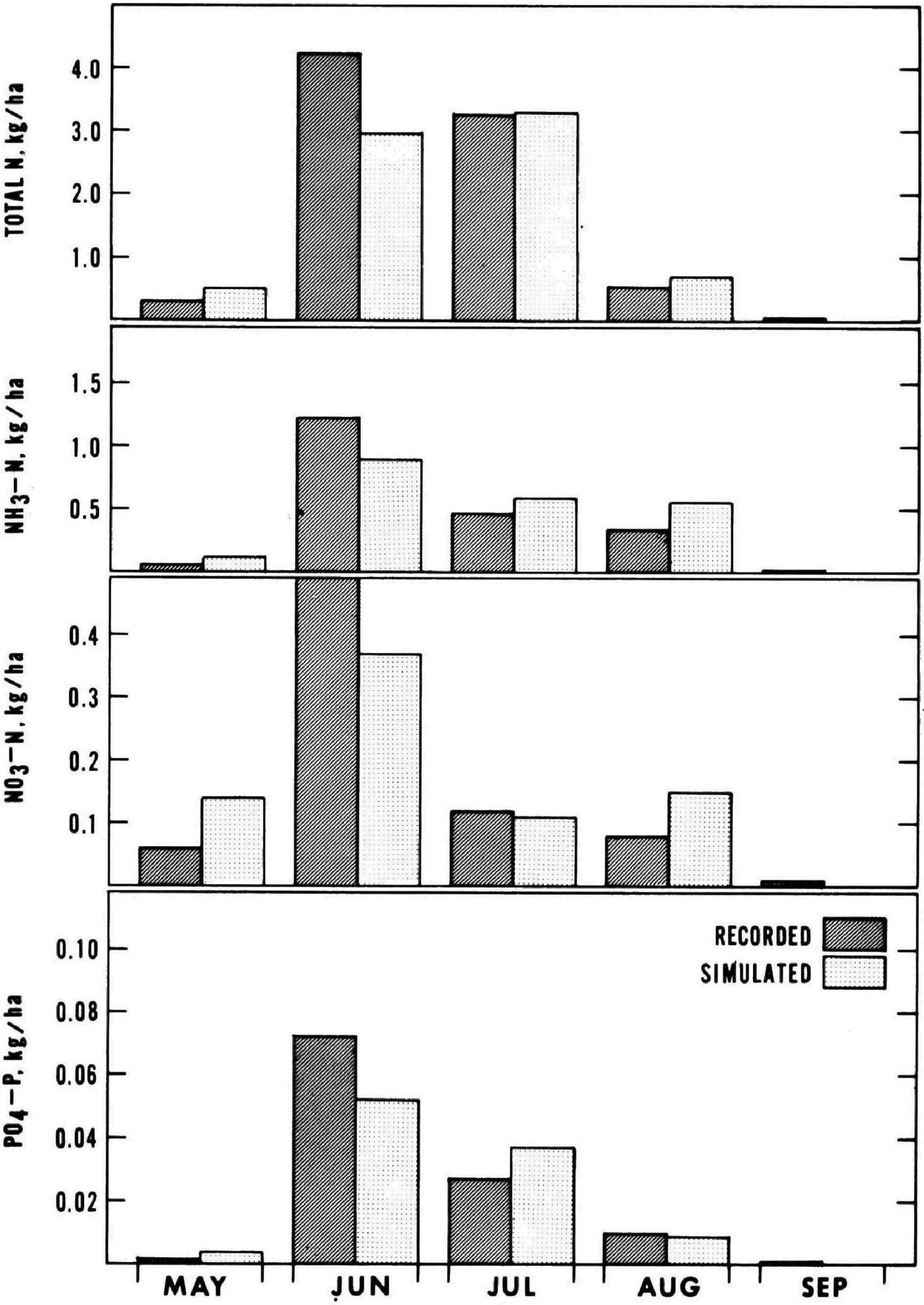

Figure 16. Monthly Total N, NH_3-N, NO_3-N and PO_4-P loss from the P2 watershed (May-September 1974).

P2 WATERSHED, WATKINSVILLE, GEORGIA

Nutrient loadings from the P2 watershed were simulated with the NPS Model for the 1974 growing season (May through September). Simulated and recorded monthly runoff, sediment, and nutrient loadings are shown in Figures 15 and 16, and listed in Table 4. The initial runoff and sediment parameters were obtained from modeling work on nearby watersheds (12) and slightly adjusted to better represent the recorded runoff and sediment

TABLE 4. SIMULATION RESULTS AND RECORDED DATA FOR THE P2 WATERSHED (May - September 1974)

Month		Runoff mm	Sediment kg/ha	Total P kg/ha	Total N kg/ha	NH_3-N kg/ha	NO_3-N kg/ha	PO_4-P kg/ha
May	Rec.	77.	103.	0.16	0.31	0.06	0.06	.002
	Sim.	118.	235.	0.35	0.52	0.12	0.14	.004
June	Rec.	418.	972.	1.26	4.24	1.23	0.49	.072
	Sim.	307.	742.	0.97	2.97	0.89	0.37	.052
July	Rec.	470.	687.	0.40	3.27	0.46	0.12	.027
	Sim.	420.	734.	0.44	3.30	0.59	0.11	.037
August	Rec.	122.	105.	0.07	0.53	0.34	0.08	.010
	Sim.	142.	186.	0.11	0.71	0.56	0.15	.009
September	Rec.	6.	1.	0.01	0.02	0.01	0.01	.001
	Sim.	0.	0.	0.	0.	0.	0.	0.
Total	Rec.	1093.	1867.	1.90	8.36	2.09	0.76	0.112
	Sim.	987.	1898.	1.87	7.50	2.15	0.77	0.101

during the summer period. The simulated nutrient values result from monthly potency factors derived from the recorded data. The potency factors were also modified slightly in calibration by comparing simulated and observed nutrient concentrations. The results indicate Total P and Total N loadings are more closely associated with the sediment fraction of surface runoff than the other nutrient forms. Improving the sediment simulation would improve both the Total P and Total N results. The simulated NH_3-N loadings would also improve with a more accurate sediment simulation, but the discrepancies between simulated and recorded loadings are somewhat greater than for Total P and Total N. These results are verified by the recorded data which indicates 79% of Total P, 64% of Total N, and 32% of NH_3-N in surface runoff during the 1974 growing season was associated with sediment.

The recorded NO_3-N and PO_4-P values were measured only in the water portion of surface runoff because the fraction of these nutrient forms attached to sediment is usually small. Thus one would not expect accurate simulation of NO_3-N and PO_4-P loadings using sediment as an indicator. Any agreement in Figure 16 reflects the dependence of sediment loss on runoff which is the transporting mechanism for these nutrient forms. However, the recorded values indicate NO_3-N and PO_4-P loadings are a small portion of the Total N and Total P losses from the P2 watershed.

Analysis of the simulation results for individual storm events was the basis for calibration of the nutrient potency factors. Unfortunately the short period of available nutrient data provided few storms with detailed data for calibration. However, sufficient results were obtained to provide another evaluation of the NPS Model and the use of sediment as a nutrient runoff indicator. Figures 17 through 24 present the simulated and recorded values for four storm events on the P2 watershed during the 1974 growing season. The runoff, sediment loss, and Total P concentrations are included in Figures 17, 19, 21, and 23, while the Total N, NH_3-N, NO_3-N, and PO_4-P concentrations are shown in Figures 18, 20, 22, and 24. Analysis of these results yields the following points:

(1) One problem in simulating the P2 watershed was the small size of the watershed in relation to the 15-minute simulation interval of the NPS Model. The steep rising limb of the recorded hydrographs could not be accurately represented in many cases where the short summer thunderstorms occurred in less than three or four simulation time intervals. However, except for some timing problems, the runoff volumes and peak flows are simulated reasonably well for the four storms.

(2) The sediment parameters were calibrated to improve agreement between simulated and recorded sediment concentrations. The results indicate the NPS Model can be calibrated to approximate sediment loss from agricultural watersheds. Although research is needed to more accurately represent the erosion process, sediment simulation with the NPS Model, as indicated by the results on the P2 watershed, is adequate for planning purposes.

(3) As noted above for the monthly loading values, Total P concentrations closely follow the sediment values. Better simulation of sediment would improve the Total P simulation. Thus the use of monthly potency factors in the NPS Model is a good assumption for simulating Total P loadings.

(4) Total N concentrations demonstrate some correlation to sediment but deviations do exist. The sediment and Total N curves for the storm of July 27 (Figures 21 and 22) are considerably different while the values for remaining storms show greater correspondence. For the latter events, an improved sediment simulation would improve the Total N simulation. Consequently, sediment is also a reasonable indicator for Total N loadings from the P2 watershed.

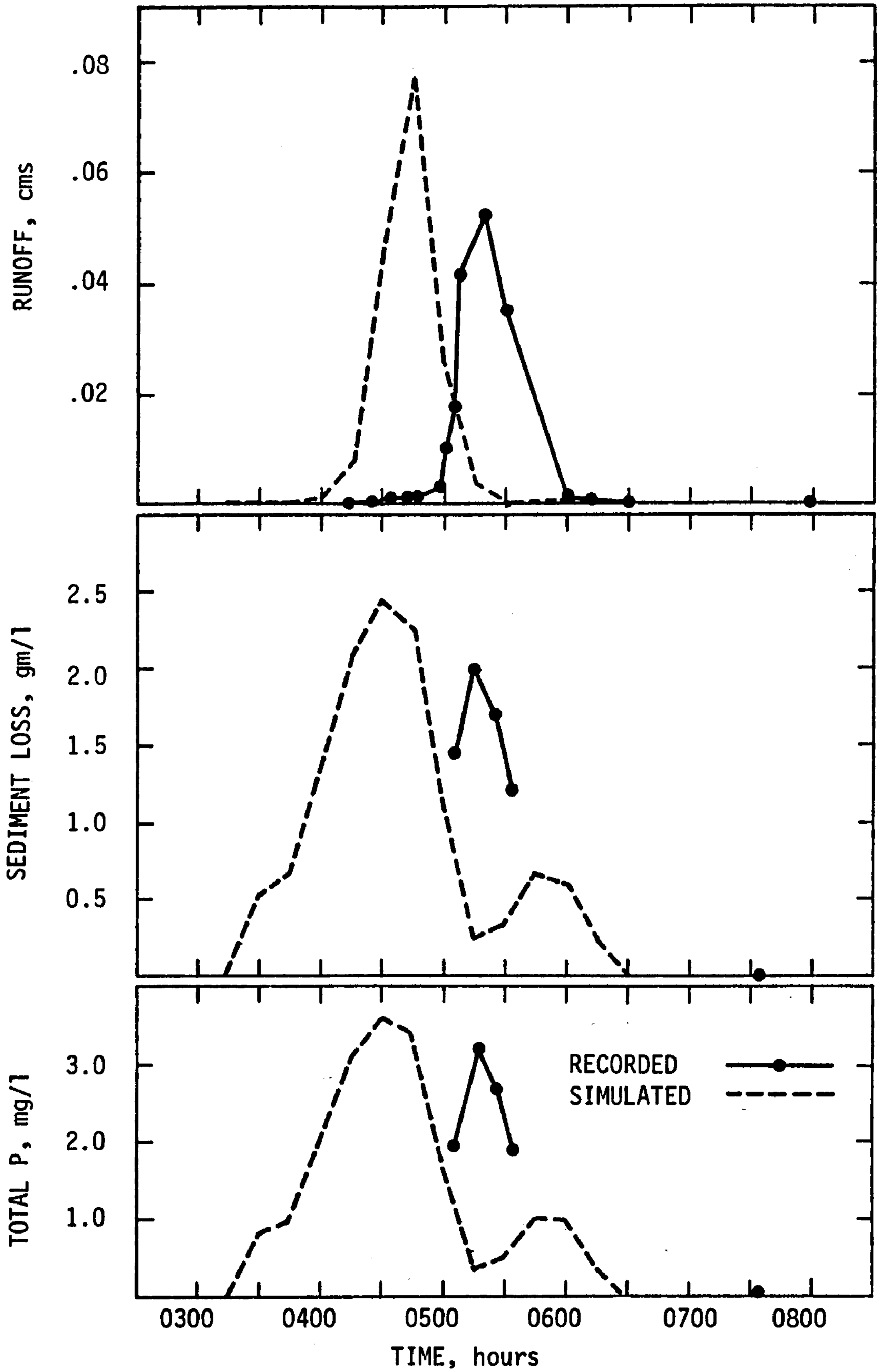

Figure 17. Runoff, sediment loss and Total P concentrations for the P2 watershed for the storm of May 23, 1974.

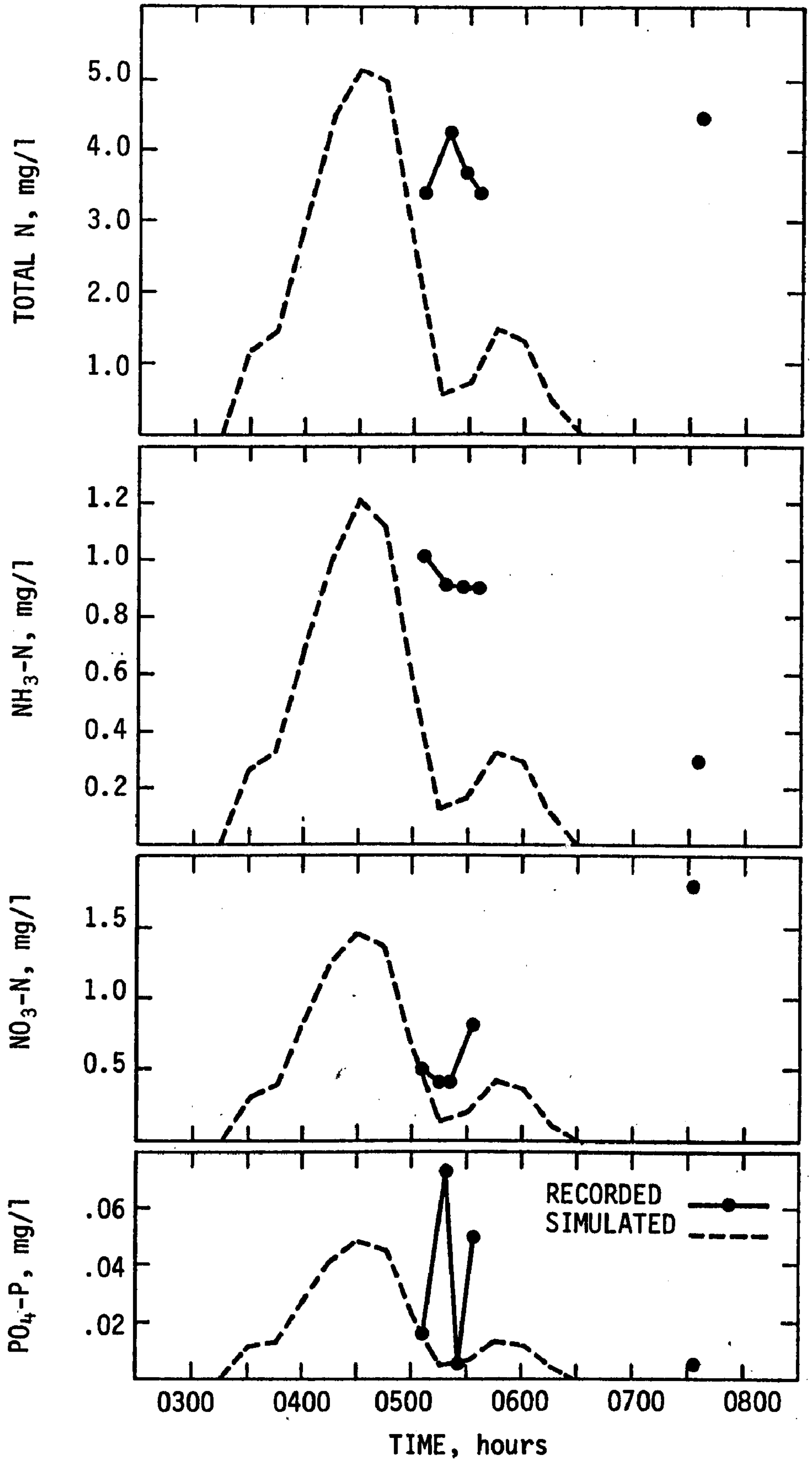

Figure 18. Total N, NH_3-N, NO_3-N and PO_4-P concentrations for the P2 watershed for the storm of May 23, 1974.

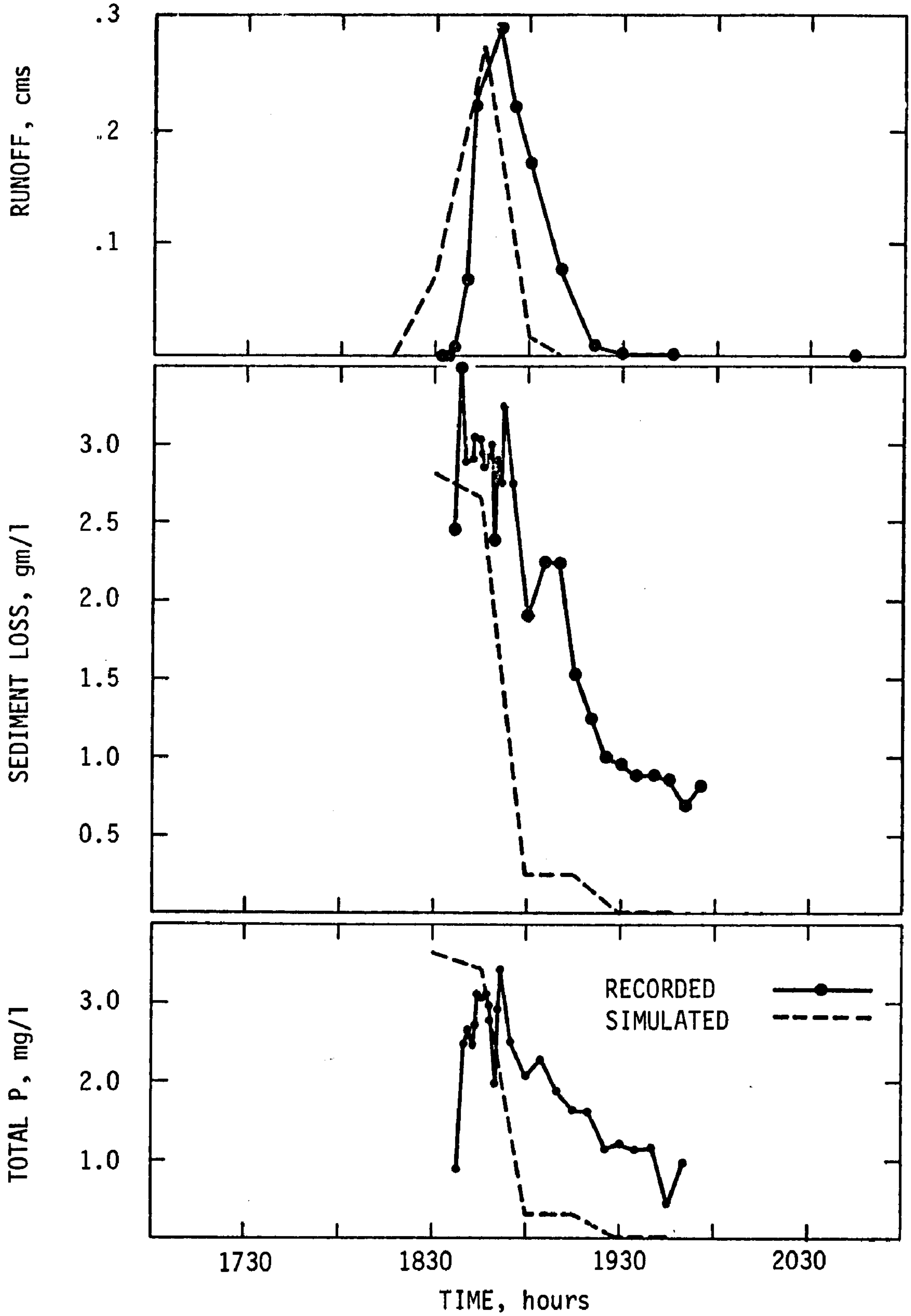

Figure 19. Runoff, sediment loss and Total P concentrations for the P2 watershed for the storm of June 27, 1974.

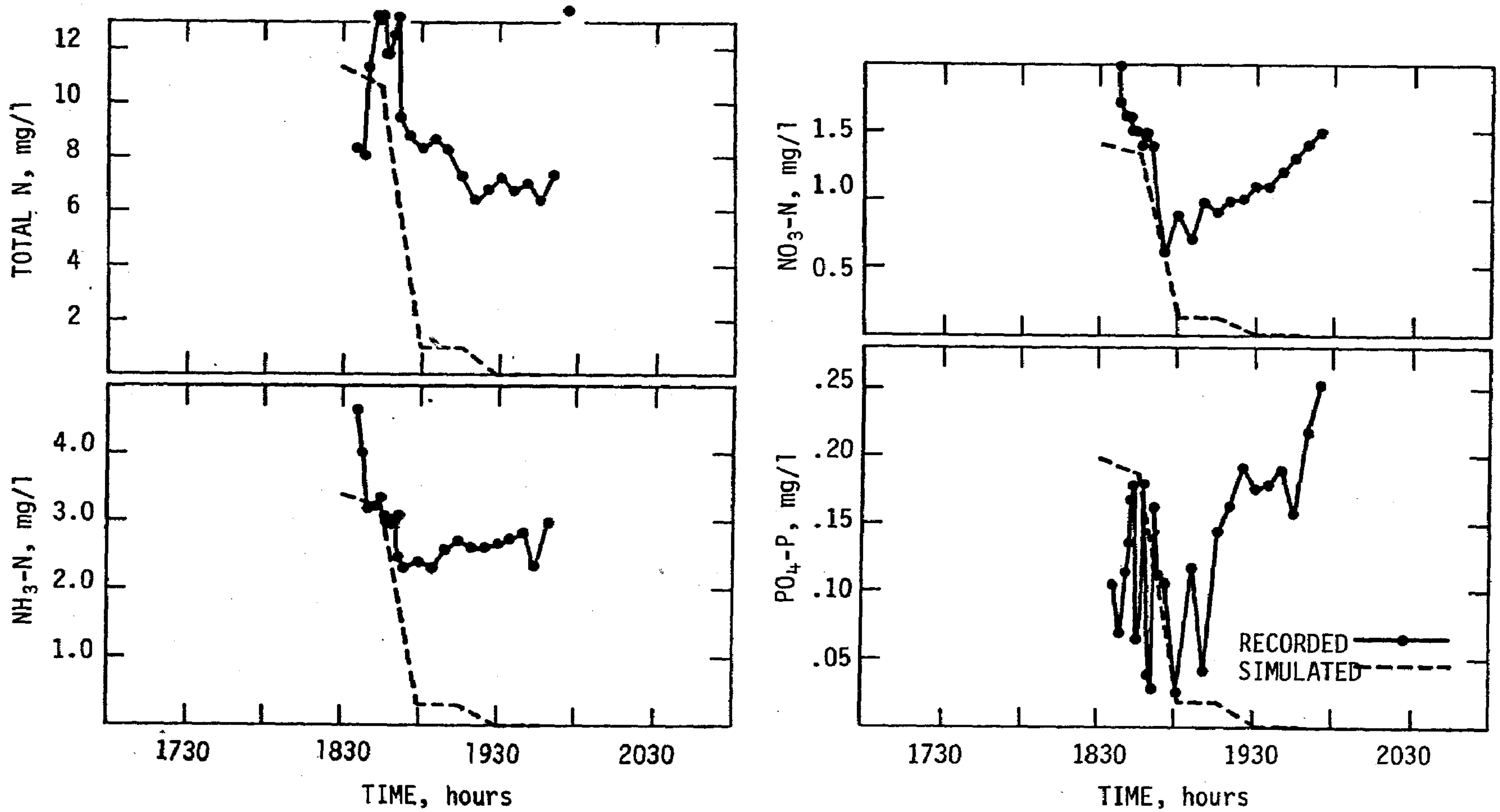

Figure 20. Total N, NH_3-N, NO_3-N and PO_4-P concentrations for the P2 watershed for the storm of June 27, 1974.

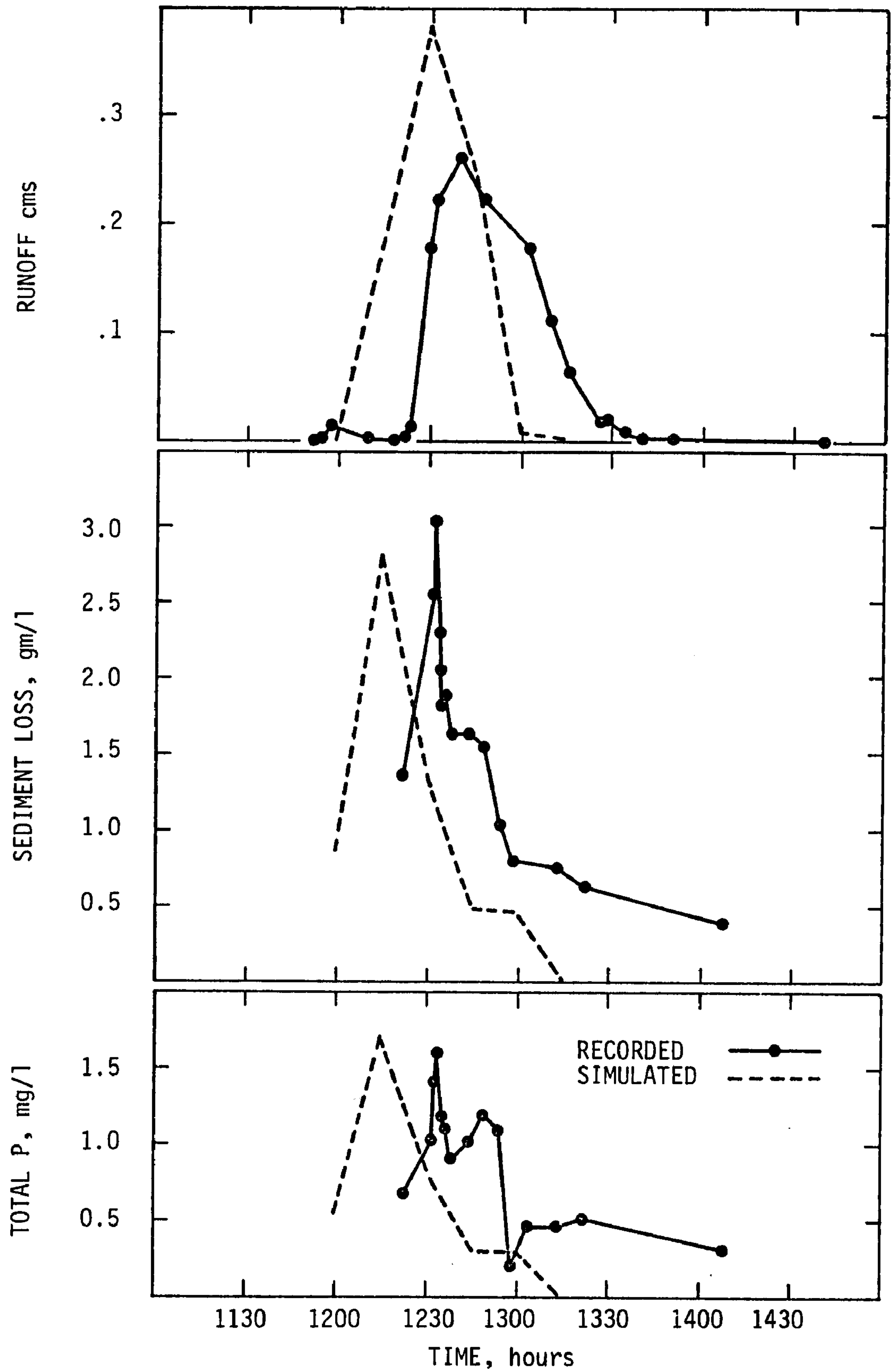

Figure 21. Runoff, sediment loss and Total P concentrations for the P2 watershed for the storm of July 27, 1974.

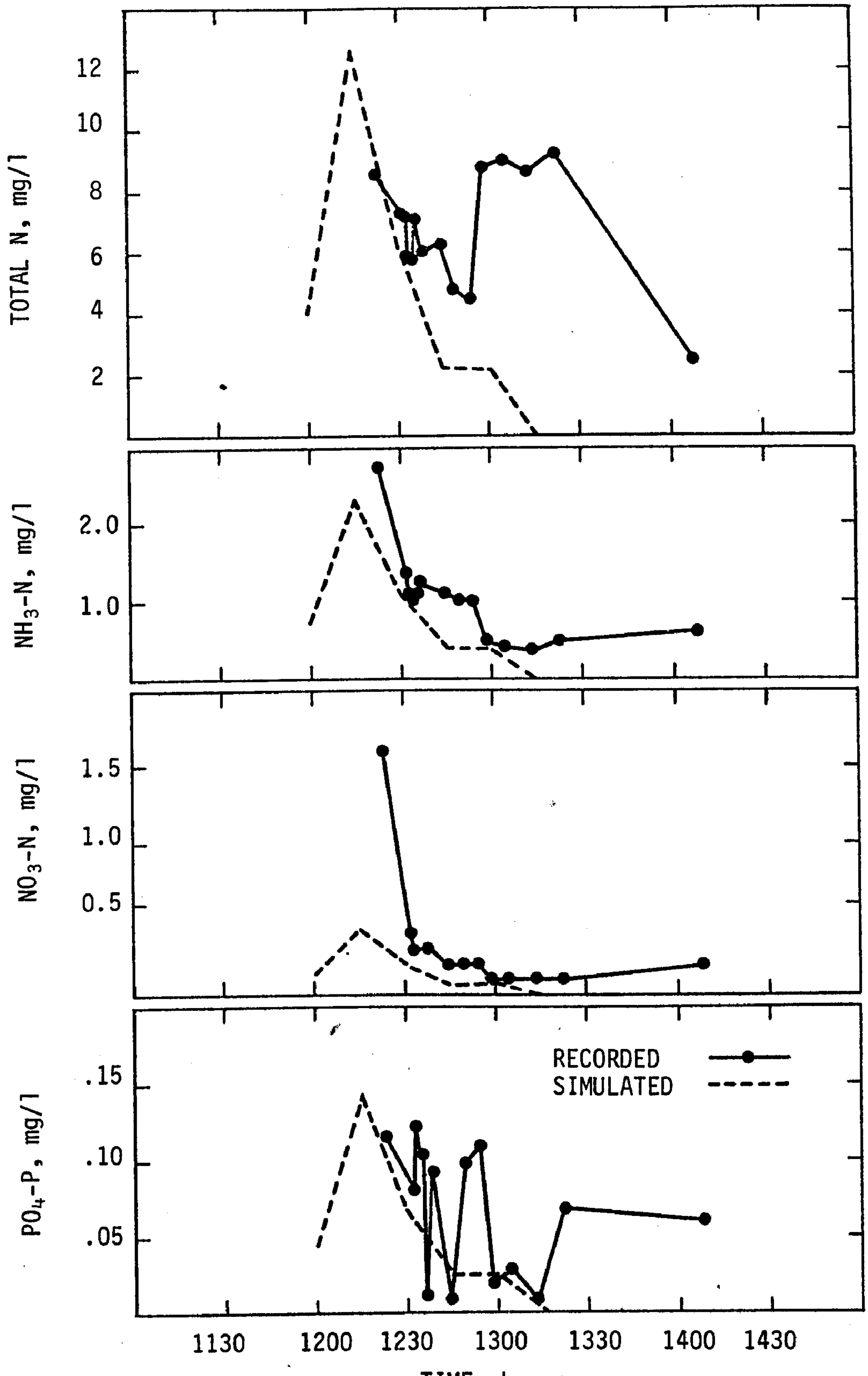

Figure 22. Total N, NH_3-N, NO_3-N and PO_4-P concentrations for the P2 watershed for the storm of July 27, 1974.

