Simulation Of Streamflow and Sediment Transport In Two Surface-Coal-Mined Basins In Fayette County, Pennsylvania

by James I. Sams III and Emitt C. Witt III

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CONVERSION FACTORS

Multiply	By	To obtain
acre	4,047	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
pound per square foot (lb/ft^2)	4.882	kilogram per square meter
square mile (mi^2)	2.590	square kilometer
ton per acre (ton/acre)	2.2242	megagram per hectare
degree Fahrenheit (°F)	°C = 5/9 (°F-32)	degree Celsius

Abbrreviated water-quality units used in this report

milligrams per liter (mg/L)

SIMULATION OF STREAMFLOW AND SEDIMENT TRANSPORT IN TWO SURFACE-COAL-MINED BASINS IN FAYETTE COUNTY, PENNSYLVANIA

by James I. Sams III and Emitt C. Witt III

ABSTRACT

The Hydrological Simulation Program - Fortran (HSPF) was used to simulate streamflow and sediment transport in two surface-mined basins of Fayette County, Pa. Hydrologic data from the Stony Fork Basin (0.93 square miles) was used to calibrate HSPF parameters. The calibrated parameters were applied to an HSPF model of the Poplar Run Basin (8.83 square miles) to evaluate the transfer value of model parameters. The results of this investigation provide information to the Pennsylvania Department of Environmental Resources, Bureau of Mining and Reclamation, regarding the value of the simulated hydrologic data for use in cumulative hydrologic-impact assessments of surface-mined basins.

The calibration period was October 1, 1985, through September 30, 1988 (water years[1] 1986-88). The simulated data were representative of the observed data from the Stony Fork Basin. Mean simulated streamflow was 1.64 cubic feet per second compared to measured streamflow of 1.58 cubic feet per second for the 3-year period. The difference between the observed and simulated peak stormflow ranged from 4.0 to 59.7 percent for 12 storms. The simulated sediment load for the 1987 water year was 127.14 tons (0.21 ton per acre), which compares to a measured sediment load of 147.09 tons (0.25 ton per acre). The total simulated suspended-sediment load for the 3-year period was 538.2 tons (0.30 ton per acre per year), which compares to a measured sediment load of 467.61 tons (0.26 ton per acre per year).

The model was verified by comparing observed and simulated data from October 1, 1988, through September 30, 1989. The results obtained were comparable to those from the calibration period. The simulated mean daily discharge was representative of the range of data observed from the basin and of the frequency with which specific discharges were equalled or exceeded.

The calibrated and verified parameters from the Stony Fork model were applied to an HSPF model of the Poplar Run Basin. The two basins are in a similar physical setting. Data from October 1, 1987, through September 30, 1989, were used to evaluate the Poplar Run model. In general, the results from the Poplar Run model were comparable to those obtained from the Stony Fork model. The difference between observed and simulated total streamflow was 1.1 percent for the 2-year period. The mean annual streamflow simulated by the Poplar Run model was 18.3 cubic feet per second. This compares to an observed streamflow of 18.15 cubic feet per second. For the 2-year period, the simulated sediment load was 2,754 tons (0.24 ton per acre per year), which compares to a measured sediment load of 3,051.2 tons (0.27 ton per acre per year) for the Poplar Run Basin. Cumulative frequency-distribution curves of the observed and simulated streamflow compared well. The comparison between observed and simulated data improved as the time span increased. Simulated annual means and totals were more representative of the observed data than hourly data used in comparing storm events.

The structure and organization of the HSPF model facilitated the simulation of a wide range of hydrologic processes. The simulation results from this investigation indicate that model parameters may be transferred to ungaged basins to generate representative hydrologic data through modeling techniques.

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[1] A water year is the 12-month period beginning on October 1 and ending on September 30. It is designated by the year in which it ends.

INTRODUCTION

The cumulative hydrologic impacts from surface coal mining has affected many streams in Pennsylvania. The enactment of the Surface Mining Control and Reclamation Act of 1977 (SMCRA) established a set of rules and regulations to limit the environmental impacts of surface mining (P.L. 95-87). Sections 507-B-11 and 510-B-3 of the act require that each permit application for surface mining be reviewed for cumulative hydrologic impacts. State regulations require that a coal-mine operator demonstrate that mining can occur without pollution of surface and ground water. If this demonstration cannot be made, the Pennsylvania Department of Environmental Resources, Bureau of Mining and Reclamation (BMR), can deny a mining permit. The BMR's decisions are based on hydrologic, geologic, and other data collected from the watershed. Section 779.13 of the SMCRA specifies that modeling techniques may be used to generate these data. The concept of computer modeling in hydrologic-impact studies of areas affected by surface mining has been discussed by Doyle (1981) and Lumb (1982). This work was done in cooperation with the BMR and the U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement.

Purpose and Scope

This report presents results of the application of a Hydrologic Simulation Program - Fortran (HSPF) for the modeling of streamflow and suspended-sediment loads in surface-mined basins. The primary objectives are to discuss the calibration procedures of the HSPF model and the simulation results. The secondary objective is to evaluate the transfer value of the calibrated parameters.

Approach

The HSPF models were developed for two basins in Fayette County, Pa. Streamflow and suspended-sediment data collected from a tributary of Stony Fork were used to calibrate the HSPF model. The calibrated HSPF parameters developed for the Stony Fork Basin were then applied to an HSPF model of the Poplar Run Basin to determine the transfer value of parameters.

Previous Investigations

Stump and Mastrilli (1985) discussed the effects of surface mining on streamflow, suspended sediments, and water quality in the Stony Fork Basin from 1977 through 1980.

McElroy (1988) described the hydrogeology of Fayette County and the impact of coal mining on the ground-water resources.

Sams III and Witt III (1989) presented hydrologic data collected from the Poplar Run Basin during an investigation of Indian Creek in Fayette County from 1985 to 1987.

Acknowledgment

Special thanks are extended to Lynn Langer of the Pennsylvania Department of Environmental Resources, BMR, for providing information on the aerial distribution of surface mining in the study areas.

DESCRIPTION OF STUDY AREA

Physical Setting

The Stony Fork and Poplar Run Basins are located in Fayette County, Pa., in the Allegheny Mountain section of the Appalachian Plateaus physiographic province (fig. 1). The Allegheny Mountain section of Fayette County is bounded by Chestnut Ridge to the west and Laurel Hill to the east. These are anticlinal mountains which trend north-northeast. The two basins are located near the eastern flank of the Chestnut Ridge anticline. The drainage basins are developed in dissected uplands from eroded sedimentary rocks. Drainage divides are defined by sharp ridges with steep-sided slopes. Ridge tops are supported by resistant sandstone.

The Stony Fork Basin in southern Fayette County has a drainage area of 0.93 mi^2. Total relief in the basin is 300 ft. The Poplar Run Basin in northeast Fayette County has a drainage area of 8.83 mi^2. Total relief in the basin is 900 ft.

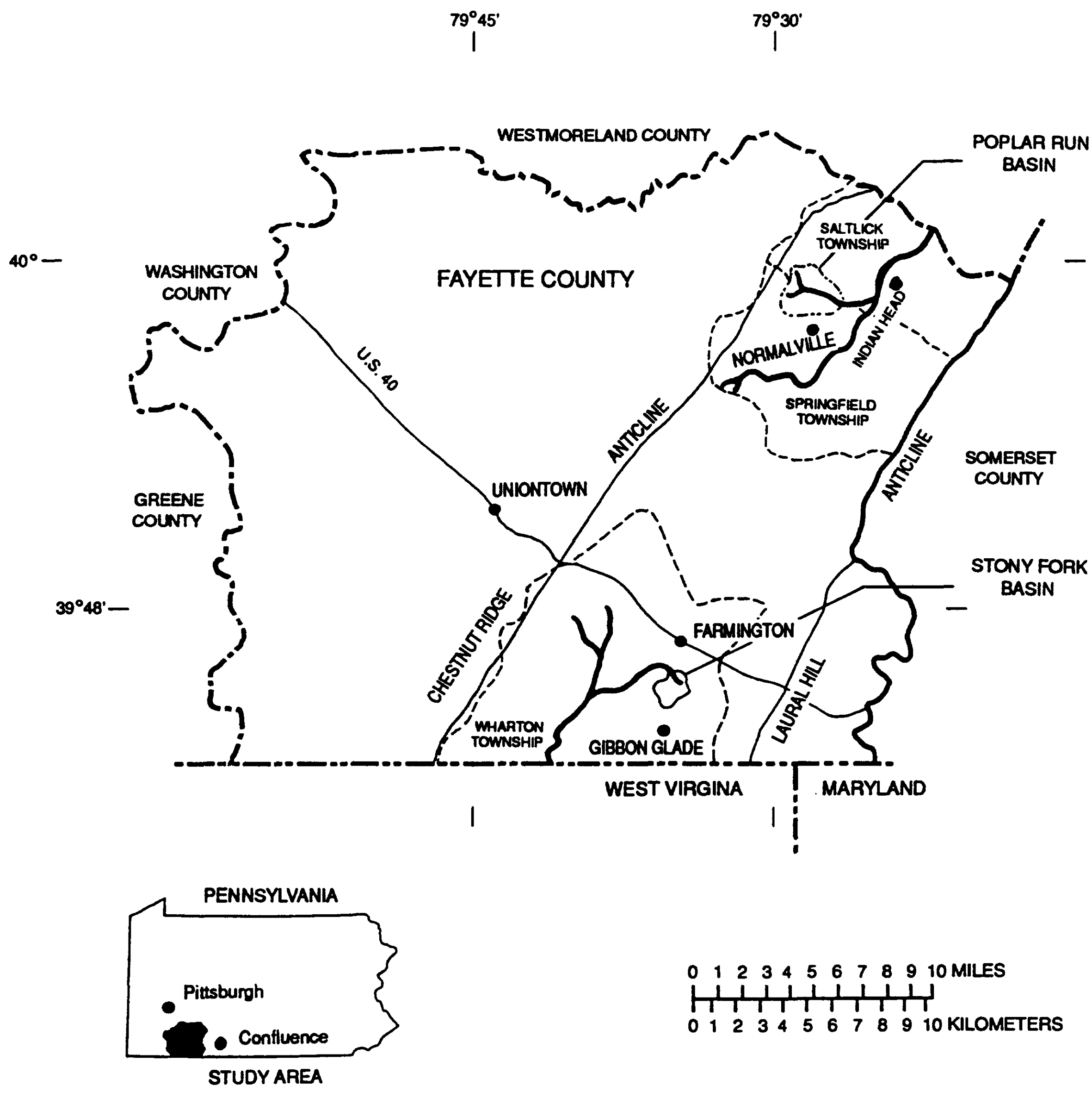

Figure 1. Location of the study area.

Climate

Fayette County has a humid continental climate, with precipitation well distributed throughout the year. Average precipitation in Uniontown, west of Chestnut Ridge (fig. 1), is 40.05 in. (U.S. Department of Commerce, 1931-79). Precipitation in the study areas is generally 2 to 5 in. greater because of lower temperature and air pressure encountered at the higher altitudes of Chestnut Ridge. The average annual temperature at Uniontown is 53.3°F. Temperatures range from 85 to 95°F in summer months and 0 to 32°F in winter months.

Geology

The areas of investigation are underlain by sedimentary rocks of Pennsylvanian age, which include the Allegheny and Conemaugh groups. Major rock types are principally sandstones and shales, and, to a lesser extent, limestone. Coal beds are present within the Allegheny and Conemaugh groups. The geologic structure is characterized by simple, open folds (synclines and anticlines) which display a nearly uniform axial trend of N. 30° E. (McElroy, 1988). The amplitude of folding approaches 3,000 ft with a bedding dip of 5°. No major faults extend to the surface in Fayette County (Hickok and Moyer, 1940). A moderate amount of jointing may be found in some limestone and sandstone beds. Sandstone jointing commonly is confined to thick homogeneous beds (McElroy, 1988).

Soils

Soils are of the Gilpin-Wharton-Ernest and the DeKalb-Hazelton-Cookport associations. Soils of the Gilpin-Wharton-Ernest association are described as moderately deep and deep, well drained and moderately well drained, medium textured, nearly level to very steep soils underlain by acid shale and some sandstone bedrock. Soils of the DeKalb-Hazelton-Cookport association are described as moderately deep and deep, well drained and moderately well drained, moderately coarse textured and medium textured, nearly level to very steep soils underlain by bedrock that is predominantly acid sandstone (U.S. Department of Agriculture, 1973).

Land Use

Land use was determined from aerial photos and field reconnaissance and is predominantly forest. Trees are mixed hardwoods and represent second- and third-growth timber. Surface mined area accounts for 6.6 percent of the drainage area in the Stony Fork Basin and 17.3 percent of the drainage area in the Poplar Run Basin.

Hydrology

Streamflow hydrographs of the Stony Fork and Poplar Run Basins reflect seasonal variations in surface-water discharge, which is affected by precipitation and evapotranspiration. Although precipitation is typically well distributed throughout the year, the greatest stream discharges commonly occur from November through April, partly because of decreases in evapotranspiration. A water budget developed for the two basins reflects the distribution of precipitation (table 1). Assuming no ground-water transfer across basin boundaries and no change in ground-water storage, the annual water budget may be expressed as

$$P = R_s + R_g + ET, \qquad (1)$$

where P is precipitation,
R_s is surface runoff,
R_g is base flow, and
ET is evapotranspiration.

Total runoff for both basins was determined from records at the streamflow-gaging station and the stage-discharge relation developed according to Rantz and others (1982). Base flow was determined by hydrograph separation by means of the fixed-interval method and a 3-day interval (Pettyjohn and Henning, 1979). Evapotranspiration was the difference between total streamflow ($R_s + R_g$) and precipitation.

Table 1. Annual water budgets for the Stony Fork and Poplar Run Basins

Water	Precipitation	Total streamflow		Base flow		Stormflow		Estimated evapotranspiration	
		Inches	Percent	Inches	Percent	Inches	Percent	Inches	Percent
				Stony Fork Basin					
1986	51.3	25.85	50	16.22	32	9.63	19	25.45	50
1987	44.1	23.60	54	16	36	7.60	17	20.50	46
1988	37.0	19.30	52	11.56	31	7.74	21	17.70	48
1989	47.0	32.73	70	19.25	41	13.48	29	14.27	30
4-year mean	44.9	25.37	57	15.76	35	9.61	21	19.48	43
2-year mean (88 & 89)	42.0	26.01	62	15.41	37	10.61	25	15.98	38
				Poplar Run Basin					
1988	40.9	24.86	61	16.37	40	8.49	21	16.04	39
1989	50.3	30.82	61	19.49	39	11.33	22	19.48	39
Mean	45.6	27.84	61	17.93	39	9.91	22	17.76	39

DESCRIPTION OF SIMULATION PROGRAM

General Description

The HSPF was developed for the U.S. Environmental Protection Agency (Johanson and others, 1984) as an engineering tool for watershed management. The model consists of a set of modules arranged in a hierarchical structure for continuous simulation of hydrologic and water-quality processes.

Several climatic time-series data are used by the HSPF model (table 2). These data are incorporated into a series of algorithms on the basis of physical laws or empirical relations for simulating evapotranspiration, snowmelt, infiltration, erosion, percolation, and runoff. The algorithms continuously update such model variables as streamflow and sediment discharge according to a user-specified time interval. Time intervals for simulation can range from 1 day to 1 minute.

Table 2. Input time-series data required by Hydrologic Simulation Program - Fortran

Precipitation
Potential evapotranspiration
Air temperature
Wind velocity
Solar radiation
Dew point

Program Components

The computer code of the HSPF is organized in a block-like structure. Primary modules are main blocks which contain secondary modules, subroutines, subordinate subroutines, and subsidiary subroutines (table 3).

The HSPF has three primary modules. The first module simulates the flow of water, sediment, and chemical constituents from pervious watersheds (PERLND). The second module simulates the same from impervious watersheds (IMPLND), and the third module simulates the flow of water and sediment in the stream channel (RCHRES). Primary modules PERLND and RCHRES were used for this study. In the following discussion, secondary modules within PERLND and RCHRES are explained.

Table 3. Computer code structure of watershed processes in Hydrologic Simulation Program - Fortran

Primary module	Secondary module	Subroutine	Subordinate subroutine	Subsidiary subroutine
PERLND	SNOW	METEOR		
		EFFPRC		
		COMPAC		
		SNOWEV	VAPOR	
		HEXCHR		
		COOLER		
		WARMUP		
		MELTER		
		LIQUID		
		ICING		
		GMELT		
		NOPACK		
	PWATER	ICEPT		
		SURFAC	DISPOS	DIVISN
				UZINF
				PROUTE
		INTFLW		
		UZONE	UZONES	
		LZONE		
		GWATER		
		EVAPT	ETBASE	
			EVICEP	
			ETUZON	ETUZS
			ETAGW	
			ETLZON	
	SEDMNT	DETACH		
		SOSED		
		ATTACH		

Snow Simulation

The HSPF simulates accumulation and melting of snow and ice by use of the secondary module SNOW (table 3). The algorithms in this subroutine use meteorologic data to determine whether precipitation is rain or snow and to simulate sublimation, freezing, and melting of the snowpack.

Five meteorologic time series required for the simulation of snow are listed in table 2. The time series of air temperature is used to determine if precipitation is rain or snow. As snow accumulates, the HSPF begins snowpack accumulation and melt calculations. The subroutine METEOR calculates the density and depth of the snowpack. The subroutine EFFPRC adds falling snow to the pack and determines the amount of rain interacting with the snowpack. The subroutine COMPAC determines the rate of compaction and calculates the actual change in the depth caused by compaction. The combined results of METEOR, EFFPRC, and COMPAC enables the HSPF to determine the liquid-water-holding capacity of the snowpack. Liquid water above the storage capacity will leave the snowpack as melt water or will freeze, depending on climatological conditions. The MELTER subroutine determines melt from the snowpack.

Moisture lost by sublimation of the snowpack is simulated by the subroutine SNOWEV. Wind velocity, temperature, and dewpoint are three time series involved in the sublimation calculations. The subroutine NOPACK is used to reset the state variables when the snowpack completely disappears.

Pervious Watershed Processes

The flux and storage of moisture associated with pervious land areas are simulated by the secondary module PWATER (fig. 2). Rainfall, as well as water from a melting snowpack, are distributed over the pervious watershed. The subroutine ICEPT is used for the simulation of rainfall interception by ground cover. Moisture that exceeds the interception capacity is available for surface detention, infiltration, or runoff.

Surface detention storage, infiltration, and direct runoff are simulated by the subroutine SURFAC. The algorithms that simulate infiltration represent both the continuous variation of infiltration with time as a function of soil moisture and the areal variation of infiltration over the land surface (Johanson and others, 1984). The HSPF uses a linear probability density function to account for areal variation.

Moisture that has infiltrated to the subsurface accumulates in four subsurface reservoirs: upper zone storage, lower zone storage, active ground-water storage, and inactive ground-water storage.