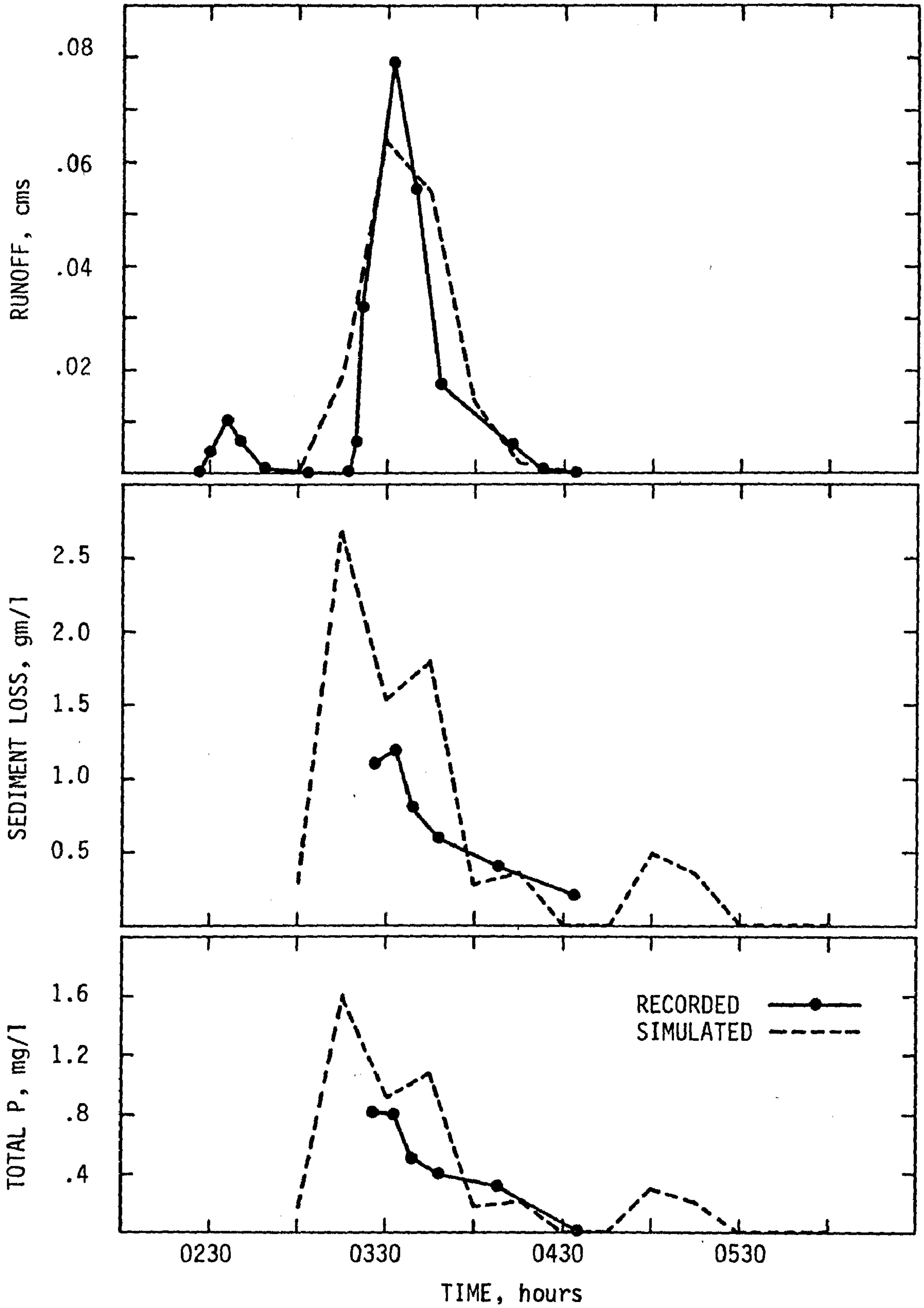

Figure 23. Runoff, sediment loss and Total P concentrations for the P2 watershed for the storm of August 16, 1974.

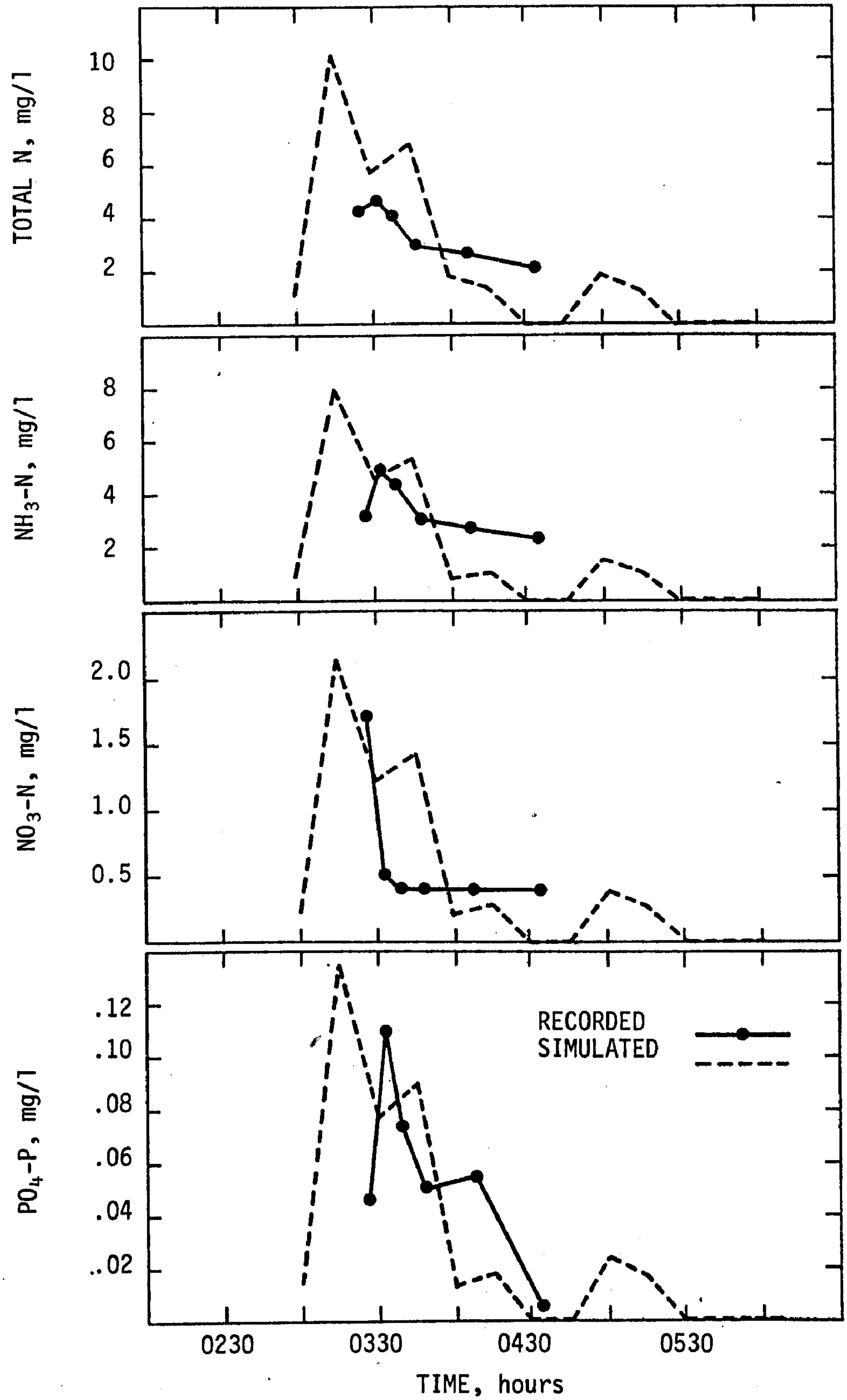

Figure 24. Total N, NH_3-N, NO_3-N and PO_4-P concentrations for the P2 watershed for the storm of August 16, 1974.

(5) For NH_3-N, the results are inconclusive. For some storm events, the NH_3-N concentrations are obviously influenced by the sediment values (Figures 21, 22, 23, and 24). In other cases, the NH_3-N concentrations are almost constant showing little variation with either flow or sediment loss. The recorded data on P2 demonstrates NH_3 is transported both on sediment and in solution.

(6) The variations in NO_3-N and PO_4-P concentrations during storm events demonstrate little or no relationship to sediment concentration. In some cases, there appears to be an inverse relation to the flow rate. The extreme variations, especially for PO_4-P, are basically unexplained. They are likely due to instantaneous variations in sediment characteristics, areal variations in soil P concentrations, and relative amounts of surface and subsurface flow. In any case, high concentrations at low flow rates have little impact on the total storm nutrient load. Burwell, et al (14) found that neglecting such high concentrations had no significant impact on the calculated storm nutrient load when compared to an integrated method over the entire event. Thus, high concentrations occurring at low flow rates can be effectively neglected in the calibration process. This is demonstrated in Figure 18 where a concentration value is recorded two hours after the major portion of the storm event. Such concentrations are highly suspect because the value is an average concentration since the previous sample. With zero flow occurring between the samples, the last recorded value is not meaningful. Ideally, nonpoint pollutants from the land surface should be analyzed in terms of mass loading rates in order to mask irrelevant concentration variations (1, 12). The simulation results are presented in concentrations because few NPS Model users will have sufficient data to calculate mass loading rates during storm events; hence, comparing simulated and recorded concentrations will be the most common method of calibration.

Although the P2 watershed was simulated for only one summer growing season, the nutrient runoff data appears to corroborate other studies on agricultural runoff discussed in Section 3.0. The NPS Model simulation results indicate sediment is a reasonable indicator for total nutrient loads (e.g. Total P, Total N) from the P2 watershed, but not for individual constituents such as NO_3-N and PO_4-P found in the solution phase of surface runoff.

P6 WATERSHED, EAST LANSING, MICHIGAN

The P6 watershed was also simulated for nutrient loadings during the 1974 growing season. The monthly values shown in Figures 25 and 26, and listed in Table 5, indicate substantial differences between the monthly simulated and recorded runoff, sediment loss, and nutrient values. The discrepancies in the nutrient loadings are a direct result of problems with the hydrologic simulation. The large over-estimate of runoff in May is due to the inability to represent the hydrologic impact of tillage operations. On May 13 and 14, the P6 watershed was plowed to a depth of 25 cm. During the following three days, up to 60 mm of rainfall soaked into the fallow ground with negligible runoff produced. The NPS Model simulated the period as if plowing had not occurred, resulting in high simulated runoff and

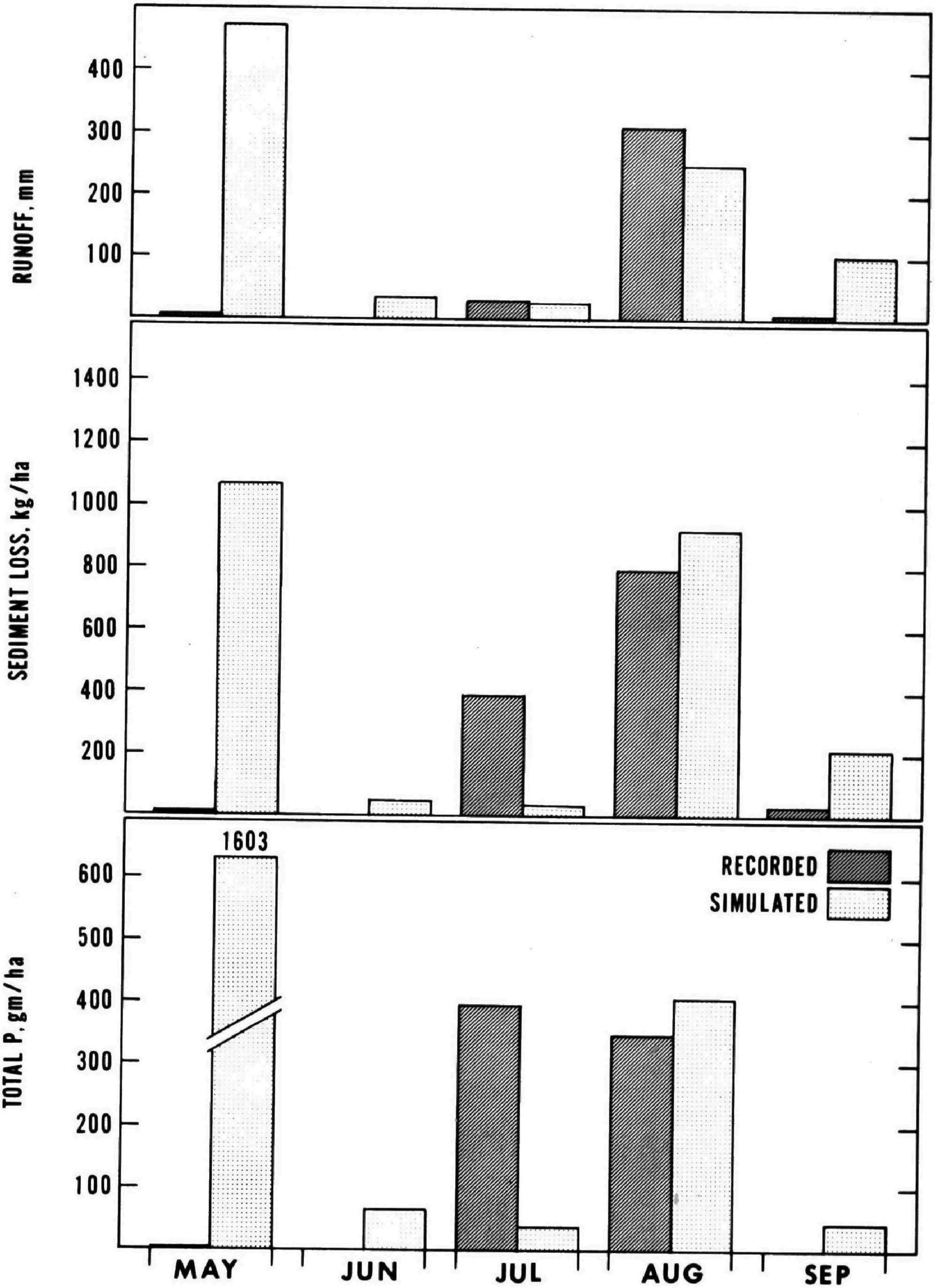

Figure 25. Monthly runoff, sediment and Total P loss from the P6 watershed (May-September 1974).

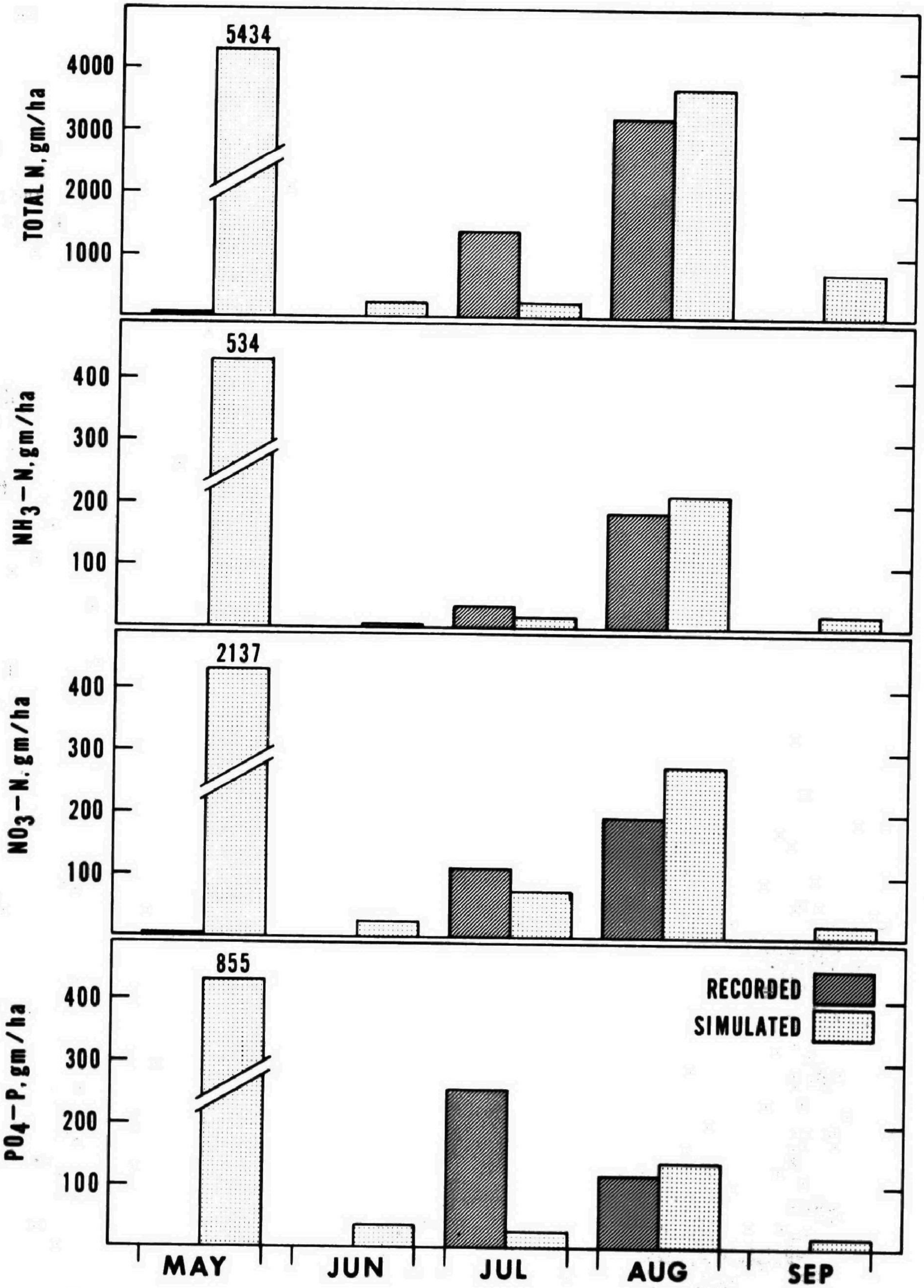

Figure 26. Monthly Total N, NH_3-N, NO_3-N and PO_4-P loss from the P6 watershed (May-September 1974).

TABLE 5. MONTHLY SIMULATION RESULTS AND RECORDED DATA FOR THE P6 WATERSHED (May - September 1974)

Month		Runoff mm	Sediment kg/ha	Total P gm/ha	Total N gm/ha	NH_3-N gm/ha	NO_3-N gm/ha	PO_4-P gm/ha
May	Rec.	3	15.	2.	59.	0	3.	0
	Sim.	472	1069.	1603.	5343.	534.	2137.	855.
June	Rec.	0	0	0	0	0	0	0
	Sim.	35	55.	66.	220.	6.	27.	38.
July	Rec.	30	390.	395.	1401.	34.	112.	256.
	Sim.	27	38.	38.	231.	19.	77.	26.
August	Rec.	310	796.	347.	3215.	187.	196.	117.
	Sim.	249	921.	405.	3683.	212.	277.	138.
September	Rec.	8	35.	0	0	0	0	0
	Sim.	102	211.	43.	737.	21.	21.	17.

sediment loss. Since monthly potency factors were used in this simulation, the over-simulated sediment loss also caused high estimates of nutrient loss in May although fertilizer applications occurred after the major events.

The other discrepancies in Figures 25 and 26 exist because the P6 watershed is too small (0.8 ha) for an accurate simulation with the 15-minute simulation time step used in the NPS Model. This is also true for the P2 watershed although the impact was not as dramatic as on P6. The entire sediment and nutrient losses for P6 in July occurred in one summer thunderstorm (7/02/76) that lasted less than 15 minutes. Although the storm was only moderate (peak flow of 0.04 cms), it was the first significant summer event and occurred with little crop canopy, resulting in high sediment and nutrient losses. Because of its short duration, the storm could not be accurately represented by the NPS Model. Except for this July storm, the only other significant storm events during the 1974 growing season occurred in August. Fortunately, these events were of sufficient duration for a reasonable simulation. Figures 27 and 29 show the runoff, sediment, and Total P concentration, and Figures 28 and 30 provide the Total N, NH_3-N, NO_3-N, and PO_4-P concentrations for each event. The problems with the hydrologic simulation are evident. For the August 13 storm (Figure 27), the two recorded flow peaks are simulated as a single peak; the first flow peak, which occurs within seven minutes from

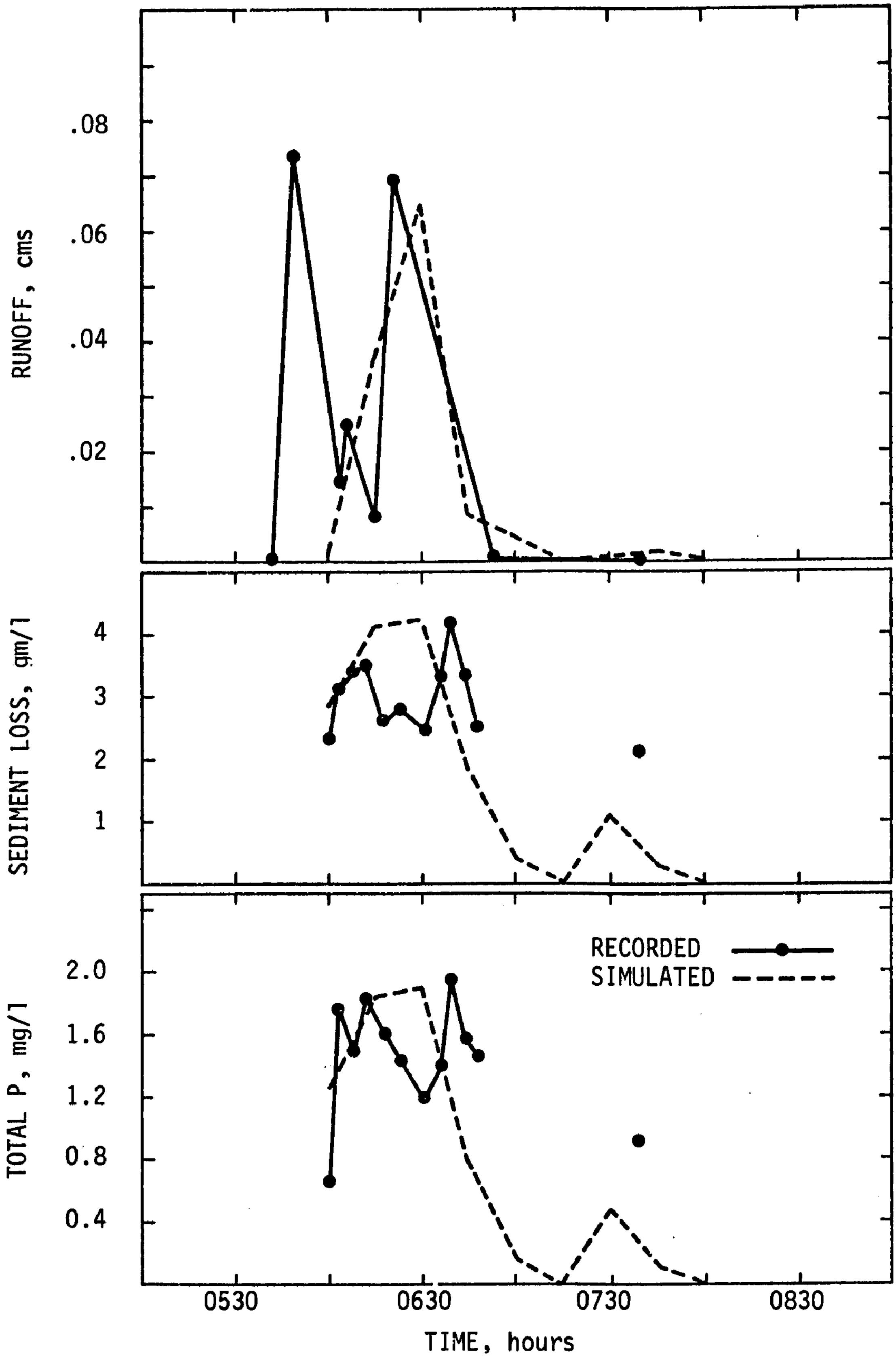

Figure 27. Runoff, sediment loss and Total P concentration for the P6 watershed for the storm of August 13, 1974.

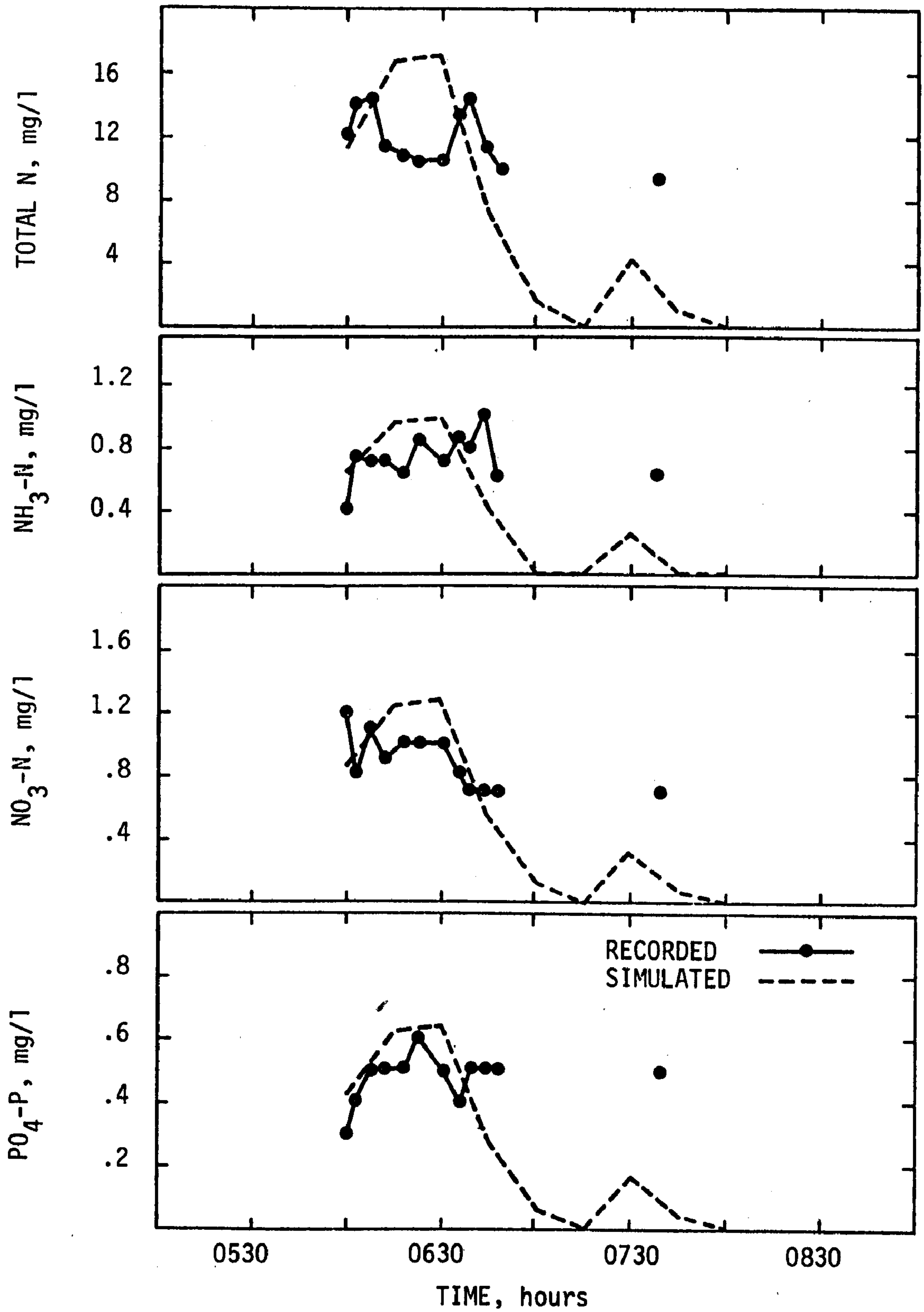

Figure 28. Total N, NH_3-N, NO_3-N and PO_4-P concentrations for the P6 watershed for the storm of August 13, 1974.

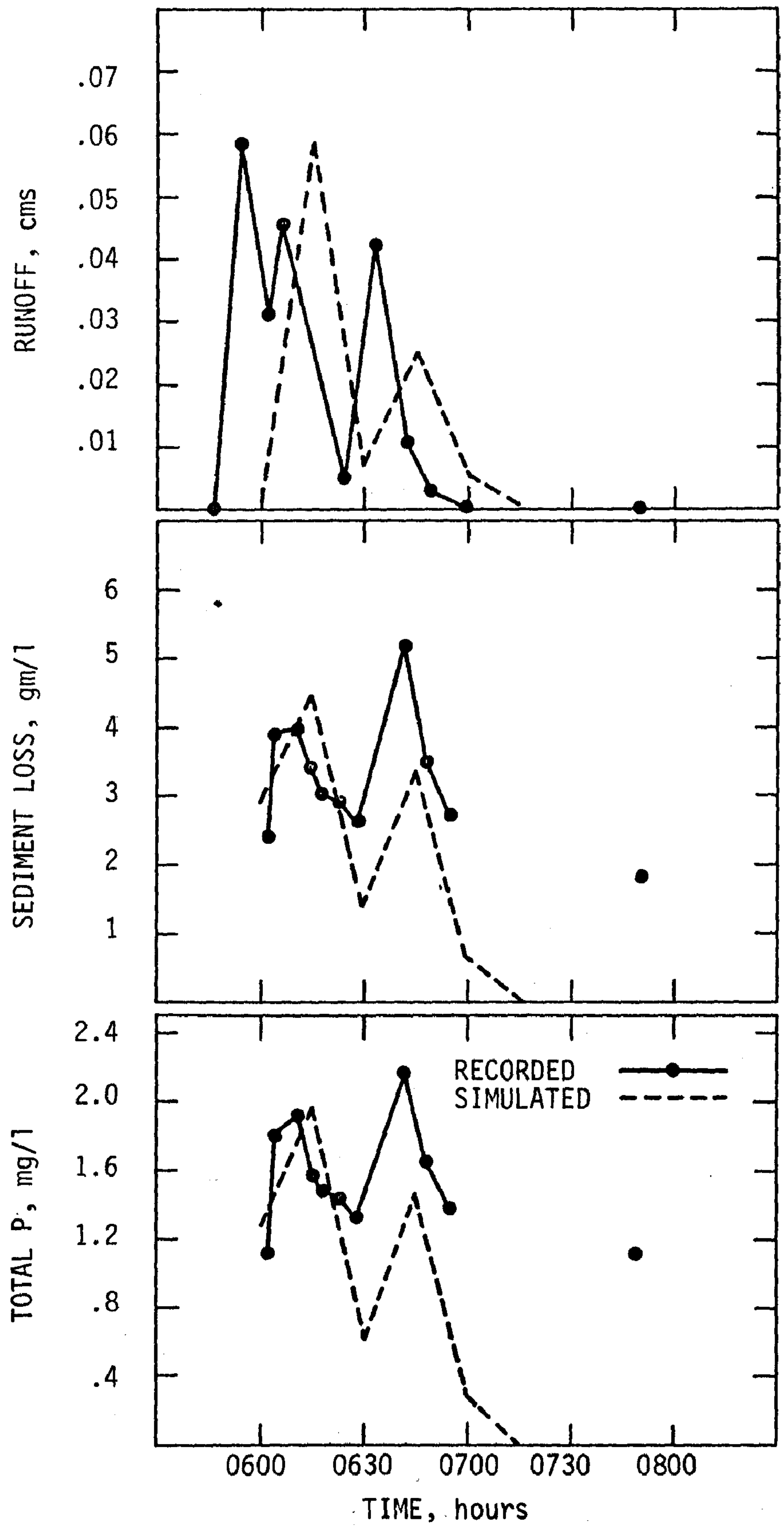

Figure 29. Runoff, sediment loss and Total P concentrations for the P6 watershed for the storm of August 27, 1974.

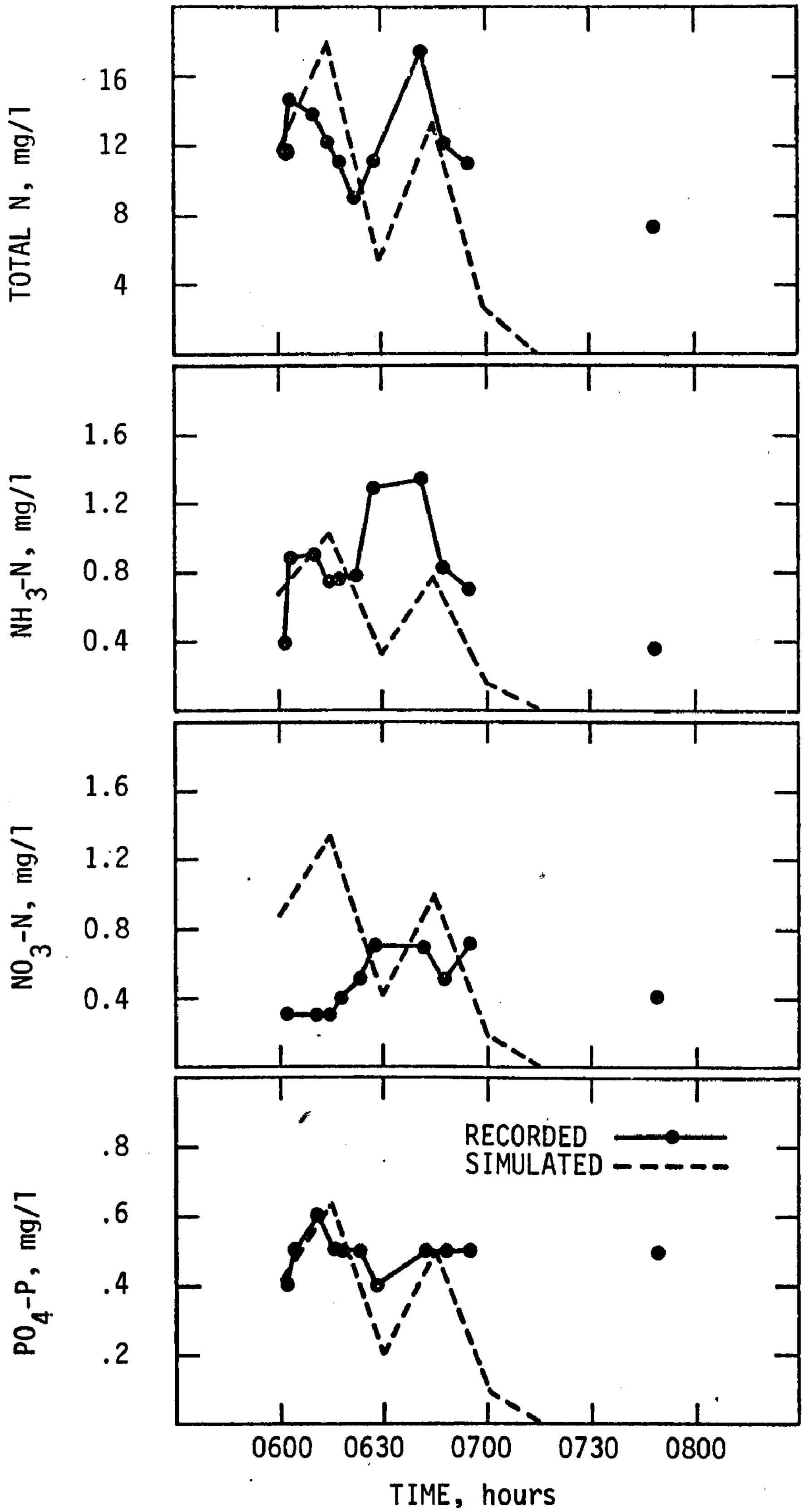

Figure 30. Total N, NH_3-N, NO_3-N and PO_4-P concentrations for the P6 watershed for the storm of August 27, 1974.

the beginning of the storm, is not represented. For the August 27 storm, the three recorded flow peaks are simulated as two. Since only one precipitation gage recorded rainfall for P6, the discrepancies between the simulated and recorded runoff are likely due to both the gross simulation interval and the areal variability in rainfall prevalent for thunderstorms in the region.

Despite these discrepancies, the runoff simulation for the August storm events is adequate for evaluating the sediment and nutrient simulation results. The conclusions stated for the P2 watershed apply also to the P6 watershed. The double-peak behavior of the recorded sediment for both storm events is reflected by the Total P and Total N concentrations. The NH_3-N, NO_3-N, and PO_4-P concentrations do not follow this pattern, except for the NH_3-N values on August 27 (Figure 32). The concentration variation in that storm would appear to indicate sediment is a significant transport medium for NH_3-N. As on the P2 watershed, high concentrations occurring at minor runoff rates at the end of the storm event are considered unreliable and are not connected to the other data points.

The simulated sediment and nutrient concentrations were adjusted by calibration of the potency factors. Since both storms occurred in August, the same potency factor was utilized verifying the use of average monthly values. Considering the discrepancies in the runoff simulation, the agreement between the simulated and recorded sediment, Total P, and Total N values is reasonable. Improving the runoff and sediment simulation would obviously improve the Total P and Total N simulation results. The same is true for NH_3-N for the August 27 storm, but the results are inconclusive for the August 13 storm. As for the P2 watershed, the NO_3-N and PO_4-P were measured only in solution; thus sediment is not a reliable indicator for these constituents. The agreement between the simulated and recorded PO_4-P concentrations is likely coincidental, especially for the August 13 storm where the sediment variations are not well represented.

In general, simulation of the P6 watershed has dramatized considerations important in calibrating the NPS Model to agricultural watersheds. The watershed should be large enough to allow a 15-minute simulation interval. Intense thunderstorms that begin and end in less than two or three intervals may not be adequately simulated. The hydrologic impact of tillage operations is not represented in the NPS Model; this topic is an area of continuing research. The monthly potency factors apply to all events in the same month; thus, events that precede and follow fertilizer applications may need to be calibrated separately. Because the day of planting and fertilizing will vary from year to year, the use of monthly potency factors should be sufficient for estimating average monthly nutrient loadings. The user needs to be aware of these considerations when calibrating the NPS Model.

Although differences exist between the simulated and recorded monthly values for P6, the storm simulation results indicate total nutrient loads can be reasonably simulated with the NPS Model using sediment as an indicator. These results confirm the findings from the P2 simulation.

SUMMARY

The NPS Model can be used to estimate total nutrient loadings from the land surface of urban and agricultural areas. Test results on a 433-ha urban watershed (Third Fork Creek) in Durham N.C. show that simulated Total P and Fe concentrations during a storm compare well with recorded values. Total annual loadings for 1972 were within 20% of the values estimated from regression analysis of the data. Simulated TKN concentrations and loadings were less accurate due to TKN concentrations in baseflow. Since in-stream processes and subsurface pollutant contributions occur in Third Fork Creek and are not simulated in the NPS Model, the size of the watershed approaches the upper limit of applicability of the model.

Where subsurface contributions are significant, the NPS Model should be modified to allow specification of average monthly pollutant concentrations in subsurface flow. If in-stream processes are major, the NPS Model should be interfaced with a stream water quality model. Both of these procedures would be required to simulate nonpoint pollution in large watersheds.

Nutrient concentrations and loadings were also simulated from two small agricultural watersheds (1.3 and 0.8 hectares) in Watkinsville, Georgia and East Lansing, Michigan for the 1974 growing season. Total P and Total N concentrations and loading were adequately simulated because these nutrient forms are largely associated with the sediment fraction of surface runoff NH_3-N values were not simulated as well as Total P and Total N since NH_3-N transport in solution was found to be significant. NO_3-N and PO_4-P values were not adequately represented because they are transported almost entirely in solution form. Accordingly, the NPS Model should not be used to estimate loadings for these nutrient forms.

Just as Third Fork Creek approaches the upper size limit for the NPS Model, the agricultural watersheds were too small for accurate representation of the hydrologic and sediment characteristics. The NPS Model should only be applied to watersheds for which the 15-minute simulation interval is reasonable. The range of watershed sizes simulated in this study (0.8 to 433 hectares) provides estimates of the upper and lower bounds of applicability.

The nutrient simulation results were obtained by estimating the nutrient potency factors (i.e. nutrient loss/sediment loss x 100%) from observed data and then calibrating the values by comparing simulated and recorded concentrations. The goal was to evaluate the use of sediment loss, as simulated in the NPS Model, as an indicator of nutrient loadings in surface runoff. Further testing and verification should be conducted to see if the potency factors can be estimated, without calibration, as a function of fertilizer applications, management practices, soil characteristics, crop behavior, etc. Only in this way can the NPS Model be effectively applied in areas where little data is available.

The conclusions presented in this report do not mean that soluble nutrient forms are unimportant. In areas where subsurface flow is a major portion of total runoff, soluble nutrient forms may comprise much of the nutrient loading. The literature and results of this work indicate that total nutrient loads in surface runoff are associated largely with sediment. Until research can accurately represent the complex reactions and transformations of nutrient forms in all flow components, the NPS Model can be used to estimate total nutrient loads in surface runoff as a function of sediment loss.

SECTION 5.0

ESTIMATION OF NUTRIENT POTENCY FACTORS

Section 4.0 noted the nutrient potency factors for the test watersheds were initially derived from the observed data and adjusted by calibration. This is the most reliable means of determining potency factors for use with the NPS Model. The factors for the three test watersheds are presented in Table 6; except for the Third Fork Creek values, they compare well with factors developed from the literature (Table 7). Third Fork Creek had unusually high sediment loss for an urban watershed, resulting in low potency factors.

Considerable variation exists in the values shown in Table 7. Nutrient potency factors are dependent upon soil characteristics, land use, climate, hydrologic behavior, etc. Obviously fertilizer applications on agricultural watersheds, lawns, and golf courses have a significant impact. It is difficult to accurately predict nutrient potency factors without calibration or observed data for the specific watershed. When applying the NPS Model, data on the watershed or on nearby watersheds with similar soils, land use, topography, etc. should be used to evaluate the potency factors and the resulting simulated nutrient loadings. If no such data is available, Tables 6 and 7 can provide a range of possible values from which the potency factors can be estimated. However, simulated nutrient loadings derived from such potency factors should be considered only as gross estimates until data for calibration is available. In Table 7, the greatest confidence can be assigned to the Total P, Total N, and TKN potency factors obtained from continuous data collection programs. The remaining constituents are not as closely associated with the sediment fraction of surface runoff; they are included for general information only. Grab sample data collection programs cannot accurately represent the variability of nonpoint pollutants in surface runoff. Table 7 is only a sample of the data available on nutrient runoff. The user should consult the references in Table 7 for a detailed description of the data collected, and should investigate the general literature for additional sources.

TABLE 6. NUTRIENT POTENCY FACTORS FOR THE TEST WATERSHEDS

Watershed	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Third Fork Creek[a], Durham, N.C.												
TKN	.090	.055	.060	.060	.055	.055	.055	.055	.060	.060	.060	.070
Total P	.080	.065	.070	.070	.070	.060	.060	.060	.060	.060	.070	.075
Fe	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.3
P2 Watershed Watkinsville, Ga.												
Total N					0.22	0.40	0.45	0.38				
Total P					0.15	0.13	0.06	0.06				
NH_3-N					0.05	0.12	0.08	0.30				
NO_3-N					0.06	0.05	0.015	0.08				
PO_4-N					.002	.007	.005	.005				
P6 Watershed East Lansing, Mi.												
Total N					.500	.400	.600	.400	.350			
Total P					.150	.120	.100	.044	.020			
NH_3-N					.050	.010	.050	.023	.010			
NO_3-N					.200	.050	.200	.030	.010			
PO_4-P					.080	.070	.066	.015	.008			

[a] Third Fork Creek had unusually high sediment loss for an urban watershed, resulting in low potency factors.

TABLE 7. NUTRIENT POTENCY FACTORS FOR URBAN AND AGRICULTURAL WATERSHEDS DERIVED FROM THE LITERATURE[a]

Location	Name	Size (ha)	Land Use	Soils	Sampling Program	Potency Factors: Total N	TKN	Total P	NH_3-N	NO_3-N	PO_4-P	Ref.
Urban												
Lubbock, TX	26th St. Storm Sewer	607	Residential & commercial		Continuous					.321	.106	15
Lubbock, TX	KN Clapp Basin	90	Residential		Continuous					.064	.031	16
Lawrence, KS	Naismith Ditch	164	Residential	Silty loam, silty clay	Grab					.37 rain .52 snow		17
Tulsa, OK	Crow Basin	777	Residential, some commercial	Sandstone & shale geology	Grab		.260[b]				.300	18
Tulsa, OK	New Block Basin	558	Residential	Sandstone & shale geology	Grab		.501[b]				.909	18
Tulsa, OK	Indian Basin	83	Streets, commercial & residential	Sandstone & shale geology	Grab		.470[b]				.425	18
12 U.S. Cities			Residential Industrial Commercial		Continuous, street surface runoff		.218 .163 .157			.006 .007 .060	.113 .142 .103	19
Madison, WI	Manitou Way Storm Drain	60	Residential		Continuous	2.39	2.12	.474	.196	.279	.171[c]	7
Seattle, WA	Viewridge One & Two	297	Single & multiple family residential		Grab	3.14	2.51	.381[d]	.281	.479	.089	20
Seattle, WA	Lake Hills	60	Single family residential		Grab	2.33	1.75	.371[d]	.202	.562	.123	20
Seattle, WA	Highlands	34	Low density single family residential		Grab	1.10	.72	.280[d]	.040	.370	.048	20
Seattle, WA	Southcenter	10	Commercial, new shopping area		Grab	2.54	1.83	.205[d]	.339	.666	.044	20
Seattle, WA	Central Business Dist.	11	Commercial downtown		Grab	1.02	.74	.303[d]	.281	.214	.039	20
Seattle, WA	South Seattle	11	Industrial		Grab	2.30	1.63	.227[d]	.252	.635	.059	20
Agricultural												
Chickama, OK	C-1, C-3, C-4	7 to 20	Cotton[e]	Silt & silt clay	Continuous	.18	.14	.140	.005	.043	.022[f]	21
Chickama, OK	C-5, C-6, C-8	5 to 11	Wheat[e]	Silt & silt clay	Continuous	.32	.25	.130	.024	.067	.023[f]	21
Chickama, OK	R-7, R-8	8 to 11	Pasture	Silt	Continuous	.05	.04	.022	.002	.009	.007[f]	21
Treynor, IA		32	Corn[e]	Fine silty loess	Continuous	.10	.10	.003	.001	.001	.0002	14

TABLE 7. (continued)

Location	Name	Size (ha)	Land Use	Soils	Sampling Program	Potency Factors						
						Total N	TKN	Total P	NH_3-N	NO_3-N	PO_4-P	Ref.
Macedonia, IA		158	Row crops, hay, pasture	Silt loam loess	Continuous	.56	.45	.041	.090	.119	.022	22
Nampa, ID		11	Sugar beets		Grab	1.70	1.27	.080	.655	.431	.053	23
Nampa, ID		14	Onions		Grab	.76	.67	.120	.260	.088	.043	23
Nampa, ID		14	Lima beans		Grab	.31	.17	.110	.043	.140	.057	23
Eastern, SD		44	Oats & corn	Sandy clay loam	Continuous	1.66	1.13	.240		.53 (snow)		24
Eastern, SD		44	Oats & corn	Sandy clay loam	Continuous	.33	.21	.085		.12 (rain)		24
Eastern, SD		15	Pasture	Sandy clay loam	Continuous	2.80	2.20	.450		.60 (snow)		24
Eastern, SD		15	Pasture	Sandy clay loam	Continuous	.95	.77	.220		.18 (rain)		24
Eastern, SD		19	Alfalfa & brome grass	Loam & sandy clay loam	Continuous	2.69	2.09	.320		.60 (snow)		24
Eastern, SD		19	Alfalfa & brome grass	Loam & sandy clay loam	Continuous	.74	.46	.320		.28 (rain)		24

Notes:

a. These values are annual averages for all storm events and were obtained from storm-event data or annual loadings. These values are provided as general information; the user should refer to the cited reference for greater detail.

b. Organic Nitrogen only

c. Dissolved Reactive Phosphorus

d. Ortho and hydroloyzable Phosphorus

e. Fertilizer was applied

f. Total Soluble Phosphorus

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APPENDIX A

MODIFICATIONS TO THE NPS MODEL

Modifications to the NPS Model performed during this study were kept to a minimum so as not to require major changes in the input sequence described in the original report. Only changes required to better represent physical processes and maintain consistency of units were included. The modifications are as follows:

(1) The units of SRERI and TSI, the initial sediment desposits on pervious and impervious areas, were changed from kg/ha (lb./ac) to tonne/ha (tons/ac) in order to coincide with the units of "accumulated sediments" output before each storm event and in the monthly summary.

(2) EPXM, the interception storage parameter, was changed from a single average annual value to 12 monthly values corresponding to the first day of each month. The interception storage on any day is calculated from linear interpolation between the monthly values. This modification was included to better represent changes in rainfall interception with crop growth on agricultural watersheds. Although EPXM is not usually a critical parameter, it can be important on extremely small watersheds highly responsive to rainfall. To accommodate this change, the input namelist, LND3, has been modified to accept 12 values for EPXM. So, LND3 may appear as

```
&LND3  K1=1.0, PETMUL=1.0, K3=0.30, EPXM=5*0.0,.01,.03,.06,
       .10,.1,2*0.0, K24L=1.0, KK24=0.0                    &END
```

If less than 12 values are input for EPXM, the remaining ones are defaulted to 0.0 mm (in).

(3) A major impact of tillage operations is to increase the amount of fine sediment material available for transport. In an attempt to accommodate this effect, the NPS Model was modified to accept the dates of tillage operations and a new value of the sediment fines storage resulting from the operation.

Two new input parameters, TIMTIL and SRERTL have been added to the WSCH namelist. TIMTIL specifies the Julian day of the operation while SRERTL indicates the corresponding new value of the sediment fines storage. Up to 12 values can be specified for each parameter; i.e. up to 12 separate tillage operations can be specified. Whenever the day of simulation corresponds to a value in TIMTIL, the fines storage is reset to the corresponding SRERTL value. Thus, the 1st value of TIMTIL is the day when the fines storage is reset to the 1st value of SRERTL, the 2nd TIMTIL value corresponds to the 2nd value of SRERTL, etc.

The input namelist, WSCH, would appear as follows for only one tillage operation.

```
&WSCH ARFRAC=1.00, IMPKQ=0.0, COVVEC=5*0.0,.05,.2,.75,.85,
      .80,2*0.0, TIMTIL=142, SRERTL=0.5                  &END
```

When day number 142 is simulated the following message is printed on the first simulation interval of day number 142:

```
*** May 22 - LAND SURFACE DISTURBANCE OCCURS ON CROPLAND
             SEDIMENT DEPOSITS ON PERVIOUS AREAS RESET
             TO 0.500 TONS/ACRE
```

Therefore, the operation is assumed to occur at the beginning of the day. TIMTIL and SRERTL do not have to be specified if tillage is not considered in a particular land use.

This procedure was developed and initially tested on small agricultural watersheds in Georgia (12). Although this does not account for all the complex impacts resulting from tillage operations, it appears to be the only method available for continuous simulation of erosion processes. Calibrated values of SRERTL range from 1.0 to 4.5 tonnes/hectare (0.5 to 2.0 tons/ac) on the limited number of watersheds tested. SRERTL is a function of soil properties, depth, and type of tillage operations, but at the present time must be determined by calibration. The effect of construction activity could also be approximated with this method although no testing on construction areas has been performed.

The user should refer to the NPS Model report for a full description of the parameters, the input formats, and the calibration process of applying the NPS Model.

APPENDIX B

CORRECTION AND ADJUSTMENTS TO THE NPS MODEL INPUT DESCRIPTION

Table 8 is an updated version of Table 36 from the NPS Model Report (1) which described the input sequences and attributes of the model parameters. Errors in the original Table 36 are noted by slashes (/) in Table 8 with the corrections inserted. Modifications performed during this study are included in the NPS Model version dated 11/15/76 and are noted by asterisks (*) in Table 8.

Also, Table 24 of the NPS Model Report incorrectly indicates that daily potential evapotranspiration (PET) is input in English units of "inches x 100"; this should be corrected to "inches x 1000".

TABLE 8. ADJUSTMENTS TO TABLE 36 OF THE NPS MODEL REPORT: NPS MODEL PARAMETER INPUT SEQUENCE AND ATTRIBUTES

Namelist Name	Parameter Name	Type	English Units	Metric Units	Comment
	Watershed Name	character			up to ~~8~~ 24 characters
	Computer Run Information	character			up to ~~8~~ 24 characters
ROPT	HYCAL	integer			1 2 3 OR 4
	HYMIN	real	ft /sec	m /sec	
	NLAND	integer			up to 5 land uses
	NQUAL	integer			up to 5 pollutants
	SNOW	integer			0 or 1
DTYP	UNIT	integer			~~0~~ -1 or 1
	PINT	integer			0 or 1
	MNVAR	integer			0 or 1
STRT	BGNDAY	integer			
	BGNMON	integer			
	BGNYR	integer			
ENDD	ENDDAY	integer			
	ENDMON	integer			
	ENDYR	integer			
LND1	UZSN	real	inches	millimeters	
	LZSN	real	inches	millimeters	
	INFIL	real	in/hr	mm/hr	
	INTER	real			
	IRC	real			
	AREA	real	acres	hectares	
LND2	NN	real			
	L	real	feet	meters	
	SS	real			
	NNI	real			
	LI	real	feet	meters	
	SSI	real			
LND3	K1	real			
	PETMUL	real			
	K3	real			
	EXPM	real	inches	millimeters	(12 MONTHLY VALUES)*
	K24L	real			
	KK24	real			

* Added to NPS Model version dated 11/15/76

TABLE 8. (continued)

Namelist Name	Parameter Name	Type	English Units	Metric Units	Comment
LND4	UZS	real	inches	millimeters	
	LZS	real	inches	millimeters	
	SGW	real	inches	millimeters	
SNO1	RADCON	real			
	CCFAC	real			
	EVAPSN	real			
SNO2	MELEV	real	feet	meters	
	ELDIF	real	1000 feet	kilometers	
	TSNOW	real	degrees F	degrees C	
SNO3	MPACK	real	inches	millimeters	
	DGM	real	in/day	mm/day	
	WC	real			
	IDNS	real			
SNO4	SCF	real			
	WMUL	real			
	RMUL	real			
	F	real			
	KUGI	integer			
SNO5	PACK	real	inches	millimeters	
	DEPTH	real	inches	millimeters	
WASH	JRER	real			
	KRER	real			
	JSER	real			
	KSER	real			
	JEIM	real			
	KEIM	real			
	TCF	real			12 values
	Pollutant name	character			up to 12 characters [a] repeat for each pollutant

REPEAT THE FOLLOWING INFORMATION FOR EACH LAND USE

Namelist Name	Parameter Name	Type	English Units	Metric Units	Comment
	Land Use Type	character			up to 12 characters
WSCH	ARFRAC	real			
	IMPKO	real			
	COVVEC	real			12 values
	TIMTIL	real			(12 VALUES, OPTIONAL)*
	SRERTL	real	ton/ac	tonne/ha	(12 VALUES, OPTIONAL)*

[a] Each pollutant name is followed by the concentration units to be used, either 'MG/L' or 'GM/L', beginning in column no. 15 (see Appendix D). 'GM/L' is the default value.

* Added to NPS Model version dated 11/15/76

TABLE 8. (continued)

Namelist Name	Parameter Name	Type	English Units	Metric Units	Comment
YPTM	PMPVEC PMIVEC	real real	percent percent	percent percent	1 value per pollutant include if MNVAR=0
MPTM	PMPMAT PMIMAT	real real	percent percent	percent percent	12 values per pollutant include if MNVAR=1
YACR	ACUP ACUI	real real	lb/ac/day lb/ac/day	km/ha/day km/ha/day	1 value ~~per pollutant~~ include if MNVAR=0
MACR	ACUPV ~~ACUPI~~ ACUIV	real real	lb/ac/day lb/ac/day	km/ha/day km/ha/day	12 values ~~per pollutant~~ include is MNVAR=1
YRMR	REPER REIMP	real real	day day	day day	1 value ~~per pollutant~~ include if MNVAR=0
MRMR	REPERV REIMPV	real real	day day	day day	12 values ~~per pollutant~~ include if MNVAR=1
INAC	SRERI TSI	real real	lb/ac lb/ac	kg/ha kg/ha	(UNITS CHANGED TO * ton/ac, tonne/ha)