Water that enters the upper zone is simulated in the UZONE subroutine. The upper zone is characteristic of the shallow root zone and is substantially affected by evapotranspiration and percolation.

The lower zone receives water by percolation from the upper zone storage and is characteristic of the deep rooting zone. This is simulated in the LZONE subroutine. Loss of water from lower zone storage is a result of evapotranspiration and percolation to ground-water storages.

Simulation of interflow (INTFLW) effects the storage of moisture between the upper and lower zones and ultimately influences the amount of water available for active ground-water storage.

Ground-water flow is simulated by subroutine GWATER. GWATER determines the amount of inflow to ground water and determines the amount of active ground-water outflow. The outflow from active ground-water storage is based on the assumption that the discharge of an aquifer is proportional to the product of the cross-sectional area and the energy gradient of the flow (Johanson and others, 1984).

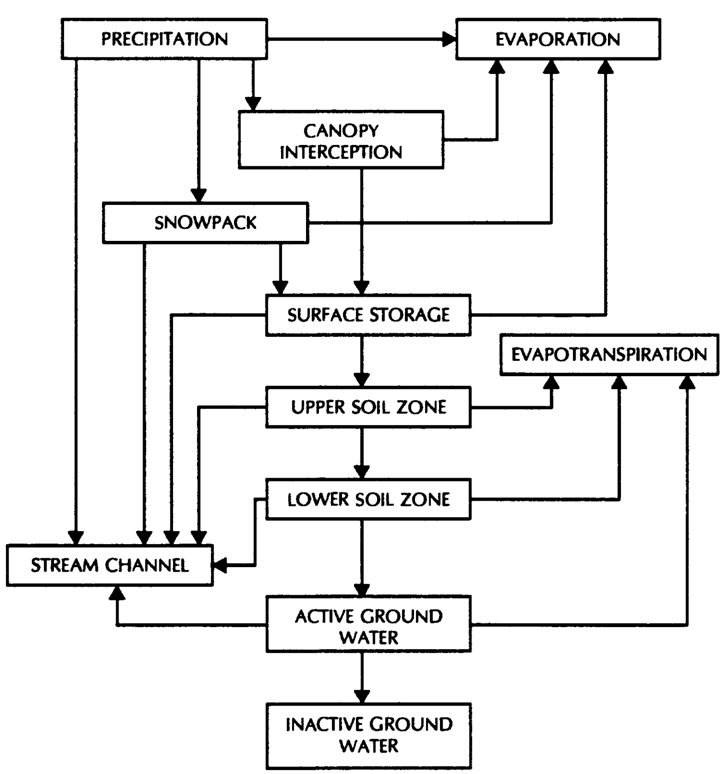

Figure 2. Flow diagram of the flux and storage of moisture associated with pervious land areas in the Hydrologic Simulation Program - Fortran.

Evapotranspiration

Evapotranspiration is the combined process of evaporation and vegetation transpiration. Simulation requires that potential evapotranspiration be an input time series. The time series of potential evapotranspiration is typically U.S. Weather Bureau Class A pan evaporation multiplied by an adjustment factor (Farnsworth and others, 1982).

The HSPF simulates evapotranspiration by use of the subroutine EVAPT and its five subordinate subroutines ETBASE, EVICEP, ETUZON, ETAGW, and ETLZON. The five subordinate subroutines simulate evapotranspiration from five sources in the hydrologic system. The sum of evapotranspiration from these five sources is the total actual evapotranspiration from the pervious land units.

ETBASE simulates evapotranspiration from riparian vegetation. This is the fraction of evapotranspiration that can be generated from water at the seepage face boundary.

EVICEP simulates evaporation from water in interception storage on the basis of the demand created by air temperature and humidity.

ETUZON simulates evapotranspiration from the upper zone on the basis of the moisture in storage in relation to its nominal capacity.

Evapotranspiration from the lower zone is simulated by the subordinate subroutine ETLZON. Evapotranspiration from this zone is dependent upon vegetative transpiration and will vary with the vegetation type, depth of rooting, density of vegetation, and the stage of plant growth.

The ETAGW subordinate subroutine simulates transpiration from active ground water.

Channel Flow

The HSPF simulates channel flow by several algorithms contained in the primary module RCHRES (table 4). The secondary module HYDR contains four subroutines and three subordinate subroutines for simulating channelized or reach flow. Subroutine ROUTE contains algorithms that calculate the rates and volumes of outflow from a reach. Subroutine AUXIL contains algorithms used to compute depth, stage, surface area, average depth, top width, and hydraulic radius. The SHEAR subroutine computes bed shear velocity and shear stress on the basis of the mean particle size of bed sediment.

Table 4. *Computer code structure for stream reach routing of water and sediment in Hydrologic Simulation Program - Fortran*

Primary module	Secondary module	Subroutine	Subordinate subroutine	Subsidiary subroutine
	RCHRES	HYDR	ROUTE	DEMAND
				SOLVE
			NOROUT	FNDROW
			AUXIL	
			SHEAR	
		SEDTRN	COHESV	ADVECT
				DBEXCH
			SANDLD	TOFFAL
				COLBY

Surface Erosion

Surface erosion is simulated by the HSPF in the primary module PERLND by three subroutines within the secondary module SEDMNT (table 3). Each subroutine contains algorithms that simulate erosion processes resulting in sediment removal from a pervious land unit. Figure 3 illustrates the HSPF processes for simulating erosion on pervious land units.

Sediment simulation begins by determining the amount of sediment detached from the soil matrix during rainfall events. The subroutine DETACH contains the algorithm used for this simulation.

The subroutine SOSED simulates the washoff of detached sediment and the scour of the soil matrix. In this subroutine, the capacity to transport sediment in overland flow is calculated.

As sediment is being washed off and scoured from the pervious land unit, the process of reattachment, or soil compaction, occurs. The reattachment of soil is simulated by subroutine ATTACH.

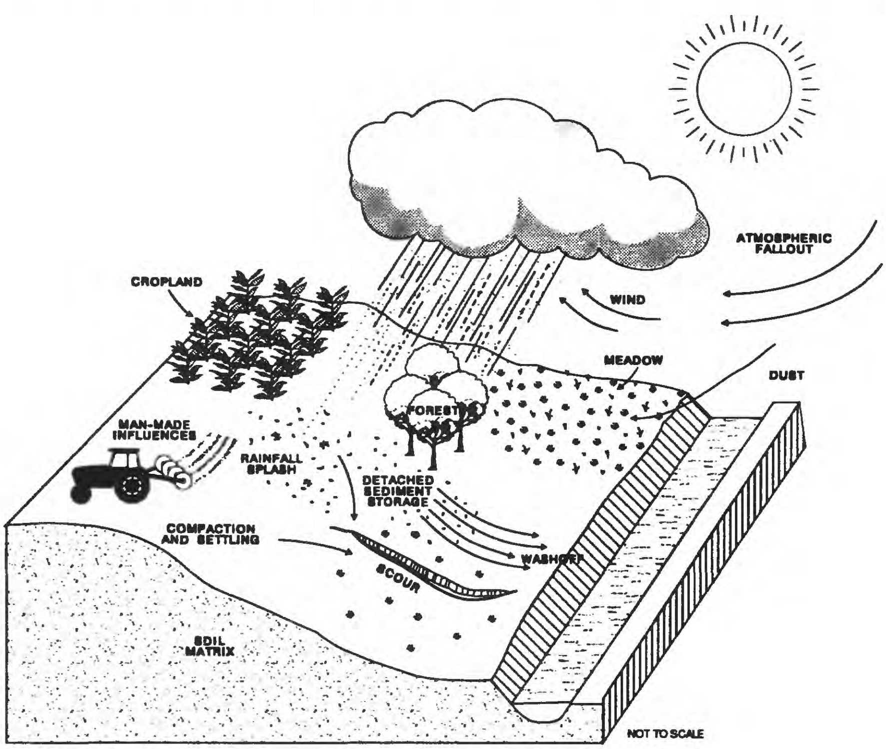

Figure 3. Schematic diagram showing erosion processes simulated by the Hydrologic Simulation Program - Fortran. [Modified from Johanson and others, 1984, fig. 4.2 (1)].

Sediment Transport

The HSPF simulates sediment flow within the stream channel in the primary module RCHRES (table 4). Particle diameter, fall velocity, density, shear stress for deposition and scour, and erodibility play significant roles in determining sediment load and transport characteristics.

Noncohesive sediment (sand) can be transported by three methods. The subroutine SANDLD contains the Toffaleti, Colby, and the "input power function" methods. Sandload routing requires the user to input specific properties of transported material.

Cohesive sediment (silts and clays) is simulated in the subroutine COHESV in two steps: (1) Sediment is transported by the algorithms contained in the subordinate subroutine ADVECT, and (2) deposition and scour are simulated in subordinate subroutine BDEXCH. Deposition and scour exchanges with the streambed are dependent upon the shear stress exerted upon the bed surface.

DATA MANAGEMENT

Organization of Data and Analytical Procedures

The management of time-series data is a major task. A utility program, ANNIE, was used to display, plot, manipulate, and analyze the time-series data (Lumb and others, 1990). ANNIE was initially used to format National Weather Service climatic data. The reformatted data was stored in the Watershed Data Management System (WDMS) data base. The data base can be accessed interactively through the ANNIE software or serve as input for the HSPF simulations. Output from the model is directed to specified data sets in the WDMS.

ANNIE was used interactively to create plot files of observed and simulated hydrographs. Flow-duration curves, water budgets, and mean monthly flows also were constructed by the ANNIE software. These analytical techniques were used throughout the calibration process and during the sensitivity evaluation of model parameters.

SIMULATION OF STREAMFLOW AND SEDIMENT TRANSPORT

The HSPF model was used to simulate streamflow and sediment loads for two basins in Fayette County, Pa. Data collected from Stony Fork near Gibbon Glade (USGS station 03070420) were used to calibrate the HSPF parameters for the Stony Fork Basin. The calibrated parameters from the Stony Fork model were then applied to a model of the Poplar Run Basin. Data collected from Poplar Run near Normalville (USGS station 03082190) were compared to the simulated data to determine the transfer value of model parameters. The following discussion describes the model development and simulation results for the two basins.

Model Calibration and Verification - Stony Fork Basin

Calibration of the Stony Fork model began by building the HSPF input file. This file is referred to as the user control input file (UCI) and is listed in Appendix 1. The UCI file directs the HSPF simulations by activating sections of the model, setting the time span for simulations, locating input data on the WDMS files, and writing output data to the WDMS files. Also, the UCI file contains parameter values which define basin characteristics and channel conditions. Some of these are measured parameters such as slope length or percentage slope, and others are calibration parameters such as the ground-water recession constant. Tables 5 and 6 list the HSPF parameters used in the Stony Fork model.

The model of the Stony Fork Basin required four sets of HSPF parameters. Each set of parameters was used to define a particular hydrologic response unit (HRU). An HRU is an area within a basin that is expected to have a similar hydrologic response to input of precipitation and potential evapotranspiration. The HRU's are used to account for the spatial variability of a basin's physical and hydrologic characteristics. A basin may be partitioned into the HRU's on the basis of climate, physiography, land use, and soil features. Because of the basin-wide similarities in climate, physiography, and soil features, the HRU's for the Stony Fork model were defined by land use. Table 7 lists the acreage and percentage of each HRU for the Stony Fork Basin. The location of the HRU's are shown in figure 4.

The UCI file also notes the WDMS files containing the input climatic data. The climatic data used to drive the model consisted of precipitation, air temperature, solar radiation, wind speed, dew point, and pan evaporation (table 8). Rain and snowfall data were provided by a heated tipping-bucket rain gage located near the streamflow-gaging station (fig. 4). Precipitation was recorded at 15-minute intervals. Hourly air temperature, solar radiation, wind speed, and dew point were obtained from the National Weather Service from a station located at the Pittsburgh International Airport (fig. 1). Daily pan-evaporation data were obtained from the National Weather Service Station at Confluence, Pa. (fig. 1).

The final step in building the UCI file was to initialize measured and calibrated parameters for each HRU. Measured parameter values were determined from topographic maps, soil surveys, field reconnaissance, and climatological reports. Calibration parameters were initialized according to ranges in the HSPF user's manual and application guide (Johanson and others, 1984; Donigian and others, 1984).

The calibration process involved adjusting the calibration parameters until the model was representative of the basin's hydrologic conditions. This was done by comparing the simulated data to actual data collected from the basin. Daily time-series data were used for the daily calibration procedures, and unit-value data at a 1-hour time step were used for the storm calibrations.

Table 5. Basin hydrology parameters with definitions for Hydrologic Simulation Program - Fortran

Secondary module	Parameter	Definition
SNOW	LAT	Latitude of the pervious land segment (PLS)
	MELEV	Mean elevation of the PLS
	SHADE	Fraction of the PLS shaded from solar radiation
	SNOWCF	Correction factor for simulated snowfall that accounts for poor catch efficiency
	COVIND	The maximum pack at which the entire PLS will be covered with snow
	RDCSN	Density of cold new snow relative to water
	TSNOW	Air temperature below which precipitation will be snow
	SNOEVP	Adapts snow sublimation to field conditions
	CCFACT	Adapts snow condensation/convection melt equation to field conditions
	MWATER	Maximum water content of the snow pack
	MGMELT	Maximum rate of snowmelt by ground heat
PWATER	FOREST	Fraction of PLS covered by forest which will transpire in winter
	LZSN	Lower zone nominal storage
	INFILT	Infiltration capacity of the soil
	LSUR	Length of the assumed overland flow plane
	SLSUR	Slope of the assumed overland flow plane
	KVARY	Affects behavior of ground-water recession flow
	AGWR	Basic ground-water recession rate when KVARY equals zero
	PETMAX	Air temperature below which evapotranspiration will be reduced
	PETMIN	Air temperature below which evapotranspiration will be zero
	INFEXP	Exponent in the infiltration equation
	INFILD	Ratio between maximum and minimum infiltration capacity
PWATER	DEEPFR	Fraction of ground-water inflow which will enter inactive zones
	BASETP	Fraction of evapotranspiration which can be satisfied from base flow
	AGWETP	Fraction of remaining potential evapotranspiration from active ground-water storage
	UZSN	Upper zone nominal storage
	NSUR	Manning's "n" for overland flowplane
	INTFW	Interflow inflow
	IRC	Interflow recession
	LZETP	Lower zone evapotranspiration
	CEPSC	Interception storage capacity
	CEPS	Initial interception storage
	SURS	Initial surface storage
	UZS	Initial upper zone storage
	IFWS	Initial interflow storage
	LZS	Initial lower zone storage
	AGWS	Initial active ground-water storage
	GWVS	Initial antecedent active ground-water inflow
		Parameters associated with stream channel routing
	FTABNO	Number of the F-table which contains the geometric and hydraulic properties
	LEN	Length of the reach
	DELTH	Drop in water elevation within the stream reach
	STCOR	Correction to the reach depth to calculate stage
	KS	Weighting factor for hydraulic routing
	DB50	Median diameter of bed sediment

Table 6. *Sediment simulation parameters with definitions for Hydrologic Simulation Program-Fortran*

Secondary module	Parameter	Definition
SEDMNT	SMPF	Management factor used to account for reduction in erosion achieved by the use of erosion control practices
	KRER	Coefficient in the soil detachment equation
	JRER	Exponent in the soil detachment equation
	AFFIX	Fraction by which detached sediment decreases each day due to soil compaction
	COVER	Fraction of land surface shielded from erosion by direct rainfall impact
	NVSI	Rate at which sediment enters detached storage from the atmosphere
	KSER	Coefficient in the detached sediment washoff equation
	JSER	Exponent in the detached sediment washoff equation
	KGER	Coefficient in the matrix soil scour equation
	JGER	Exponent in the matrix soil scour equation
SEDTRN	BEDWID	Width of the stream bed
	BEDWRN	Depth of the stream bed
	POR	Porosity of the stream bed
	D	Effective diameter of the transported sand particles
	W	Fall velocity of the transported sand particles in still water
	RHO	Density of the sand particles
	KSAND	Coefficient in the HSPF sandload equation
	EXPSND	Exponent in the HSPF sandload equation
	TAUCD	Critical bed shear stress for deposition
	TAUCS	Critical bed shear stress for scour
	M	Erodibility coefficient of the sediment

Table 7. *Hydrologic response units in the Stony Fork Basin*

Hydrologic response unit[1]	Description	Acres	Percent
1	Forestland	384	64.5
2	Cropland	51.6	8.7
3	Surface mined	39.6	6.6
4	Grassland	120	20.2

[1] The hydrologic response unit is the land use described above on soils of the Gilpin-Wharton-Ernest and Dekalb-Hazelton-Cookport associations developed from bedrock of predominately the Allegheny and Conernaugh groups.

Table 8. *Time series data used in the Stony Fork Model*

[USGS, U.S. Geological Survey; NOAA, National Oceanic and Atmospheric Administration]

Site name	Station number	Source of data	Type of data
Stony Fork near Gibbon Glade	03070420	USGS	Streamflow, sediment, precipitation
Confluence	170509	NOAA	PAN evaporation
Pittsburgh	94823	NOAA	Air temperature, dew point, solar radiation, wind speed

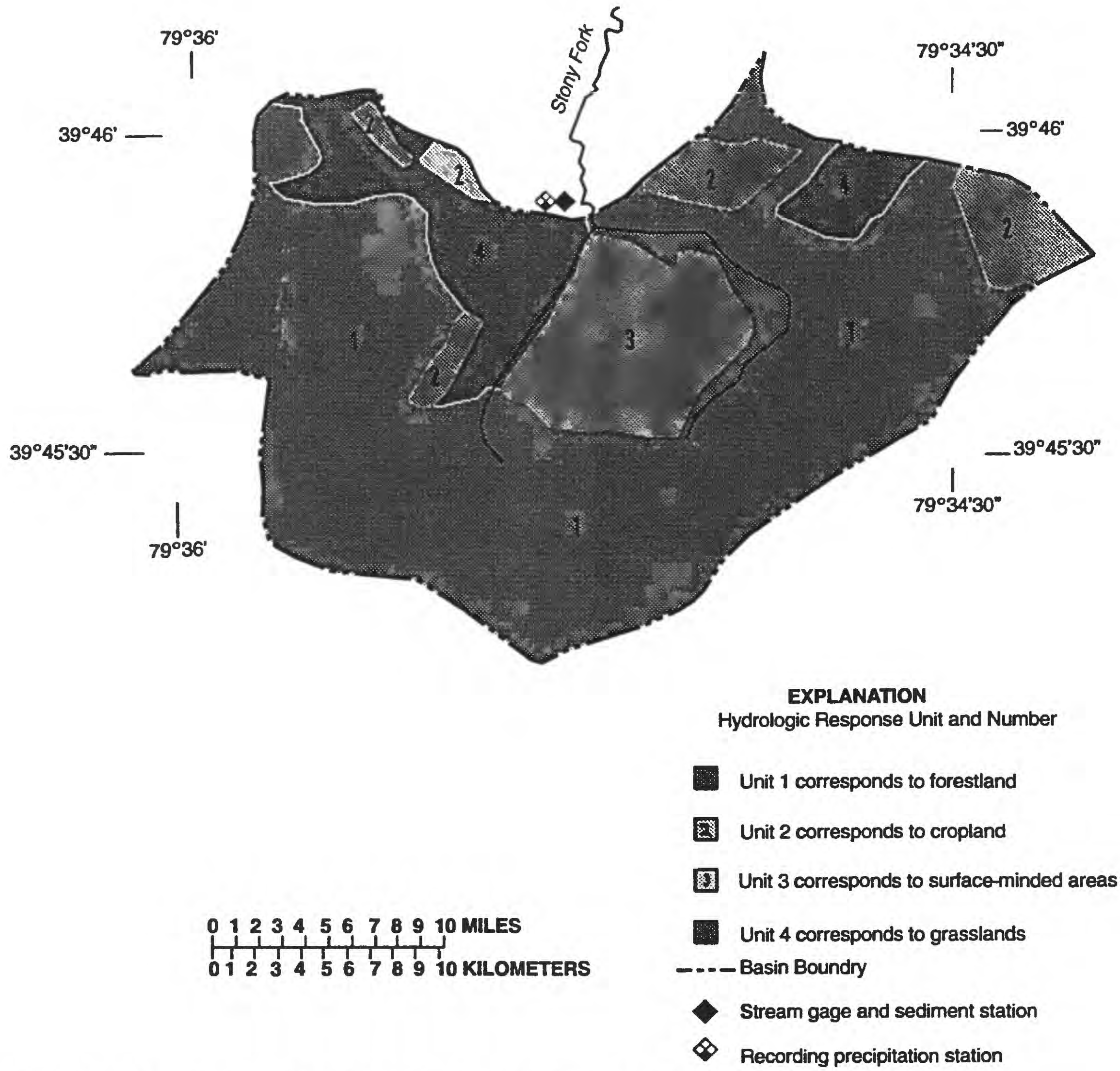

Figure 4. Hydrologic response units and data-collection sites in Stony Fork Basin.