* Added to NPS Model version dated 11/15/76

APPENDIX C

NPS MODEL SOURCE LISTING

```
//A20NPS  JOB (A20$X2,510,0.5,25),'TONY.T7508.NPS',REGION=330K
/*JOBPARM COPIES=1
//STEP1 EXEC FORTCL,PARM.FORT='OPT=1,MAP,XREF'
//FORT.SYSIN DD *
C
C
C
C
C      ****************************************************************
C      *                                                              *
C      *          NONPOINT SOURCE POLLUTANT LOADING (NPS) MODEL       *
C      *                                                              *
C      ****************************************************************
C
C                          VERSION DATED: NOV. 15, 1976
C
C                              DEVELOPED BY:  HYDROCOMP, INCORPORATED
C                                             1502 PAGE MILL ROAD
C                                             PALO ALTO, CA.  94304
C                                               415-493-5522
C
C                                      FOR:   U.S. ENVIRONMENTAL
C                                              PROTECTION AGENCY
C                                             OFFICE OF RESEARCH
C                                              AND DEVELOPMENT
C                                             ENVIRONMENTAL
C                                              RESEARCH LABORATORY
C                                             ATHENS, GA.  30601
C                                               404-546-3581
C
C
C                              NPS - MAIN PROGRAM
C
      IMPLICIT  REAL(L)
C
      DIMENSION MNAM(24),RAD(24),TEMPX(24),WINDX(24),RAIN(96),
     1          IRAIN(96),IRAD(12,31),IEVAP(12,31),IWIND(12,31),
     2          ITEMP(12,31,2),GRAD(24),RADDIS(24),WINDIS(24),
     3          AR1OUT(28),AR2OUT(29),COVVEC(12),REPERM(5,12),TCF(12),
     4          TOTAL(24),VMIN(24),VMAX(24),SD(24),RANGE(24),AVER(24),
     5          REIMPM(5,12),ACUIM(5,12),PMPTAB(5,5,12),PMITAB(5,5,12),
     6          ACUPM(5,12)
C
      COMMON /ALL/ RU,HYMIN,HYCAL,DPST,UNIT,TIMFAC,LZS,AREA,RESB,SFLAG,
     1             RESB1,ROSB,SRGX,INTF,RGX,RUZB,UZSB,PERCB,RIB,P3,TF,
     2             KGPLB,LAST,FREV,TEMPX,IHR,IHRR,PR,RUI,A,PA,GWF,NCSY,
     3             SRER(5),TS(5),LNDUSE(3,5),AR(5),QUALIN(3,5),NOSI,NOS,
     4             NOSIM,UPL,UTMP,UNT1(2,2),UNT2(2,2),UNT3(2,2),WHGT,
     5             WHT,DEPW,ROSBI,RESBI,RESBI1,ARUN,LNTS(5),IMPK(5),
     6             NLAND,NQUAL,STMCH(200,24),RECOUT(5),FLOUT,SCALBF(5),
     7             SNOW,PACK,IPACK
C
      COMMON /LAND/DAY,PRTM,IMIN,IX,TWBAL,SGW,GWS,KV,LIBC4,LKK4,ALTR(9),
     1             UZS,IZ,UZSN,LZSN,INFIL,INTER,SGW1,DEC,DECI,TIT(13),
     2             K24L,KK24,K24EL,EP,IFS,K3,EPXMI,RESS1,RESS,SCEP,IRC,
     3             SRGXT1,MMPIN,KGPHA,METOPT,CCFAC,SCEP1,SRGXT,RAIN,SRC,
     4             SCF,IDNS,F,DGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,
     5             DEWX,DEPTH,MONTH,TMIN,PETMAX,ELDIF,SDEN,WINDX,INFTOM,
     6             TSNBAL,ROBTOM,ROBTOT,RXB,ROITOM,ROITOT,YEAR,CUNIT(7),
     7             INFTOT,MNAM,RAD,SRCI,FORM(42)
```

```
C
      COMMON /OLS/ WSNAME(6),KRER,JRER,KSER,JSER,TEMPCF,COVMAT(5,12),
     1             KEIM,JEIM,NDSR,ARP(5),ARI(5),ACCP(5),ACCI(5),RPER(5),
     2             PMP(5,5),PMI(5,5),QSNOW,SNOWY,SEDTM,SEDTY,SEDTCA,
     3             ACPOLP(5,5),ACERSN(5),APOLP(5,5),AERSN(5),COVER(5),
     4             APOLI(5,5),ACEIM(5),AEIM(5),POLTM(5),POLTY(5),
     5             TEMPA,DOA,POLTCA(5),AERSNY(5),AEIMY(5),APOLPY(5,5),
     6             APOLIY(5,5),POLTC(5),PLTCAY(5),ACPOLI(5,5),RIMP(5)
C
      COMMON /LNDOUT/ ROSTOM,RINTOM,RITOM,RUTOM,BASTOM,RCHTOM,PRTOM,
     1                SUMSNM,PXSNM,MELRAM,RADMEM,CONMEM,CDRMEM,
     2                CRAINM,SGMM,SNEGMM,PACKOT,SEVAPM,EPTOM,NEPTOM,
     3                UZSOT,LZSOT,SGWOT,SCEPOT,RESSOT,SRGXTO,TWBALO,
     4                TSNBOL,ROSTOT,RINTOT,RITOT,RUTOT,BASTOT,RCHTOT,
     5                PRTOT,SUMSNY,PXSNY,MELRAY,RADMEY,CONMEY,CDRMEY,
     6                CRAINY,SGMY,SNEGMY,PACK1,SEVAPY,EPTOT,NEPTOT,
     7                UZSMT,LZSMT,SGWMT,SCEPT,RESST,SRGXTT,TWBLMT
C
      COMMON /INTM/ RTYPE(4,4),UTYPE(2),GRAD,RADDIS,WINDIS,ICS,OPS,
     1              TEMPAY,DOAY,NOSIY,INTRVL,WMUL,NN,L,SS,NNI,LI,SSI,
     2             RMUL,KUGI,SEDTCY,REPERV(12),REIMPV(12),ACUPV(12),
     3             ACUIV(12),PMPMAT(12,5),PMIMAT(12,5),PMPVEC(5),
     4             PMIVEC(5),ACUI,ACUP,REIMP,REPER,PRINTR,
     5             EPXM(12),TIMTIL(12),SRERTL(12),TILDAY(5,12),
     6             TILSED(5,12),DPM(12),TCF
C
      EQUIVALENCE (ROSTOM,AR1OUT(1)),(TSNBOL,AR2OUT(1))
C
      LOGICAL LAST, PREV
C
      INTEGER  BGNDAY, BGNMON, BGNYR, ENDDAY, ENDMON, ENDYR,
     1         DYSTRT, DYEND, YEAR, DAY, H, HYCAL, TIME, PINT, PRINTR,
     2         YR, CN, TF, DA, DY, UNIT, SNOW, LMTS, RECOUT, SFLAG,
     3         TIMTIL, TILDAY, DPM
C
      REAL  IRC, NN, NNI, KV, K24L, KK24, INFIL, INTER,
     1      IFS, ICS, K24EL, K3, NEPTOM, NEPTOT, IDNS, MPACK,
     2      JRER, KRER, JSER, KSER,KEIM,JEIM, MELEV, KUGI,
     3      K1, KK4, IRC4, MELRAM, MELRAY, IPACK, IMPKO,
     4      INFTOM, INFTOT, IMPK, MNPIN, METOPT,
     5      KGPLB,KGPHA
C
      REAL*8  WSNAME,RTYPE,UTYPE
C
C                   NAMELIST INPUT VARIABLES
C
      NAMELIST /ROPT/  HYCAL, HYMIN, NLAND, NQUAL, SNOW
      NAMELIST /DTYP/  UNIT, PINT, MNVAR
      NAMELIST /STRT/  BGNDAY, BGNMON, BGNYR
      NAMELIST /ENDD/  ENDDAY, ENDMON, ENDYR
      NAMELIST /LND1/  UZSN, LZSN, INFIL, INTER ,IRC, AREA
      NAMELIST /LND2/  NN, L, SS, NNI, LI, SSI
      NAMELIST /LND3/  K1, PETMUL, K3 ,EPXM, K24L, KK24
      NAMELIST /LND4/  UZS, LZS, SGW
      NAMELIST /SNO1/  RADCON, CCFAC, EVAPSN
      NAMELIST /SNO2/  MELEV, ELDIF, TSNOW
      NAMELIST /SNO3/  MPACK, DGM, WC, IDNS
      NAMELIST /SNO4/  SCF, WMUL, RMUL, F, KUGI
      NAMELIST /SNO5/  PACK, DEPTH
      NAMELIST /WSCH/  ARFRAC ,IMPKO, COVVEC, TIMTIL, SRERTL
      NAMELIST /YPTM/  PMPVEC, PMIVEC
```

```
      NAMELIST /MPTM/  PMPMAT,PMIMAT
      NAMELIST /WASH/  JRER, KRER, JSER ,KSER, JEIM, KEIM, TCP
      NAMELIST /YACR/  ACUP,ACUI
      NAMELIST /MACR/  ACUPV,ACUIV
      NAMELIST /YRMR/  REPER, REIMP
      NAMELIST /MRMR/  REPERV,REIMPV
      NAMELIST /INAC/  SRERI, TSI
C
C          NAMELIST INPUT PARAMETER DESCRIPTION
C   HYCAL : INDICATES TYPE OF SIMULATION RUN
C         =  1   HYDROLOGIC CALIBRATION
C         =  2   SEDIMENTS AND QUALITY CALIBRATION
C         =  3   PRODUCTION RUN (PRINTER OUTPUT)
C         =  4   PRODUCTION RUN (PRINTER & W/O HEADINGS OUTPUT ON UNIT 4)
C   HYMIN : MINIMUM FLOW FOR OUTPUT DURING A TIME INTERVAL (CFS, CMS)
C   UNIT  : ENGLISH(-1), METRIC(1)
C   NLAND : NUMBER OF LAND TYPE USES IN THE WATERSHED
C   NQUAL : NUMBER OF QUALITY CONSTITUENTS SIMULATED
C   SNOW  : (0) SNOWMELT NOT PERFORMED, (1) SNOWMELT CALC'S PERFORMED
C   MNVAR : MONTHLY VARIATION IN ACCUMULATION RATES, REMOVAL RATES,
C           AND POTENCY FACTORS USED (1), OR NOT USED (0)
C   PINT  : INPUT PRECIPITATION IN INTERVALS OF 15 MIN.(0), OR HOURLY (1)
C   BGNDAY, BGNMON, BGNYR : DATE SIMULATION BEGINS
C   ENDDAY, ENDMON, ENDYR : DATE SIMULATION ENDS
C   UZSN  : NOMINAL UPPER ZONE STORAGE (IN, MM)
C   LZSN  : NOMINAL LOWER ZONE STORAGE (IN, MM)
C   INFIL : INFILTRATION RATE (IN/HR, MM/HR)
C   INTER : INTERFLOW PARAMETER, ALTERS RUNOFF TIMING
C   IRC   : INTERFLOW RECESSION RATE
C   AREA  : WATERSHED AREA IN ACRES
C   NN    : MANNING'S N FOR OVERLAND PERVIOUS FLOW
C   NNI   : MANNING'S N FOR OVERLAND IMPERVIOUS FLOW
C   L     : LENGTH OF OVERLAND PERVIOUS FLOW TO CHANNEL (FT, M)
C   LI    : LENGTH OF OVERLAND IMPERVIOUS FLOW TO CHANNEL (FT, M)
C   SS    : AVERAGE OVERLAND PERVIOUS FLOW SLOPE
C   SSI   : AVERAGE OVERLAND IMPERVIOUS FLOW SLOPE
C   K1    : RATIO OF SPATIAL AVERAGE RAINFALL TO GAGE RAINFALL
C   K3    : INDEX TO ACTUAL EVAPORATION
C   PETMUL: POTENTIAL EVAPOTRANSPIRATION MULTIPLICATION FACTOR
C   EPXM  : INTERCEPTION STORAGE, 12 MONTHLY VALUES (IN,MM)
C   K24L  : FRACTION OF GROUNDWATER RECHARGE PERCOLATING TO DEEP
C           GROUNDWATER
C   KK24  : GROUNDWATER RECESSION RATE
C   UZS   : INITIAL UPPER ZONE STORAGE (IN, MM)
C   LZS   : INITIAL LOWER ZONE STORAGE (IN, MM)
C   SGW   : INITIAL GROUNDWATER STORAGE (IN, MM)
C   RADCON: CORRECTION FACTOR FOR RADIATION
C   CCFAC : CORRECTION FACTOR FOR CONDENSATION AND CONVECTION
C   SCF   : SNOW CORRECTION FACTOR FOR RAINGAGE CATCH DEFICIENCY
C   ELDIF : ELEVATION DIFFERENCE FROM TEMP. STATION TO MEAN SEGMENT ELEVA
C           (1000 FT, KM)
C   IDNS  : DENSITY OF NEW SNOW AT 0 DEGREES F.
C   F     : FRACTION OF SEGMENT WITH COMPLETE FOREST COVER
C   DGM   : DAILY GROUNDMELT (IN/DAY, MM/DAY)
C   WC    : MAXIMUM WATER CONTENT OF SNOWPACK BY WEIGHT
C   MPACK : ESTIMATED WATER EQUIVALENT OF SNOWPACK FOR COMPLETE COVERAGE
C   EVAPSN: CORRECTION FACTOR FOR SNOW EVAPORATION
C   MELEV : MEAN ELEVATION OF WATERSHED (FT, M)
C   TSNOW : TEMPERATURE BELOW WHICH SNOW FALLS (F, C)
C   PACK  : INITIAL WATER EQUIVALENT OF SNOWPACK (IN, MM)
C   DEPTH : INITIAL DEPTH OF SNOWPACK (IN, MM)
```

```
C  ARFRAC: PERCENT OF A GIVEN LAND TYPE USE
C  IMPKO : PERCENTAGE OF IMPERVIOUS AREA FOR A GIVEN LAND TYPE USE
C  COVVEC: MONTHLY COVER COEFF. FOR A GIVEN LAND TYPE USE
C  PMPVEC: POTENCY FACTORS FOR A GIVEN LAND TYPE - PERVIOUS AREAS
C  PMPMAT: MATRIX OF POTENCY FACTORS FOR MONTHLY VARIATIONS
C          - PERVIOUUS AREAS, 12 VALUES PER CONSTITUENT
C  PMIVEC: POTENCY FACTORS FOR A GIVEN LAND TYPE - IMPERVIOUS AREAS
C  PMIMAT: MATRIX OF POTENCY FACTORS FOR MONTHLY VARIATIONS
C          - IMPERVIOUS AREAS, 12 VALUES PER CONSTITUENT
C  TCF   : TEMPERATURE CORRECTION FACTOR RELATING RUNOFF AND
C          AIR TEMPERATURES
C  JRER  : EXPONENT IN RAINDROP SOIL SPLASH EQUATION
C  KRER  : COEF. IN RAINDROP SOIL SPLASH EQUATION
C  JSER  : EXPONENT IN WASH OFF FUNCTION FOR PERVIOUS AREAS
C  KSER  : COEF. IN WASH OFF FUNCTION FOR PERVIOUS AREAS
C  JEIM  : EXPONENT IN WASH OFF FUNCTION FOR IMPERVIOUS AREAS
C  KEIM  : COEF. IN WASH OFF FUNCTION FOR IMPERVIOUS AREAS
C  ACUI  : ACCUMULATION RATES - IMPERVIOUS AREAS
C  ACUIV : MONTHLY ACCUMULATION RATES - IMPERVIOUS AREAS, 12 VALUES
C  ACUP  : ACCUMULATION RATES - PERVIOUS AREAS
C  ACUPV : MONTHLY ACCULUMATION RATES - PERVIOUS AREAS, 12 VALUES
C  REIMP : REMOVAL COEF. -IMPERVIOUS AREAS
C  REIMPV: MONTHLY REMOVAL COEF.- IMPERVIOUS AREAS, 12 VALUES
C  REPER : REMOVAL COEF. - PERVIOUS AREAS
C  REPERV: MONTHLY REMOVAL COEF.- PERVIOUS AREAS, 12 VALUES
C  SRERI : INITIAL AMOUNT OF FINES AVAILABLE FOR TRANSPORT
C  TSI   : INITIAL AMOUNT OF SOLIDS AVAILABLE FOR TRANSPORT
C
      READ (5,4520) (WSNAME(I),I=1,6)
      READ (5,ROPT)
      READ (5,DTYP)
      READ (5,STRT)
      READ (5,ENDD)
      READ (5,LND1)
      READ (5,LND2)
      READ (5,LND3)
      READ (5,LND4)
      IF (SNOW .LT. 1) GO TO 20
      QSNOW=SNOWY
      READ (5,SNO1)
      READ (5,SNO2)
      READ (5,SNO3)
      READ (5,SNO4)
      READ (5,SNO5)
   20 READ (5,WASH)
      DO 30 J=1,NQUAL
   30 READ (5,4060) (QUALIN (I,J),I=1,3),CUNIT(J)
      DO 100 II=1,NLAND
      READ (5,4060) (LNDUSE(K,II),K=1,3)
      READ (5,WSCH)
      AR(II)=ARFRAC
      IMPK(II)=IMPKO
      DO 40 IJ=1,12
   40 COVMAT(II,IJ)=COVVEC(IJ)
C
      DO 42 JJ=1,12
      TILDAY(II,JJ) = TIMTIL(JJ)
   42 TILSED(II,JJ) = SPERTL(JJ)
C
      IF (MNVAR.EQ.1) GO TO 60
C
```

```
C
C              READ INPUT DATA OF ACCUMULATION RATES, REMOVAL RATES, AND
C              POTENCY MATRICES WITHOUT MONTHLY VARIATION
C
           READ (5,YPTM)
           READ (5,YACR)
           READ (5,YRMR)
           DO 50 IJ=1,NQUAL
           PMPTAB(IJ,II,BGNMON)=PMPVEC(IJ)
        50 PMITAB(IJ,II,BGNMON)=PMIVEC(IJ)
           ACUPM(II,BGNMON)=ACUP
           ACUIM(II,BGNMON)=ACUI
           REPERM(II,BGNMON)=REPER
           REIMPM(II,BGNMON)=REIMP
           GO TO 90
C
C              READ INPUT DATA OF ACCUMULATION RATES, REMOVAL RATES, AND
C              POTENCY MATRICES WITH MONTHLY VARIATION
C
        60 READ (5,MPTM)
           READ (5,MACR)
           READ (5,MRMR)
           DO 70 IJ=1,NQUAL
           DO 70 MN=1,12
           PMPTAB(IJ,II,MN)=PMPMAT(MN,IJ)
        70 PMITAB(IJ,II,MN)=PMIMAT(MN,IJ)
           DO 80 MN=1,12
           ACUPM(II,MN)=ACUPV(MN)
           ACUIM(II,MN)=ACUIV(MN)
           REPERM(II,MN)=REPERV(MN)
        80 REIMPM(II,MN)=REIMPV(MN)
        90 CONTINUE
           READ (5,INAC)
           SRER(II)=SRERI
           TS(II)=TSI
       100 CONTINUE
           IF (UNIT .EQ. -1) GO TO 120
           DEPW=UNT1(2,1)
           WHGT=UNT1(1,1)
           WHT=UNT2(1,1)
           UFL=UNT2(2,1)
           UTMP=UNT3(1,1)
           ARUN=UNT3(2,1)
           KUNT=1
           GO TO 130
       120 DEPW=UNT1(2,2)
           WHGT=UNT1(1,2)
           WHT=UNT2(1,2)
           UFL=UNT2(2,2)
           UTMP=UNT3(1,2)
           ARUN=UNT3(2,2)
           KUNT=2
C
C                        PRINTING OF TITLE PAGE AND INPUT PARAMETERS
C
       130 WRITE (6,4070)
           WRITE (6,4080)  (WSNAME(I),I=1,6),ARUN,AREA
           WRITE (6,4090) ARUN,ARUN,ARUN
           ARPT=0.0
           ARIT=0.0
           DO 140 I=1,NLAND
           TEM=AREA*AR(I)
```

```
      ARP(I)=TEM*(1.-IMPK(I))
      ARPT=ARPT+ARP(I)
      ARI(I)=TEM*IMPK(I)
      ARIT=ARIT+ARI(I)
      AR(I)=AR(I)*100.
      PER=IMPK(I)*100.
      WRITE (6,4100) (LNDUSE(KK,I),KK=1,3),AR(I),TEM,ARP(I),ARI(I),PER
      AR(I)=TEM
  140 CONTINUE
      A=ARIT/AREA
      WRITE (6,4110) A
      IF (ABS((ARIT+ARPT-AREA)/AREA).LE.0.001) GO TO 150
      WRITE (6,4120)
      GO TO 1600
C
C                       PRINTING OF SIMULATION CHARACTERISTICS
C
  150 IZ=BGNMON*2-1
      IX=IZ+1
      IP=ENDMON*2-1
      IQ=IP+1
      NQI=NQUAL+3
      IF (PINT.EQ.1) PRINTR=60
      WRITE (6,4130) (RTYPE(HYCAL,I),I=1,4),MNAM(IZ),MNAM(IX),BGNDAY,
     *                BGNYR,MNAM(IP),MNAM(IQ),ENDDAY,ENDYR,PRINTR,INTRVL,
     *                QSNCW,UTYPE(KUNT),UTYPE(KUNT),UFL,
     *                HYMIN,NQI,((QUALIN(I,J),I=1,3),J=1,NQUAL)
      WRITE (6,4140) INTER,IRC,INFIL,NN,L,SS,NNI,LI,SSI,K1,
     *                PETMUL,K3,K24L,KK24,UZSN,LZSN
      IF (SNOW.EQ.1) WRITE (6,4150) RADCON,CCFAC,EVAPSN,MELEV,
     *                               ELDIF,TSNOW,MPACK,DGM,WC,IDNS,SCF,
     *                               WMUL,RMUL,F,KUGI
      WRITE (6,4160) JRER,KRER,JSER,KSER,JEIM,KEIM
      WRITE (6,4162)
      DO 158 I=1,NLAND
  158 WRITE (6,4165) (LNDUSE(K,I),K=1,3),(TILDAY(I,J),J=1,12),
     *                (TILSED(I,J),J=1,12)
      IF (MNVAR.EQ.1) GO TO 200
C
C             PRINTING OF ACCUMULATION RATES,REMOVAL RATES,
C             AND POTENCY FACTORS WITHOUT MONTHLY VARIATION
C
      WRITE (6,4010)
      DO 160 I=1,NLAND
  160 WRITE (6,4230) (LNDUSE(K,I),K=1,3),ACUPM(I,BGNMON),ACUIM(I,BGNMON)
      WRITE (6,4010)
      DO 170 I=1,NLAND
  170 WRITE (6,4240) (LNDUSE(KK,I),KK=1,3),REPERM(I,BGNMON),
     *                 REIMPM(I,BGNMON)
      WRITE (6,4250) ((LNDUSE(KK,I),KK=1,3),I=1,NLAND)
      DO 180 I=1,NQUAL
  180 WRITE (6,4260) (QUALIN(J,I),J=1,3),(PMPTAB(I,K,BGNMON),K=1,NLAND)
      WRITE (6,4270) ((LNDUSE(KK,I),KK=1,3),I=1,NLAND)
      DO 190 I=1,NQUAL
  190 WRITE (6,4260) (QUALIN(J,I),J=1,3),(PMITAB(I,K,BGNMON),K=1,NLAND)
C
C  PRINTING OF MONTHLY COVER FUNCTION, EPXM  AND TEMP CORRECTION FACTORS
C
  200 WRITE (6,4170) (MNAM(I),I=1,24,2),(TCF(I),I=1,12),
     *          (EPXM(II),II=1,12),
     *          (LNDUSE(KK,1),KK=1,3),(COVMAT(1,KK),KK=1,12)
```

```
      IF (NLAND.EQ.1) GO TO 220
      DO 210 I=2,NLAND
  210 WRITE (6,4180) (LNDUSE(KK,I),KK=1,3),(COVMAT(I,KK),KK=1,12)
  220 IF (MNVAR.EQ.0) GO TO 290
C
C             PRINTING OF ACCUMULATION RATES,REMOVAL RATES,
C             AND POTENCY FACTORS WITH MONTHLY VARIATION
C
      WRITE (6,4190)
      DO 230 I=1,NLAND
  230 WRITE (6,4180) (LNDUSE(KK,I),KK=1,3),(ACUPM(I,J),J=1,12)
      WRITE (6,4200)
      DO 240 I=1,NLAND
  240 WRITE (6,4180) (LNDUSE(KK,I),KK=1,3),(REPERM(I,J),J=1,12)
      DO 250 J=1,NQUAL
      WRITE (6,4210) (QUALIN(KK,J),KK=1,3)
      DO 250 I=1,NLAND
  250 WRITE (6,4180) (LNDUSE(KK,I),KK=1,3),(PMPTAB(J,I,K),K=1,12)
      WRITE (6,4220)
      WRITE (6,4190)
      DO 260 I=1,NLAND
  260 WRITE (6,4180) (LNDUSE(KK,I),KK=1,3),(ACUIM(I,J),J=1,12)
      WRITE (6,4200)
      DO 270 I=1,NLAND
  270 WRITE (6,4180) (LNDUSE(KK,I),KK=1,3),(REIMPM(I,J),J=1,12)
      DO 280 J=1,NQUAL
      WRITE (6,4210) (QUALIN(KK,J),KK=1,3)
      DO 280 I=1,NLAND
  280 WRITE (6,4180) (LNDUSE(KK,I),KK=1,3),(PMITAB(J,I,K),K=1,12)
C
C            PRINTING OF INITIAL CONDITIONS
C
  290 WRITE (6,4280) UZS,LZS,SGW
      IF (SNOW.EQ.1) WRITE (6,4290) PACK,DEPTH
      WRITE (6,4300) (LNDUSE(KK,1),KK=1,3),TS(1),SRER(1)
      IF (NLAND.EQ.1) GO TO 310
      DO 300 I=2,NLAND
  300 WRITE (6,4310) (LNDUSE(KK,I),KK=1,3),TS(I),SRER(I)
  310 IF (UNIT.EQ.-1) GO TO 350
C
C  CONVERSION OF METRIC INPUT DATA TO ENGLISH UNITS
C
      HYMIN= HYMIN*35.3
      UZSN = UZSN/MMPIN
      LZSN = LZSN/MMPIN
      INFIL= INFIL/MMPIN
      L    = L*3.281
      LI   = LI*3.281
      UZS  = UZS/MMPIN
      LZS  = LZS/MMPIN
      SGW  = SGW/MMPIN
      ICS  = ICS/MMPIN
      OPS  = OPS/MMPIN
      IFS  = IFS/MMPIN
      DO 315 I=1,12
  315 EPXM(I) = EPXM(I)/MMPIN
      AREA = AREA*2.471
      DO 340 I=1,NLAND
      AR(I)=AR(I)*2.471
      ARP(I)=ARP(I)*2.471
      ARI(I)=ARI(I)*2.471
```

```
      SRER(I)=SRER(I)/2.24
      TS(I)=TS(I)/2.24
      DO 318 JJ=1,12
  318 TILSED(I,JJ) = TILSED(I,JJ)/2.24
      IF (MNVAR.GT.0) GO TO 320
      ACUPM(I,BGNMON)=ACUPM(I,BGNMON)*KGPHA
      ACUIM(I,BGNMON)=ACUIM(I,BGNMON)*KGPHA
      GO TO 340
  320 DO 330 J=1,12
      ACUPM(I,J)=ACUPM(I,J)*KGPHA
  330 ACUIM(I,J)=ACUIM(I,J)*KGPHA
  340 CONTINUE
      DO 345 I=7,37,6
  345 FORM(I)=ALTR(2)
      IF (SNOW.LT.1) GO TO 350
      ELDIF = ELDIF/0.3048
      DGM   = DGM/MMPIN
      MELEV = MELEV/0.3048
      TSNOW = 1.8*TSNOW + 32.0
      PACK  = PACK/MMPIN
      DEPTH = DEPTH/MMPIN
C
C                     ADJUSTMENT OF CONSTANTS
C
  350 H = 60/INTRVL
      TIMFAC = INTRVL
      INTRVL = 24*H
      ARIT=0.0
      KRER=KRER*H**(JRER-1.0)
      KSER=KSER*H**(JSER-1.0)
      KEIM=KEIM*H**(JEIM-1.0)
      DO 355 I=1,NQUAL
      IF (CUNIT(I).EQ.TIT(1)) CUNIT(I)=CUNIT(7)
  355 IF (CUNIT(I).EQ.CUNIT(6)) SCALEF(I)=1000.
      IF (NQUAL.EQ.5) GO TO 357
      II=11+NQUAL*6
      DO 356 I=II,40
  356 FORM(I)=ALTR(1)
  357 I=NQUAL+4
      TIT(1)=ALTR(I)
      J=0
      DO 358 I=15,39,6
      J=J+1
      IF(SCALEF(J).LE.2.) GO TO 358
      FORM(I)=ALTR(3)
  358 CONTINUE
C
C        CONVERT ACCUMULATION RATES INTO TONS/ACRE/DAY
C
      DO 380 I=1,NLAND
      IF (MNVAR.GT.0) GO TO 360
      ACUPM(I,BGNMON)=ACUPM(I,BGNMON)/2000.
      ACUIM(I,BGNMON)=ACUIM(I,BGNMON)/2000.
      GO TO 380
  360 DO 370 J=1,12
      ACUIM(I,J)=ACUIM(I,J)/2000.
      ACUPM(I,J)=ACUPM(I,J)/2000.
  370 CONTINUE
  380 CONTINUE
      PA=1.0-A
        IRC4=IRC**(1.0/96.0)
```

```
            IF (SNOW .LT. 1)  GO TO 450
              DO  430 DA = 1,31
      430     READ(5,4050) (IWIND(MN,DA), MN=1,12)
C
              DO 440 DA =1,31
      440     READ (5,4050) (IRAD(MN,DA), MN=1,12)
C
      450     IF (UNIT .EQ. -1) GO TO 490
              DO 480 DA=1,31
                 DO 470 MN=1,12
                    IEVAP(MN,DA) = IEVAP(MN,DA)*3.937
                   IF (SNOW.EQ.1) IWIND(MN,DA) = IWIND(MN,DA)*0.6214
                      DO 460 IT=1,2
      460             ITEMP(MN,DA,IT) = 1.8*ITEMP(MN,DA,IT) + 32.5
      470          CONTINUE
      480        CONTINUE
C                                                SAV TMIN OF JAN 1 ON 11/31
      490 ITEMP(11.31,2) = ITEMP(1,1,2)
C
C
C
C                                                            BEGIN MONTHLY LOOP
      500      DO 1240  MONTH=MNSTRT,MNEND
C
C                  ASSIGN CURRENT MONTHLY VALUES OF ACCUMULATION RATES,
C                  REMOVAL RATES, AND POTENCY FACTORS
C
          IF (HYCAL.EQ.1) GO TO 530
          IF (MNVAR.EQ.0.AND.MONTH.NE.BGNMON) GO TO 530
          DO 520 I=1,NLAND
          DO 510 J=1,NQUAL
          PMP(J,I)=PMPTAB(J,I,MONTH)
      510 PMI(J,I)=PMITAB(J,I,MONTH)
          ACCP(I)=ACUPM(I,MONTH)
          ACCI(I)=ACUIM(I,MONTH)
          RPEP(I)=REPERM(I,MONTH)
      520 RIMP(I)=REIMPM(I,MONTH)
      530 CONTINUE
          TEMPCF=TCF(MONTH)
C
C                         ZEROING OF VARIABLES
C
          DO 540 I=1,28
C              ZEROING OF THE FIRST 28 VARIABLES CONTAINED IN COMMON/LNDOUT/
      540 AR1OUT(I)=0.0
          PRTM=0.
          ROBTOM=0.
          INFTOM=0.
          DO 560 J=1,NQUAL
          DO 550 I=1,NLAND
          APOLP(I,J)=0.0
          APOLI(I,J)=0.0
      550 CONTINUE
          POLTCA(J)=0.0
      560 POLTC(J)=0.0
          DO 570 I=1,NLAND
          AEFSN(I)=0.0
          AEIM(I)=0.0
      570 CONTINUE
          NOSIM=0
          NOS=0
```

```
            TEMPA=0.0
            DOA=0.0
            SEDTCA=0.0
            IX=2*MONTH
            IZ=IX-1
            RECOUT(1)=YEAR
                  DYSTRT = 1
                  IF (MOD(YEAR,4))  590, 580, 590
      580            GO TO (630,610,630,620,630,620,630,630,620,630,620,630),
     *MONTH
      590            GO TO (630,600,630,620,630,620,630,630,620,630,620,630),
     *MONTH
      600                  DYEND = 28
                           GO TO 640
      610                  DYEND = 29
                           GO TO 640
      620                  DYEND = 30
                           GO TO 640
      630                  DYEND = 31
C
      640         IMDEND=DYEND
                  IF (YEAR .NE. BGNYR)  GO TO 650
                  IF (MONTH .NE. BGNMON)  GO TO 650
                  DYSTRT = BGNDAY
C
      650         IF (YEAR .NE. ENDYR)  GO TO 660
                  IF (MONTH .NE. ENDMON)  GO TO 660
                  DYEND = ENDDAY
C                                                       BEGIN DAILY LOOP
      660         DO 990  DAY=DYSTRT,DYEND
C
                     IF (MONTH.EQ.1 .AND. DAY.EQ.1) JCOUNT = 0
                     JCOUNT = JCOUNT + 1
C
                     TIME = 0
                     RAINT = 0.0
                     EP = PETMUL*IEVAP(MONTH,DAY)/1000.
                     DO 670  I=1,INTRVL
                        IRAIN(I) = 0
                        RAIN(I) = 0.0
      670               CONTINUE
C
            MTX=MONTH
            NTX=MONTH+1
            IF (NTX.GT.12) NTX=1
C
C              CALCULATE EPXMI FOR EACH DAY AS LINEAR INTERPOLATION
C              BETWEEN MONTHLY VALUES
C
            EPXMI=EPXM(MTX)+(EPXM(NTX)-EPXM(MTX))*(FLOAT(DAY-1)/
     *           FLOAT(DYEND))
C
C
C                CHECK FOR TILLAGE DATES AND RESET SBER
C
            J=1
            DO 676 I=1,NLAND
            DO 674 II=1,12
            IF (JCOUNT.NE.TILDAY(I,II))  GO TO 674
            SBER(I) =TILSED(I,II)
            IF (J.GT.0) WRITE(6,4610)
```

```
          J=0
          ADEP=SREP(I)
          IF (UNIT.GT.0) ADEP=ADEP*2.24
          WRITE (6,4600) MNAM(IZ),DAY,(LNDUSE(IK,I),IK=1,3),
     *                    ADEP,WHT,ARUN
  674 CONTINUE
  676 CONTINUE
C
C            CHECK TO SEE IF SNOWMELT CALC'S WILL BE DONE - IF YES THEN
C            CALCULATE CONTINUOUS TEMP, WIND, RAD AND APPLY CORRES MULT
C            FACTORS
C
          IF (SNOW.LT.1) GO TO 790
          WINF=(1.0-F) + F*(.35-.03*KUGI)
C                                       WINF REDUCES WIND FOR FORESTED AREAS
C
C           /* KUGI IS INDEX TO UNDERGROWTH AND FOREST DENSITY,*/
C           /* WITH VALUES 0 TO 10 - WIND IN FOREST IS 35% OF   */
C           /* WIND IN OPEN WHEN KUGI=0, AND 5% WHEN KUGI=10 - */
C           /* WIND IS ASSUMED MEASURED AT 1-5 FT ABOVE GROUND */
C           /* OR SNOW SURFACE  */
C
                WIND = IWIND(MONTH,DAY)
          TMIN = ITEMP(MONTH,DAY,2)
          DEWX = TMIN - 1.0*ELDIF
          RR = IRAD(MONTH,DAY)
C                                  DEWPT ASSUMED TO BE MIN TEMP AND USES
C                                  LAPSE RATE OF 1 DEGREE/1000 FT
C
C         CALCULATE CONTINUOUS TEMP, WIND, AND RAD
  680 CONTINUE
      TGRAD = 0.0
      DO 780 I=1,24
        IF (I-7)  740, 690, 700
  690   CHANGE = ITEMP(MONTH,DAY,1) - TEMPI
  700   IF (I-17)  740, 710, 740
C                             IMDEND IS LAST DAY OF PRESENT MONTH
  710   IF (DAY .NE. IMDEND)  CHANGE =ITEMP(MONTH,DAY+1,2) - TEMPI
        IF (MONTH-12)  730, 720, 730
  720   IF (DAY .EQ. IMDEND)  CHANGE = ITEMP(11,31,2) - TEMPI
        GO TO 740
  730   IF (DAY .EQ. IMDEND)  CHANGE = ITEMP(MONTH+1,1,2) - TEMPI
C
  740   IF (ABS(CHANGE)-0.001)  750, 750, 760
  750   TGRAD = 0.0
        GO TO 770
  760   TGRAD = GRAD(I)*CHANGE
  770   TEMPX(I) = TEMPI + TGRAD
        TEMPI = TEMPI + TGRAD
       IF (SNOW.LT.1) GO TO 780
        WINDX(I)  = WMUL*WIND*WINF*WINDIS(I)
        RAD(I)    = RMUL*RR*RADCON*RADDIS(I)
  780 CONTINUE
      IF (SNOW.LT.1) GO TO 950
C                                          15-MIN PRECIP INPUT
  790           IF (PINT.EQ.1)  GO TO 850
                   J=0
  800              J=J+1
                   JK = J*12
                   JJ = JK - 11
                   READ (5,4020)  YR, MO, DY, CN, (IRAIN(I), I=JJ,JK)
```

```
                    IF (UNIT .EQ. -1) GO TO 820
                    DO 810 I=JJ,JK
                       IRAIN(I) = IRAIN(I)*3.937 + 0.5
      810              CONTINUE
      820           IF (CN .EQ. 9)  J=9
                    YR = YR + 1900
                    IT = (YEAR-YR) + (MONTH-MO) + (DAY-DY) + (J-CN)
                    IF (IT .EQ. 0)  GO TO 830
                    WRITE (6,4000)  J, MONTH, DAY, YEAR, CN, MO, DY, YR
                    GO TO 1600
      830           IF (J.LT.8) GO TO 800
                 DO 840  I=1,INTRVL
                    RAIN(I) = IRAIN(I)*K1/100.
                    RAINT = RAINT + RAIN(I)
      840           CONTINUE
                 GO TO 920
C
C                                          HOURLY PRECIP INPUT
      850           J=0
      860           J=J+1
                    JK = J*48
                    JJ = JK - 47
                    READ (5,4020)  YR, MO, DY, CN, (IRAIN(I), I=JJ,JK,4)
                    IF (UNIT .EQ. -1) GO TO 880
                    DO 870 I=JJ,JK,4
                       IRAIN(I) =IRAIN(I)*3.937 + 0.5
      870              CONTINUE
      880           IF (CN .EQ. 9)  J=9
                    YR = YR + 1900
                    IT = (YEAR-YR) + (MONTH-MO) + (DAY-DY) + (J-CN)
                    IF (IT .EQ. 0)  GO TO 890
                    WRITE (6,4000)  J, MONTH, DAY, YEAR, CN, MO, DY, YR
                    GO TO 1600
      890           IF(J.LT.2) GO TO 860
C
                 DO 910  I=1,INTRVL,4
                    TEM = IRAIN(I)*(K1/100.)/4.
                    DO 900 K=1,4
      900           RAIN(I+4-K)=TEM
                    RAINT = RAINT + RAIN(I)
      910           CONTINUE
C
      920        IF (RAINT)  930, 930, 940
C
C  USE RAIN LOOP IF MOISTURE STORAGES ARE NOT EMPTY
C
      930  IF ((RESS .LT. 0.001).OR.(SRGXT .LT. 0.001)) GO TO 980
C
C                    RAIN LOOP
C
C        CONDITIONAL BRANCHING TO CALCULATE HOURLY TEMPERATURES
C
      940  IF (SNOW.LT.1) GO TO 680
      950  CONTINUE
C
C         CALCULATE COVER FUNCTION  FOR THE PERVIOUS
C                AREAS WITHIN EACH LAND TYPE USE
C
           MTX=MONTH
           NTX=MONTH+1
           IF (NTX.GT.12) NTX=1
```

```
            DO 960 I=1,NLAND
            COVER(I)=COVMAT(I,MTX)+(FLOAT(DAY-1)/FLOAT(DYEND))*
     1            (COVMAT(I,NTX)-COVMAT(I,MTX))
  960 CONTINUE
                      DO 970  I=1,INTRVL
                         TIME = TIME + 1
                         TP = 1
                         PR = RAIN(I)
C
                         IMIN = MOD(TIME,H)
                         IHR = (TIME - IMIN)/H
                         IMIN = TIMFAC*IMIN
                         IX = 2*MONTH
                         IZ = IX - 1
                        CALL LANDS
                 IF (HYCAL.EQ.1) GC TO 970
                        CALL QUAL
  970 CONTINUE
                        NDSR=0
C
                      GO TO 990
C
C                            NO RAIN LOOP
C
  980                 TP = INTRVL
                      PR = 0.0
                      P3 = 0.0
                         RESB1 = 0.0
                      IMIN = 00
                      IHR = 24
                      IX = 2*MONTH
                      IZ = IX - 1
                       NDSR=NDSR+1
                       CALL LANDS
                 IF (HYCAL.EQ.1) GO TO 990
                       CALL QUAL
C                                                              END DAILY LOOP
  990                 CONTINUE
C
C                                     MONTHLY SUMMARY
C
            WRITE (6,4320) MNAM(IZ),MNAM(IX),YEAR
            UZSOT=UZS
            LZSOT=LZS
            SGWOT=SGW
            SCEPOT=SCEP
            RESSOT=RESS
            SRGXTO=SRGXT
            TWBALO=TWBAL
            TSNBOL=TSNBAL
            PACKOT=PACK
            IF (UNIT.EQ.-1) GO TO 1010
            DO 1000 I=1,28
C                CONVERSION TO METRIC UNITS OF THE FIRST 28 VARIABLES
C                  CONTAINED IN COMMON/LNDOUT/
            AR1OUT(I)=AR1OUT(I)*MMPIN
 1000 CONTINUE
 1010 WRITE (6,4330) DEPW,RCSTCM,RINTOM,RITOM,BASTOM,RUTOM,RCHTCM,PETOM
            IF (SNOW.LT.1) GO TO 1030
            COVR=100.
            IF (PACK.LT.IPACK) COVR=(PACK/IPACK)*100.
```

```
      IF (PACK.GT.0.01) GO TO 1020
      COVR=0.0
      SDEN=0.0
 1020 WRITE (6,4340) SUMSNM,PXSNM,MELRAM,RADMEM,CONMEM,CDRMEM,CRAINM,
     *               SGMM,SNEGMM,PACKOT,SDEN,COVR,SEVAPM
 1030 WRITE (6,4350) EPTOM,NEPTOM,UZSOT,LZSOT,SGWOT,SCEPOT,RESSOT,
     *               SRGXTO,TWBALO
      IF (SNOW.GT.0) WRITE (6,4360) TSNBOL
        IF (HYCAL.EQ.1) GO TO 1230
C
C           OUTPUT OF SEDIMENTS DEPOSIT ON GROUND AT MONTH'S END
C
      WRITE (6,4370) WHT,ARUN
       TEM1=0.0
       TEM2=0.0
       TEM3=0.0
       TEM4=0.0
      DO 1050 I=1,NLAND
      TEM=SRER(I)*(1-IMPK(I))+TS(I)*IMPK(I)
      WHFUN1=(AR(I)/AREA)*(1-IMPK(I))
      WHFUN2=(AR(I)/AREA)*IMPK(I)
      TEM1=TEM1+SRER(I)*WHFUN1
      TEM2=TEM2+TS(I)*WHFUN2
      TEM3=TEM3+WHFUN1
      TEM4=TEM4+WHFUN2
      IF (UNIT.GT.-1) GO TO 1040
      WRITE (6,4390) (LNDUSE(IK,I),IK=1,3),TEM,SRER(I),TS(I)
      GO TO 1050
 1040 TEM5=SRER(I)*2.24
      TEM6=TS(I)*2.24
      TEM=TEM*2.24
      WRITE (6,4390) (LNDUSE(IK,I),IK=1,3),TEM,TEM5,TEM6
 1050 CONTINUE
      IF (NLAND.EQ.1) GO TO 1070
      IF (TEM3.GT.0.0) TEM1=TEM1/TEM3
      IF (TEM3.LE.0.0) TEM1=0.0
      IF (TEM4.GT.0.0) TEM2=TEM2/TEM4
      IF (TEM4.LE.0.0) TEM2=0.0
      TEM=TEM1*(1-A)+TEM2*A
      IF (UNIT.LT.1) GO TO 1060
      TEM=TEM*2.24
      TEM1=TEM1*2.24
      TEM2=TEM2*2.24
 1060 WRITE (6,4380) TEM,TEM1,TEM2
C
C           OUTPUT MONTHLY SEDIMENTS LOSS FOR EACH LAND TYPE USE
C
 1070 WRITE (6,4400) WHT,WHGT,ARUN
      AERSNT=0.0
      AEIMT=0.0
      DO 1100 I=1,NLAND
      TEM=AEIM(I)+AERSN(I)
      IF (TEM.GT.0.0) GO TO 1080
      TEM1=0.0
      TEM2=0.0
      TEM3=0.0
      GO TO 1090
 1080 TEM1=TEM*2000./AR(I)
      TEM2=100.*AERSN(I)/TEM
      TEM3=100.*AEIM(I)/TEM
      IF (UNIT.LT.1) GO TO 1090
```

```
      TEM=TEM*.9072
      TEM1=TEM1*1.12
 1090 WRITE (6,4410) (LNDUSE(IK,I),IK=1,3),TEM,TEM1,TEM2,TEM3
      AERSNT=AERSNT+AERSN(I)
      AEIMT=AEIMT+AEIM(I)
 1100 CONTINUE
C
C           OUTPUT MONTHLY SEDIMENTS LOSS FOR THE ENTIRE WATERSHED
C
      TEM=AERSNT+AEIMT
      IF (TEM.GT.0.0) GO TO 1110
      TEM1=0.0
      TEM2=0.0
      TEM3=0.0
      GO TO 1120
 1110 TEM1=TEM*2000./AREA
      TEM2=100.*AERSNT/TEM
      TEM3=100.*AEIMT/TEM
      IF (UNIT.LT.1) GO TO 1120
      TEM=TEM*.9072
      TEM1=TEM1*1.12
 1120 WRITE (6,4470) TEM,TEM1,TEM2,TEM3
      WRITE (6,4420) WHGT ,WHGT,ARUN
C
C           OUTPUT MONTHLY WASHOFF FOR EACH OF THE ANALYZED POLLUTANTS
C
      DO 1180 J=1,NQUAL
      WRITE (6,4430) (QUALIN(I,J),I=1,3)
      APOLPT=0.0
      APOLIT=0.0
      DO 1150 I=1,NLAND
C
C           MONTHLY WASHOFF OF A GIVEN POLLUTANT FROM EACH LAND TYPE USE
C
      TEM=APOLP(I,J)+APOLI(I,J)
      IF (TEM.GT.0.0) GO TO 1130
      TEM1=0.0
      TEM2=0.0
      TEM3=0.0
      GO TO 1140
 1130 TEM1=TEM/AR(I)
      TEM2=100.*APOLP(I,J)/TEM
      TEM3=100.*APOLI(I,J)/TEM
      IF (UNIT.LT.1) GO TO 1140
      TEM=TEM*.454
      TEM1=TEM1/KGPHA
 1140 WRITE (6,4410) (LNDUSE(KK,I),KK=1,3),TEM,TEM1,TEM2,TEM3
      APOLPT=APOLPT+APOLP(I,J)
      APOLIT=APOLIT+APOLI(I,J)
 1150 CONTINUE
C
C          TOTAL MONTHLY WASHOFF OF A GIVEN POLLUTANT
C
      TEM=APOLPT+APOLIT
      IF (TEM.GT.0.0) GO TO 1160
      TEM1=0.0
      TEM2=0.0
      TEM3=0.0
      GO TO 1170
 1160 TEM1=TEM/AREA
      TEM2=100.*APOLPT/TEM
```

```
      TEM3=100.*APOLIT/TEM
      IF (UNIT.LT.1) GO TO 1170
      TEM=TEM*.454
      TEM1=TEM1/KGPHA
 1170 WRITE (6,4440) TEM,TEM1,TEM2,TEM3
 1180 CONTINUE
      TEMPAY=TEMPAY+TEMPA
      DOAY=DOAY+DOA
      SEDTCY=SEDTCY+SEDTCA
C
C           CALCULATE AND PRINT MONTHLY AVERAGES OF TEMPERATURE,
C           DISSOLVED OXYGEN,AND EACH OF THE ANALYSED POLLUTANT
C
      IF (NOSIM.LE.0) GO TO 1190
      TEMPA=TEMPA/NOSIM
      DOA=DOA/NOSIM
      SEDTCA=SEDTCA/NOSIM
 1190 TEMPO=TEMPA
      IF (UNIT.EQ.1) TEMPO=(TEMPO-32.)*5/9
      WRITE (6,4450) UTMP,TEMPO,DOA,SEDTCA
      DO 1210 J=1,NQUAL
      PLTCAY(J)=PLTCAY(J)+POLTCA(J)
      IF (NOSIM.LE.0) GO TO 1200
      POLTCA(J)=POLTCA(J)/NOSIM
 1200 WRITE (6,4460) (QUALIN(I,J),I=1,3),CUNIT(J),POLTCA(J)
 1210 CONTINUE
C
C                ACCUMULATION FOR YEARLY SUMMARIES
C
      DO 1220 I=1,NLAND
      AERSNY(I)=AERSNY(I)+AERSN(I)
      AEIMY(I)=AEIMY(I)+AEIM(I)
      DO 1220 J=1,NQUAL
      APOLPY(I,J)=APOLPY(I,J)+APOLP(I,J)
      APOLIY(I,J)=APOLIY(I,J)+APOLI(I,J)
 1220 CONTINUE
 1230 CONTINUE
      WRITE (6,4490) NOS
      NOSIY=NOSIY+NOSIM
      NOSY=NOSY+NOS
 1240 CONTINUE
C                                    END MONTHLY LOOP
C                              YEARLY SUMMARIES
C
      WRITE (6,4480) YEAR
      UZSMT=UZS
      LZSMT=LZS
      SGWMT=SGW
      SCEPT=SCEP
      RESST=RESS
      SRGXTT=SRGX
      TWBLMT=TWBAL
      TSNBOL=TSNBAL
      IF (UNIT.EQ.-1) GO TO 1260
      DO 1250 I=1,28
C          CONVERSION TO METRIC UNITS OF THE LAST 28 VARIABLES
C            CONTAINED IN COMMON/LNDOUT/
 1250 AR2OUT(I)=AR2OUT(I)*MMPIN
 1260 WRITE (6,4330) DEPW,RCSTCT,RINTOT,RITOT,BASTOT,RUTOT,RCHTOT,PBTOT
      IF (SNOW.LT.1) GO TO 1280
      COVR=100.
```

```
      IF (PACK.LT.IPACK) COVR=(PACK/IPACK)*100.
      IF (PACK.GT.0.01) GO TO 1270
      COVR=0.0
      SDEN=0.0
 1270 WRITE (6,4340) SUMSNY,PXSNY,MELRAY,RADMEY,CONMEY,CDRMEY,CRAINY,
     *              SGMY,SNEGMY,PACKOT,SDEN,COVR,SEVAPY
 1280 WRITE (6,4350) EPTOT,NEPTOT,UZSMT,LZSMT,SGWMT,SCEPT,RESST,
     *              SRGXTT,TWBLMT
      IF (SNOW.GT.0) WRITE (6,4360) TSNBOL
      IF (HYCAL.EQ.1) GO TO 1425
      WRITE (6,4400) WHT,WHT,ARUN
C
C          OUTPUT YEARLY SEDIMENTS LOSS FOR EACH LAND TYPE USE
C
      AERSNT=0.0
      AEIMT=0.0
      DO 1310 I=1,NLAND
      TEM=AEIMY(I)+AERSNY(I)
      IF (TEM.GT.0.0) GO TO 1290
      TEM1=0.0
      TEM2=0.0
      TEM3=0.0
      GO TO 1300
 1290 TEM1=TEM/AR(I)
      TEM3=100.*AEIMY(I)/TEM
      TEM2=100.*AERSNY(I)/TEM
      IF (UNIT.LT.1) GO TO 1300
      TEM=TEM*.9072
      TEM1=TEM1/KGPHA
 1300 WRITE (6,4410) (LNDUSE(KK,I),KK=1,3),TEM,TEM1,TEM2,TEM3
      AERSNT=AERSNT+AERSNY(I)
      AEIMT=AEIMT+AEIMY(I)
 1310 CONTINUE
C
C          OUTPUT YEARLY SEDIMENTS LOSS FOR THE ENTIRE WATERSHED
C
      TEM=AERSNT+AEIMT
      IF (TEM.GT.0.0) GO TO 1320
      TEM1=0.0
      TEM2=0.0
      TEM3=0.0
      GO TO 1330
 1320 TEM1=TEM/AREA
      TEM2=100.*AERSNT/TEM
      TEM3=100.*AEIMT/TEM
      IF (UNIT.LT.1) GO TO 1330
      TEM=TEM*.9072
      TEM1=TEM1*2.24
 1330 WRITE (6,4470) TEM,TEM1,TEM2,TEM3
      WRITE (6,4420) WHGT,WHGT,ARUN
C
C          OUTPUT YEARLY WASHOFF FOR EACH OF THE ANALYZED POLLUTANTS
C
      DO 1390 J=1,NQUAL
      WRITE (6,4430) (QUALIN(I,J),I=1,3)
      APOLPT=0.0
      APCLIT=0.0
      DO 1360 I=1,NLAND
C
C          YEARLY WASHOFF OF A GIVEN POLLUTANT FROM EACH LAND TYPE USE
C
```

```
      TEM=APOLPY(I,J)+APOLIY(I,J)
      IF (TEM.GT.0.0) GO TO 1340
      TEM1=0.0
      TEM2=0.0
      TEM3=0.0
      GO TO 1350
 1340 TEM1=TEM/AR(I)
      TEM2=100.*APOLPY(I,J)/TEM
      TEM3=100.*APOLIY(I,J)/TEM
      IF (UNIT.LT.1) GO TO 1350
      TEM=TEM*.454
      TEM1=TEM1/KGPHA
 1350 WRITE (6,4410) (LNDUSE(KK,I),KK=1,3),TEM,TEM1,TEM2,TEM3
      APOLPT=APOLPT+APOLPY(I,J)
      APOLIT=APOLIT+APOLIY(I,J)
 1360 CONTINUE
C
C          TOTAL YEARLY WASHOFF OF A GIVEN POLLUTANT
C
      TEM=APOLPT+APOLIT
      IF (TEM.GT.0.0) GO TO 1370
      TEM1=0.0
      TEM2=0.0
      TEM3=0.0
      GO TO 1380
 1370 TEM1=TEM/AREA
      TEM2=100.*APOLPT/TEM
      TEM3=100.*APOLIT/TEM
      IF (UNIT.LT.1) GO TO 1380
      TEM=TEM*.454
      TEM1=TEM1/KGPHA
 1380 WRITE (6,4440) TEM,TEM1,TEM2,TEM3
 1390 CONTINUE
C
C           CALCULATE AND PRINT YEARLY AVERAGES OF TEMPERATURE,
C           DISSOLVED OXYGEN,AND EACH OF THE ANALYZED POLLUTANT
C
      IF (NOSIY.LE.0) GO TO 1400
      TEMPAY=TEMPAY/NOSIY
      DOAY=DOAY/NOSIY
      SEDTCY=SEDTCY/NOSIY
 1400 TEMPO=TEMPAY
      IF (UNIT.EQ.1) TEMPO=(TEMPO-32.)*5/9
      WRITE (6,4450) UTME,TEMPO,DOAY,SEDTCY
      DO 1420 J=1,NQUAL
      IF (NOSIY.LE.0) GO TO 1410
      PLTCAY(J)= PLTCAY(J)/NOSIY
 1410 WRITE (6,4460) (QUALIN(I,J),I=1,3),CUNIT(J),PLTCAY(J)
 1420 CONTINUE
 1425 WRITE (6,4490) NOSY
C
C                         ZEROING OF VARIABLES
C
      DO 1430 I=1,28
C           ZEROING OF THE LAST 28 VARIABLES CONTAINED IN COMMON/LNDOUT/
 1430 AR2OUT(I)=0.0
      DO 1450 J=1,NQUAL
      DO 1440 I=1,5
      APOLPY(I,J)=0.0
 1440 APOLIY(I,J)=0.0
 1450 PLTCAY(J)=0.0
```

```
      DO 1460 I=1,5
      AERSNY(I)=0.0
 1460 AEIMY(I)=0.0
      NOSY=0
      TEMPAY=0.0
      DOAY=0.0
C
C        SUMMARY OF STORMS' CHARACTERISTICS
C
      NV=(NQUAL+1)*4
      IF (HYCAL.EQ.1) NV=2
      IF (NOSY.LT.2.OR.NOSY.GT.200) GO TO 1560
C
C        CLEAR OUTPUT VECTORS AND INITIALIZE VMIN AND VMAX
C
      DO 1470 K=1,NV
      TOTAL(K)=0.0
      SD(K)=0.0
      VMIN(K)=1.0E75
 1470 VMAX(K)=-1.0E75
C
C       CALCULATE MEANS, ST.DEV'S,MAXIMA, AND MINIMA
C
      DO 1520 I=1,NOSY
      DO 1520 K=1,NV
      TOTAL (K)=TOTAL(K)+STMCH(I,K)
      IF (STMCH(I,K)-VMIN(K)) 1480,1490,1490
 1480 VMIN(K)=STMCH(I,K)
 1490 IF (STMCH(I,K)-VMAX(K)) 1510,1510,1500
 1500 VMAX(K)=STMCH(I,K)
 1510 SD(K)=SD(K)+STMCH(I,K)*STMCH(I,K)
 1520 CONTINUE
      DO 1530 K=1,NV
      RANGE(K)=VMAX(K)-VMIN(K)
      AVER(K)=TOTAL(K)/NOSY
      SD(K)=SQRT(ABS((SD(K)-TOTAL(K)*TOTAL(K)/NOSY)/(NOSY-1)))
 1530 CONTINUE
C
C        PRINT STORM CHARACTERISTICS
C
      IF (HYCAL.NE.1) GO TO 1540
      WRITE (6,4500)
      WRITE (6,4580) DEPW,AVER(1),SD(1),VMAX(1),VMIN(1),RANGE(1)
      WRITE (6,4590) UPL,AVER(2),SD(2),VMAX(2),VMIN(2),RANGE(2)
      GO TO 1570
 1540 WRITE (6,4500)
      WRITE (6,4510)
      WRITE (6,4530) WHT,AVER(1),SD(1),VMAX(1),VMIN(1),RANGE(1)
      WRITE (6,4540) WHGT,AVER(2),SD(2),VMAX(2),VMIN(2),RANGE(2)
      WRITE (6,4545) AVER(3),SD(3),VMAX(3),VMIN(3),RANGE(3)
      WRITE (6,4555) AVER(4),SD(4),VMAX(4),VMIN(4),RANGE(4)
      DO 1550 J=1,NQUAL
      WRITE (6,4430) (QUALIN(I,J),I=1,3)
      K=J*4+1
      WRITE (6,4530) WHT,AVER(K),SD(K),VMAX(K),VMIN(K),RANGE(K)
      K=K+1
      WRITE (6,4540) WHGT,AVER(K),SD(K),VMAX(K),VMIN(K),RANGE(K)
      K=K+1
      WRITE (6,4550) CUNIT(J),AVER(K),SD(K),VMAX(K),VMIN(K),RANGE(K)
      K=K+1
      WRITE (6,4560) CUNIT(J),AVER(K),SD(K),VMAX(K),VMIN(K),RANGE(K)
```

```
 1550 CONTINUE
      GO TO 1570
 1560 WRITE (6,4570)
      IF (NOSY.EQ.0) GO TO 1590
 1570 DO 1580 I=1,NOSY
      DO 1580 K=1,NV
 1580 STMCH(I,K)=0.0
      NOSY=0
C                                    END OF YEARLY LOOP
 1590    CONTINUE
C
 1600 CONTINUE
C
C                        FORMAT STATEMENTS
C
 4000 FORMAT ('1','*****ERROR*****  INCORRECT INPUT DATA!   DESIRED ',
     *   'CARD ',I1,' FOR ',I2,'/',I2,'/',I4,'; READ CARD ',I1,' FOR ',
     *   I2,'/',I2,'/',I4)
 4010 FORMAT ('0')
 4020 FORMAT (1X,3I2,I1,12I6)
 4040 FORMAT (8X,24I3)
 4050 FORMAT (8X,12I6)
 4060 FORMAT (3A4,2X,A4 )
 4070 FORMAT ('1',9(/),45X,'NONPOINT SOURCE POLLUTANT LOADING MODEL',
     1        /,44X,42('='),5(/))
 4080 FORMAT (' ',1X,'WATERSHED CHARACTERISTICS :',///,6X,'NAME',8X,
     1        3A8,/,18X,3A8,//,6X,'TOTAL AREA (',A4,')',8X,F9.2,/)
 4090 FORMAT (9X,'LAND USE',5X,'% OF TOTAL',6X,'AREA (',A4,'S)',6X,
     1        'PERVIOUS (',A4,'S)',3X,'IMPERVIOUS (',A4,'S)',3X,
     2        'IMPERVIOUS (%)',/)
 4100 FORMAT (' ',7X,3A4,5X,F5.1,4(10X,F9.2))
 4110 FORMAT (/,6X,'FRACTION OF IMPERVIOUS AREA',2X,F5.2)
 4120 FORMAT ('0',8X,'**WARNING**',3X,'CHECK IF THE LAND TYPES AREAS ',
     1         'ARE CORRECT')
 4130 FORMAT (5(/),' ',1X,'SIMULATION CHARACTERISTICS :',///,6X,
     1        'TYPE OF RUN',10X,4A8,/,6X,'DATE SIMULATION BEGINS',
     2        13X,2A4,2X,I2,', ',I4,/,6X,'DATE SIMULATION ENDS',15X,
     3        2A4,2X,I2,', ',I4,/,6X,'INPUT PRECIPITATION TIME INTERVAL',
     4        9X,I3,1X,'MINUTES',/,6X,'SIMULATION TIME INTERVAL',19X,I2,
     5        1X,'MINUTES',/,6X,'IS SNOWMELT CONSIDERED ?',26X,A4,/,
     6        6X,'INPUT UNITS',34X,1A8,/,6X,'OUTPUT UNITS',33X,1A8,/,6X,
     7        'MINIMUM FLOW FOR OUTPUT PER INTERVAL (',A4,')',1X,F9.4,
     8        /,6X,'NUMBER OF QUALITY INDICATORS ANALYZED',14X,I2,
     9        /,6X,'THE ANALYZED QUALITY INDICATORS',4X,
     X        'SEDIMENTS,DO,TEMP,',/,5(46X,3A4,',',/))
 4140 FORMAT (5(/),2X,'SUMMARY OF INPUT PARAMETERS :',///,6X,
     1         'LANDS',13X,'INTER =',F7.3,4X,'IRC    =',F7.3,4X,
     2         'INFIL =',F7.3,/,24X,'NN     =',F7.3,4X,'L      =',
     3         F7.3,4X,'SS     =',F7.3,/,24X,'NNI   =',F7.3,4X,
     4         'LI     =',F7.3,4X,'SSI   =',F7.3,/,24X,'K1     =',F7.3,
     5         4X,'PETMUL=',F7.3,4X,'K3     =',F7.3,/,24X,14X,
     6         4X,'K24L  =',F7.3,4X,'KK24  =',F7.3,/,24X,
     7         'UZSN  =',F7.3,4X,'LZSN  =',F7.3)
 4150 FORMAT (/,6X,'SNOW',14X,'RADCON=',F7.3,4X,'CCFAC =',F7.3,4X,
     1         'EVAPSN=',F7.3,/24X,'MELEV =',F7.3,4X,'ELDIF =',F7.3,4X,
     2         'TSNOW =',F7.3,/,24X,'MPACK =',F7.3,4X,'DGM    =',F7.3,
     3         4X,'WC     =',F7.3,/,24X,'IDNS  =',F7.3,4X,'SCF    =',F7.3,
     4         4X,'WMUL  =',F7.3,/,24X,'RMUL  =',F7.3,4X,'F      =',
     5         F7.3,4X,'KUGI  =',F7.3,/)
 4160 FORMAT (/,6X,'QUAL  ',12X,'JRER  =',F7.3,4X,'KRER  =',F7.3,/,
     1         24X,'JSER  =',F7.3,4X,'KSER  =',F7.3,/,
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        2              24X,'JEIM  =',F7.3,4X,'KEIM  =',F7.3,/)
     4162 FORMAT (/,24X,'TIMTIL AND SRERTL-')
     4165 FORMAT (/,24X,3A4,12(5X,I3),/,36X,12(3X,F5.2))
     4170 FORMAT (//,6X,'MONTHLY DISTRIBUTION',7X,11(A4,4X),A4,//,6X,
        1         'TEMP CORRECTION FACTOR',1X,12(2X,F6.2),
        2         /,6X,'EPXM',19X,12(2X,F6.2),///,7X,
        3         '- PERVIOUS LANDS -',///,6X,'LAND COVER-',3A4,1X,12(1X,F7.3))
     4180 FORMAT (17X,3A4,1X,12(1X,F7.3))
     4190 FORMAT (/,6X,'ACCUMULATION RATES')
     4200 FORMAT (/,6X,'REMOVAL RATES')
     4210 FORMAT (/,6X,'POTENCY FACTORS FOR',1X,3A4)
     4220 FORMAT (//,6X,'-IMPERVIOUS LANDS-',/)
     4230 FORMAT (24X,3A4,6X,'ACUP  =',F7.3,4X,'ACUI  =',F7.3)
     4240 FORMAT (24X,3A4,6X,'RFER  =',F7.3,4X,'RIMP  =',F7.3)
     4250 FORMAT (//,6X,'POTENCY FACTORS FOR PERVIOUS AREAS',5X,5(3A4,3X),/)
     4260 FORMAT (24X,3A4,8X,5(F8.3,7X))
     4270 FORMAT (//,6X,'POTENCY FACTORS FOR IMPERVIOUS AREAS',5(3X,3A4),/)
     4280 FORMAT (5(/),2X,'INITIAL CONDITIONS :',3(/),6X,'LANDS',13X,
        1          'UZS   =',F7.3,4X,'LZS   =',F7.3,4X,'SGW   =',F7.3,/)
     4290 FORMAT (6X,'SNOW',14X,'PACK  =',F7.3,4X,'DEPTH =',F7.3,/)
     4300 FORMAT (6X,'QUAL',14X,3A4,6X,'TSI =',F9.3,4X,'SRERI =',F9.3)
     4310 FORMAT (24X,3A4,6X,'TSI =',F9.3,4X,'SRERI =',F9.3)
     4320 FORMAT ('1',25X,'SUMMARY FOR MONTH OF ',2A4,1X,I4,/,
        1          25X,35('='),//,35X,'TOTAL')
     4330 FORMAT ('0',8X,'WATER,  ',A4,//,11X,'RUNOFF',/,14X,
        1          'OVERLAND FLOW',5X,F9.3,/,14X,'INTERFLOW',9X,F9.3,
        2          /,14X,'IMPERVIOUS',8X,F9.3,/,14X,'BASE FLOW',9X,
        3          F9.3,/,14X,'TOTAL',13X,F9.3,//,11X,
        4          'GRDWATER RECHARGE',4X,F9.3,//,11X,'PRECIPITATION',
        5          8X,F9.3)
     4340 FORMAT (' ',13X,'SNOW',14X,F9.3,/,14X,'RAIN ON SNOW',6X,
        1          F9.3,/,14X,'MELT & RAIN',7X,F9.3,//,11X,'MELT',
        2         /,14X,'RADIATION',9X,F9.3,/,14X,'CONVECTION',8X,
        3          F9.3,/,14X,'CONDENSATION',6X,F9.3,/,14X,'RAIN - MELT',
        4          7X,F9.3,/,14X,'GROUND-MELT',7X,F9.3,/,14X,
        5          'CUM-NEG-HEAT',6X,F9.3,//,11X,'SNOW-PACK',12X,F9.3,
        6          /,11X,'SNOW DENSITY',9X,F9.3,/,11X,'% SNOW COVER',
        7          9X,F9.3,//,11X,'SNOW EVAP',12X,F9.3)
     4350 FORMAT ('0',11X,'EVAPOTRANSPIRATION',/,14X,'POTENIAL',10X,
        1          F9.3,/,14X,'NET',15X,F9.3,//,11X,'STORAGES',/,
        2          14X,'UPPER ZONE',8X,F9.3,/,14X,'LOWER ZONE',8X,F9.3,
        3          /,14X,'GROUNDWATER',7X,F9.3,/,14X,'INTERCEPTION',6X,
        4          F9.3,/,14X,'OVERLAND FLOW',5X,F9.3,/,14X,'INTERFLOW',
        5          9X,F9.3,//,11X,'WATER BALANCE',8X,F9.3)
     4360 FORMAT (' ',10X,'SNOW BALANCE',9X,F9.3)
     4370 FORMAT ('0',8X,'SEDIMENTS ACCUMULATION ,',A4,'/',A4,9X,
        1          'WEIGHTED MEAN',7X,'PERVIOUS',11X,'IMPERVIOUS',/)
     4380 FORMAT (11X,'WEIGHTED MEAN',27X,F10.3,3(10X,F10.3))
     4390 FORMAT (' ',8X,3A4,29X,F11.3,3(9X,F11.3))
     4400 FORMAT ('0',8X,'SEDIMENTS LOSS, ',11X,'TOTAL (',A4,')',3X,
        1       'TOTAL (',A4,'/',A4,')',3X,'PERVIOUS (%)',7X,'IMPERVIOUS (%)')
     4410 FORMAT (' ',8X,3A4,9X,F11.3,3(5X,F15.3))
     4420 FORMAT ('0',8X,'POLLUTANT WASHOFF, ',8X,'TOTAL (',A4,')',3X,
        1       'TOTAL (',A4,'/',A4,')',3X,'PERVIOUS (%)',7X,'IMPERVIOUS (%)')
     4430 FORMAT ('0', 9X,'WASHOFF OF ',3A4)
     4440 FORMAT (' ',10X,'TOTAL WASHOFF',6X,F11.3,3(9X,F11.3))
     4450 FORMAT ('0',8X,'STORM WATER QUALITY - AVERAGES',//,
        1          11X,'TEMPERATURE ',A4,6X,F7.2,//,11X,
        2          'DISSOLVED OXYGEN (PPM)',1X,F7.3,//,12X,
        3          'SEDIMENTS    (GM/L)',F11.3)
     4460 FORMAT (' ',11X,3A4,'(',A4,')',F11.3)
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      4470 FORMAT (' ',10X,'TOTAL LOSS',10X,F10.3,3(10X,F10.3))
      4480 FORMAT ('1',25X,'SUMMARY FOR ',I4,/,25X,16('_'),//,35X,'TOTAL')
      4490 FORMAT ('0',8X,'NO. OF STORMS',14X,I3)
      4500 FORMAT ('0',8X,'SUMMARY OF STORMS'' CHARACTERISTICS',4X,
          1          'AVERAGE',8X,'ST.DEV.',9X,'MAXIMA',9X,'MINIMA',
          2        9X,'RANGE',//)
      4510 FORMAT (11X,'SEDIMENTS LOSS')
      4520 FORMAT (3A8/3A8)
      4530 FORMAT (/,14X,'TOTAL WASHOFF (',A4,')',4X,5(5X,F10.3))
      4540 FORMAT (14X,'MAX WASHOFF (',A4,'/15MIN)',5X,F10.3,
          1          4(5X,F10.3))
      4545 FORMAT (14X,'MEAN CONCENTRATION (GM/L)',4X,F10.3,4(5X,F10.3))
      4550 FORMAT (14X,'MEAN CONCENTRATION (',A4,')',4X,F10.3,4(5X,F10.3))
      4555 FORMAT (14X,'MAX CONCENTRATION (GM/L)',5X,F10.3,4(5X,F10.3 ))
      4560 FORMAT (14X,'MAX CONCENTRATION (',A4,')',5X,F10.3,4(5X,F10.3 ))
      4570 FORMAT ('0',8X,'**WARNING**',3X,
          1          'SUMMARY OF STORM CHARACTERISTICS NOT PRINTED',
          2          /,22X,'NUMBER OF STORMS LESS THAN 2 OR MORE THAN 200',
          3          '  -  CHECK YOUR HYMIN PARAMETER')
      4580 FORMAT (/,14X,'TOTAL RUNOFF (',A4,')',5X,5(5X,F10.3))
      4590 FORMAT (14X,'MAX RUNOFF (',A4,')',12X,F10.3,
          1          4(5X,F10.3))
      4600 FORMAT (/,' *** ',A4,1X,I2,'  -  LAND SURFACE DISTURBANCE OCCURS
          * ON  ',3A4,/,17X,'SEDIMENT DEPOSITS ON PERVIOUS AREAS RESET TO',
          * F9.3,1X,A4,'/',A4)
      4610 FORMAT ('1')
C
           STOP
           END
           BLOCK DATA
C
C
C                          BLOCK DATA TO INITIALIZE VARIABLES
C
C
C
           IMPLICIT  REAL(I)
C
           DIMENSION MNAM(24),RAD(24),TEMPX(24),WINDX(24),RAIN(96),
          1          GRAD(24),RADDIS(24),WINDIS(24)
C
           COMMON /ALL/ RU,HYMIN,HYCAL,DPST,UNIT,TIMFAC,LZS,AREA,RESB,SFLAG,
          1             RESB1,ROSB,SRGX,INTF,RGX,RUZB,UZSB,PERCB,RIB,P3,TF,
          2             KGPLB,LAST,PREV,TEMPX,IHR,IHRR,PR,RUI,A,PA,GWF,NOSY,
          3             SRER(5),TS(5),LNDUSE(3,5),AR(5),QUALIN(3,5),NOSI,NOS,
          4             NOSIM,UFL,UTMP,UNT1(2,2),UNT2(2,2),UNT3(2,2),WHGT,
          5             WHT,DEPW,ROSBI,RESBI,RESBI1,ARUN,LMTS(5),IMPK(5),
          6             NLAND,NQUAL,STMCH(200,24),RECOUT(5),FLOUT,SCALEF(5),
          7             SNOW,PACK,IPACK
C
           COMMON /LAND/DAY,PRTM,IMIN,IX,TWBAL,SGW,GWS,KV,LIRC4,LKK4,ALTB(9),
          1             UZS,IZ,UZSN,LZSN,INFIL,INTER,SGW1,DEC,DECI,TIT(13),
          2             K24L,KK24,K24EL,EP,IFS,K3,EPXMI,RESS1,RESS,SCEP,IRC,
          3             SRGXT1,MMPIN,KGPHA,METOPT,CCFAC,SCEP1,SRGXT,RAIN,SRC,
          4             SCF,IDNS,F,DGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,
          5             DEWX,DEPTH,MONTH,TMIN,PETMAX,ELDIF,SDEN,WINDX,INFTOM,
          6             TSNBAL,RCBTCM,ROBTOT,RXB,ROITOM,ROITOT,YEAR,CUNIT(7),
          7             INFTOT,MNAM,RAD,SRCI,FORM(42)
C
           COMMON /QLS/ WSNAMF(6),KRER,JRER,KSER,JSER,TEMPCF,COVMAT(5,12),
          1             KEIM,JEIM,NDSR,ARP(5),ARI(5),ACCP(5),ACCI(5),RPER(5),
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     2            PMP(5,5),PMI(5,5),QSNOW,SNOWY,SEDTM,SEDTY,SEDTCA,
     3            ACPOLP(5,5),ACERSN(5),APOLP(5,5),AERSN(5),COVER(5),
     4            APOLI(5,5),ACEIM(5),AEIM(5),POLTM(5),POLTY(5),
     5            TEMPA,DCA,PCLTCA(5),AERSNY(5),AEIMY(5),APOLPY(5,5),
     6            APOLIY(5,5),POLTC(5),PLTCAY(5),ACPOLI(5,5),RIMP(5)
C
      COMMON /LNDOUT/ ROSTOM,RINTOM,RITOM,RUTOM,BASTOM,RCHTOM,PRTOM,
     1              SUMSNM,PXSNM,MELRAM,RADMEM,CONMEM,CDRMEM,
     2              CRAINM,SGMM,SNEGMM,PACKOT,SEVAPM,EPTOM,NEPTOM,
     3              UZSOT,LZSOT,SGWOT,SCEPOT,RESSOT,SRGXTO,TWBALO,
     4              TSNBOL,ROSTOT,RINTOT,RITOT,RUTOT,BASTOT,RCHTOT,
     5              PRTOT,SUMSNY,PXSNY,MELRAY,RADMEY,CONMEY,CDRMEY,
     6              CRAINY,SGMY,SNEGMY,PACK1,SEVAPY,EPTOT,NEPTOT,
     7              UZSMT,LZSMT,SGWMT,SCEPT,RESST,SRGXTT,TWBLMT
C
      COMMON /STS/ ACPOLT(5),PLTMX(5),POLTSC(5),PLTMXC(5),
     1            ACSEDT,SEDMX,SEDTSC,SEDMXC,TOTRUN,PEAKRU
C
      COMMON /INTM/ RTYPE(4,4),UTYPE(2),GRAD,RADDIS,WINDIS,ICS,OFS,
     1             TEMPAY,DOAY,NOSIY,INTRVL,WMUL,NN,L,SS,NNI,LI,SSI,