Streamflow-Calibration Procedures

Daily flow

Data from October 1, 1985, through September 30, 1988, were used to calibrate the model. The initial calibration procedure was to establish an annual water balance. The annual water balance specifies the destination of precipitation. Precipitation is partitioned to evapotranspiration, runoff, storage, or inactive ground water.

The lower zone storage parameter (LZSN) and the lower zone evapotranspiration parameter (LZETP) were identified as major parameters in regulating the storage and evapotranspiration from soil-moisture zones. Increasing LZSN and LZETP increased actual evapotranspiration and reduced runoff. LZETP was adjusted on a monthly basis to account for the seasonal variability of evapotranspiration. The infiltration parameter (INFILT) affected the amount of water available to subsurface flows and the lower zone for evapotranspiration. Decreasing infiltration reduced actual evapotranspiration and increased surface runoff. Finally, adjustments were made to parameter DEEPFR, which regulates water lost to the inactive ground-water zone.

Table 9 summarizes the water budget for the simulated data. The data are derived from the HSPF simulation summary for each water year. Table 10 shows a comparison of observed and simulated annual streamflow data. The observed and simulated base flow in table 10 were determined by hydrograph separation by means of the fixed-interval method and a 3-day interval (Pettyjohn and Henning, 1979). The observed and simulated total annual streamflow differed by 4.3, 0.4, and 6.0 percent for the 1986, 1987, and 1988 water years, respectively. The simulated stormflow and base flow compared well with the observed data.

Once the annual water balance was achieved, the monthly distribution of flows was analyzed for the purpose of adjusting seasonal calibration parameters LZETP and INTERCP. The parameter INTERCP regulates the interception storage capacity at the start of each month. Table 11 compares the monthly distribution of flows for the 3 calibration years. Most of the simulated monthly flows compared well to the observed monthly flows. Mean monthly streamflow simulated by the model was 1.64 ft^3/s for the 36-month period. Mean monthly streamflow determined from the gaging station data was 1.57 ft^3/s. No consistent departures were noted in the simulated data. Transitions from wet to dry periods appear to be representative of the observed data. The simulation of snow and the associated melt processes improved the models performance during winter periods (December through February).

Table 9. *Simulated water budget for the Stony Fork Basin during the calibration period (water years 1986-88)*

[All values are in inches.]

Water year	Measured precipitation	Evapotrans-piration	Surface runoff	Interflow	Ground-water flow	Ground-water sink	Total streamflow
1986	51.30	22.54	2.54	10.96	13.47	0.27	26.97
1987	44.10	23.14	1.45	8.87	13.19	.28	23.51
1988	37.00	20.29	1.00	8.05	11.40	.24	20.45

Table 10. *Observed and simulated annual streamflow data for the Stony Fork Basin during the calibration period (water years 1986-88)*

[All values are in inches.]

Water year	Observed stormflow	Simulated stormflow	Observed base flow[1]	Simulated base flow[1]	Observed total streamflow	Simulates total streamflow
1986	9.63	9.75	16.22	17.22	25.85	26.97
1987	7.60	8.71	16.00	14.80	23.60	23.51
1988	7.74	8.62	11.56	11.83	19.30	20.45
Mean	8.32	9.03	14.59	14.62	22.92	23.64

[1] Base flow determined by hydrograph separation.

Table 11. *Observed and simulated mean discharge by month and year for Stony Fork near Gibbon Glade during the calibration period (water years 1986-88)*

[All values are in cubic feet per second.]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Mean monthly
1986 Observed	0.16	6.02	1.71	1.46	6.57	2.39	1.83	0.41	0.10	0.85	0.09	0.16	1.81
1986 Simulated	.87	3.83	1.79	1.02	6.63	2.03	3.47	.52	.19	1.39	.45	.47	1.89
1987 Observed	2.14	3.75	3.30	1.72	1.72	.91	4.20	.69	.51	.30	.06	.17	1.62
1987 Simulated	2.44	3.88	2.95	1.34	1.69	.84	3.85	.66	.57	.52	.13	.53	1.62
1988 Observed	.17	.67	2.65	2.09	2.77	2.81	1.91	1.58	.21	.11	.16	.73	1.32
1988 Simulated	.50	2.22	2.75	1.95	2.37	3.53	1.50	1.10	.21	.12	.09	.50	1.40

The last major step in calibrating the daily streamflow data was to match peak mean-daily discharges and recession rates. Hydrographs of the observed and simulated data were compared during this phase of calibration. Adjustments to the infiltration parameter (INFILT) were used to improve the fit for peak discharges. The active ground-water recession rate (AGWR) and the interflow recession constant (IRC) were adjusted to improve the fit between the simulated and observed recessions.

Hydrographs of the observed and simulated mean-daily streamflows for the calibration period are presented in figure 5. Recessions in the simulated hydrographs are generally parallel to recessions in the observed hydrographs. Peak simulated discharges are somewhat variable in timing and magnitude during some periods. Continued adjustments to INFILT and AGWR did not improve the general fit of the simulated data. Inconsistencies between the simulated and observed hydrographs may be caused by nonrepresentative precipitation, error in precipitation measurement, error in streamflow measurement, or errors in model algorithms. All of these factors can be present to some degree and contribute to the differences in the simulated and observed streamflow.

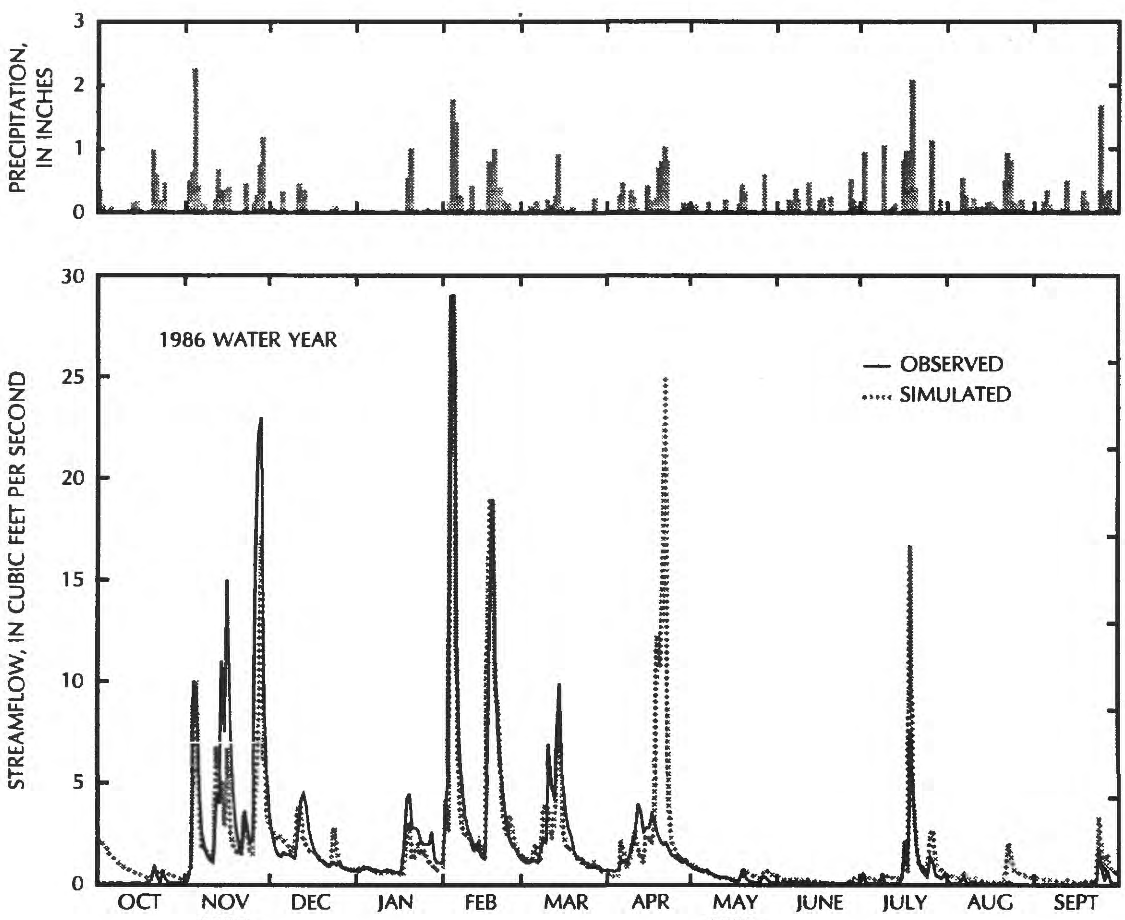

Figure 5. Hydrographs of observed and simulated daily mean streamflow at Stony Fork near Gibbon Glade for the calibration period (water years 1986-88).

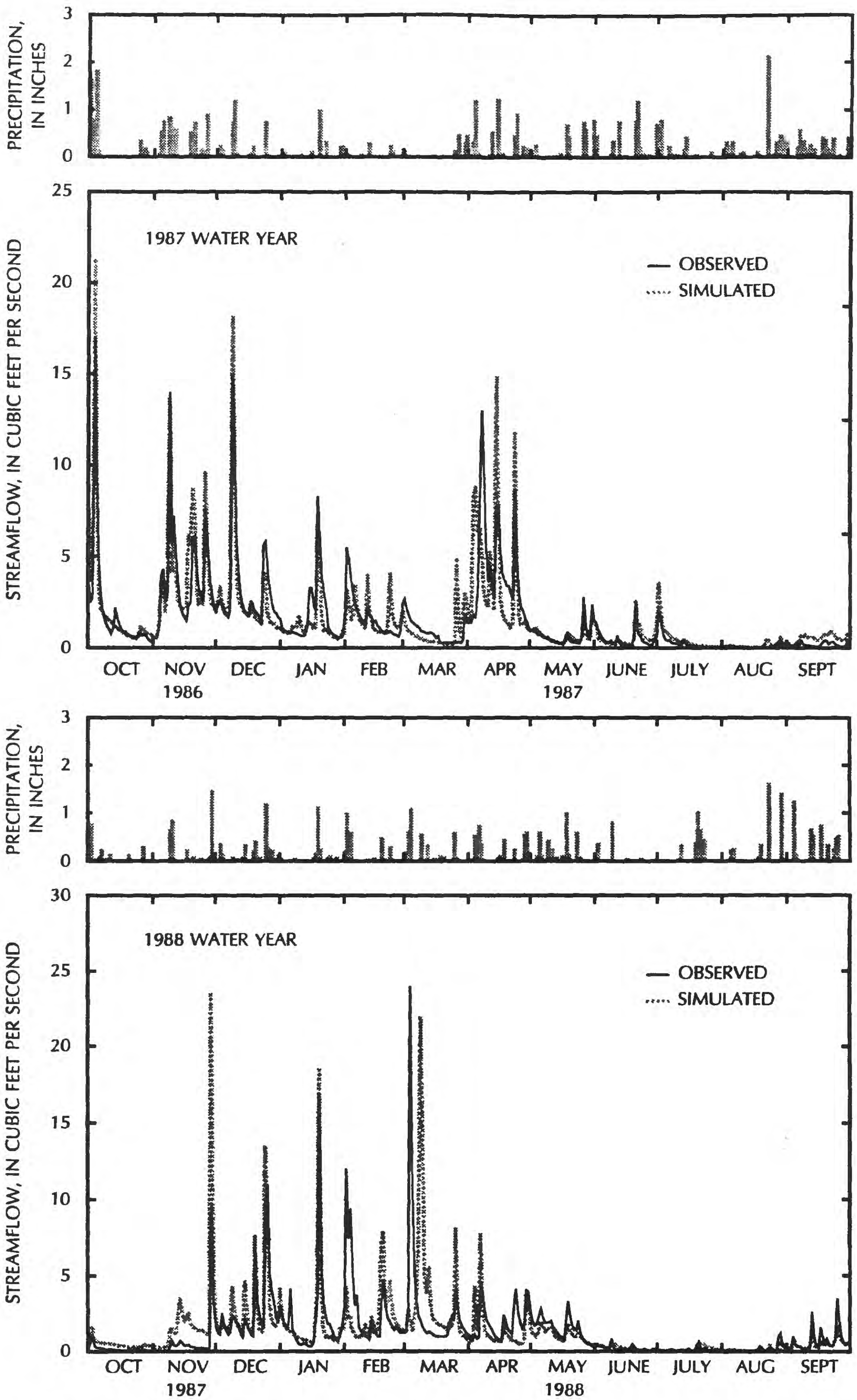

Figure 5. Hydrographs of observed and simulated daily mean streamflow at Stony Fork near Gibbon Glade for the calibration period (water years 1986-88)—Continued.

Stormflow

Storm calibration was designed to simulate runoff volumes and peak discharges. Twelve storms were selected from the calibration period (1986-88 water years) for this phase of calibration. Parameters affecting runoff volume, peak discharge, and hydrograph shape were calibrated during this phase of model development.

Minor adjustments to the infiltration parameter (INFILT) were made to regulate the volume of storm runoff. Increasing INFILT resulted in a decrease in storm runoff and a decrease in peak discharge. The shape of the storm hydrograph was altered by adjusting the interflow parameter (INTFW). Increasing INTFW reduced peak discharges and prolonged the hydrograph recession.

The timing and magnitude of the simulated peak discharges were adjusted by the F-tables section of the model. The F-tables are contained in the UCI file (Appendix 1). The F-tables are based on channel geometry and stage/discharge data. The F-tables specify values for surface area, reach volume, and discharge for a series of selected average depths of water in each reach (Donigian and others, 1984). Increasing the discharge column of the F-tables by 25 percent resulted in a 15-percent increase in peak discharge. Decreasing the volume column of the F-tables by 25 percent resulted in a 15-percent increase in peak discharge. Adjustments to the surface area column of the F-table had little effect on peak discharge.

Hydrographs of 12 storm events are presented in figure 6. Precipitation and runoff data are shown in table 12. The simulated storm runoff volume, reported as inches over the watershed, compared well to the observed runoff volume. The difference between the observed and simulated peak discharge ranged from 4.0 to 59.7 percent. In most cases, the timing of the simulated runoff paralleled the observed runoff. Recessions of the simulated and observed runoff events compared well for the 12 storms.

Table 12. *Precipitation and runoff data for selected storms at Stony Fork near Gibbon Glade for the calibration period (water years 1986-88)*

[ft^3/s, cubic foot per second]

Storm number	Beginning date	Ending date	Observed precipitation (inches)	Observed runoff (inches)	Simulated runoff (inches)	Observed peak discharge (ft^3/s)	Simulated peak discharge (ft^3/s)
1	02-03-86	02-06-86	3.55	3.08	2.94	46	38
2	02-17-86	02-19-86	2.06	1.61	2.01	36	30
3	07-19-86	07-21-86	2.44	.55	.94	53	73
4	10-03-86	10-05-86	2.73	1.22	1.42	35	38
5	11-08 86	11-09-86	1.43	.70	.72	23	21
6	12-08-86	12-10-86	1.96	1.13	1.29	23	24
7	04-24-87	04-25-87	.91	.52	.64	15	17
8	05-26-87	05-27-87	1.31	.14	.09	8.7	3.5
9	06-21-87	06-22-87	1.40	.13	.15	12	11
10	12-20-87	12-21-87	.41	.43	.42	13	12
11	12-25-87	12-27-87	1.44	1.04	1.05	17	20
12	01-19-88	01-21-88	1.35	1.02	1.09	47	37

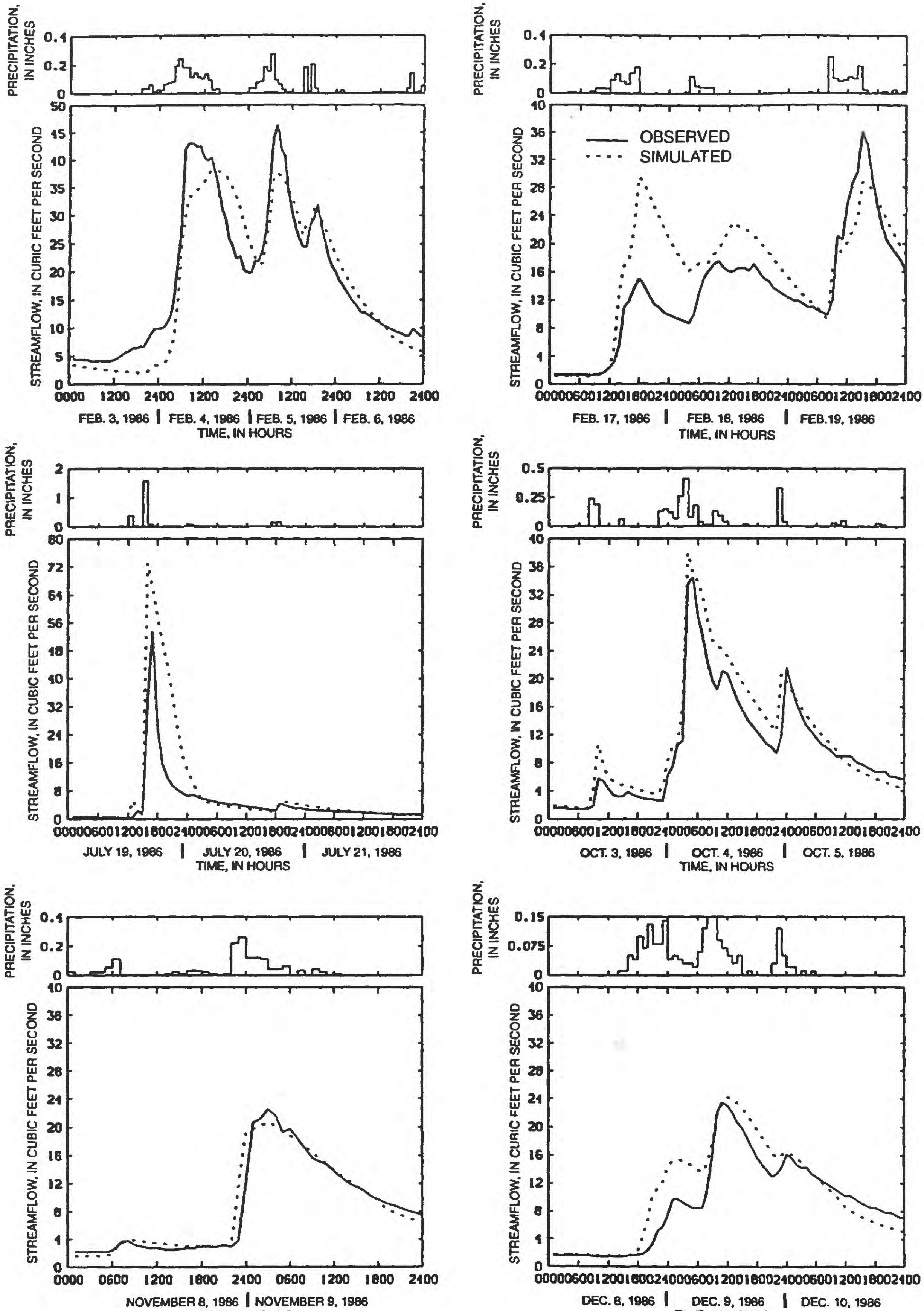

Figure 6. Hydrographs of selected storms at Stony Fork near Gibbon Glade for the calibration period (water years 1986-88).

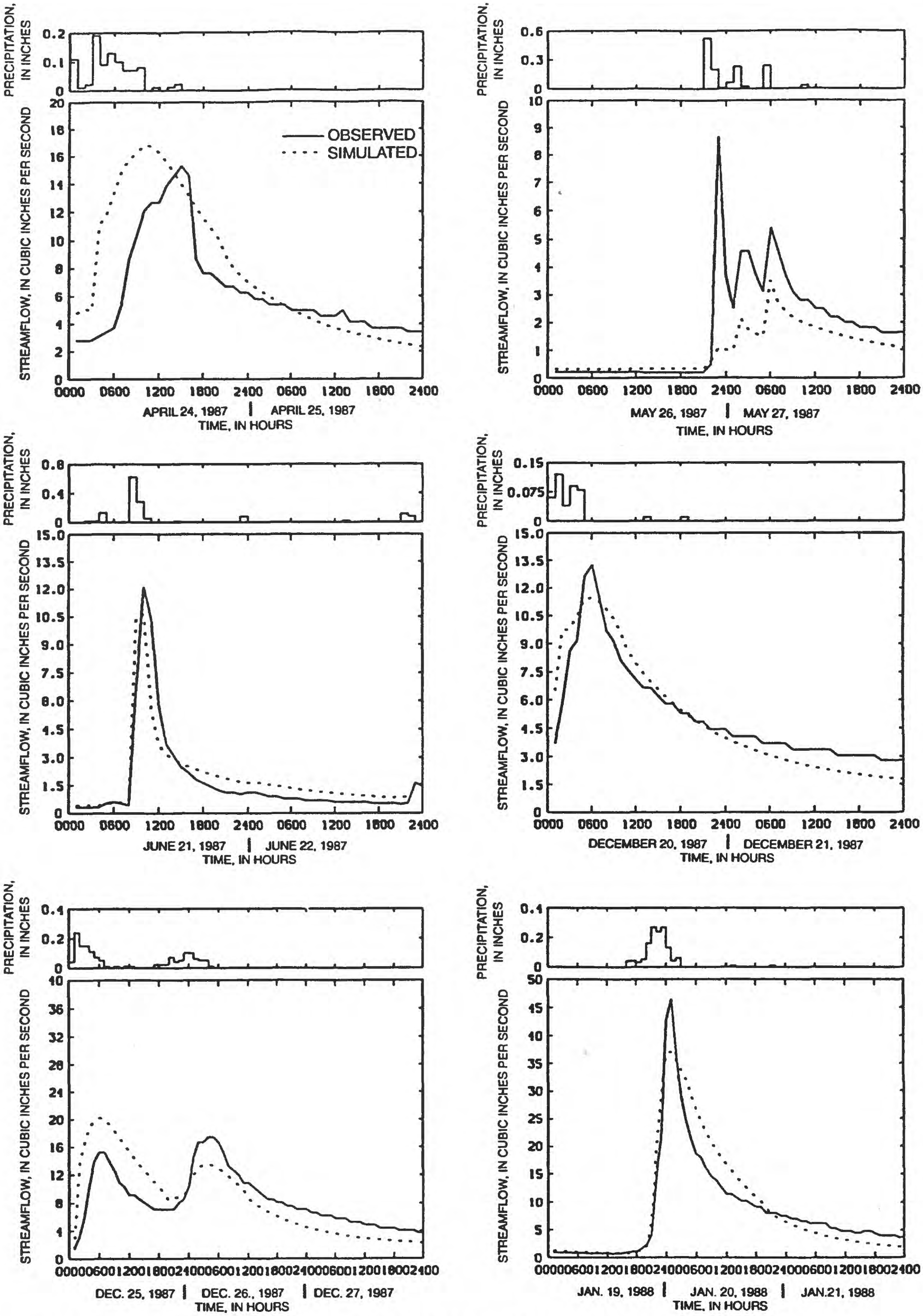

Figure 6. Hydrographs of selected storms at Stony Fork near Gibbon Glade for the calibration period (water years 1986-88)—Continued.

Sediment-Calibration Procedures

An estimate of sediment yield from each HRU was necessary in order to calibrate the sediment modules of HSPF. Several methods for estimating the sediment yield were considered. One method was to monitor sediment concentrations in tributary flows from drainage areas comprised of the individual HRU's. Monitoring fluvial sediment concentrations is discussed by Guy and Norman (1970). Another method considered was to conduct plot studies within each HRU. Sams and Rogowski (1984) discuss the use of a rainfall simulator for estimating erosion on plots of reclaimed mine spoil. These methods provide site-specific information.

For this investigation, sediment yield from the basin was based on sediment data collected at the streamflow-gaging station near Gibbon Glade. At this location, the sediment data represented the total contribution from each HRU. Sediment data were collected according to methods described by Guy and Norman (1970). Sediment loads were determined by methods described by Porterfield (1972).

The sediment load from each HRU was estimated by methods described by Wischmeier and Smith (1970). Wischmeier and Smith developed the Universal Soil Loss Equation (USLE) as an empirical method for estimating soil loss. The USLE only considers the movement of sediment within an area or field and does not account for the amount of sediment that washes off into the drainage system. Also, the USLE does not account for rill or gully erosion. The USLE estimated soil loss was 0.7 (ton/acre)/yr for the forest and grassland HRU's, and 5.0 (tons/acre)/yr for the surface mined and cropland HRU's.

Field reconnaissance of the study area also provided information on the degree of erosion occurring on HRU's. The surface of the reclaimed surface-mine site was scarred by rills and gullies in areas of poor vegetative cover. Some rills and gullies were noticed on the grassland and cropland areas. The surface of the forested areas had only a few rills and gullies.

The USLE estimates and the field reconnaissance were used as a guideline for the initial calibration of the model.

The HSPF uses two modules for sediment simulation. The first module, SEDMNT, is responsible for generating sediment as a result of surface erosion from each HRU. The second module, SEDTRN, is responsible for transporting sediment in the stream channel.

Surface erosion

The calibration of the SEDMNT module involved three processes. They are detachment of sediment, scour of the soil matrix, and washoff of detached sediment.

The detachment of sediment by rainfall impact is adjusted by parameters COVER, SMPF, AFFIX, KRER, and JRER (table 6). These parameters were adjusted on the basis of land-use characteristics of each HRU.

The parameter COVER represents, in percent, the vegetative canopy over the soil. COVER can be a fixed value for the entire year, or it can be varied on a monthly basis. Forest and grassland were given the highest percentage of cover. For the cropland HRU, a monthly table was supplied to account for variation throughout the year.

The equation responsible for simulating soil-matrix scour is adjusted by two parameters, KGER and JGER, which are the coefficient and exponent of the soil-matrix-scour equation, respectively. The equation for soil-matrix scour is such that low values of JGER produce high scour. Forest and grassland HRU's have the greatest protection from runoff, therefore, less scour is expected from these areas than from other areas.

The SMPF parameter accounts for reduction in soil detachment as a result of erosion-control practices such as contour plowing. A value of 1.0 for SMPF represents no erosion-control practices.

The parameter responsible for the reattachment of soil during its overland transport is AFFIX. AFFIX can be defined as the percentage of detached soil that is reattached as it washes off the HRU.

KRER and JRER are the coefficient and exponent of the soil-detachment equation, respectively. Forest and grassland were expected to have the least soil detachment.

Washoff is an important calibration feature of the HSPF. Sediment washoff is calibrated by two parameters, KSER and JSER, which are the coefficient and exponent of the washoff equation, respectively. The sediment available for washoff is from soil detachment and soil-matrix scour. KSER produced small changes in washoff. Increasing the value for JSER substantially decreased sediment washoff.

The results of SEDMNT module calibration for each year are listed in table 13. The calibrated parameters for the SEDMNT module are shown in the UCI file listed in Appendix 1.

Table 13. *Simulated surface erosion for land-use types in the Stony Fork Basin*

[(ton/acre)/yr, ton per acre per year; ton/yr, ton per year]

Water year	Land use					
	Forest [(ton/acre)/yr]	Grassland [(ton/acre)/yr]	Surface mine [(ton/acre)/yr]	Cropland [(ton/acre)/yr]	Total (ton/yr)	Average [(ton/acre)/yr]
1986	0.115	0.508	2.01	2.96	330	0.55
1987	.004	.039	.737	1.83	127	.21
1988	.001	.021	.546	1.11	80	.13
Mean	.040	.189	1.10	1.97	179	.30

Sediment transport

After soil erosion has been simulated for each HRU in the SEDMNT module, the module SEDTRN simulates the transport of sediment in the stream channel. With respect to sediment transport, SEDTRN evaluates particle size, fall velocity, base-flow sediment concentration, bed depth, and the shear stress exerted on the stream bed. Measurable parameters were determined by experiment and field survey and defined prior to adjusting the calibration parameters.

The diameter and fall velocities of the sediment size fractions were determined by petrographic and pipet analysis. Sand particle diameter averaged 0.01 in. Silt and clay diameters averaged 0.001 and 0.00004 in., respectively. The fall velocity for a sand particle was determined to be 1.2 in/s. Silt and clay fall velocities were determined to be 0.001 and 0.0001 in/s, respectively.

SEDTRN requires the density of particles within each size fraction. Particle density was estimated on the basis of the mineralogy of particles in a sample. For a particular sediment fraction, an overall density was determined from a volume-weighted average. Particles in the sand fraction were assigned the highest density (2.50), whereas particles in the clay fraction were assigned the lowest density (2.30). Silt particles were assigned a density of 2.40.

The initial sediment concentration suspended in the stream water at base flow is also required by SEDTRN. Size fraction analysis of base-flow water samples determined that silt and clay were the only suspended fractions. Each of these fractions measured about 10 mg/L.

The depth of the stream bed was estimated by averaging depths at transects along the entire reach. The average bed depth was determined to be about 0.5 ft. In addition to bed depth, at these same transects, stream bed samples were collected for determining fractional composition. The bed of Stony Fork is composed of 80 percent sand, 15 percent silt, and 5 percent clay.

The parameters for sediment routing, which cannot be determined by physical experiments, are those which define the limits for bed scour and sediment deposition. TAUCD and TAUCS are the shear stress for deposition and the shear stress for scour, respectively. TAUCD and TAUCS were set to the HSPF default values of 10 lb/ft^2. This approach significantly limits deposition or scour of silt and clay in the stream channel. The sand fraction is simulated by a power function equation that does not use shear stress to simulate either deposition or scour.

The calibration effort was aimed at simulating peak sediment concentrations for storm events and annual sediment loads. Sediment hydrographs of the observed and simulated data are shown for four stormflows during the calibration period (fig. 7). Table 14 summarizes sediment-discharge data for six storms during the calibration period.

In general, the simulated sediment hydrographs were representative of the observed sediment hydrographs. The simulated storm events produced the peak sediment concentrations and sharp recessions noted in the observed data. Adjusting the volume and discharge values in the F-tables section of the model significantly affected the shape of the sediment hydrograph. Decreasing the volume and increasing the discharge value for the F-table increases the peak sediment concentrations without changing the sediment load.

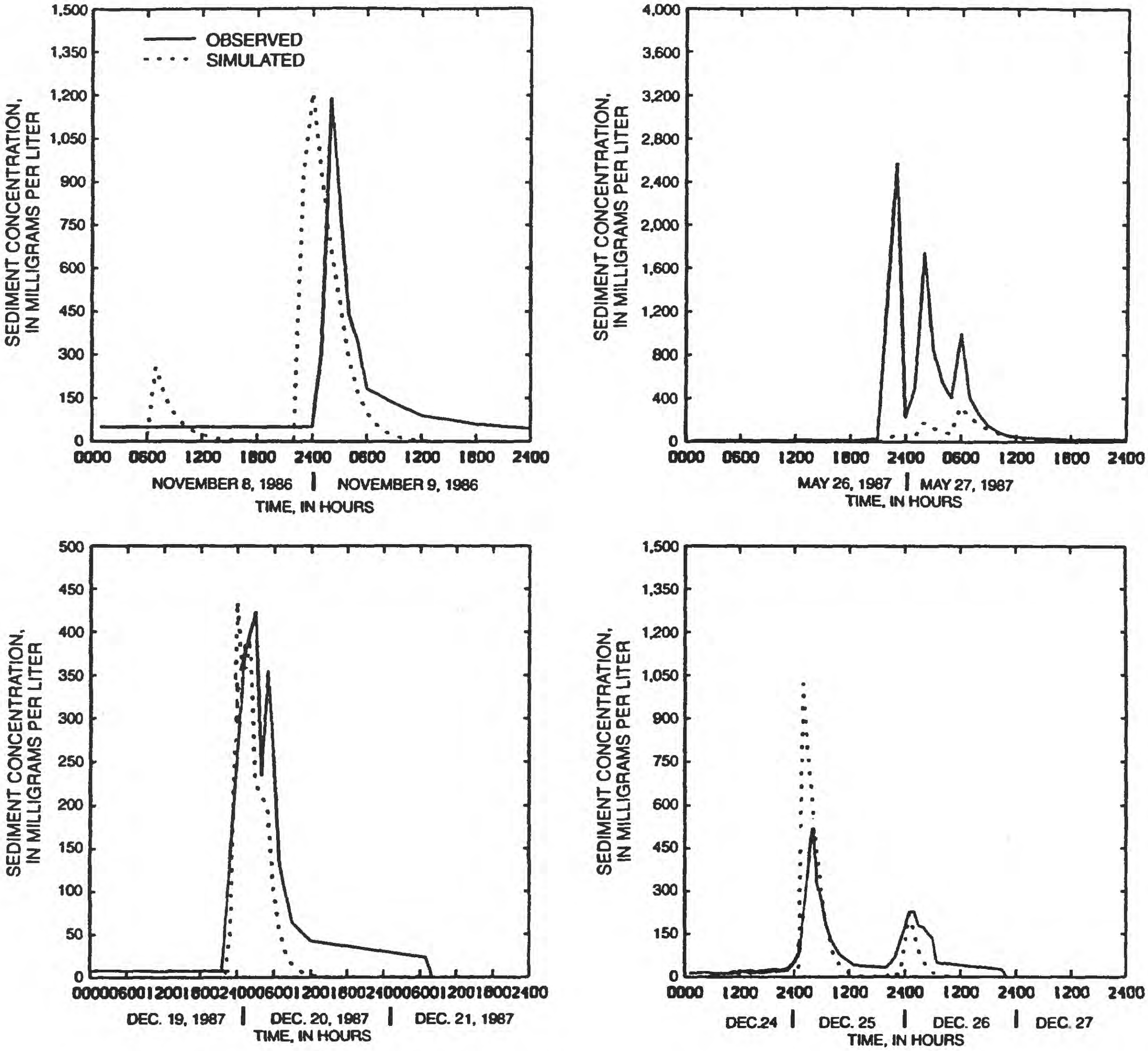

Figure 7. Sediment discharge for selected storms at Stony Fork near Gibbon Glade for the calibration period (water years 1986-88).

The simulated storm loads were somewhat variable in comparison to the observed storm loads. This is partially because of the fact that the simulated sediment data is based on conditions in the watershed that are considered to be somewhat constant. In reality, the measured sediment data represents conditions in the watershed at the time of individual storm events. For example, sediment from plowed fields, stream bank erosion, and channel storage contribute to variable sediment loads for storm events of the same intensity.

Monthly and annual comparisons of observed and simulated sediment loads are shown in table 15. The comparison of monthly sediment loads was highly variable. However, the annual loads are somewhat representative of the observed data. The total simulated suspended-sediment load for the 3-year period was 538 tons [0.30 (ton/acre)/yr]. The total observed suspended sediment load was 467.61 tons [0.26 (ton/acre)/yr] for the 3-year period.