     2             RMUL,KUGI,SEDTCY,REPERV(12),REIMPV(12),ACUPV(12),
     3             ACUIV(12),EMPMAT(12,5),PMIMAT(12,5),PMPVEC(5),
     4             PMIVEC(5),ACUI,ACUP,REIMP,REPER,PRINTR,
     5             EPXM(12),TIMTIL(12),SRERTL(12),TILDAY(5,12),
     6             TILSED(5,12),DPM(12),TCF(12)
C
      INTEGER UNIT , LMTS, RECOUT, SFLAG, PRINTR
      INTEGER TIMTIL, TILDAY, DPM
C
      LOGICAL LAST, PREV
C
      REAL*8  WSNAME,RTYPE,UTYPE
      REAL  JRER, KRER, JSER, KSER,KEIM,JEIM
      REAL  LZSN, IRC, NN, L, LZS, KV, K24L, KK24, INFIL, INTER
      REAL  IFS, K24EL, K3, NEPTOM, NEPTOT, ICS, NNI, KUGI
      REAL  INFTOM, INFTOT, INTF
      REAL  MMPIN, METOPT, KGPLB, KGPHA
      REAL  STU, STI ,IMPK
      REAL  MELRAM, MELRAY
C
      DATA  LAST/.FALSE./, PREV/.FALSE./
      DATA  PRTOT/0.0/
      DATA  PRTOM,PRTM/2*0.0/
      DATA  RUTOM, ROSTOM, RITOM, RINTOM, NEPTOM/5*0.0/
      DATA  RUTOT, ROSTOT, RITOT, RINTOT, NEPTOT/5*0.0/
      DATA  ROBTOM, ROBTOT, INFTOM, INFTOT, ROITOM, ROITOT/6*0.0/
      DATA  TWBAL, RESB, RESBI, ROSBI, RESBI1,SRGX, INTF/7*0.0/
      DATA  RESB1, BASTOM, RCHTOM, BASTOT, RCHTOT/5*0.0/
      DATA  EPTOM, EPTOT/2*0.0/
      DATA  PR, P3, RXB, RGX, RUZB, UZSB, PERCB, DPST/8*0.0/
      DATA  TIMFAC, UZSN, LZSN, INFIL, INTER, IRC/6*0.0/
      DATA  A, UZS, LZS, SGW, GWS, KV, K24L, K24EL, KK24/9*0.0/
      DATA  IFS, K3/2*0.0/
      DATA  EPXM, EPXMI/13*0.0/
      DATA  DPM/31,28,31,30,31,30,31,31,30,31,30,31/
      DATA  TIMTIL, TILDAY/72*0/
      DATA  SRERTL, TILSED/72*0.0/
      DATA  TCF/12*1.0/
      DATA  PETMIN,PETMAX/35.,40./
      DATA  TOTRUN,PEAKRU,ACSEDT,SEDMX,SEDTSC,SEDMXC/6*0.0/
      DATA  ACPOLT,PLTMX,POLTSC,PLTMXC/20*0.0/
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      DATA  MNAM/' JAN','UARY','FEBR','UARY',' MAR','CH  ',' APR',
     *      'IL  ',' MAY','    ',' JUN','E   ',' JUL','Y   ',' AUG',
     *      'UST ','SEPT','MBER',' OCT','OBER','NOVE','MBER','DECE',
     *      'MBER'/
      DATA  MMPIN/25.4/, METOPT/0.9072/, KGPLB/0.4536/, KGPHA/0.892/
      DATA SUMSNM, PXSNM, MELRAM, RADMEM, CDRMEM, CRAINM,PACK,DEPTH,
     *       CONMEM, SGMM, SNEGMM, SEVAPM, SUMSNY, PXSNY, MELRAY,
     *       RADMEY, CDRMEY, CONMEY, CRAINY, SGMY, SNEGMY, SEVAPY,
     *       TSNBAL/23*0.0/
      DATA  INTRVL,PRINTR/15,15/,  WMUL,RMUL,KUGI,SFLAG/1.0,1.0,0.0,0/
      DATA  ICS, OFS/2*0.0/
      DATA GRAD/0.04,0.04,0.03,0.02,
     *0.02,0.02,0.02,0.06,0.14,0.18,0.20,0.17,0.13,0.06,0.03,0.01,0.05,
     *0.07,0.10,0.13,0.15,0.13,0.12,0.08/
      DATA RADDIS/6*0.0,0.019,
     *0.041,0.067,0.088,0.102,0.110,0.110,0.110,0.105,0.095,0.081,0.055,
     *0.017,5*0.0/
      DATA WINDIS/7*0.034,0.035,
     *0.037,0.041,0.046,0.050,0.053,0.054,0.058,0.057,0.056,0.050,0.043,
     *0.040,0.038,0.036,0.036,0.035/
      DATA NN,NNI/.2,.1/, L,LI/2*100./, SS,SSI/2*.01/
      DATA TEMPAY,DOAY,SEDTCA,SEDTCY/4*0.0/, NOSIY,NOSY/2*0/
      DATA CUNIT/5*4HGM/L,4HMG/L,4HGM/L/
      DATA FORM/4H(17X , 4H,A4, , 4H4X,A , 4H4,7X , 4H  ,4 , 4HX,'( ,
     *          4HLB)' , 4H,2X, ,4H'(GM , 4H/L)', 4H  ,4 , 4HX,'( ,
     *          4HLB)' , 4H,2X, ,4H'(GM , 4H/L)', 4H  ,4 , 4HX,'( ,
     *          4HLB)' , 4H,2X, ,4H'(GM , 4H/L)', 4H  ,4 , 4HX,'( ,
     *          4HLB)' , 4H,2X, ,4H'(GM , 4H/L)', 4H  ,4 , 4HX,'( ,
     *          4HLB)' , 4H,2X, ,4H'(GM , 4H/L)', 4H  ,4 , 4HX,'( ,
     *          4HLB)' , 4H,2X, ,4H'(GM , 4H/L)', 4H ,2( , 4H/))  /
      DATA ALTR/4H     , 4HKG)',
     *       4H'(MG, 4H( 21, 4H( 27, 4H( 41, 4H( 54, 4H( 63, 4H( 74 /
      DATA TIT/4H    , 4HX,'Q, 4H U A, 4H L I,  4H T Y, 4H   C,
     *    4H O N, 4H S T, 4H I T, 4H U E, 4H N T, 4H S', ,4H / )/
      DATA RTYPE/8H        ,'SEDIMENT','PRODUCTI','   PRODU',' HYDROL',
     *' AND QUA','ON (PRIN','CTION (O','OGIC CAL','LITY CAL','TER OUTP',
     *'UTPUT ON','IBRATION','IBRATION','UT ONLY)',' UNIT 4)'/
      DATA  UTYPE/'  METRIC',' ENGLISH'/
      DATA  COVMAT/60*0.0/, COVER/5*0.0/
      DATA  IMPK,SCALEF/5*0.,5*1./, NDSR,IERR/2*0/
      DATA  PMP/25*0.0/, PMI/25*0.0/
      DATA QUALIN/' BOD',2*4H    ,' TDS',11*4H    /
      DATA OSNOW/' NO '/, SNOWY/'YES '/
      DATA JRER/0.0/, KRER/0.0/
      DATA JSER/0.0/, KSER/0.0/
      DATA JEIM/0.0/, KEIM/0.0/
      DATA UNT1/' KG ',' MM ',' LB ',' IN '/
      DATA  STMCH/4800*0.0/
      DATA UNT2/'  T ','CMS ','TONS','CFS '/
      DATA UNT3/'(C) ',' HA ','(F) ','ACRE'/
      DATA AERSN/5*0.0/, AEIM/5*0.0/, APOLP/25*0.0/, APOLI/25*0.0/
      DATA AERSNY/5*0.0/, AEIMY/5*0.0/, APOLPY/25*0.0/, APOLIY/25*0.0/
      DATA TEMPA,DOA/2*0.0/ ,NOSI,NOSIM,NOS/3*0/
      DATA POLTCA/5*0.0/,PLTCAY/5*0.0/
      DATA ACPOLP/25*0.0/, ACPOLI/25*0.0/
      DATA ACEIM,ACERSN/10*0.0/
      DATA  ACCP/5*0./, ACCI/5*0./, RIMP/5*0./, RPER/5*0./
      DATA  SRER/5*0./, TS/5*0./, LMTS/5*0/
      DATA  PMPVEC,PMIVEC,PMPMAT,PMIMAT/5*0.,5*0.,60*0.,60*0./
      DATA  ACUP,ACUI,ACUPV,ACUIV/0.,0., 12*0.,12*0./
      DATA  REPER,REIMP,REPERV,REIMPV/0.,0.,12*0.,12*0./
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      C
            END
             SUBROUTINE LANDS
      C
      C
      C                                    HSP LANDS
      C
      C
            IMPLICIT  REAL(L,K)
      C
            DIMENSION EVDIST(24),LAPSE(24),SVP(40),SNOUT(24,16),STRBGN (4),
           1          MNAM(24),RAD(24),TEMPX(24),WINDX(24),RAIN(96),DUM1(5),
           2          DUM2(5)
      C
            COMMON /ALL/ RU,HYMIN,HYCAL,DPST,UNIT,TIMFAC,LZS,AREA,RESB,SFLAG,
           1             RESB1,ROSB,SRGX,INTF,RGX,RUZE,UZSB,PERCB,RIB,P3,TF,
           2             KGPLB,LAST,PREV,TEMPX,IHR,IHFR,PR,RUI,A,PA,GWF,NOSY,
           3             SPEP(5),TS(5),LNDUSE(3,5),AR(5),QUALIN(3,5),NOSI,NOS,
           4             NOSIM,UFL,UTMP,UNT1(2,2),UNT2(2,2),UNT3(2,2),WHGT,
           5             WHT,DEPW,ROSBI,RESBI,RESBI1,ARUN,LMTS(5),IMPK(5),
           6             NLAND,NQUAL,STMCH(200,24),RECOUT(5),FLOUT,SCALEF(5),
           7             SNOW,PACK,IPACK
      C
            COMMON /LAND/DAY,PRTM,IMIN,IX,TWBAL,SGW,GWS,KV,LIRC4,LKK4,ALTS(9),
           1             UZS,IZ,UZSN,LZSN,INFIL,INTER,SGW1,DEC,DECI,TIT(13),
           2             K24L,KK24,K24EL,EP,IFS,K3,EPXMI,RESS1,RESS,SCEP,IRC,
           3             SRGXT1,MMPIN,KGPHA,METOPT,CCFAC,SCEP1,SRGXT,RAIN,SRC,
           4             SCF,IDNS,F,DGM,WC,MPACK,EVAPSN,MELEV,TSNOW,PETMIN,
           5             DEWX,DEPTH,MONTH,TMIN,PETMAX,ELDIF,SDEN,WINDX,INFTOM,
           6             TSNBAL,RCBTCM,ROBTOT,RXB,ROITOM,ROITOT,YEAR,CUNIT(7),
           7             INFTOT,MNAM,RAD,SRCI,FORM(42)
      C
            COMMON /LNDOUT/ ROSTOM,RINTOM,RITOM,RUTOM,BASTOM,RCHTOM,PRTCM,
           1                SUMSNM,PXSNM,MELRAM,RADMEM,CONMEM,CDRMEM,
           2                CRAINM,SGMM,SNEGMM,PACKOT,SEVAPM,EPTOM,NEPTOM,
           3                UZSOT,LZSOT,SGWOT,SCEPOT,RESSOT,SRGXTO,TWBALO,
           4                TSNBOL,ROSTOT,RINTOT,RITOT,RUTOT,BASTOT,RCHTOT,
           5                PRTOT,SUMSNY,PXSNY,MELRAY,RADMEY,CONMEY,CDRMEY,
           6                CRAINY,SGMY,SNEGMY,PACK1,SEVAPY,EPTOT,NEPTOT,
           7                UZSMT,LZSMT,SGWMT,SCEPT,RESST,SRGXTT,TWBLMT
      C
            COMMON /STS/ ACPOLT(5),PLTMX(5),POLTSC(5),PLTMXC(5),
           1             ACSEDT,SEDMX,SEDTSC,SEDMXC,TCTRUN,PEAKRU
      C
            LOGICAL LAST, PREV
      C
            INTEGER  TF,HYCAL, DAY, UNIT, SNOW, HRFLAG, H, SFLAG ,LMTS,STRBGN,
           1         RECOUT,YEAR
      C
            REAL  INFIL, INTER, NN, INFLT, IRC, INTF, INFL
            REAL  IRC4, ICS, IFS, NEPTOM, NEPTOT
            REAL  INFTOM, INFTCT, CMETFC ,IMPK
            REAL  MMPIN, METOPT, KGPLB
            REAL  UZSMET, LZSMET, SGWMET, SCEPMT, RESSMT
            REAL  TWBLMT, SRGXTM, RESBMT, SRGXMT
            REAL IDNS, MPACK, MELEV, KUGI, NEGMLT, NEGMM
            REAL MELT, INDT, KCLD, IPACK, MELRAM, MELRAY
      C
            DATA  PERC, INFLT, SBAS, HRFLAG/0.0,0.0,0.0,0/
            DATA  SNET1, SNET, SRCH/3*0.0/, NUMI/0/
            DATA  ROSINT, REPIN, EPIN1, AETR, KP/5*0.0/
```

```
      DATA  EVDIST/6*0.0,0.019,0.041,0.067,0.088,0.102,3*0.11,0.105,
     C      0.095,0.081,0.055,0.017,5*0.0/
      DATA SVP/10*1.005,1.01,1.01,1.015,1.02,
     *1.03,1.04,1.06,1.08,1.1,1.29,1.66,2.13,2.74,3.49,4.40,5.55,6.87,
     *8.36,10.09,12.19,14.63,17.51,20.86,24.79,29.32,34.61,40.67,47.68,
     *55.71,64.88/
      DATA LAPSE/6*3.5,3.7,4.0,4.1,
     *4.3,4.6,4.7,4.8,4.9,5.0,5.0,4.8,4.6,4.4,4.2,4.0,3.8,3.7,3.6/
      DATA  APR, AEPIN/2*0.0/
      DATA  AROSB, AINTF, AROSIT/3*0.0/
      DATA  ARU, ARUI, AROS, ARGXT, ASNET, ASBAS, ASRCH/7*0.0/
      DATA  SUMSN, INDT, KCID, PXONSN, SEVAPT, RADME, CDRME, LIQW1,
     *      CONME, CRAIN, NEGMLT, SNEGM, NEGMM, LIQS,  LIQW, XICE,
     *      XLNMLT,SGM, SPX, WBAL, SEVAP/21*0.0/
      DATA  SNOUT/384*0.0/
      DATA  CLDF/-1.0/
C
C                       ZEROING OF VARIABLES
C
      LZS1 = LZS
      UZS1 = UZS
      NUMI = 0
      DPST = 0.0
      PACK1 = PACK
      LIQW1 = LIQW
      PRR = PR
C
      LNRAT=LZS/LZSN
      D3FV=(2.0*INFIL)/(LNRAT*LNRAT)
      D4F= (TIMFAC/60.)*D3FV
C                                        REDUCE INFILTRATION IF ICE EXISTS
C                                        AT THE BOTTOM OF THE PACK -
C                                       ATTEMPT TO CORRECT FOR FROZEN LAND
      IF (SNOW .LT. 1)  GO TO 20
      D4FX = (1.0 -XICE)
      IF (D4FX .LT. 0.1)  D4FX = 0.1
      D4F = D4F*D4FX
C
   20 RATIO= INTER*EXP(0.693147*LNRAT)
      IF ((RATIO).LT.(1.0)) RATIO=1.0
      D4RA= D4F*RATIO
      H = TF/24
C
C                                     TF IS 1 FOR RAIN DAYS, AND 96
C                                     OR 288 FOR NON-RAIN DAYS
C
      IF (TF .GT. 2)  IHRR=0
C
      DO 1480  III=1,TF
C
      LNRAT = LZS/LZSN
      IF (TF .LT. 2)  GO TO 40
      NUMI =NUMI + 1
      IF (NUMI .EQ. H)  GO TO 30
      GO TO 40
   30 NUMI = 0
C
   40 SBAS = 0.0
      SRCH = 0.0
      ROS = 0.0
      RU = 0.0
```

```
      GWF = 0.0
      RGXT = 0.0
      PERC = 0.0
      INFLT = 0.0
      RESS = 0.0
C
C   TIMFAC - TIME INTERVAL IN MINUTES
C   L      - LENGTH OF OVERLAND SLOPE
C   NN     - MANNING'S N FOR OVERLAND SLOPE
C   A      - IMPERVIOUS AREA
C   PA    - PERVIOUS AREA
C
C
C
C
C PR IS INCOMING RAINFALL
C P3 IS RAIN REACHING SURFACE(.00'S INCHES)
C P4 IS TOTAL MOISTURE AVAILABLE( IN.)
C RESS  IS OVERLAND FLOW STORAGE( IN.)
C D4F IS 'B' IN OP. MANUAL
C RATIO IS 'C' IN OP. MANUAL
C EP -  DAILY EVAP ( IN.)
C EPHR - HOURLY EVAP
C EPIN - INTERVAL EVAP
C EPXX - FACTOR FOR REDUCING EVAP FOR SNOW AND TEMP
C
C
C
C
C      DETERMINE IF SNOWMELT IS TO BE DONE
C
   50 HRFLAG=0
      TEST = IMIN/TIMFAC
      IF (NUMI .EQ. 1)  HRFLAG = 1
      IF ((TEST .LE. 1.001).AND.(TEST .GE. 0.999)) HRFLAG = 1
C
C     HRFLAG=1 INDICATES BEGINNING OF THE HOUR
C
      IF (HRFLAG) 770, 770, 60
   60 IEND = 0
      IF (IHR-24)   70,80,70
   70 IHRR = IHR + 1
      GO TO 90
   80 IHRR = IHRR + 1
   90  EPHR = EVDIST(IHRR)*EP
       IF (EPHR.LE.(0.0001))  EPHR=0.0
       EPIN= EPHR
       EPIN1=EPIN
      IF (SNOW .EQ. 0) GO TO 770
      IF ((PACK .LE. 0.0).AND.(TMIN .GT. PETMAX))  GO TO 770
C                                    ************************************
C                                                 BEGIN SNOWMELT
C                                    ************************************
      TSNOW1 = TSNOW + 1.
      SNTEMP = 32.
      SEVAP = 0.0
      SFLAG = 0
      PRHR=0.0
      EPXX = 1.0
      IKEND = 60./(TIMFAC)
      IPT =  (IHRR-1)*IKEND
```

```
C                                             SUM PRECIP FOR THE HOUR
      PX=0.0
      DO 100 II = 1,IKEND
  100 PRHR = PRHR + RAIN(IPT+II)
C                                                CORRECT TEMP FOR ELEVATION DIFF
C                                                USING LAPSE RATE OF 3.5 DURING RAIN
C                                                PERIODS, ANC AN HOURLY VARIATION IN
C                                                LAPSE RATE (LAPSE(I)) FOR DRY PERIOD
C
      LAPS = LAPSE(IHRR)
      IF (PRHR .GT. 0.05)  LAPS = 3.5
      TX = TEMPX(IHRR) - LAPS*ELDIF
C
C
C                                              REDUCE REG EVAP FOR SNOWMELT
C                                              CONDITIONS BASED ON PETMIN AND
C                                              PETMAX VALUES
C
      IF (PACK-IPACK) 120,120,110
  110 E1E=0.C
      PACKRA = 1.0
      GO TO 130
  120 PACKRA = PACK/IPACK
      E1E=1.0 - PACKRA
  130 EPXX = (1.0-F)*E1E + F
      IF (TX-PETMAX)  140,170,170
  140 IF (EPXX .GT. 0.5)  EPXX=0.5
C
C                                             REDUCE EVAP BY 50% IF TX IS BETWEEN
C                                             PETMIN AND PETMAX
  150 IF (TX-PETMIN)  160,170,170
  160 EPXX=0.0
C
C
  170 EPHR = EPHR*EPXX
      EPIN=EPIN*EPXX
      IEND=0
      IF ((TX .GT. TSNOW) .AND. (PRHR .GT. .02)) DEWX = TX
C
C     SET DEWPT TEMP EQUAL TO AIR TEMP WHEN RAINING
C     ON SNOW TO INCREASE SNOWMELT
C
      IF (DEWX .GT. TX) DEWX = TX
      SNTEMP = TSNOW + (TX-DEWX)*(0.12 + 0.008*TX)
C
C     RAIN/SNOW TEMP. DIVISION - SEE ANDERSON, WRR, VOL. 4, NO. 1,
C     FEB. 1968, P. 27, EG. 28
C
      IF (SNTEMP .GT. TSNOW1) SNTEMP = TSNOW1
      IF (TX -SNTEMP) 190, 180, 180
  180 IF  (PACK) 770, 77C, 200
  190 SFLAG = 1
      IF ((PACK.LE.0.0).AND.(PRHR.LE.0.0)) GO TO 770
C
C           SKIP SNOWMELT IF BOTH PACK AND PRECIP ARE ZERO
C           FOR THE HOUR
C
  200 IEND = 1
C
C     SNOWMELT CALCULATICNS ARE DONE IF IT IS SNOWING, OR,
C     IF A SNOWPACK EXISTS
```

```
C
      PX = PRHR
      IF (PX)  250, 250, 210
C                                         KCLD IS INDEX TO CLOUD COVER
  210 KCLD = 35.
      IF (SFLAG) 260, 260, 220
C                                       SNOW IS FALLING
  220 PX = PX*SCF
      APR = APR+(SCF-1.0)*PRHR
      PRHR = PRHR*SCF
      SUMSN = SUMSN + PX
      DNS = IDNS
      IF (TX .GT. 0.0)  DNS = DNS + ((TX/100.)**2)
C
C     SNOW DENSITY WITH TEMP. - APPROX TO FIG. 4, PLATE B-1
C     SNOW HYDROLOGY  SEE ALSO ANDERSON, TR 36, P. 21
C
      PACK = PACK + PX
C
      IF (PACK-IPACK)  240,240,230
  230 IPACK = PACK
      IF (IPACK .GT. MPACK)  IPACK = MPACK
C
  240 DEPTH = DEPTH + (PX/DNS)
      IF (DEPTH .GT. 0.0) SDEN = PACK/DEPTH
      INDT = INDT - 1000*PX
      IF (INDT .LT. 0.0) INDT = 0.0
      PX = 0.0
      GO TO 260
  250 KCLD = KCLD - 1.
  260 IF (KCLD .LT. 0.0) KCLD = 0.0
      PACKRA = PACK/IPACK
      IF (PACK .GT. IPACK)  PACKRA = 1.0
C
  270 IF (PACK - 0.005)  280, 300, 300
C
C     IPACK IS AN INDEX TO AREAL COVERAGE OF THE SNOWPACK
C     FOR INITIAL STORMS IPACK = .1*MPACK SO THAT COMPLETE
C     AREAL COVERAGE RESULTS.  IF EXISTING PACK > .1 *MPACK THEN
C     IPACK IS SET EQUAL TO MPACK WHICH IS THE WATER EQUI. FOR
C     COMPLETE AREAL COVERAGE PACKRA IS THE FRACTION AREAL COVERAGE
C     AT ANY TIME.
C
  280 IPACK = 0.1*MPACK
      XICE = 0.0
      XLNMLT = 0.0
      NEGMLT = 0.0
      PX = PX + PACK + LIQW
      PACK = 0.0
      LIQW = 0.0
C
C                 ZERO SNOWMELT OUTPUT ARRAY
C
      DO 290 I=1,24
      DO 290 MM=1,16
  290 SNOUT(I,MM)=0.0
      GO TO 760
  300 PXONSN = PXONSN + PX
      IF (DEPTH .GT. 0.0) SDEN = PACK/DEPTH
      IF (INDT .LT. 800.) INDT = INDT + 1.
C                                       INDT IS INDEX TO ALBEDO
```

```
      MELT = 0.0
      IF (SDEN .LT. 0.55) DEPTH=DEPTH*(1.0 - 0.00002*(DEPTH*(.55-SDEN)))
C
C     EMPIRICAL RELATIONSHIP FOR SNOW COMPACTION
C
      IF (DEPTH .GT. 0.0) SDEN = PACK/DEPTH
      WIN = WINDX(IHRR)
C
C     HOURLY WIND VALUE
C
      LREF = (TX + 100.)/5
      LREF = IFIX(LREF)
      SVPP = SVP (LREF)
      ITX = IFIX(TX)
      SATVAP = SVPP +(MOD(ITX,5)/5)*(SVP(LREF + 1) - SVPP)
      LREF = (DEWX + 100.)/5
      LREF = IFIX(LREF)
      SVPP = SVP (LREF)
      IDEWX = IFIX(DEWX)
      VAPP = SVPP + (MOD(IDEWX,5)/5)*(SVP(LREF + 1) - SVPP)
C                      CALCULATION OF VAPOR PRESSURE AT AIRTEMP
C                      AND DEWPOINT
      IF (VAPP - 6.108)  320, 320, 310
  310 CNM = 8.59*(VAPP - 6.108)
      GO TO 330
  320 CNM = 0.0
      DUMMY=(VAPP-SATVAP)*PACKPA
      IF (VAPP .LT. SATVAP) SEVAP = EVAPSN*0.0002*WIN*DUMMY
      PACK = PACK + SEVAP
      SEVAPT = SEVAPT - SEVAP
C
C     CONDENSATION - CONVECTION MELT, EQ. T-29B, P.176, SNOW HYDROLOGY
C     CONV - CONVECTION, CCNDS - CONDENSATION
C     SEVAP - EVAP FROM SNOW (NEGATIVE VALUE)
C
  330 CNV = 0.0
      IF (TX .GT. 32.) CNV = (TX-32.)*(1.0 - 0.3*(MELEV/10000.))
      CCXC = CCPAC*.00026*WIN
C
C     .00026 = .00629/24, I.E. .00026 IS THE DAILY COEFFICIENT
C     (FROM SNOW HYDROLOGY) REDUCED TO HOURLY VALUES.
C
      CONV = CNV*CCXC
      CONDS = CNM*CCXC
C                         CLOUD COVER
C                         CLDF IS FRACTION OPEN SKY - MINIMUM VALUE 0.15
      IF ((IHRR.EQ.1).OR.(CLDF.LT.0.0)) CLDF = (1.0 - 0.085*(KCLD/3.5))
C                         ALBEDO
      IF (MONTH - 9)  340, 340, 360
  340 IF (MONTH - 4)  360, 350, 350
  350 ALBEDO = 0.8 - 0.1*(SQRT(INDT/24.))
      IF (ALBEDO .LT. 0.45)  ALBEDO = 0.45
      GO TO 370
  360 ALBEDO = 0.85 - 0.07*(SQRT(INDT/24.0))
      IF (ALBEDO.LT.0.6) ALBEDO=0.6
C                         SHORT WAVE RADIATION-RA - POSITIVE INCOMING
  370 RA = RAD(IHRR)*(1.0 -ALBEDO)*(1.0-F)
C                         LONG WAVE RADIATION - LW - POSITIVE INCOMING
      DEGHR = TX - 32.0
      IF (DEGHR)  390, 390, 380
  380 LW = F* 0.26*DEGHR + (1.0 - F)*(0.2*DEGHR - 6.6)
```

```
      GO TO 400
  390 LW = F*0.2*DEGHR + (1.0 - F)*(0.17*DEGHR - 6.6)
C
C                               LW IS A LINEAR APPROX. TO CURVES IN
C                               FIG. 6, PL 5-3, IN SNOW HYDROLOGY.  6.6
C                               IS AVE BACK RADIATION LOST FROM THE SNOWPACK
C                               IN OPEN AREAS, IN LANGLEYS/HR.
C
C                               CLOUD COVER CORRECTION
  400 IF (LW .LT. 0.0)  LW = LW*CLDF
C
C                               RAIN MELT
      RAINM = 0.0
C
C                                          RAINMELT IS OPERATIVE IF IT IS
C                                          RAINING AND TEMP IS ABOVE 32 F
C
      IF ((SFLAG .LT. 1).AND.(TX .GT. 32.))  RAINM = DEGHR*PX/144.
C                               TOTAL MELT
      RM = (LW + RA)/203.2
C                               203.2 LANGLEYS REQUIRED TO PRODUCE I INCH
C                               RUNOFF FROM SNOW AT 32 DEGREES F
      IF (PACK - IPACK )  410, 430, 430
  410 RM = RM*PACKRA
      CONV = CONV*PACKRA
      CONDS = CONDS*PACKRA
      RAINM = RAINM*PACKRA
      IF (IHRR - 6)  430, 420, 430
  420 XLNEM = 0.01*(32.0 - TX)
      IF (XLNEM .GT. XLNMLT) XLNMLT = XLNEM
  430 RADME = RADME + RM
      CDRME = CDRME + CONDS
      CONME = CONME + CONV
      CRAIN = CRAIN + RAINM
      MELT = RM + CONV + CONDS + RAINM
      IF (MELT)  440, 470, 470
  440 NEGMM = 0.0
      IF (TX .LT. 32.) NEGMM = 0.00695*(PACK/2.0)*(32.0 - TX)
C
C                                          HALF OF PACK IS USED TO CALCULATE
C                                          MAXIMUM NEGATIVE MELT
C
      TP = 32.0 - (NEGMLT/(0.00695*PACK))
C
C     TP IS TEMP OF THE SNOWPACK
C     0.00695 IS IN. MELT/IN. SNOW/DEGREE F
C
      IF (TP - TX)  460, 460, 450
  450 GM = 0.0007*(TP - TX)
      NEGMLT = NEGMLT + GM
      SNEGM = SNEGM + GM
  460 IF (NEGMLT .GT. NEGMM)  NEGMLT = NEGMM
      MELT = 0.0
C
C                               MELTING PROCESS BALANCE
C
  470 PXBY = (1.0 - PACKRA)*PX
      PX = PACKRA*PX
C
C     PXBY IS FRACTION OF PRECIP FALLING ON BARE GROUND
C
```

```
            IF (MELT + PX)   650,650,480
      C
      C     SATISFY NEGMLT FRCM PRECIP(RAIN) AND SNOWMELT
      C
        480 IF (MELT - NEGMLT) 490, 500, 500
        490 NEGMLT = NEGMLT - MELT
            MELT = 0.0
            GO TO 510
        500 MELT = MELT - NEGMLT
            NEGMLT = 0.0
      C
        510 IF (PX - NEGMLT)  520, 530, 530
        520 NEGMLT = NEGMLT - PX
            PACK = PACK + PX
            PX = 0.0
            GO TO 540
        530 PX = PX - NEGMLT
            PACK = PACK + NEGMLT
            NEGMLT = 0.0
      C
        540 IF ((PX + MELT) .EQ. 0.0) GO TO  660
      C
      C     COMPARE SNOWMELT TO EXISTING SNOWPACK AND WATER CONTENT OR
      C     THE PACK
      C
            IF (MELT - PACK)  560, 560, 550
        550 MELT = PACK + LIQW
            DEPTH = 0.0
            PACK = 0.0
            LIQW = 0.0
            INDT = 0.0
            GO TO 590
        560 PACK = PACK - MELT
            IF (SDEN .GT. 0.0)  DEPTH = DEPTH - (MELT/SDEN)
            IF (PACK .GE. (0.9*DEPTH))  DEPTH = 1.11*PACK
            IF (PACK - 0.001)  570, 580, 580
        570 LIQW = LIQW + PACK
            PACK = 0.0
        580 LIQS = WC*PACK
            IF (SDEN .GT. 0.6) LIQS = WC*(3.0 - (3.33)*SDEN)*PACK
            IF (LIQS .LT. 0.0) LIQS = 0.0
      C
      C     COMPARE AVAILABLE MOISTURE WITH AVAILABLE STORAGE IN SNOWPACK
      C     -LIQS
      C
        590 IF ((LIQW + MELT + PX) - LIQS)  610, 610, 600
        600 PX = MELT + PX + LIQW - LIQS
            LIQW = LIQS
            GO TO 620
        610 LIQW = LIQW + MELT + PX
            PX = 0.0
        620 IF (PX - XLNMLT)  640, 640, 630
        630 PX = PX - XLNMLT
            PACK = PACK + XLNMLT
            XICE = XICE + XLNMLT
            XLNMLT = 0.0
            GO TO 650
        640 PACK = PACK + PX
            XICE = XICE + PX
            XLNMLT = XLNMLT - PX
            PX = 0.0
```

```
  650 IF (XICE .GT. PACK) XICE = PACK
C
C
C                                   END MELTING PROCESS BALANCE
C
  660 IF (DEPTH .GT. 0.0) SDEN = PACK/DEPTH
      IF (SDEN .LT. 0.1) SDEN = 0.1
C                                      GROUNDMELT
      IF (IHPR - 12)  700, 670, 700
  670 DGMM = DGM
      IF (TP .LT. 5.0)  TP = 5.0
      IF (TP .LT. 32.)  DGMM = DGMM - DGM*.03*(32.0 - TP)
      IF (PACK - DGMM)  690, 690, 680
  680 PX = PX + DGMM
      PACK = PACK - DGMM
      DEPTH = DEPTH - (DGMM/SDEN)
      SGM = SGM + DGMM
      GO TO 700
  690 PX = PACK + PX + LIQW
      SGM = SGM + PACK
      PACK = 0.0
      DEPTH = 0.0
      LIQW = 0.0
      NEGMLT = 0.0
  700 CONTINUE
      PX = PX + PXBY
      SPX = SPX + PX
C
C                                       MONTHLY SUMS
      SUMSNM = SUMSNM + SUMSN
      PXSNM  = PXSNM  + PXONSN
      MELRAM = MELRAM + SEX
      RADMEM = RADMEM + RADME
      CDRMEM = CDRMEM + CDRME
      CONMEM = CONMEM + CONME
      CRAINM = CRAINM + CRAIN
      SGMM   = SGMM   + SGM
      SNEGMM = SNEGMM + SNEGM
      SEVAPM = SEVAPM + SEVAPT
C
C                                       YEARLY SUMS
      SUMSNY = SUMSNY + SUMSN
      PXSNY  = PXSNY  + PXONSN
      MELRAY = MELRAY + SEX
      RADMEY = RADMEY + RADME
      CDRMEY = CDRMEY + CDRME
      CONMEY = CONMEY + CONME
      CRAINY = CRAINY + CRAIN
      SGMY   = SGMY   + SGM
      SNEGMY = SNEGMY + SNEGM
      SEVAPY = SEVAPY + SEVAPT
C                                           ZERO HOURLY VALUES
      SUMSN = 0.0
      PXONSN = 0.0
      RADME = 0.0
      CDRME = 0.0
      CONME = 0.0
      CRAIN = 0.0
      SGM = 0.0
      SNEGM = 0.0
      SEVAPT = 0.0
```

```
            SPX = 0.0
C                                           SNOWMELT OUTPUT
C
            SNOUT(IHRR,1)  = PACK
            SNOUT(IHRR,2)  = DEPTH
            SNOUT(IHRR,3)  = SDEN
            SNOUT(IHRR,4)  = ALBEDO
            SNOUT(IHRR,5)  = CLDF
            SNOUT(IHRR,6)  = NEGMLT
            SNOUT(IHRR,7)  = LIQW
            SNOUT(IHRR,8)  = TX
            SNOUT(IHRR,9)  = RA
            SNOUT(IHRR,10)  = LW
            SNOUT(IHRR,11)  = PX
            SNOUT(IHRR,12)  = MELT
            SNOUT(IHRR,13)  = CONV
            SNOUT(IHRR,14)  = RAINM
            SNOUT(IHRR,15)  = CONDS
            SNOUT(IHRR,16)  = XICE
            IF  (UNIT.LT.1.OR.HYCAL.GT.1)  GO TO 730
C
C  CONVERSION TO METRIC SNOW OUTPUT
C
              SNOUT(IHRR,1)  =  PACK*MMPIN
              SNOUT(IHRR,2)  =  DEPTH*MMPIN
              SNOUT(IHRR,6)  =  NEGMLT*MMPIN
              SNOUT(IHRR,7)  =  LIQW*MMPIN
              SNOUT(IHRR,8)  =  0.556*(TX-32.0)
              DO 720  ISNOUT=11,16
                 SNOUT(IHRR,ISNOUT)  =  SNOUT(IHRR,ISNOUT)*MMPIN
   720        CONTINUE
C
C
C
   730 IF  (HYCAL.GT.1)  GO TO 760
       IF  (IHRR .NE. 24)   GO TO 760
       WRITE  (6,4020)  MNAM(IZ),MNAM(IX),DAY
       WRITE(6,4000)
C
       DO 750  I=1,24
       WRITE  (6,4010)  I,(SNOUT(I,MM),MM=1,16)
       DO 740  MM=1,16
   740 SNOUT(I,MM)=0.0
   750 CONTINUE
C
C
  4000 FORMAT('0','HOUR  PACK   DEPTH  SDEN  ALBEDO  CLDF  NEGMELT  LIQW
      *  TX      RA    LW     PX    MELT      CONV      RAINM   CONDS    ICE')
  4010 FORMAT(' ',I2,2X,F6.1,2X,F6.1,5(1X,F6.3),1X,F6.2,2(1X,F4.0),
      *5(1X,F7.4),2X,F5.2)
  4020 FORMAT ('0',25X,'SNOWMELT OUTPUT FOR',4X,A4,A4,2X,I2)
C
C                                   CORRECT WATER BALANCE FOR SNOWMELT
C                                   PACK AND SNOW EVAP
C
C                                   PRR IS INCOMING PRECIP
C                                   PX  IS MOISTURE TO THE LAND SURFACE
C                                   SEVAP IS SNOW EVAP - NEGATIVE
   760 SNBAL = PRHR+SEVAP-PX-PACK+PACK1-LIQW+LIQW1
       IF  ((SNBAL.LT.0.0001).AND.(SNBAL.GT.-0.0001))   SNBAL=0.0
       TSNBAL = TSNBAL + SNBAL
```

```
C
C
      PACK1 = PACK