Table 14. *Sediment-discharge data for selected storms at Stony Fork near Gibbon Glade during the calibration period (water years 1986-88)*

[ft^3/s, cubic foot per second; mg/L, milligram per liter]

Storm number	Beginning date	Ending date	Observed peak runoff (ft^3/s)	Simulated peak runoff (ft^3/s)	Observed sediment load (ton)	Simulated sediment load (ton)	Observed peak sediment concentration (mg/L)	Simulated peak sediment concentration (mg/L)
3	07-19-86	07-21-86	53	73	32	142	4,890	4,260
5	11-08-86	11-09-86	23	21	10	10	1,190	1,210
8	05-26-87	05-27-87	8.7	3.5	6.8	.4	2,570	323
10	12-20-87	12-21-87	13	12	3.0	1.8	423	393
11	12-25-87	12-27-87	17	20	6.4	7.2	554	1,020
12	01-19-88	01-21-88	47	37	34	17	2,070	991

Table 15. *Observed and simulated total suspended-sediment load by month and year for Stony Fork near Gibbon Glade during the calibration period (water years 1986-88)*

[All values are in tons unless otherwise noted; ton/acre, tons per acre]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total	Total (ton/acre)
1986 Observed	1.06	50.57	3.93	4.44	50.0	7.08	6.16	0.61	0.16	38.46	0.19	4.34	167.00	0.28
1986 Simulated	.04	38.42	.86	.51	39.74	2.05	92.01	.01	.01	148.16	2.84	5.88	330.53	.56
1987 Observed	16.13	19.74	10.31	8.52	4.16	2.12	51.12	12.63	15.60	2.01	4.59	.16	147.09	.25
1987 Simulated	41.87	24.92	8.03	2.90	1.08	9.79	29.26	2.38	3.43	2.75	.43	.32	127.14	.21
1988 Observed	.22	16.53	11.98	36.60	22.13	48.76	5.77	6.42	.73	.53	2.97	3.96	156.60	.26
1988 Simulated	.39	28.34	9.59	16.95	3.40	13.91	5.62	.55	.01	.07	.20	1.51	80.53	.13

Verification

The verification process was designed to evaluate the models performance outside the calibration period. Data collected during the 1989 water year was used for this purpose. Precipitation during the year totaled 47.0 in. and was well distributed. Simulated data for the 1989 water year was generated by running the model from the beginning of the calibration period (October 1, 1985) through the end of the verification period (September 30, 1989). No changes were made to the calibration parameters established during the calibration procedures.

Streamflow

Verification of the model-generated streamflow was conducted by comparing simulated and observed annual streamflow data, mean-monthly streamflows, hydrographs of mean-daily streamflow, stormflows, and flow-duration curves.

The observed and simulated annual streamflow data is listed in table 16. The base flow in table 16 was determined by hydrograph separation by means of the fixed-interval method and a 3-day interval (Pettyjohn and Henning, 1979). The simulated base flow and stormflow compared well with the observed data. The simulated total streamflow was 3.9 percent less than the observed total streamflow for the 1989 water year.

The observed and simulated mean streamflow by month and year for Stony Fork are presented in table 17. The results were consistent with results from the calibration period.

Hydrographs of observed and simulated mean daily streamflow for the 1989 water year are shown in figure 8.

Verification of the model for storm periods was based on six storms selected from the 1989 water year. The results for the six storms (table 18, fig. 9) were consistent with the storms simulated during the calibration period.

A final check on the simulated streamflow was done by comparing flow-duration curves (cumulative frequency-distribution curves) of the observed and simulated daily streamflows (fig. 10). Flow-duration curves provide information on the range of streamflows and the frequency with which specified streamflows were equalled or exceeded (Searcy, 1959). The flow-duration curve tends to smooth out the day-to-day discrepancies between the observed and simulated streamflow. In general, figure 10 shows that the model simulated a representative range of streamflow during the 1989 water year.

Table 16. *Observed and simulated annual streamflow data for the Stony Fork Basin during the verification period (water year 1989)*

[All values are in inches.]

Water year	Observed stormflow	Simulated stormflow	Observed base flow[1]	Simulated base flow[1]	Observed total streamflow	Simulates total streamflow
1989	13.48	12.37	19.25	19.09	32.73	31.46

[1] Base flow determined by hydrograph separation.

Table 17. *Observed and simulated mean discharge by month and year for Stony Fork near Gibbon Glade during the verification period (water year 1989)*

[All values are in cubic feet per second.]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Mean
1989 Observed	0.83	2.78	1.79	3.67	4.02	4.63	1.70	3.83	1.69	1.20	0.27	0.57	2.24
1989 Simulated	.69	2.56	2.19	2.79	3.88	5.27	1.50	2.76	1.82	1.26	.29	.96	2.16

Table 18. *Precipitation and runoff data for selected storms at Stony Fork near Gibbon Glade for the verification period (water year 1989)*

[ft³/s, cubic foot per second]

Storm number	Beginning date	Ending date	Observed precipitation (inches)	Observed runoff (inches)	Simulated runoff (inches)	Observed peak discharge (ft³/s)	Simulated peak discharge (ft³/s)
13	11-05-88	11-06-88	1.11	0.62	0.47	20	29
14	12-24-88	12-25-88	.93	.96	1.25	26	31
15	02-15-89	02-16-89	2.10	1.44	1.61	31	35
16	05-01-89	05-02-89	1.07	.44	.49	15	17
17	06-15-89	06-17-89	1.60	.66	.32	28	13
18	09-22-89	09-23-89	1.25	.17	.26	6.6	8.7

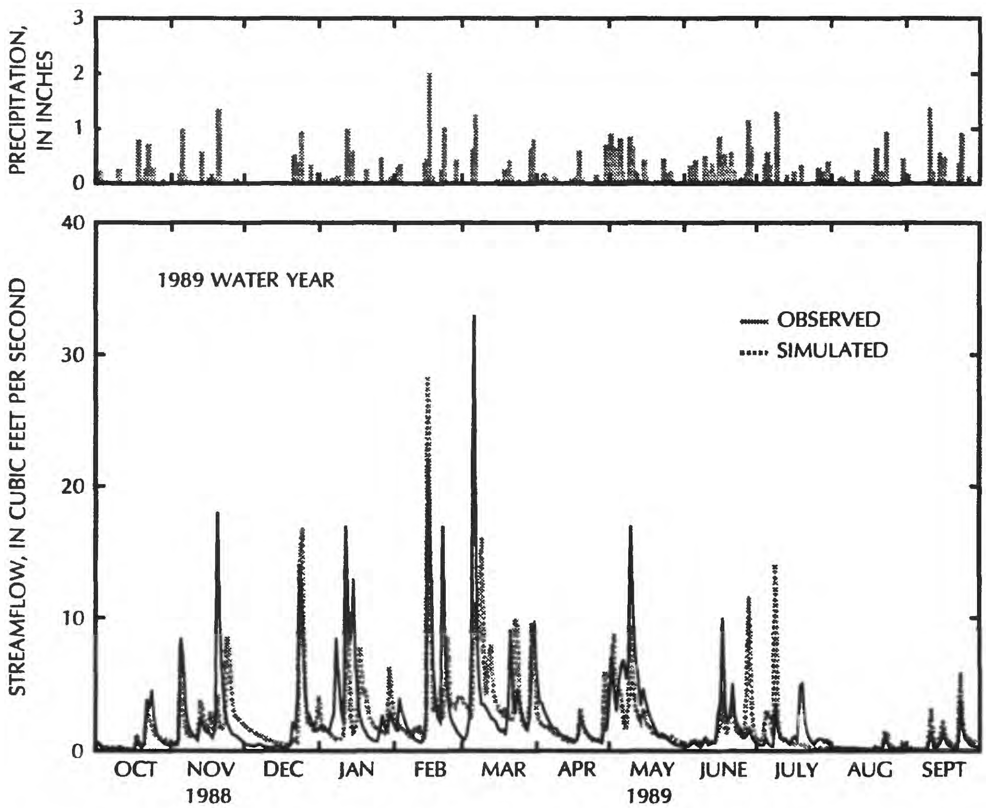

Figure 8. Hydrographs of observed and simulated daily mean streamflow at Stony Fork near Gibbon Glade for the verification period (water year 1989).

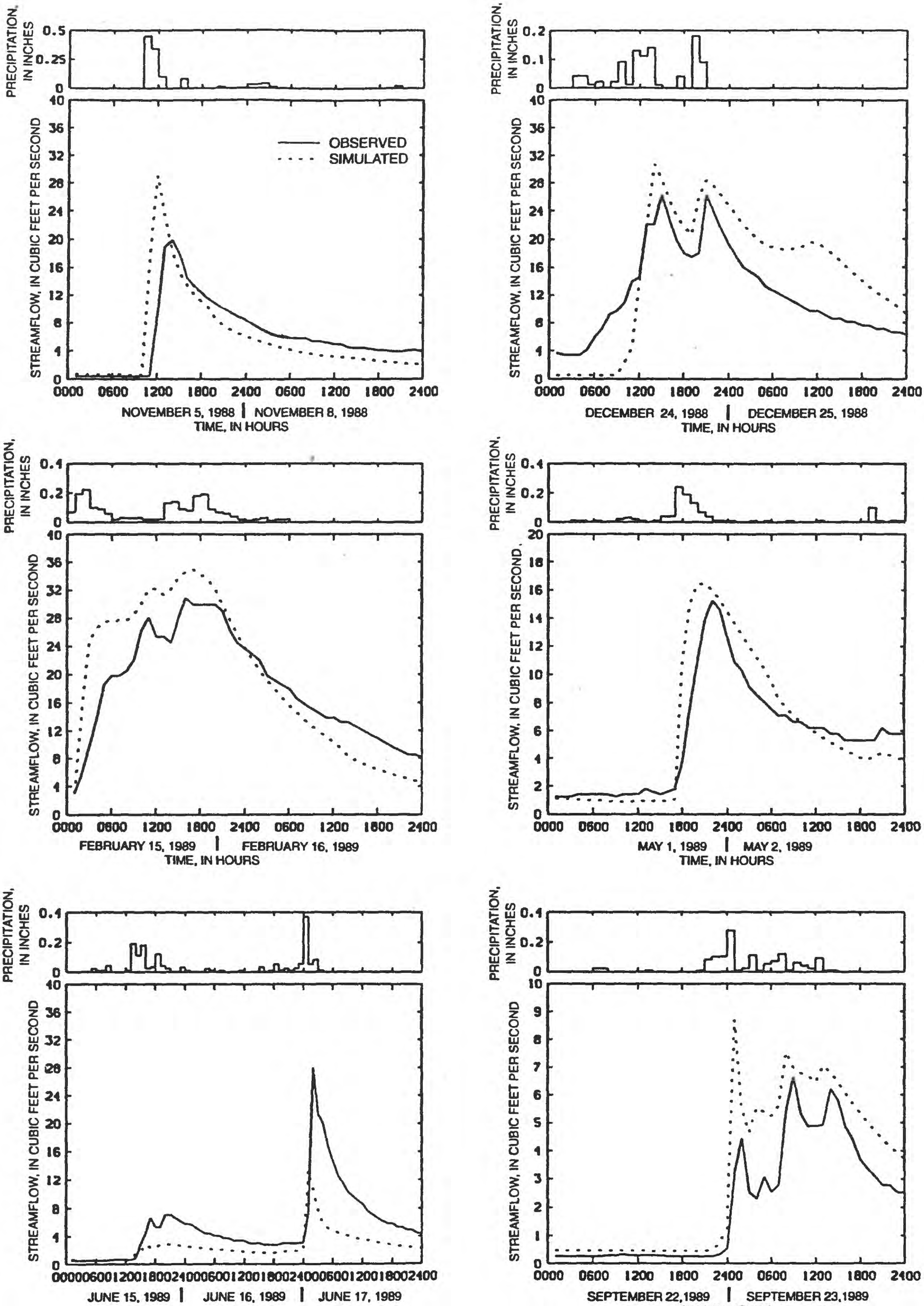

Figure 9. Hydrographs of selected storms at Stony Fork near Gibbon Glade for the verification period (water year 1989).

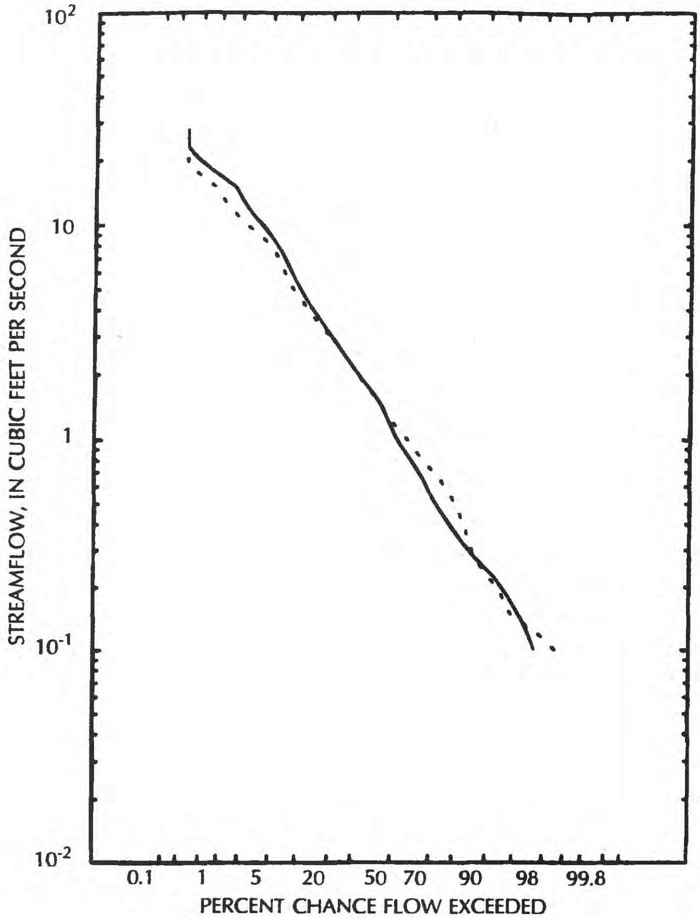

Figure 10. Duration curves of observed and simulated daily mean streamflow at Stony Fork near Gibbon Glade for the verification period (water year 1989).

Sediment

Suspended-sediment discharge was verified by comparing observed and simulated data for the 1989 water year. Observed and simulated sediment discharge were compared on a storm, monthly, and annual basis.

Peak suspended-sediment concentrations were compared for six storms (table 19 and fig. 11). The storms showed a good comparison between observed and simulated peak sediment concentrations and sediment loads.

Monthly observed and simulated suspended-sediment loads are listed in table 20. The results were consistent with the calibration period.

The simulated annual sediment load compared well to the observed sediment load for the verification year. The total simulated sediment load was 161.98 tons [0.27 (ton/acre)/yr] compared to the observed sediment load of 208.22 tons [0.35 (ton/acre)/yr].

Table 19. *Sediment-discharge data for selected storms at Stony Fork near Gibbon Glade during the verification period (water year 1989)*

[ft^3/s, cubic foot per second; mg/L, milligram per liter]

Storm number	Beginning date	Ending date	Observed peak runoff (ft^3/s)	Simulated peak runoff (ft^3/s)	Observed sediment load (ton)	Simulated sediment load (ton)	Observed peak sediment concentration (mg/L)	Simulated peak sediment concentration (mg/L)
13	11-05-88	11-06-88	20	29	6.1	12	1,660	1,460
14	12-24-88	12-25-88	26	31	5.9	5.7	450	370
15	02-15-89	02-16-89	31	35	16	5.6	408	393
16	05-01-89	05-02-89	15	17	4.6	6.8	759	1,300
17	06-15-89	06-17-89	28	13	7.0	4.3	1,550	1,440
18	09-22-89	09-23-89	6.6	8.7	.9	1.7	455	857

Table 20. *Observed and simulated total suspended-sediment load by month and year for Stony Fork near Gibbon Glade during the verification period (water year 1989)*

[All values are in tons unless otherwise noted; ton/acre, tons per acre]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total	Total (ton/acre)
1989 Observed	1.44	10.82	9.39	20.54	30.70	72.93	3.15	26.90	12.12	16.26	1.38	2.59	208.22	0.35
1989 Simulated	2.32	15.02	5.85	2.11	6.24	10.23	4.25	28.59	18.93	60.92	2.14	5.37	161.98	.27

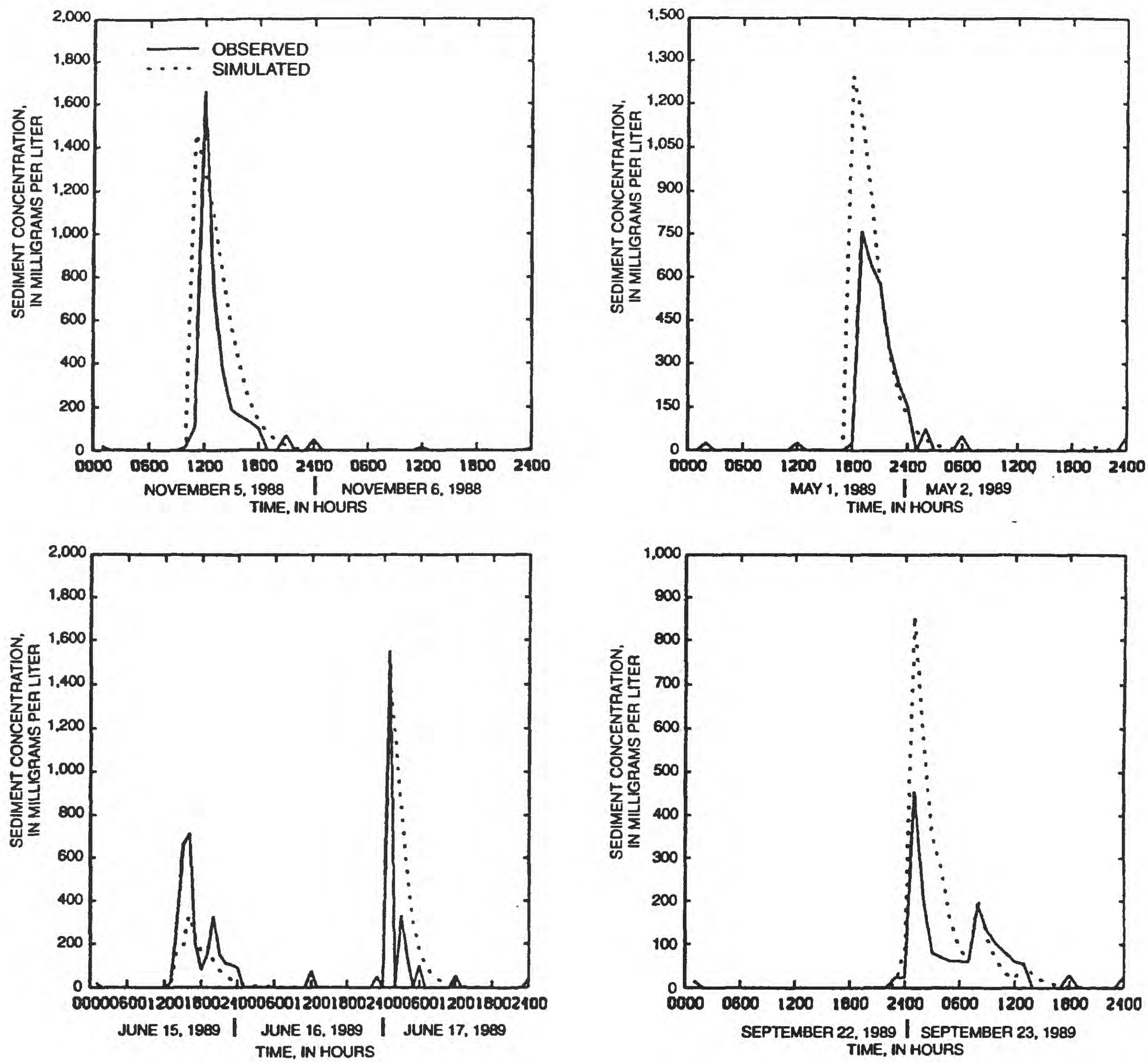

Figure 11. Sediment discharge for selected storms at Stony Fork near Gibbon Glade for the verification period (water year 1989).