      LIQW1 = LIQW
C                 **********************************
C                              END SNOWMELT
C                 *********************************
C                                                             PX IS TOTAL MOISTURE INPUT TO
C                                                             THE LAND SURFACE FROM PRECIP
C                                                             AND SNOWMELT DURING THE HOUR
C
  770 IF (IEND .GT. 0) PR=PX*TIMFAC/60.
C                                                          IEND>0 INDICATES SNOWMELT
C                                                          OCCURRED DURING THE HOUR
C
C
C
C
C   * * *    INTERCEPTION  FUNC.     * * *
C
C
C EPXMI - MAX. INTERCEPTION STORAGE  FOR THAT DAY
C SCEP - EXISTING INTER. STORAGE
C EPX  - AVAILABLE INTER. STORAGE
C RUI  - IMPERVIOUS RUNOFF DURING INTERVAL
C
C
        EPX=EPXMI-SCEP
        IF(EPX.LT.(0.0001))  EPX=0.0
        IF (PR-EPX)   790,780,780
  780   F3= PR-EPX
        SCEP = SCEP+EPX
        GO TO 800
  790   SCEP = SCEP+PR
        F3=0.0
        RU=0.0
        RUI=0.0
C
C ***    OVERLAND IMPERVIOUS FLOW ROUTING ***
C
C
C RXBI = VOLUME OF IMPERVIOUS OVERLAND FLOW ON SURFACE
C  ROSBI = VOLUME OF OVERLAND IMPERVIOUS FLOW TO STREAM
C  RESBI = VOLUME OF OVERLAND IMPERVIOUS Q REMAINING ON SURFACE
C
C
  800 IF (A) 810,810,820
  810 RUI=0.0
      GO TO 930
  820 RXBI=F3+RESBI
      IF (RXBI-0.001) 830,830,840
  830 RUI=RXBI*A
      RXBI=0.0
      ROSBI=RUI
      GO TO 930
  840 F1= RXBI-(RESBI)
      F3= (RESBI)+ RXBI
      IF (RXBI-(RESBI)) 860,860,850
  850 DE= DECI*((F1)**0.6)
      GO TO 870
  860 DE= (F3)/2.0
```

```
      870 IF (F3-(2.0*DE)) 890,890,880
      880 DE=(F3)/2.0
      890 IF ((F3)-(.005)) 900,900,910
      900 ROSBI= 0.0
          GO TO 920
      910    DUMV=(1.0+0.6*(F3/(2.0*DE))**3.)**1.67
          ROSBI=(TIMFAC/60.)*SRCI*((F3/2.)**1.67)*DUMV
          IF ((ROSBI).GT.(.95*RXBI)) ROSBI=.95*RXBI
      920 RESBI= RXBI-ROSBI
          RUI=ROSBI*A
      930 RU=RUI
C
C
C
C    * * *        INTERCEPTION EVAP        * * *
C
C
      940  IF ((NUMI .EQ. 0) .AND.(IMIN .EQ. 0))   GO TO 950
           GO TO 1000
C
      950  IF  (SCEP)   1000,1000,960
      960  IF (SCEP-EPIN)   970,980,980
      970  EPIN = EPIN - SCEP
           SNET = SNET + SCEP
           SCEP = 0.0
           GO TO 1000
      980  SCEP=SCEP-EPIN
      990  SNET=SNET+EPIN
           EPIN = 0.0
C
C
C      ***  INFILTRATION FUNC.  ***
C  P4 IS TOTAL MOISTURE
C SHRD = SURFACE DETENTION AND INTERFLOW
C RXX = SURFACE DETENTION
C RGXX = INTERFLOW  COMPONENT
C  RGX = VOLUME IO INTER. DETEN STOR.
C
C
     1000 P4 = P3 + RESB
          RESB1 = RESB
          IF (P4 - D4F) 1010,1010,1020
     1010 SHRD=(P4**2)/(2.0*D4F)
          GO TO 1030
     1020 SHRD= P4 - 0.5*D4F
          IF (P4 - D4RA) 1030,1030,1040
     1030 RXX = (P4**2)/(2.0*D4RA)
          GO TO 1050
     1040 RXX= P4 - 0.5*D4RA
     1050 RGXX  = SHRD-RXX
C
C
C   ***  UPPER ZONE FUNCTION ***
C
C PRE  - % SURFACE DETENTION TO OVERLAND FLOW
C UZSB -  UPPER ZONE STORAGE
C UZS  - TOTAL UPPER ZONE STORAGE
C RUZB - ADDITION TO U.Z. STORAGE DURING INTERVAL
C
          IF (UZSB.LT.0.0)  UZSB=0.0
          UZRA= UZSB/UZSN
```

```
      IF (UZRA.GT.6.0) GO TO 1060
      IF (UZRA.GT.2.0) GO TO 1070
      UZI= 2.0*ABS((UZRA/2.0)-1.0) +1.0
      PRE= (UZRA/2.0)*((1.0/(1.0+UZI))**UZI)
      GO TO 1080
 1060 PRE = 1.0
      GO TO 1080
 1070 UZI= (2.0*ABS(UZRA-2.0))+1.0
      PRE= 1.0-((1.0/(1.0+UZI))**UZI)
 1080 RXB= RXX* PRE
        RGX=RGXX*PRE
        RGXX=0.0
        RUZB=SHRD-RGX-RXB
        UZSB=UZSB+RUZB
C
        RIB = P4 - RXB
C
C
C
C   * * *      UPPER ZONE EVAP    * * *
C
C
C REPIN - ACCUM DAILY EVAP POT. FOR L.Z. AND GRDWATER, I.E
C          PORTION NOT SATISFIED FROM U.Z.
C
C
        IF ((NUMI .EQ. 0).AND.(IMIN .EQ. 0))  GO TO 1090
        GO TO 1150
C
 1090   IF (EPIN.LE.(0.0))  GO TO 1150
          EFFECT=1.0
          IF(UZRA-2.0)  1120,1120,1100
 1100     IF (UZSB-EPIN)  1140,1140,1110
 1110     UZSB=UZSB-EPIN
          RUZB= RUZB-EPIN
          SNET=SNET+PA*EPIN
          GO TO 1150
 1120     EFFECT= 0.5*UZRA
          IF (EFFECT.LT.(0.02))  EFFECT=0.02
          IF (UZSB-EPIN*EFFECT)  1140,1140,1130
 1130     UZSB=UZSB - (EPIN*EFFECT)
          RUZB= RUZB-(EPIN*EFFECT)
          EDIFF= (1.0-EFFECT)*EPIN
          REPIN=REPIN + EDIFF
          EDIFF=0.0
          SNET= SNET + (PA*EPIN*EFFECT)
          GO TO 1150
 1140     EDIFF= EPIN - UZSB
          REPIN= REPIN + EDIFF
          EDIFF=0.0
          SNET= SNET + PA*UZSB
          UZSB=0.0
          RUZB=0.0
C
C
C    * * * *    INTERFLOW FUNCTION * * *
C
C      SRGX - INTERFLOW DETENTION STORAGE
C      INTF - INTERFLOW LEAVING STORAGE
C      SRGXT - TOTAL INTERFLOW STORAGE
C      RGXT  - TOTAL INTERFLOW LEAVING STORAGE DURING INTERVAL
```

```
C
 1150    INTF = LIRC4*SRGX
         SRGX=SRGX+(RGX*PA)-INTF
          RU=RU + INTF
         SRGXT= SRGXT + (RGX*PA-INTF)
         RGXT=RGXT + INTF
C
C ***    OVERLAND PERVIOUS FLOW ROUTING ***
C
C
C RXB = VOLUME TO OVERLAND SURFACE DETENTION
C  ROSB = VOLUME OF OVERLAND FLOW TO STREAM
C  RESB = VOLUME OF OVERLAND Q REMAINING ON SURFACE
C
C
      F1= RXB-(RESB)
      F3= (RESB)+ RXB
      IF (RXB-(RESB)) 1170,1170,1160
 1160 DE= DEC*((F1)**0.6)
      GO TO 1180
 1170 DE= (F3)/2.0
 1180 IF (F3-(2.0*DE)) 1200,1200,1190
 1190 DE=(F3)/2.0
 1200 IF ((F3)-(.005)) 1210,1210,1220
 1210 ROSB= 0.0
      GO TO 1230
 1220    DUMV=(1.0+0.6*(F3/(2.0*DE))**3.)**1.67
      ROSB=(TIMFAC/60.)*SRC*((F3/2.)**1.67)*DUMV
      IF ((ROSB).GT.(.95*RXB)) ROSB=0.95*RXB
 1230 RESB= RXB-ROSB
         ROSP = ROSB*PA
        ROSINT = ROSB + INTF
C
C
C
C          * * *  UPPER ZONE DEPLETION * * *
C
C  DEEPL - DIFFERENCE IN UPPER AND LOWER ZONE RATIOS
C  PERCB - UPPER ZONE DEPLETION
C  PERC  - TOTAL U.Z. DEPLETION
C  INFLT  - TOTAL INFILTRATION
C  ROS  - TOTAL OVERLAND FLOW TO THE STREAM
C
         IF ((NUMI .EQ. 0).AND.(IMIN .EQ. 0))  GO TO 1240
         PERCB = 0.0
         GO TO 1280
C
 1240    DEEPL= ((UZSB/UZSN)-(LZS/LZSN))
         IF (DEEPL-.01)    1280,1280,1250
 1250     PERCB=0.1*INFIL*UZSN*(DEEPL**3)
C
      IF (SNOW .GT. 0) PERCB = PERCB*D4FX
C
          IF (UZSB - PERCB) 1260,1260,1270
 1260     PERCB = 0.0
          GO TO 1280
C
 1270     UZSB=UZSB-PERCB
          PERC=PERC+PERCB
          RUZB = RUZB - PERCB
 1280     INFL= P4-SHRD
```

```
                INFLT=INFLT + INFL
          RESS = RESS + RESB
           UZS= UZS + RUZB
          ROS = ROS + ROSB
          IF (UZS .LE. 0.0001) UZS=0.0
C
C END OF BLOCK LOOP
C
              RU=RU + ROS
             IF ((RESS).LT.(0.0001))  GO TO 1290
             GO TO 1300
  1290       LZS = LZS + RESS
             RESS = 0.0
             RESB = 0.0
  1300       IF (SRGXT.LT.(0.0001))  GO TO 1310
             GO TO 1320
  1310       LZS = LZS + SRGXT/PA
             SRGXT = 0.0
               SRGX = 0.0
C
C
C    * * * LOWER ZONE AND GROUNDWATER  * * *
C
C  SBAS  - BASE STREAMFLOW
C  SRCH  - SUM OF GRDWATER RECHARGE
C PREL - % OF INFILTRATION AND U.Z. DEPLETION ENTERING L.Z
C  F1A  - GROUNDWATER RECHARGE - IE. PORTION OF INFIL.
C          AND U.Z. DEPLETION ENTERING GRDWATER
C  K24L  - FRACTION OF F1A LOST TO DEEP GRDWATER
C
 1320           LZI=1.5*ABS((LZS/LZSN)-1.0)+1.0
                PREL=(1.0/(1.0+LZI))**LZI
                IF (LZS.LT.LZSN)   PREL=1.0-PREL*LNRAT
                F3= PREL*(INFLT)
                F1A = (1.0-PREL)*INFLT
                IF ((NUMI .EQ. 0).AND.(IMIN .EQ. 0))  GO TO 1330
                GO TO 1340
 1330           F3 = F3 + PREL*PERC
                F1A = F1A + (1.0-PREL)*PERC
 1340           LZS= LZS+F3
             F1= F1A*(1.0 - K24L)*PA
             GWF=SGW*LKK4*(1.0 + KV*GWS)
             SBAS= GWF
             RU=RU+GWF
             SRCH= F1A*K24L*PA
              SGW=SGW - GWF + F1
              GWS=GWS + F1
C
C   * * *        GROUNDWATER EVAP    * * *
C
C
C LOS  - EVAP LOST FROM GROUNDWATER
C
C      NOTE: EVAP FROM GRDWATER AND LZ IS CALCULATED ONLY DAILY
C
             IF ((HRFLAG.EQ.1).AND.(IHRR.EQ.21)) GO TO 1350
             GO TO 1430
 1350        IF (GWS .GT. 0.0001)  GWS = 0.97*GWS
             LOS= SGW*K24EL*REPIN*PA
             SGW=SGW - LOS
             GWS=GWS - LOS
```

```
              SNET= SNET + LOS
              REPIN= REPIN - LOS
              IF (GWS.LT.(0.0))  GWS=0.0
C
C  * * *        LOWER ZONE EVAP  * * *
C
C AETR - EVAP LOST FROM L.Z.
C
C
             IF (REPIN.LT.(0.0001))  GO TO 1420
             LNRAT = LZS/LZSN
              IF (K3-1.0)   1370,1360,1360
 1360         KF=50.0
              GO TO 1380
 1370         KF=0.25/(1.0-K3)
 1380         IF (REPIN - (KF*LNRAT))  1390,1400,1400
 1390         AETR= REPIN*(1.0-(REPIN/(2.0*KF*LNRAT)))
              GO TO 1410
 1400         AETR= 0.5*(KF*LNRAT)
 1410         IF (K3.LT.(0.50))  AETR=AETR*(2.0*K3)
              LZS=LZS - AETR
              SNET= SNET + PA*AETR
              ASNET = ASNET + LOS + PA*AETR
 1420         REPIN = 0.0
 1430         SNETI = SNET - SNET1
C
C
C
C WBAL - WATER BALANCE IN THE INTERVAL
C TWBAL - ACCUMULATED WATER BALANCE
C
C
 1440         WBAL = (LZS-LZS1+UZS-UZS1+RESS-RESS1)*PA+(SNET-SNET1+SGW-SGW1+
     X                SCEP-SCEP1+SRCH+SRGXT-SRGXT1+RU-PR)+(RESBI-RESBI1)*A
 1450         IF ((WBAL .LE. 0.0001).AND.(WBAL .GE. -0.0001))  WBAL = 0.0
             TWBAL=TWBAL+WBAL
C
            DPS = F1A*PA
            DPST = DPST + DPS
C
C
C                        RESETTING VARIABLES
C
            LZS1=LZS
            UZS1=UZS
            RESS1=RESS
            SCEP1=SCEP
            SRGXT1=SRGXT
            SGW1=SGW
            SNET1=SNET
            RESBI1=RESBI
             ASBAS = ASBAS + SBAS
             ASRCH = ASRCH + SRCH
            APR = APR + PRR
               ARU = ARU + RU
               ARUI = ARUI + RUI
               AROS = AROS + ROS
               ARGXT = ARGXT + RGXT
               IF ((NUMI.EQ.0).AND.(IMIN.EQ.0))  GO TO 1460
               GO TO 1470
 1460          AEPIN = AEPIN + EPIN1
```

```
                ASNET = ASNET + SNETI
       1470     AROSB = AROSB + ROSB
                AINTF = AINTF + INTF
                AROSIT = AROSIT + ROSINT
      C
       1480 CONTINUE
      C
      C
      C                        CUMULATIVE RECORDS
      C
            PRTOM = PRTOM + APR
            EPTOM = EPTOM + AEPIN
            RUTOM = RUTOM + ARU
            ROSTOM = ROSTOM + AROS
            RITOM = RITOM + ARUI
            RINTOM = RINTOM + ARGXT
            NEPTOM = NEPTOM + ASNET
            BASTOM = BASTOM + ASBAS
            RCHTOM = RCHTOM + ASRCH
      C
                 RCBTOM = ROBTOM + AROSB
                 ROBTOT = ROBTOT + AROSB
                 INFTOM = INFTOM + AINTF
                 INFTOT = INFTOT + AINTF
                 ROITOM = ROITOM + AROSIT
                 ROITOT = ROITOT + AROSIT
      C
            PRTOT = PRTOT + APR
            EPTOT = EPTOT + AEPIN
            RUTOT = RUTOT + ARU
            ROSTOT = ROSTOT + AROS
            RITOT = RITOT + ARUI
            RINTOT =RINTOT + ARGXT
            NEPTOT = NEPTOT + ASNET
            BASTOT = BASTOT + ASBAS
            RCHTOT = RCHTOT + ASRCH
      C
      C          LOGICAL VARIABLES LAST AND PREV ARE USED TO DETERMINE
      C          BEGINNING AND END OF EACH STORM. STORM BEGINS IF RU
      C          IS LESS THAN HYMIN IN ONE TIME INTERVAL, AND GREATER IN
      C          THE FOLLOWING ONE (PREV=.FALSE. , LAST=.TRUE.). STORM ENDS
      C          IF THE OPPOSIT OCCURS (PREV=.TRUE. , LAST=.FALSE.)
      C
            RUINCH=RU
            RU = (RU*AREA*43560.)/(TIMFAC*720.)
            IF ((RU.GE.HYMIN).AND.(TF.LE.2))  GO TO 1490
            LAST=.FALSE.
            GO TO 1570
       1490 LAST=.TRUE.
            IF (PREV) GO TO 1550
      C
      C          COUNT NUMBER OF STORMS AND RECORD TIME OF STORM BEGINNING
      C
            NOS=NOS+1
            IF (NOS.EQ.1) WRITE(6,4045)
            WRITE (6,4050) NOS,MNAM(IZ),MNAM(IX),YEAR
            STRBGN(1)=MNAM(IZ)
            STRBGN(2)=DAY
            STRBGN(3)=IHR
            STRBGN(4)=IMIN
      C
```

```
C         INITIALIZATION OF VARIABLES FOR STORM SUMMARY
      NOSI=0
      TOTRUN=0.
      PEAKRU=0.
      ACSEDT=0.
      SEDMX=0.
      SEDTSC=0.
      SEDMXC=0.
      DO 1495 I=1,5
      ACPOLT(I)=0.
      PLTMX(I)=0.
      POLTSC(I)=0.
      PLTMXC(I)=0.
 1495 LMTS(I)=0
C
C          PRINT INITIAL CONDITION FOR A NEW STORM
C
      IF (HYCAL.EQ.1) GO TO 1530
      WRITE (6,4060) WHT,ARUN
C
C          CALCULATE AND PRINT MEAN ACCUMULATION FOR (1) EACH
C          LAND TYPE USE (WEIGHTED BY % OF PERVIOUS AND IMPERVIOUS
C          AREAS), (2) THE ENTIRE WATERSHED AND THE TOTAL PERVIOUS
C          AND IMPERVIOUS AREAS (WEIGHTED BY % OF VARIOUS LAND TYPE USE)
C
       TEM1=0.0
       TEM2=0.0
       TEM3=0.0
       TEM4=0.0
      DO 1510 I=1,NLAND
      TEM=SRER(I)*(1-IMPK(I))+TS(I)*IMPK(I)
      WHFUN1=(AR(I)/AREA)*(1-IMPK(I))
      WHFUN2=(AR(I)/AREA)*IMPK(I)
      TEM1=TEM1+SRER(I)*WHFUN1
      TEM2=TEM2+TS(I)*WHFUN2
      TEM3=TEM3+WHFUN1
      TEM4=TEM4+WHFUN2
      IF (UNIT.GT.-1) GO TO 1500
      WRITE (6,4070) (LNDUSE(IK,I),IK=1,3),TEM,SRER(I),TS(I)
      GO TO 1510
 1500 TEM5=SRER(I)*2.24
      TEM6=TS(I)*2.24
      TEM=TEM*2.24
      WRITE (6,4070) (LNDUSE(IK,I),IK=1,3),TEM,TEM5,TEM6
      IF (LMTS(I).EQ.1) WRITE (6,4040)
 1510 CONTINUE
      IF (NLAND.EQ.1) GO TO 1530
      IF (TEM3.GT.0.0) TEM1=TEM1/TEM3
      IF (TEM3.LE.0.0) TEM1=0.0
      IF (TEM4.GT.0.0) TEM2=TEM2/TEM4
      IF (TEM4.LE.0.0) TEM2=0.0
      TEM=TEM1*(1-A)+TEM2*A
      IF (UNIT.LT.1) GO TO 1520
      TEM=TEM*2.24
      TEM1=TEM1*2.24
      TEM2=TEM2*2.24
 1520 WRITE (6,4080) TEM,TEM1,TEM2
 1530 CONTINUE
      WRITE (6,4090)
      IF (HYCAL.GT.1) GO TO 1540
      WRITE (6,4110) UFL
```

```
      GO TO 1550
 1540 WRITE (6,TIT)
      WRITE (6,4100) ((QUALIN(I,J),I=1,3),J=1,NQUAL)
      IF (UNIT.EQ.-1) GO TO 1545
 1545 WRITE (6,FORM) UFL,UTMP
 1550 CMETRC=RU*.0283
C
C                    PRINT DATE,TIME,AND FLOW
C
      WRITE (6,4130) MNAM(IZ),DAY,IHR,IMIN
      NOSI=NOSI+1
      FLOUT=RU
      IF (UNIT.GT.0) FLOUT=CMETRC
      WRITE (6,4120) FLOUT
      IF (HYCAL.NE.4) GO TO 1560
      RECOUT(2)=MNAM(IZ)
      RECOUT(3)=DAY
      RECOUT(4)=IHR
      RECOUT(5)=IMIN
 1560 IF (RU.GT.PEAKRU) PEAKRU=RU
      TOTRUN=TOTRUN+RUINCH
 1570 APR = 0.0
      AEPIN = 0.0
      ARU = 0.0
      ARUI = 0.0
      AROS = 0.0
      ARGXT = 0.0
      ASNET = 0.0
      ASBAS = 0.0
      ASRCH = 0.0
         AROSB = 0.0
         AINTF = 0.0
         AROSIT = 0.0
      IF (LAST.OR..NOT.PREV) GO TO 1640
C
C                    STORM SUMMARY
C
      IF (UNIT.LT.1) GO TO 1590
      TOTRUN=TOTRUN*25.4
      PEAKRU=PEAKRU*0.0283
      ACSEDT=ACSEDT*0.9072
      SEDMX=SEDMX*0.454
      DO 1580 I=1,NQUAL
      ACPOLT(I)=ACPOLT(I)*0.454
 1580 PLTMX(I)=PLTMX(I)*0.454
 1590 WRITE (6,4150)
      IF (HYCAL.EQ.4) WRITE (4,4150)
      WRITE (6,4140) NOS
      WRITE (6,4160) NOSI,(STRBGN(I),I=1,4),MNAM(IZ),DAY,IHR,
     *
     *             IMIN,DEPW,TOTRUN,UFL,PEAKRU
      IF (HYCAL.EQ.1) GO TO 1610
      WRITE (6,4170) ((QUALIN(I,J),I=1,3),J=1,NQUAL)
      WRITE (6,4180) WHT,ACSEDT,(ACPOLT(I),I=1,NQUAL)
      WRITE (6,4190) WHGT,SEDMX,(PLTMX(I),I=1,NQUAL)
      SEDTSC=SEDTSC/NOSI
      DO 1600 I=1,5
 1600 POLTSC(I)=POLTSC(I)/NOSI
      DO 1605 I=1,NQUAL
      DUM1(I)=POLTSC(I)/SCALEF(I)
 1605 DUM2(I)=PLTMXC(I)/SCALEF(I)
```

```
      WRITE (6,4200) SEDTSC,(DUM1(I),I=1,NQUAL)
      WRITE (6,4210) SEDMXC,(DUM2(I),I=1,NQUAL)
 1610 WRITE (6,4150)
C
C              ACCUMULATION FOR OVERALL STORM SUMMARY
C
      IF (HYCAL.NE.1) GO TO 1620
      STMCH(NOSY+NOS,1)=TOTRUN
      STMCH(NOSY+NOS,2)=PEAKRU
      GO TO 1640
 1620 IF (NOSY+NOS.GT.200) GO TO 1640
      STMCH(NOSY+NOS,1)=ACSEDT
      STMCH(NOSY+NOS,2)=SEDMX
      STMCH(NOSY+NOS,3)=SEDTSC
      STMCH(NOSY+NOS,4)=SEDMXC
      DO 1630 I=1,NQUAL
      KI=4*I
      STMCH(NOSY+NOS,KI+1)=ACPOLT(I)
      STMCH(NOSY+NOS,KI+2)=PLTMX(I)
      STMCH(NOSY+NOS,KI+3)=POLTSC(I)
      STMCH(NOSY+NOS,KI+4)=PLTMXC(I)
 1630 CONTINUE
      WRITE (6,4030)
 1640 CONTINUE
      PREV=LAST
C
C                        FORMAT STATEMENTS
C
 4030 FORMAT ('0')
 4040 FORMAT ('+',70X,'** LIMIT REACHED **')
 4045 FORMAT ('1')
 4050 FORMAT (3(/),130('*'),2(/),55X,'OUTPUT FOR STORM NO.',I3,
     1       ' - ',A4,A4,1X,I4)
 4060 FORMAT (//,1X,'ACCUMULATION OF DEPOSITS ON GROUND AT THE ',
     1       'BEGINNING OF STORM,',A4,'/',A4,
     2       /,3X,'LAND USE',8X,'WEIGHTED MEAN',9X,'PERVIOUS',8X,
     4       'IMPERVIOUS',/)
 4070 FORMAT (1X,3A4,9X,F7.3,2(12X,F7.3))
 4080 FORMAT (3X,'WEIGHTED MEAN',6X,F7.3,2(12X,F7.3))
 4090 FORMAT (//)
 4100 FORMAT (2X,'DATE    TIME    FLOW    TEMP   DO(PPM)    SEDIMENTS
     1       5(4X,3A4))
 4110 FORMAT ('  DATA    TIME   FLOW (',A4,')')
 4120 FORMAT ('+',14X,F8.3)
 4130 FORMAT (1X,A4,1X,I2,1X,I2,':',I2)
 4140 FORMAT (/,' SUMMARY FOR STORM # ',I3)
 4150 FORMAT (29('_'))
 4160 FORMAT (/,' NUMBER OF TIME INTERVALS',I4,/,
     1        ' STORM BEGINS',3X,A4,1X,I2,1X,I2,':',I2,/,
     2       ' STORM ENDS',5X,A4,1X,I2,1X,I2,':',I2,/,
     3       ' TOTAL FLOW (',A4,')',1X,F10.3,/,
     4        ' PEAK FLOW (',A4,')',2X,F10.3)
 4170 FORMAT (37X,' SEDIMENTS ',4X,5(4X,3A4))
 4180 FORMAT (' TOTAL WASHOFF (',A4,')',14X,F10.2,5X,5(F14.5,2X))
 4190 FORMAT (' MAX WASHOFF (',A4,'/15MIN)',10X,F10.2,5X,5(F14.5,2X))
 4200 FORMAT (' MEAN CONCENTRATION (GM/L)',9X,F10.2,5X,5(F14.5,2X))
 4210 FORMAT (' MAX CONCENTRATION (GM/L)',10X,F10.2,5X,5(F14.5,2X))
C
       RETURN
      END
      SUBROUTINE QUAL
```

```
C
C
      DIMENSION POLP(5,5),POLI(5,5),EIM(5),POLTLU(5,5),POLT(5),
     1          TSS(5),RER(5),ERSN(5),SER(5),TEMPX(24)
C
      COMMON /ALL/ RU,HYMIN,HYCAL,DPST,UNIT,TIMFAC,LZS,AREA,RESB,SFLAG,
     1             RESB1,ROSB,SRGX,INTF,RGX,RUZB,UZSB,PERCB,RIB,P3,TF,
     2             KGPLB,LAST,PREV,TEMPX,IHR,IHRR,PR,RUI,A,PA,GWF,NCSY,
     3             SREP(5),TS(5),LNDUSE(3,5),AR(5),QUALIN(3,5),NOSI,NOS,
     4             NOSIM,UFI,UTMP,UNT1(2,2),UNT2(2,2),UNT3(2,2),WHGT,
     5             WHT,DEPW,ROSBI,RESBI,RESBI1,ARUN,LMTS(5),IMPK(5),
     6             NLAND,NQUAL,STMCH(200,24),RECOUT(5),FLOUT,SCALEF(5),
     7             SNOW,PACK,IPACK
C
      COMMON /QLS/ WSNAME(6),KRER,JRER,KSER,JSER,TEMPCF,COVMAT(5,12),
     1             KEIM,JEIM,NDSF,ARP(5),ARI(5),ACCP(5),ACCI(5),RERR(5),
     2             PMP(5,5),PMI(5,5),QSNOW,SNOWY,SEDTM,SEDTY,SEDTCA,
     3             ACPOLP(5,5),ACERSN(5),APOLP(5,5),AERSN(5),COVER(5),
     4             APOLI(5,5),ACEIM(5),AEIM(5),POLTM(5),POLTY(5),
     5             TEMPA,DCA,PCLTCA(5),AERSNY(5),AEIMY(5),APOLPY(5,5),
     6             APOLIY(5,5),POLTC(5),PLTCAY(5),ACPOLI(5,5),RIMP(5)
C
      COMMON /STS/ ACPOLT(5),PLTMX(5),POLTSC(5),PLTMXC(5),
     1             ACSEDT,SEDMX,SEDTSC,SEDMXC,TOTRUN,PEAKRU
C
      DIMENSION LIMP(5),LIMI(5)
      REAL  JRER, KRER, JSER, KSER,KEIM,JEIM
      INTEGER HYCAL,TF,UNIT,LMTS ,RECOUT,SFLAG
C
      REAL*8 WSNAME
      DO 10 I=1,5
      LIMP(I)=.0
   10 LIMI(I)=.0
C
      IF (TF.GT.2) GO TO 250
C
C          CONVERT ROSB - VOLUME OF OVERLAND FLOW REACHING STREAM -
C                         IN INCHES PER WHOLE WATERSHED TO INCHES
C                         PER PERVIOUS AREAS ONLY
C
      IF ((1.-A).GT.0.00001) GO TO 20
      ROSBQ=0.0
      GO TO 30
   20 ROSBQ=ROSB/(1.-A)
   30 CONTINUE
      DO 90 I=1,NLAND
C
C                    IF RAIN ON SNOW, INCREASE COVER BY % OF SNOW COVER
C
      IF (SNOW.EQ.0.OR.(PACK/IPACK).LT.COVER(I)) GO TO 35
      CR=COVER(I)+(1-COVER(I))*(PACK/IPACK)
      IF (CR.LT.COVER(I)) GO TO 35
      IF (CR.LE.1.0) COVER(I)=CR
   35 CONTINUE
C
C                              WASHOFF FROM PERVIOUS AREAS
C
      IF (SFLAG.EQ.1) GO TO 40
C
C                    IF SNOWS, BRANCH OVER FINES GENERATION
C
```

```
      RER(I)=(1-COVER(I))*KRER*PR**JRER
      SRER(I)=SRER(I)+RER(I)
   40 IF (RU.LE.0.0) GO TO 270
      IF((ROSBQ+RESB).GT.0.0) GO TO 60
      ERSN(I)=0.0
      DO 50 J=1,NQUAL
   50 POLP(I,J)=0.0
      GO TO 90
   60 SER(I)=KSER*(ROSBQ+RESB)**JSER
      IF(SER(I).LE.SRER(I)) GO TO 70
      SER(I)=SRER(I)
      LIMP(I)=1
   70 ERSN(I)=SER(I)*(ROSBQ/(ROSBQ+RESB))
      SRER(I)=SRER(I)-ERSN(I)
      ERSN(I)=ERSN(I)*ARE(I)
      IF(SRER(I).LT.0.0) SRER(I)=0.0
C
C      MONTHLY ACCUMULATION OF WASHOFF FROM PERVIOUS AREAS
C
      DO 80 J=1,NQUAL
      POLP(I,J)=ERSN(I)*(PMP(J,I)/100.)*2000.
      ACPOLP(I,J)=ACPOLP(I,J)+POLP(I,J)
   80 APOLP(I,J)=APOLP(I,J)+POLP(I,J)
      ACERSN(I)=ACERSN(I)+ERSN(I)
      AERSN(I)=AERSN(I)+ERSN(I)
   90 CONTINUE
C
C                                 WASHOFF FROM IMPERVIOUS AREAS
C
      DO 140 I=1,NLAND
      IF ((ROSBI+RESBI).GT.0.) GO TO 110
      EIM(I)=0.0
      DO 100 J=1,NQUAL
  100 POLI(I,J)=0.0
      GO TO 140
  110 TSS(I)=KEIM*((ROSBI+RESBI)**JEIM)
      IF(TSS(I).LE.TS(I)) GO TO 120
      TSS(I)=TS(I)
      LIMI(I)=1
  120 EIM(I)=TSS(I)*(ROSBI/(ROSBI+RESBI))
      TS(I)=TS(I)-EIM(I)
      EIM(I)=EIM(I)*ARI(I)
      DO 130 J=1,NQUAL
      POLI(I,J)=EIM(I)*(PMI(J,I)/100.)*2000.
      APOLI(I,J)=APOLI(I,J)+POLI(I,J)
  130 ACPOLI(I,J)=ACPOLI(I,J)+POLI(I,J)
      ACEIM(I)=ACEIM(I)+EIM(I)
      AEIM(I)=AEIM(I)+EIM(I)
  140 CONTINUE
C
C                                 STORMWATER TEMPERATURE AND DISSOLVED OXYGEN
C                                                    (ASCE,SE4(86),P41)
C
      TEMPC=(TEMPX(IHRR)*TEMPCF-32.)*5/9
      IF (TEMPC.LT.0.0) TEMPC=0.00
      DO=14.652-0.41022*TEMPC+0.007991*(TEMPC**2)-.000077774*(TEMPC**3)
C
C                                 WASHOFF SUMMARY FOR A GIVEN TIME INTERVAL
C
      DO 160 J=1,NQUAL
      POLT(J)=0.000
```

```
      DO 150 I=1,NLAND
      POLTLU(I,J)=POLP(I,J)+PCLI(I,J)
      POLT(J)=PCLT(J)+POLTLU(I,J)
  150 CONTINUE
      ACPOLT(J)=ACPOLT(J)+PCLT(J)/2000.
      IF (POLT(J).GT.PLTMX(J)) PLTMX(J)=POLT(J)
      POLTC(J)=POLT(J)*454.*SCALEF(J)/(RU*TIMFAC*60.0*28.32)
      POLTSC(J)=POLTSC(J)+PCLTC(J)
      IF (POLTC(J).GT.PLTMXC(J)) PLTMXC(J)=POLTC(J)
      POLTCA(J)=POLTCA(J)+PCLTC(J)
  160 CONTINUE
      SEDT=0.000
      DO 170 I=1,NLAND
      SEDT=SEDT+ERSN(I)+EIM(I)
  170 CONTINUE
      ACSEDT=ACSEDT+SEDT
      SEDT=SEDT*2000.
      IF (SEDT.GT.SEDMX) SEDMX=SEDT
      SEDTC=SEDT*454./(RU*TIMFAC*60.0*28.32)
      SEDTSC=SEDTSC+SEDTC
      IF (SEDTC.GT.SEDMXC) SEDMXC=SEDTC
C
C                           PRINTING OF OUTPUT FOR ONE TIME INTERVAL
C
      TEMP=TEMPX(IHRP)*TEMPCF
      IF (TEMP.LT.32.0) TEMP=32.00
      DOA=DOA+DO
      TEMPA=TEMPA+TEMP
      SEDTCA=SEDTCA+SEDTC
      NOSIM=NOSIM+1
      IF (RU.LT.HYMIN) GO TO 270
      IF(UNIT.EQ.-1) GO TO 190
      TEMP=TEMPC
      SEDT=SEDT*0.454
      DO 180 J=1,NQUAL
  180 POLT(J)=POLT(J)*0.454
  190 CONTINUE
      WRITE(6,4000) TEMP,DO,SEDT,SEDTC,(POLT(J),POLTC(J),J=1,NQUAL)
      IF (HYCAL.LT.4) GO TO 200
      WRITE(4,4100) (RECCUT(I),I=1,5),PLOUT,
     *                TEMP,DO,SEDT,SEDTC,(POLT(J),POLTC(J),J=1,NQUAL)
C
C           PRINT OF ADDITIONAL OUTPUT FOR CALIBRATION RUN
C
  200 IF ((SEDT.LE.0.001).OR.(HYCAL.GT.2)) GO TO 270
      RUI=(RUI*AREA*43560.)/(TIMFAC*720.)
      TEM=RU
      IF (UNIT.LT.1) GO TO 210
      TEM=TEM*0.0283
      RUI=RUI*0.0283
      PR=PR*25.4
  210 WRITE(6,4010) RU,UFL
      WRITE(6,4020) RUI,UFL
      WRITE (6,4030) PR,DEPW
      DO 240 I=1,NLAND
      ERSN(I)=ERSN(I)*2000.
      EIM(I)=EIM(I)*2000.
      TEM=ERSN(I)+EIM(I)
      IF (TEM.LE.0.001) GO TO 240
      IF (UNIT.LT.1) GO TO 230
      TEM=TEM*0.454
```

```
      EIM(I)=EIM(I)*0.454
      ERSN(I)=ERSN(I)*0.454
      DO 220 J=1,NQUAL
      POLTLU(I,J)=POLTLU(I,J)*0.454
      POLP(I,J)=POLP(I,J)*0.454
  220 POLI(I,J)=POLI(I,J)*0.454
  230 WRITE(6,4040) (LNDUSE(KK,I),KK=1,3),TEM,(POLTLU(I,J),J=1,NQUAL)
      IF (LIMP(I).EQ.0)
     *                  WRITE(6,4050) COVER(I),ERSN(I),(POLP(I,J),J=1,NQUAL)
      IF (LIMP(I).EQ.1)
     *                  WRITE(6,4060) COVER(I),ERSN(I),(POLP(I,J),J=1,NQUAL)
      IF (LIMI(I).EQ.0) WRITE(6,4070) EIM(I),(POLI(I,J),J=1,NQUAL)
      IF (LIMI(I).EQ.1) WRITE(6,4080) EIM(I),(POLI(I,J),J=1,NQUAL)
  240 CONTINUE
      WRITE (6,4090)
      GO TO 270
C
C          ACCUMULATION OF DEPOSITS DURING THE NO RAIN DAYS
C
  250 DO 260 I=1,NLAND
      TS(I)=TS(I)*(1.0-RIMP(I))+ACCI(I)
      SRER(I)=SRER(I)*(1.0-RPER(I))+ACCP(I)
      IF (RIMP(I).LE.0.0) GO TO 260
      TEM=ACCI(I)/RIMP(I)
      IF (TS(I).LT.TEM) GO TO 260
      TS(I)=TEM
      LMTS(I)=+1
  260 CONTINUE
  270 CONTINUE
C
 4000 FORMAT ('+',22X,F6.2,2X,F5.2,F9.2,F8.3,5(F8.2,F8.3))
 4010 FORMAT ('0',3X,'TOTAL FLOW',F8.3,', ',A4)
 4020 FORMAT (' ',1X,'IMPERV. FLOW',F8.3,', ',A4)
 4030 FORMAT (' PRECIPITATION ',F7.3,', ',A4)
 4040 FORMAT ('0',21X,3A4,1X,F10.2,8X,5(F10.3,6X))
 4050 FORMAT (' ',8X,'COVER=',F5.2,7X,'PERV.',3X,F10.2,8X,5(F10.3,6X))
 4060 FORMAT (9X,'COVER=',F5.2,7X,'PERV.',2X,'*',F10.2,8X,5(F10.3,6X))
 4070 FORMAT (27X,'IMPERV.',1X,F10.2,8X,5(F10.3,6X))
 4080 FORMAT (27X,'IMPERV.','*',F10.2,8X,5(F10.3,6X))
 4090 FORMAT (/)
 4100 FORMAT (I4,A4,1X,I2,1X,I2,':',I2,F8.3,F5.2,F5.2,F9.2,
     1          F8.3,5(F8.2,F8.3))
C
      RETURN
      END
/*
//LKED.SYSLMOD DD DSNAME=WYL.X2.A20.TONY.T7508.NPS.LM111576,
//             DISP=(NEW,KEEP),SPACE=(TRK,(15,1,1),RLSE),UNIT=DISK,
//             VOL=SER=PUB003
//LKED.SYSIN DD *
   NAME NPS
/*
```