Significant Calibration Parameters

The sensitivity of selected HSPF parameters was evaluated to determine the relative effect of parameters on hydrologic processes. The sensitivity test was done after the Stony Fork Basin was calibrated. The 1987 water year was used for the sensitivity test. Only one parameter was evaluated in each sensitivity run. Data in the HSPF print files, which contain summary data from the simulation run, were compared for the before and after conditions. These data were then tabulated in a format to indicate the percentage change the parameter had on various parts of the hydrologic system. The parameter would then be reset to its former value and the sensitivity test would continue with the next parameter. The results of the sensitivity test are listed in tables 21 and 22.

Table 21. *Sensitivity results for selected parameters affecting the annual water balance*

[+, positive percent change; -, negative percent change; <, less than]

Parameter	Value		Streamflow				Storage			Evapotranspiration	
			Total flow	Surface runoff	Interflow	Base flow	Upper zone	Lower zone	Ground water	Upper zone	Lower zone
	Before	After	(percent change)								
LZSN	6.00	3.00	+2.0	+11.0	+4.0	-9.0	-34.0	-49.0	-18.0	-2.0	-2.0
INFILT	.03	.06	<1.0	-32.0	-1.0	+39.0	-10.0	+7.0	+29.0	-5.0	+5.0
UZSN	.50	1.00	-1.0	-6.0	-8.0	+8.0	+97.0	+8.0	+22.0	+27.0	-18.0
IRC	.75	.37	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
INTFW	1.00	3.00	<1.0	-42.0	+49.0	-1.0	<1.0	<1.0	<1.0	<1.0	<1.0
AGWR	.86	.43	<1.0	<1.0	<1.0	<1.0	-1.0	<1.0	-67.0	<1.0	+1.0
LZETP	.80	.40	+6.0	+12.0	+5.0	+3.0	+33.0	+18.0	+61.0	+5.0	-30.0
BASETP	.01	.02	<1.0	+1.0	<1.0	-2.0	<1.0	<1.0	<1.0	<1.0	-2.0
AGWETP	.01	.02	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
DEEPFR	.01	.02	<1.0	<1.0	<1.0	-1.0	<1.0	<1.0	<1.0	<1.0	<1.0
CEPC	.30	.15	+2.0	<1.0	<1.0	+3.0	-5.0	-3.0	+8.0	+33.0	+16.0
NSUR	.03	.30	<1.0	-17.0	+16.0	+5.0	+1.0	+2.0	+8.0	+1.0	-1.0
SLSUR	.40	.80	<1.0	+2.0	-1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
LSUR	400.00	200.00	<1.0	+3.0	-2.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
INFEXP	3.00	1.50	<1.0	-18.0	+6.0	+13.0	<1.0	+2.0	<1.0	-2.0	+2.0
INFILD	2.00	1.00	<1.0	-10.0	+10.0	+3.0	<1.0	<1.0	<1.0	<1.0	<1.0

Table 22. *Sensitivity results for selected parameters affecting surface erosion*

[+, positive percent change; -, negative percent change]

Parameter name	Value		Soil matrix detachment	Washoff of sediment	Scour of matrix	Total sediment removed
	Before	After	(percent change)			
SMPF	0.50	1.00	+100.0	+95.0	0.0	+56.0
KRER	.50	1.00	+95.0	+95.0	.0	+56.0
JRER	3.50	7.00	-78.0	-84.0	.0	-50.0
AFFIX	.25	.50	.0	-2.9	.0	-1.7
COVER	.50	1.00	-100.0	-100.0	.0	-60.0
KSER	2.00	4.00	.0	+2.3	.0	+1.4
JSER	1.75	3.00	.0	-57.0	.0	-33.9
KGER	1.20	2.40	.0	.0	+100.0	+40.1
JGER	3.60	7.20	.0	.0	-99.0	-40.5
LSUR	400.00	800.00	.0	.0	+3.4	+1.0
SLSUR	.40	.80	.0	.0	-1.7	-1.0
NSUR	.03	.30	.0	-3.5	+16.0	+4.5

Transfer of Calibration Parameters - Poplar Run Basin

Data from the Poplar Run Basin, located 20 mi north of the Stony Fork Basin (fig. 1), were used to evaluate the transfer value of the Stony Fork model parameters. In theory, the Poplar Run Basin was to represent an ungaged basin with no background hydrologic data. In reality, water quantity and quality data have been collected from the basin since 1985. Precipitation data were supplied by the two gages shown in figure 12. The precipitation gage located near the streamflow- gaging station was used for back-up purposes only. Data used in the Poplar Run model are listed in table 23.

The first step in developing the Poplar Run model was to construct the UCI file. As mentioned, the UCI file is based on parameters for individual HRU's. The basin was partitioned into HRU's on the basis of land-use types identified in the Stony Fork Basin. This was possible because of the basin to basin similarities in geology, topography, soils, and land use. Table 24 lists the acreage and percentage for each HRU in the Poplar Run Basin. Figure 12 shows how the basin was partitioned and also the location of monitor points.

The UCI file directed simulations for a 1-hour time step. Output from the model was directed to specified WDMS files. Nontransferable parameters were set to conditions observed in the basin. The UCI file was completed by setting calibration parameters to the values established in the model of the Stony Fork Basin. The model was set up for the simulation of streamflow and sediment. The UCI file is listed in Appendix 2.

Table 23. *Time series data used in the Poplar Run Model*

[USGS, U.S. Geological Survey; NOAA, National Oceanic and Atmospheric Administration]

Site name	Station number	Source of data	Type of data
Poplar Run near Normalville	03082190	USGS	Streamflow, sediment, precipitation
Clinton rain gage	400250079274201	USGS	Precipitation
Confluence	170509	NOAA	Pan evaporation
Pittsburgh	94823	NOAA	Air temperature, dew point, solar radiation, wind speed

Table 24. *Hydrologic response units in the Poplar Run Basin*

Hydrologic response unit[1]	Description	Acres	Percent
1	Forestland	3,610.0	63.9
2	Cropland	208.0	3.7
3	Surface mined	979.0	17.3
4	Grassland	853.0	15.1

[1] The hydrologic response unit is the land use described above on soils of the Gilpin-Wharton-Ernest and Dekalb-Hazelton-Cookport associations developed from bedrock of predominately the Allegheny and Conemaugh groups.

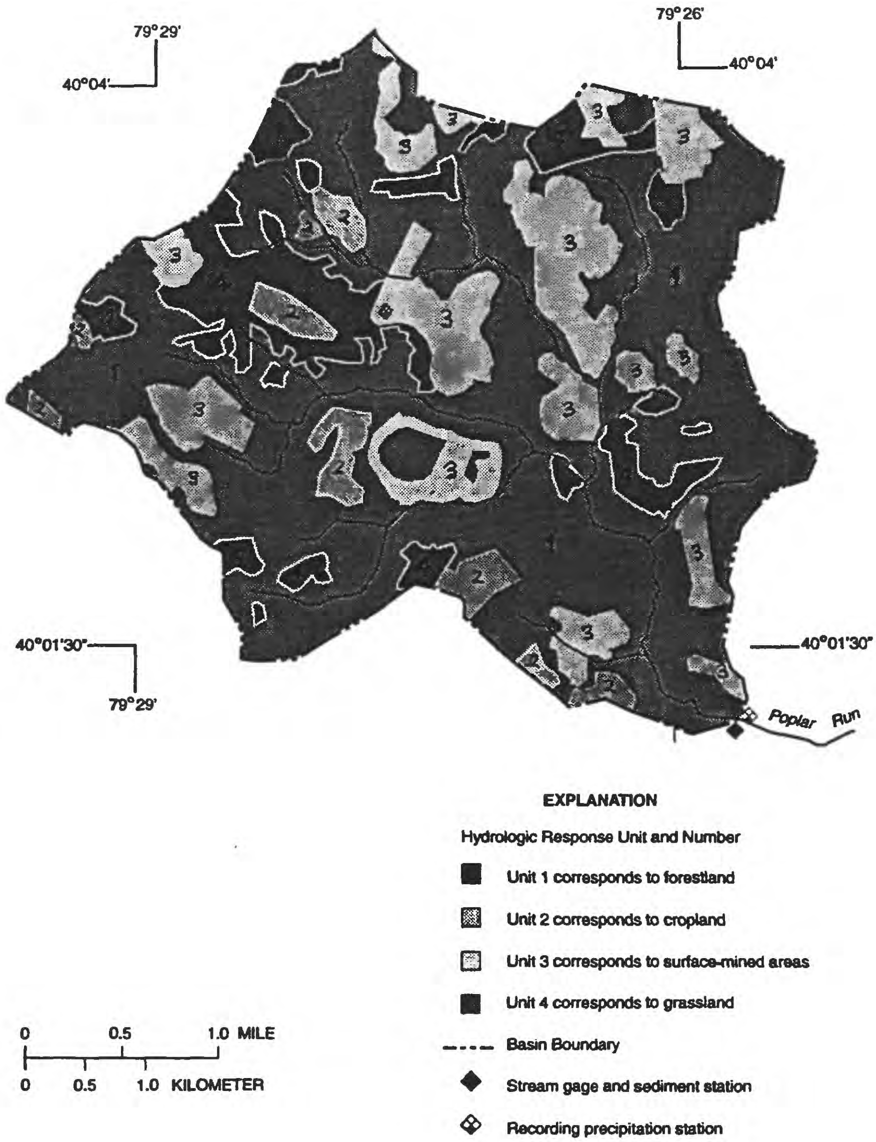

Figure 12. Hydrologic response units and data-collection sites in Poplar Run Basin.

Streamflow

The model of the Poplar Run Basin was used to generate streamflow data for the 1988-89 water years. The simulated data were evaluated by comparing observed and simulated water budgets, mean-monthly flows, hydrographs of mean-daily streamflow, runoff data from storm events, and flow-duration curves.

The simulated water budget for water years 1988-89 for the Poplar Run Basin is listed in table 25. Measured precipitation was 40.9 in. for the 1988 water year and 50.3 in. for the 1989 water year. The simulated total streamflow was 53 percent of the measured precipitation for the 1988 water year. For the 1989 water year, simulated streamflow was 66 percent of precipitation.

Annual streamflow data is listed in table 26. The base flow in table 26 was determined by hydrograph separation by means of the fixed-interval method and a 3-day interval (Pettyjohn and Henning, 1979). In general, the simulated base flow and stormflow compared well to the observed data. The difference between observed and simulated total streamflow was 1.6 percent for the 2-year period.

The value of the Poplar Run model in representing the seasonal distribution of streamflows was evaluated by comparing observed and simulated mean monthly streamflow (table 27). A month by month comparison of the simulated data indicates no consistent departure from the observed record. Transitions from wet to dry periods were generally representative of the observed data. The mean streamflow simulated by the model was 18.3 ft^3/s. This compares to an observed streamflow of 18.15 ft^3/s.

Table 25. *Simulated water budget for the Poplar Run Basin (water years 1988-89)*

[All values are in inches.]

Water year	Measured precipitation	Evapotranspiration	Surface runoff	Interflow	Ground-water flow	Ground-water sink	Total streamflow
1988	40.90	20.83	1.01	8.34	12.22	0.25	21.57
1989	50.30	17.46	1.86	13.78	17.59	.37	33.23

Table 26. *Observed and simulated annual streamflow data for the Poplar Run Basin (water years 1988-89)*

[All values are in inches.]

Water year	Observed stormflow	Simulated stormflow	Observed base flow[1]	Simulated base flow[1]	Observed total streamflow	Simulates total streamflow
1988	8.49	8.66	16.37	12.91	24.86	21.57
1989	11.33	13.22	19.49	20.01	30.82	33.23
Mean	9.91	10.94	17.93	16.46	27.84	27.40

[1] Base flow determined by hydrograph separation.

Table 27. *Observed and simulated mean discharge by month and year for Poplar Run near Normalville (water years 1988-89)*

[All values are in cubic feet per second.]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
1988 Observed	12.8	13.8	30.0	15.6	33.8	29.3	16.8	26.9	3.31	3.35	1.95	6.11	16.1
1988 Simulated	7.48	17.8	15.0	15.9	28.2	30.6	13.9	19.2	2.99	5.55	3.12	9.42	14.1
1989 Observed	4.96	22.6	15.1	24.3	37.1	40.3	18.0	31.0	26.5	12.7	3.08	6.27	20.2
1989 Simulated	7.88	29.3	22.8	28.6	37.4	52.7	16.0	20.9	30.0	13.0	2.00	9.07	22.5

Hydrographs of observed and simulated mean-daily discharges were compared to evaluate the day-to-day performance of the model (fig. 13). The hydrographs were used mainly for analyzing peak discharges and recession rates. The simulated hydrograph shows peak discharges that are somewhat higher than the observed discharges. Also, the simulated recessions occur at a faster rate than do the observed recessions. These conditions may be attributed to the size of the drainage basin. The parameters in the Poplar Run model were taken from the calibrated Stony Fork model which reflects hydrologic conditions for 0.93 mi^2 of drainage area. Streams draining this size area exhibit a fast response, which is typical of small streams. The ground-water recession rate (AGWR) and the interflow recession constant (IRC) had a significant effect on hydrograph shape. These parameters were calibrated to conditions observed in the Stony Fork Basin.

The performance of the Poplar Run model during storm-runoff events was evaluated by comparing observed and simulated hourly data. Precipitation and runoff data for 12 storms are presented in table 28. Hydrographs of the 12 storms are shown in figure 14. The simulated runoff compared well to the observed runoff. The model seems to account for seasonal conditions in terms of the amount of runoff in relation to precipitation. This was evident for the storm which occurred on July 20, 1988, during a summer drought. The measured rainfall for the 2-day period was 2.73 in. The model simulated a runoff volume of 0.35 in.; the measured runoff volume was 0.22 in. It seems that a significant amount of rainfall from this storm was used to recharge depleted upper zone, lower zone, and ground-water reservoirs.

The streamflow evaluation of the Poplar Run model was concluded by comparing flow-duration curves of the observed and simulated data. Duration curves of daily mean streamflow from the 1988 and 1989 water years are shown in figure 15. The simulated data from the Poplar Run model were representative of the range of streamflow data collected from the basin.

Table 28. *Precipitation and runoff data for selected storms at Poplar Run near Normalville (water years 1988-89)*

[ft^3/s, cubic foot per second]

Storm number	Beginning date	Ending date	Observed precipitation (inches)	Observed runoff (inches)	Simulated runoff (inches)	Observed peak discharge (ft^3/s)	Simulated peak discharge (ft^3/s)
1	01-19-88	01-20-88	1.02	0.55	0.68	273	255
2	05-05-88	05-06-88	1.20	.47	.38	136	109
3	05-19-88	05-21-88	1.17	.84	.57	169	154
4	07-20-88	07-21-88	2.73	.22	.35	154	356
5	08-29-88	08-30-88	1.39	.10	.14	55	65
6	09-12-88	09-13-88	1.16	.08	.14	40	87
7	09-25-88	09-26-88	.55	.17	.17	79	54
8	10-23-88	10-24-88	.88	.20	.25	79	81
9	04-29-89	04-30-89	.56	.12	.26	30	115
10	06-16-89	06-17-89	1.23	.49	.26	231	170
11	06-21-89	06-22-89	.95	.69	.48	273	255
12	07-06-89	07-07-89	.33	.23	.21	150	66

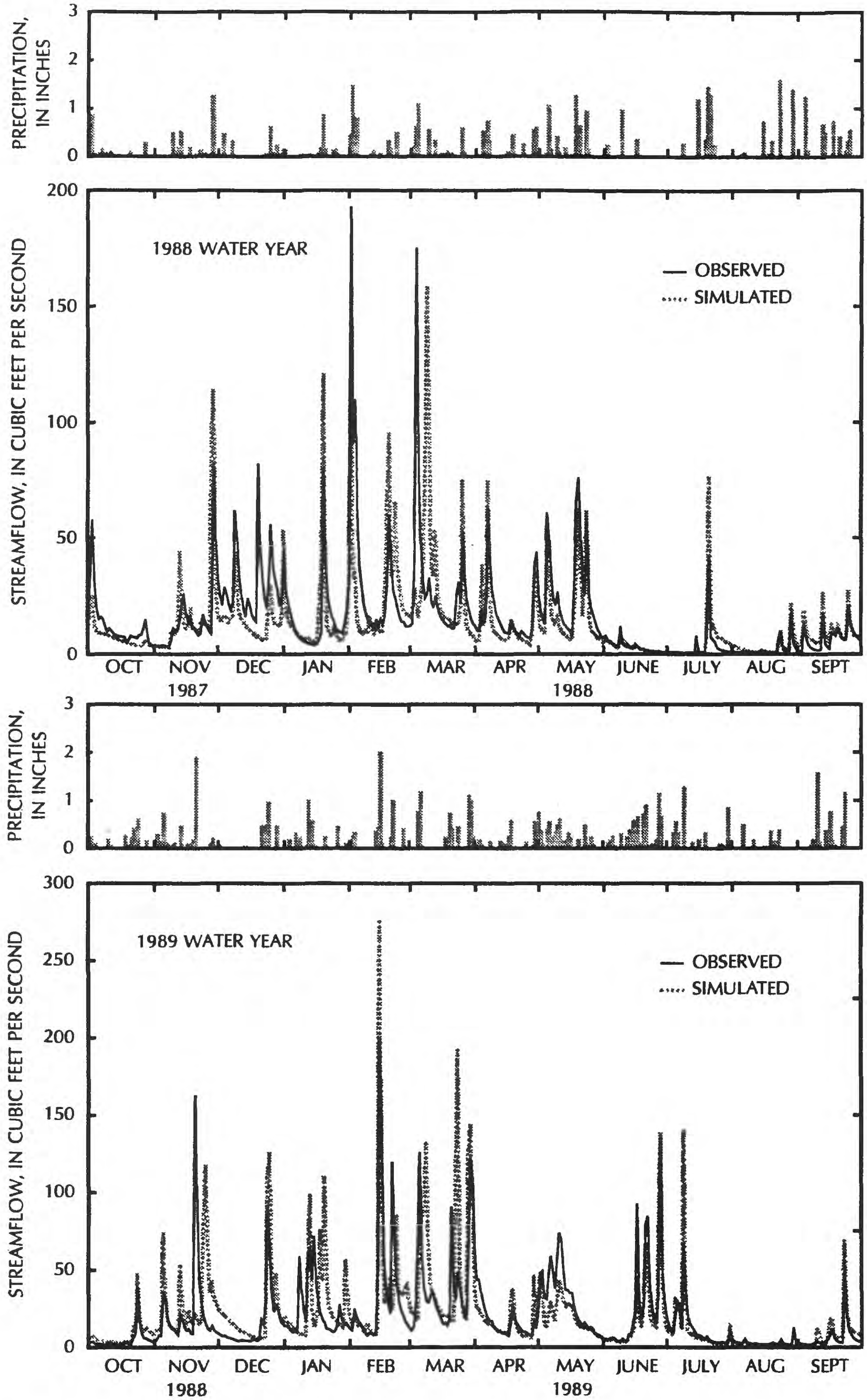

Figure 13. Hydrographs of observed and simulated daily mean streamflow at Poplar Run near Normalville (water years 1988-89).

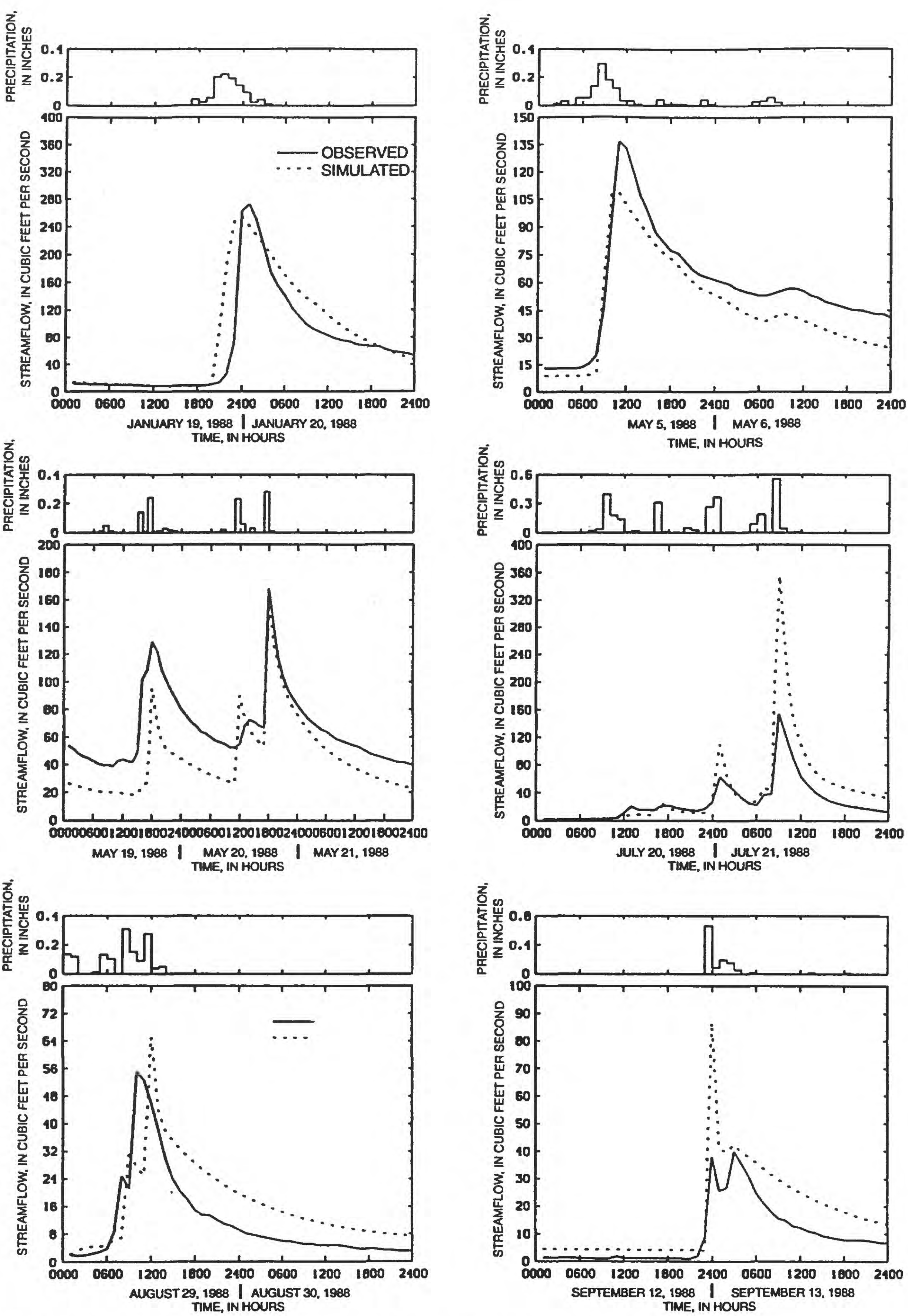

Figure 14. Hydrographs of selected storms at Poplar Run near Normalville (water years 1988-89).

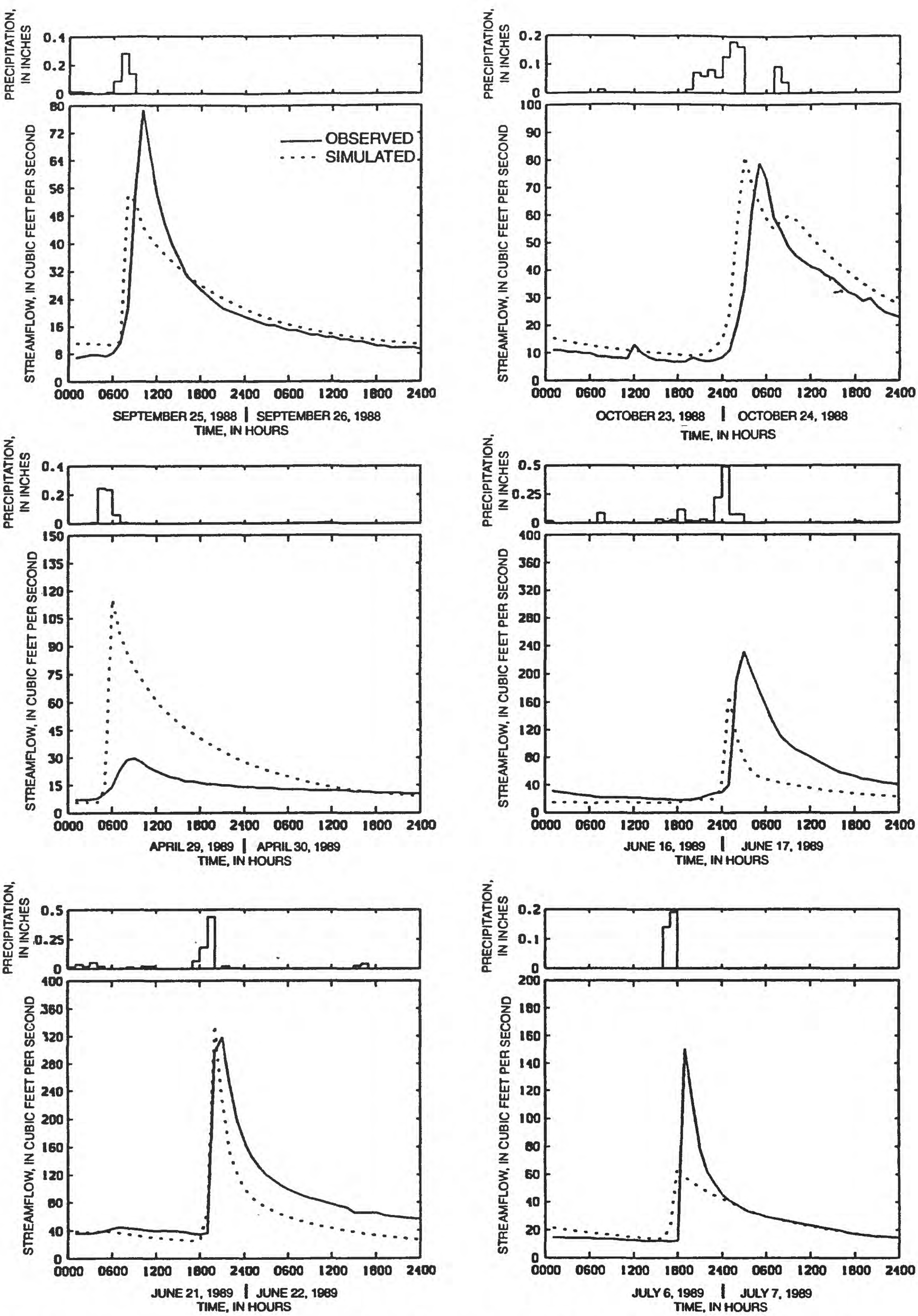

Figure 14. Hydrographs of selected storms at Poplar Run near Normalville (water years 1988-89)—Continued.

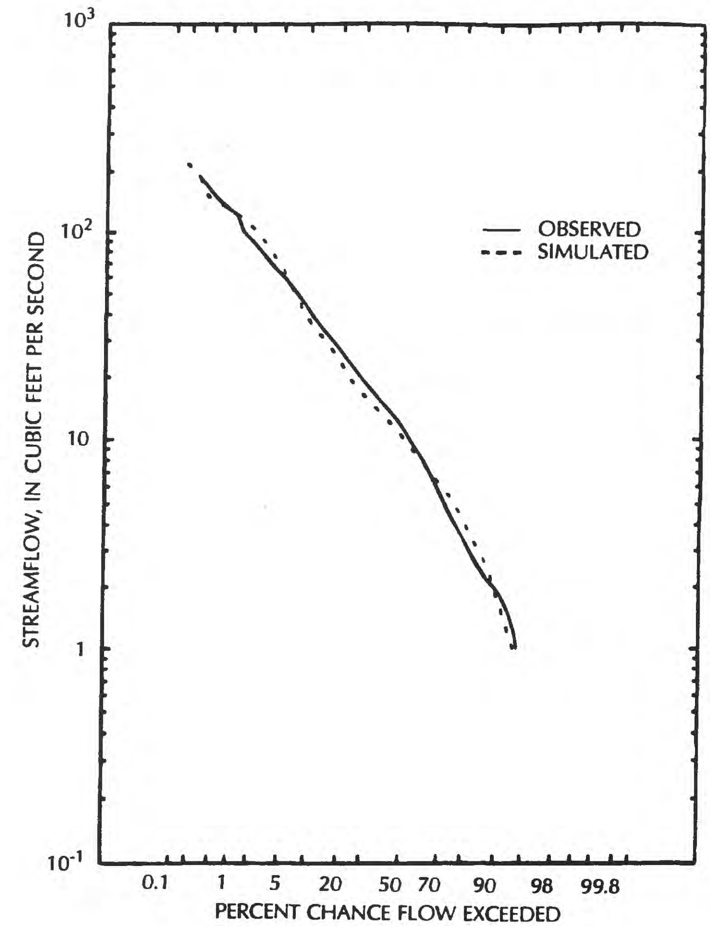

Figure 15. Duration curves of observed and simulated daily mean streamflow at Poplar Run near Normalville (water years 1988-89).

Sediment

Parameters from the calibrated suspended-sediment modules for the Stony Fork model were used in the suspended-sediment modules for the Poplar Run Basin. The nontransferable parameters were adjusted to represent the hydraulic characteristics of the stream channel. The model was used to generate suspended-sediment data for the 1988-89 water years. The model was evaluated by comparing observed and simulated data on a stormflow, monthly, and annual basis.

Eight storms were used for comparison of observed and simulated suspended sediment (table 29). Six of these storms are shown in figure 16.

The simulated peak sediment concentrations and sediment loads did not compare well with the observed data. The model failed to simulate the sediment yield necessary to reproduce the peak sediment concentrations and sediment loads noted in the observed data for these storm events. Sediment data collected from the watershed since 1985 indicate that some storm events produced large sediment loads (Sams and Witt, 1989). Surface mines in the basin with poor vegetative cover can contribute to the increased sediment yield. It would be necessary to recalibrate SEDMNT sections of the model to improve the simulations. In as much as the purpose of this investigation was to evaluate the direct transfer of parameters from the Stony Fork model, the Poplar Run model was not recalibrated.

Monthly and yearly observed and simulated suspended-sediment loads were compared for the evaluation period and showed a high degree of variation (table 30). During the 2 years, the simulated sediment load was 2,754 tons [0.24 (ton/acre)/yr], which compares to a measured sediment load of 3051.2 tons [0.27 (ton/acre)/yr].

In general, results from the sediment simulation indicate that long-term simulated data, such as annual totals, are more representative of the observed data than short-term simulated storm events.

Table 29. *Sediment-discharge data for selected storms at Poplar Run near Normalville (water years 1988-89)*

[ft^3/s, cubic foot per second; mg/L, milligram per liter]

Storm number	Beginning date	Ending date	Observed peak runoff (ft^3/s)	Simulated peak runoff (ft^3/s)	Observed sediment load (ton)	Simulated sediment load (ton)	Observed peak sediment concentration (mg/L)	Simulated peak sediment concentration (mg/L)
3	05-19-88	05-21-88	169	154	119	63	3,670	1,160
4	07-20-88	07-21-88	154	356	136	161	3,680	2,160
5	08-29-88	08-30-88	55	65	44	12	4,000	774
6	09-12-88	09-13-88	40	87	65	22	8,130	1,770
7	09-25-88	09-26-88	79	54	49	8.9	3,800	824
8	10-23-88	10-24-88	79	81	21	15	684	709
10	06-16-89	06-17-89	231	170	88	52	1,480	1,760
12	07-06-89	07-07-89	150	66	25	3.8	1,000	347

Table 30. *Observed and simulated total suspended-sediment load by month and year for Poplar Run near Normalville (water years 1988-89)*

[All values are in tons unless otherwise noted; ton/acre, tons per acre]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total	Total (ton/acre)
1988 Observed	24.58	81.87	35.33	33.89	328.28	236.76	56.68	187.14	2.93	138.45	104.38	130.77	1,361.06	0.24
1988 Simulated	27.36	229.12	1.27	93.76	48.98	63.67	36.74	248.16	.17	161.74	19.47	36.73	967.17	.17
1989 Observed	25.44	288.85	63.06	60.37	369.09	185.38	30.42	76.91	388.64	162.88	11.02	31.06	1,693.12	.30
1989 Simulated	17.09	182.98	53.52	65.32	53.96	121.48	31.84	18.69	385.99	781.55	2.14	72.23	1,786.79	.32

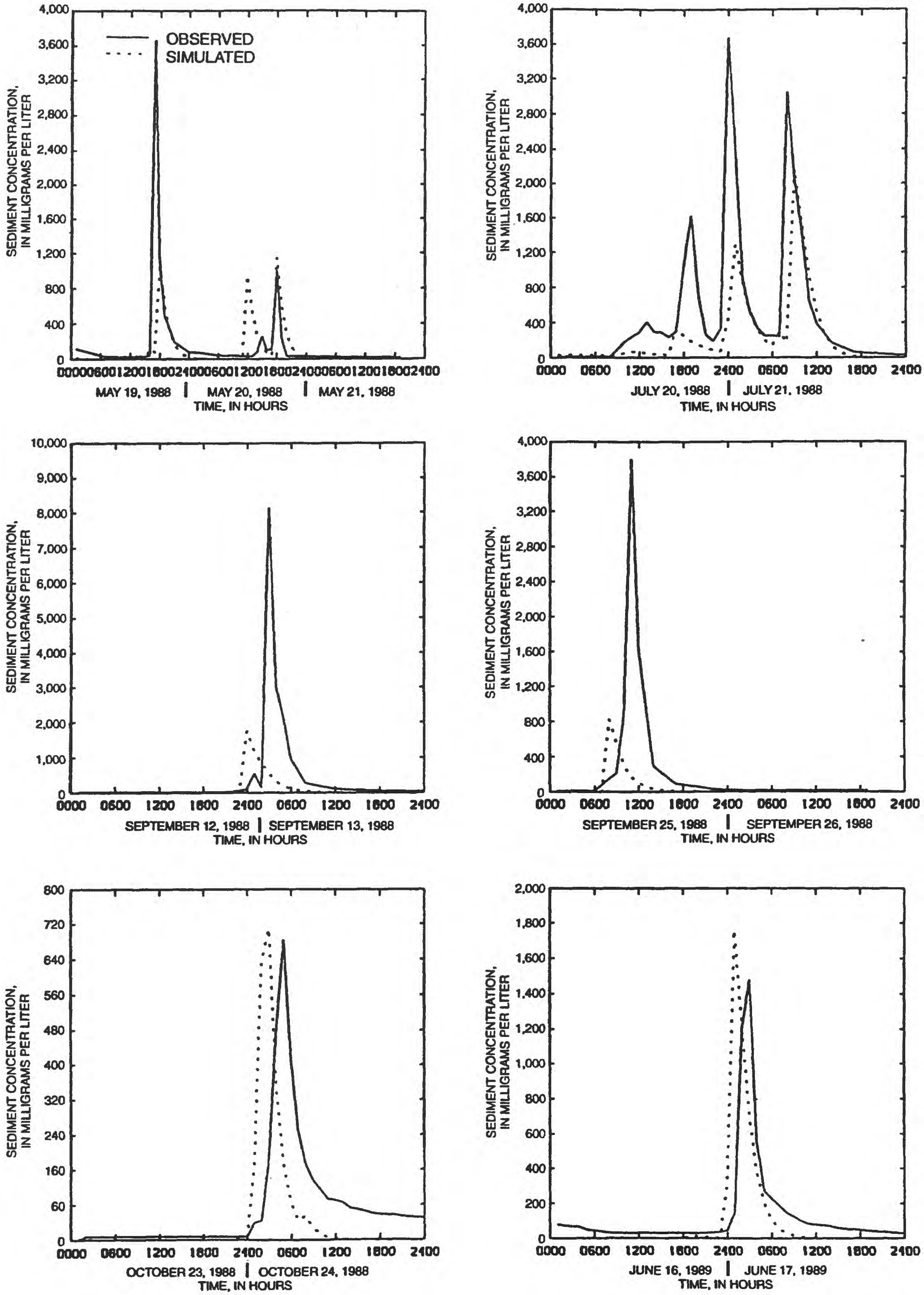

Figure 16. Sediment discharge for selected storms at Poplar Run near Normalville (water years 1988-89).

SUMMARY AND CONCLUSIONS

The Hydrologic Simulation Program - Fortran (HSPF) was used to simulate streamflow and sediment transport in two surface-mined basins of Fayette County, Pa. Hydrologic data from the Stony Fork Basin were used to calibrate HSPF parameters that were then applied to an HSPF model of the Poplar Run Basin to evaluate the transfer value of model parameters. The results of this investigation will provide information to the Pennsylvania Department of Environmental Resources, Bureau of Mining and Reclamation, regarding the value of the simulated hydrologic data for assessing the cumulative hydrologic impacts of surface mining. Section 779.13 of the Surface Mining Control and Reclamation Act (P.L. 95-87) specifies that modeling techniques may be used to generate these data.