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(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The Nonpoint Source Pollutant Loading (NPS) Model was applied to one urban and two small agricultural watersheds to simulate nutrient loadings in surface runoff. Since the NPS Model simulates all nonpoint pollutants as a function of sediment loss, the key question was whether sediment is a reliable indicator of nutrients in surface runoff. Both the literature surveyed and the results of this work indicate Total nitrogen (N) and Total phosphorus (P) can be reasonably simulated in this manner. Also, organic components of N and P can be simulated since they are generally associated with sediment and comprise a major portion of the total nutrients in surface runoff.

Nitrate N (NO_3-N) and phosphate P (PO_4-P) are almost entirely contained in the soluble fraction of surface runoff and are not adequately simulated with the NPS Model. Ammonia N (NH_3-N) appears to be transported in significant amounts both in solution and attached to sediment; thus, the simulation results were inconclusive. Total Kjeldahl N (TKN) was simulated on the urban watershed which was large enough to provide a continuous baseflow. The simulated TKN values agreed reasonably well with recorded values except when baseflow TKN concentrations were high. Over 50% of the annual TKN loading was estimated to originate from the baseflow. Therefore, the NPS Model can simulate total nutrient loadings only in areas where subsurface contributions are minimal.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Simulation, Surface Water Runoff, Planning, Erosion, Nutrients, Nitrogen, Phosphorus, Hydrology, Urban Areas	NPS Model, Nonpoint pollution, Urban runoff, Agricultural runoff Agricultural watersheds, Model studies	2A 2B 8H 8L 8M 13B 20D

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