The calibration period was October 1, 1985, through September 30, 1988 (water years 1986-88). The calibration process involved adjusting parameters to improve the fit between the observed and simulated data. Data from the Stony Fork Basin were used to calibrate the model. Precipitation data were obtained from a rain gage located at the streamflow-gaging station. The calibration process for streamflow involved four steps: (1) calibrating the annual water balance, (2) calibrating the seasonal distribution of flows, (3) calibrating peak discharges and recession rates, and (4) calibrating runoff volumes and peak flows for storm events. The calibration process for sediment transport involved two steps: (1) calibrating the sediment yield from the basin by land use, and (2) calibrating the transport of sediment in the stream channel.

In general, the simulated data were representative of the observed data from the Stony Fork Basin. The observed and simulated total annual streamflow varied by 4.3, 0.4, and 6.0 percent for the 1986, 1987, and 1988 water years, respectively. Mean streamflow simulated by the model was 1.64 ft^3/s for the 3 years. Mean streamflow determined from the gaging-station data was 1.57 ft^3/s for the 3 years. The difference between the observed and simulated peak stormflows ranged from 4.0 to 59.7 percent for 12 storms. Sediment hydrographs of the simulated storm events were representative of the high peak sediment concentrations and sharp recessions noted in the observed data. During the 1987 water year, the simulated sediment load was 127.14 tons (0.21 ton/acre), which compares to a measured sediment load of 147.09 tons (0.25 ton/acre). The total simulated suspended-sediment load for the 3-year period was 538.2 tons [0.30 (ton/acre)/yr], which compares to a measured sediment load of 467.61 tons [0.26 (ton/acre)/yr].

The model was verified by comparing observed and simulated data outside the calibration period. Data from October 1, 1988, through September 30, 1989, were used to verify the model. The results obtained were comparable to those from the calibration period. Cumulative frequency-distribution curves of the observed and simulated streamflow data show that the simulated mean-daily discharge was representative of the range of data observed from the basin and of the frequency with which specific discharges were equalled or exceeded.

The calibrated and verified parameters from the Stony Fork model were applied to an HSPF model of the Poplar Run Basin. The Poplar Run Basin is located approximately 20 mi north of Stony Fork. The two basins are in a similar physical setting and contain the same types of land use. Data from October 1, 1987, to September 30, 1989, were used to evaluate the transfer value of the Stony Fork parameters. Precipitation data were obtained from a rain gage located near the center of the basin.

In general, the results from the Poplar Run model were comparable to those obtained from the Stony Fork model. The difference between observed and simulated total streamflow was 1.1 percent for the 2-year period. The mean streamflow simulated by the model was 18.3 ft^3/s. This compares to an observed streamflow of 18.15 ft^3/s. Cumulative frequency distribution curves of the observed and simulated streamflow compared well. For the 2-year period, the simulated sediment load was 2,754 tons (0.24 (ton/acre)/yr), which compares to a measured sediment load of 3,051 tons (0.27 (ton/acre) yr). The simulated peak sediment concentrations and sediment loads for storm events did not compare well with the observed data. In general, the comparison between observed and simulated data improved as the time span increased. Simulated annual means and totals were more representative of the observed data than hourly data used in comparing storm events.

The simulation results from this investigation indicate that representative hydrologic data can be provided through modeling techniques. The structure and organization of the HSPF model facilitated the simulation of a wide range of hydrologic processes. In addition to the simulation of streamflow and sediment, HSPF contains algorithms for the simulation of water quality. Recent updates to HSPF (1989) included new algorithms for simulating water quality in streams affected by acid mine drainage. The comprehensive modeling of streamflow and water quality may provide useful information for assessing the cumulative hydrologic impacts of mining.

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Appendix 1. Hydrologic Simulation Program-Fortran user control input file for the Stony Fork Basin

```
RUN
 Any card with *** is ignored by the program HSPF,
    so they are used for comments and explanations. ***
GLOBAL
    HSPF MODEL FOR UPPER STONY FORK BASIN NEAR GIBBON GLADE,PA.
  START       1985/10/01        END    1989/09/30
  RUN INTERP OUTPUT LEVEL    3
  RESUME     0 RUN     1 TSSFL       WDMSFL   16
END GLOBAL

OPN SEQUENCE
    INGRP              INDELT  1:00
      PERLND       1
      PERLND       2
      PERLND       3
      PERLND       4
      RCHRES       1
    END INGRP
END OPN SEQUENCE

EXT SOURCES
<-volume-> <member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name> ### <Name> # tem strg<-factor->strg <Name> ### ###        <Name> # #  ***
WDM    620 DEWP    ENGL                    PERLND   1   4 EXTNL  DTMPG
WDM   3112 PRCP    ENGL      1.00          PERLND   1   4 EXTNL  PREC
WDM    120 PET     ENGL       .74          PERLND   1   4 EXTNL  PETINP
WDM    600 SUN     ENGL      .042          PERLND   1   4 EXTNL  SOLRAD
WDM    640 WIND    ENGL                    PERLND   1   4 EXTNL  WINMOV
WDM    660 AIRT    ENGL      .90           PERLND   1   4 ATEMP  AIRTMP
END EXT SOURCES


NETWORK
************************************************************************************
***
***                  LAND USE IDENTIFICATION
***
***               PERLND #               LAND USE
***             ------------           ----------------
***                  1                   FORESTLAND
***                  2                   CROPLAND
***                  3                   STRIP MINE
***                  4                   GRASSLAND/PASTURE
*****************************************************************************
PERLND   1 PWATER PERO          32.0       RCHRES   1      INFLOW IVOL    1
PERLND   2 PWATER PERO           4.3       RCHRES   1      INFLOW IVOL    1
PERLND   3 PWATER PERO           3.3       RCHRES   1      INFLOW IVOL    1
PERLND   4 PWATER PERO          10.0       RCHRES   1      INFLOW IVOL    1
PERLND   1 SEDMNT SOSED        6.9         RCHRES   1      INFLOW ISED    1
PERLND   1 SEDMNT SOSED      157.4         RCHRES   1      INFLOW ISED    2
PERLND   1 SEDMNT SOSED      218.3         RCHRES   1      INFLOW ISED    3
PERLND   2 SEDMNT SOSED         0.92       RCHRES   1      INFLOW ISED    1
PERLND   2 SEDMNT SOSED       21.1         RCHRES   1      INFLOW ISED    2
PERLND   2 SEDMNT SOSED       29.1         RCHRES   1      INFLOW ISED    3
PERLND   3 SEDMNT SOSED       0.72         RCHRES   1      INFLOW ISED    1
PERLND   3 SEDMNT SOSED       16.5         RCHRES   1      INFLOW ISED    2
PERLND   3 SEDMNT SOSED       22.7         RCHRES   1      INFLOW ISED    3
PERLND   4 SEDMNT SOSED       2.17         RCHRES   1      INFLOW ISED    1
PERLND   4 SEDMNT SOSED       49.6         RCHRES   1      INFLOW ISED    2
PERLND   4 SEDMNT SOSED       68.2         RCHRES   1      INFLOW ISED    3
END NETWORK
```

```
EXT TARGETS
<-volume-> <-GRP> <-MEMBER_><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name> ###        <NAME> # #<-factor->strg <Name> ### <Name> #  tem strg strg***
RCHRES   1 HYDR   RO                1.0 AVER WDM   3060 MFLO     ENGL AGGR REPL
RCHRES   1 HYDR   RO                1.0 SAME WDM   3064 MFLO     ENGL AGGR REPL
RCHRES   1 SEDTRN ROSED  4          1.0 SAME WDM   3500 SFLO     ENGL AGGR REPL
RCHRES   1 SEDTRN SSED   4          1.0 AVER WDM   3510 SSED     ENGL AGGR REPL
END EXT TARGETS

PERLND
  ACTIVITY
    #THRU# ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC***
    1    4    0    1    1    1    0    0    0    0    0    0    0     0
  END ACTIVITY
  PRINT-INFO
 ***#THRU# ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC PIVL  PYR
    1    4    6    5    5    5    6    6    6    6    6    6    6    6    6    9
  END PRINT-INFO
  GEN-INFO
                                         1=ENGL 2=METR PRINT FILES ***
    #THRU#<-----NAME--------->NBLKS<----UNITS----> ENGL METR  ***
    1    4  SFT Fork Trib          1    1    1    1    6    0
  END GEN-INFO

*************************************************************************************
***
***                                 SNOW MELT CALCULATIONS
***
  SNOW-PARM1
     PLS        LAT         ELEV         SHADE    SNOWCF       COVIND     ***
    #  - #      ##.#        ####         #.#        #.#          ##        ***
    1           39.75       1800         0.9        1.6         0.1
    2    4      39.75       1800         0.1        1.6         0.1
  END SNOW-PARM1
  SNOW-PARM2

    PLS        RDCSN      TSNOW       SNOEVP      CCFACT     MWATER     MGMELT     ***
    #  - #      ##.#       ####         #.#         #.#         ##        ###       ***
    1    4      .15         32.0       0.05         0.5         .03      .0001
  END SNOW-PARM2
  PWAT-PARM1
    #thru# CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE                ***
    1    4    1    0    0    1    1    0    0    0    1
  END PWAT-PARM1

  PWAT-PARM2
    #THRU#FOREST       LZSN     INFILT      LSUR      SLSUR      KVARY      AGWR***
    1       0.2        6.00       .060       400.        .20          .00      .90
    2       0.1        5.00       .010       400.        .20          .00      .90
    3       0.1        8.00       .025       400.        .20          .00      .90
    4       0.0        6.00       .030       400.        .20          .00      .90
  END PWAT-PARM2


  PWAT-PARM3
    #THRU# ***PETMAX     PETMIN     INFEXP     INFILD     DEEPFR     BASETP     AGWETP
    1    4       39.        33.        1.0        1.0       0.02        .02        .01
  END PWAT-PARM3

  PWAT-PARM4
```

```
  #THRU# CEPSC      UZSN      NSUR     INTFW       IRC     LZETP    ***
  1    4            0.75      .150      2.5       0.15      0.20
END PWAT-PARM4


MON-INTERCEP
  #THRU#  JAN  FEB  MAR  APR  MAY JUNE JULY  AUG SEPT  OCT  NOV  DEC ***
  1       .01  .01  .01  .02  .04  .23  .33  .33  .33  .33  .10  .01
  2       .01  .01  .01  .01  .03  .15  .20  .20  .15  .15  .05  .01
  3    4  .01  .01  .01  .01  .03  .04  .04  .04  .03  .03  .01  .01
END MON-INTERCEP

MON-UZSN
  #THRU#  JAN  FEB  MAR  APR  MAY JUNE JULY  AUG SEPT  OCT  NOV  DEC ***
  1    4  .05  .05  .05  .09  0.1  1.0  1.3  1.3  1.5  1.5  .90  .25
END MON-UZSN

MON-LZETPARM
  #THRU#  JAN  FEB  MAR  APR  MAY JUNE JULY  AUG SEPT  OCT  NOV  DEC ***
  1       .02  .02  .03  .05  .07  .25  .75  .85  .85  .75  .20  .02
  2       .02  .02  .03  .04  .05  .20  .65  .75  .75  .55  .02  .02
  3    4  .02  .02  .03  .04  .05  .20  .45  .55  .50  .25  .07  .02
END MON-LZETPARM

PWAT-STATE1
  #THRU#  CEPS      SURS      UZS      IFWS       LZS      AGWS  *** GWVS
  1       0.00      0.00      0.40     0.00       4.00     1.00      0.00
  2       0.00      0.00      0.40     0.00       4.00     1.00      0.00
  3    4  0.00      0.00      0.40     0.00       4.00     1.00      0.00
END PWAT-STATE1
SED-PARM1
 <PLS>***
 # - #        CRV  VSIV SDOP ***
 1            0    0    1
 2            1    0    1
 3            0    0    1
 4            0    0    1
END SED-PARM1

SED-PARM2
  <PLS>***
  # - #         SMPF      KRER       JRER       AFFIX      COVER    NVSI***
  1             1.00      0.60       3.00       0.50       0.98     0
  2             0.50      0.60       1.50       0.25       0.50     0
  3             0.50      0.60       1.25       0.10       0.50     0
  4             1.00      0.60       3.00       0.50       0.98     0
END SED-PARM2

SED-PARM3
  <PLS>***
  # - #        KSER      JSER      KGER       JGER***
  1            0.60      3.00       .50       3.0
  2            0.60      1.50       .50       2.0
  3            0.60      1.50       .50       2.0
  4            0.60      2.50       .50       3.0
END SED-PARM3

MON-COVER
  <PLS>  MONTHLY VALUES FOR EROSION RELATED COVER***
  # - #   JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
  2       .35  .35  .35  .00  .10  .45  .95  .90  .80  .55  .35  .35
```

```
  END MON-COVER

END PERLND
RCHRES
  ACTIVITY
    RCHRES  ACTIVE SECTIONS ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1        1    1    0    0    1    0    0    0    0    0
  END ACTIVITY
  GEN-INFO
    RCHRES       NAME         NEXITS   UNIT SYSTEMS   PRINTER ***
                                      USER T-SERIES  ENGL METR LKFG ***
    # -  #                                   IN  OUT                ***
    1       UPPER STONY FORK       1    1    1    1    6         0
  END GEN-INFO
  PRINT-INFO
   # - #    HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR ***
    1          5    6    6    6    5    6    6    6    6    6    0    9
  END PRINT-INFO
  HYDR-PARM1
    RCHRES  FLAGS FOR HYDR SECTION ***
    # -  #  VC A1 A2 A3  ODFVFG FOR EACH *** ODGTFG FOR EACH     FUNCT  FOR EACH
            FG FG FG FG  POSSIBLE   EXIT *** POSSIBLE   EXIT     POSSIBLE   EXIT
    1        0  1  1  1    4  0  0  0  0       0  0  0  0  0       2  0  0  0  0
  END HYDR-PARM1
  HYDR-PARM2
    RCHRES ***
    # -  #    FTABNO       LEN     DELTH      STCOR         KS       DB50 ***
    1              1      .500     100.         0.0        0.5      0.01
  END HYDR-PARM2
  HYDR-INIT
    RCHRES  INITIAL CONDITIONS FOR HYDR SECTION ***
    # -  # ***   VOL     INITIAL  VALUE  OF COLIND     INITIAL  VALUE  OF OUTDGT
           ***  AC-FT    FOR EACH  POSSIBLE   EXIT     FOR EACH  POSSIBLE   EXIT
    1            0.07      4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT


  ADCALC-DATA
    RCHRES           ***
    # -  #    CRRAT      VOL        ***
    1           3.5      0.0
  END ADCALC-DATA
  SANDFG
    RCHRES         ***
    # -  #  SNDFG     ***
    1          3
  END SANDFG
  SED-GENPARM
    RCHRES    BEDWID     BEDWRN        POR ***
    # -  #      (FT)       (FT)            ***
    1           10.0       3.00       0.35
  END SED-GENPARM
  SAND-PM
    RCHRES         D          W        RHO      KSAND     EXPSND ***
    # -  #      (IN)   (IN/SEC) ***
    1           0.01        1.2       2.50          1          1
  END SAND-PM
  SILT-CLAY-PM
    RCHRES         D          W        RHO      TAUCD      TAUCS          M ***
    # -  #      (IN)   (IN/SEC)               (LB/FT2)   (LB/FT2)(LB/FT2-D) ***
```

```
    1          0.001      .001        2.40
  END SILT-CLAY-PM
  SILT-CLAY-PM
    RCHRES          D           W        RHO      TAUCD      TAUCS          M ***
    # - #        (IN)   (IN/SEC)               (LB/FT2)   (LB/FT2)(LB/FT2-D) ***
    1         0.00004     .0001       2.30
  END SILT-CLAY-PM
  SSED-INIT
    RCHRES     SUSPENDED SED CONCS (MG/L) ***
    # - #         SAND       SILT      CLAY ***
    1              0.0       10.0      10
  END SSED-INIT
  BED-INIT
    RCHRES    BEDDEP  INITIAL BED COMPOSITION     ***
    # - #       (FT)       SAND      SILT      CLAY ***
    1            0.5       0.80      0.15      0.05
  END BED-INIT

END RCHRES
FTABLES
  FTABLE      1
 ROWS COLS                                             ***
   9   4
     DEPTH      AREA    VOLUME DISCHARGE               ***
      (FT)   (ACRES) (ACRE-FT)    (FT3/S)              ***
       0.6       .22      .000      0.00
       0.8       .61      0.20      0.03
       1.0      1.00      0.40      0.38
       1.2      1.50      0.70      3.70
       1.4      2.00      1.10      10.0
       1.6      2.50      3.00      20.0
       1.7      2.70      5.00      32.0
       1.8      3.00      9.00      45.0
       2.0      3.50      17.0      60.0
  END FTABLE1
END FTABLES
END RUN
```

Appendix 2. Hydrologic Simulation Program-Fortran user control input file for the Stony Fork Basin

```
RUN
 Any card with *** is ignored by the program HSPF,
    so they are used for comments and explanations. ***
GLOBAL
    CALIBRATION RUN #1: POPLAR RUN AT NORMALVILLE, PA
  START       1987/10/01        END    1989/09/30
  RUN INTERP OUTPUT LEVEL    1
  RESUME     0 RUN      1 TSSFL        WDMSFL   16
END GLOBAL
OPN SEQUENCE
    INGRP              INDELT  1:00
      PERLND       1
      PERLND       2
      PERLND       3
      PERLND       4
      RCHRES       1
    END INGRP
END OPN SEQUENCE
EXT SOURCES
<-volume-> <member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name> ### <Name> # tem strg<-factor->strg <Name> ### ###        <Name> # #  ***
WDM     620 DEWP     ENGL                  PERLND   1    4 EXTNL  DTMPG
WDM    2120 PRCP     ENGL       1.00       PERLND   1    4 EXTNL  PREC
WDM     120 PET      ENGL        .74       PERLND   1    4 EXTNL  PETINP
WDM     600 SUN      ENGL       .042       PERLND   1    4 EXTNL  SOLRAD
WDM     640 WIND     ENGL                  PERLND   1    4 EXTNL  WINMOV
WDM     660 AIRT     ENGL       .90        PERLND   1    4 ATEMP  AIRTMP
END EXT SOURCES
NETWORK
*************************************************************************************
***
***                     LAND USE IDENTIFICATION
***
***                  PERLND #                 LAND USE
***               ------------             ----------------
***
***                    1                    FORESTLAND
***                    2                    CROPLAND
***                    3                    SURFACE MINE
***                    4                    GRASSLAND
****************************************************************************
PERLND   1 PWATER PERO         301.1       RCHRES   1      INFLOW IVOL   1
PERLND   2 PWATER PERO          17.3       RCHRES   1      INFLOW IVOL   1
PERLND   3 PWATER PERO           81.6      RCHRES   1      INFLOW IVOL   1
PERLND   4 PWATER PERO          70.9       RCHRES   1      INFLOW IVOL   1
PERLND   1 SEDMNT SOSED        23.31       RCHRES   1      INFLOW ISED   1
PERLND   1 SEDMNT SOSED       1643         RCHRES   1      INFLOW ISED   2
PERLND   1 SEDMNT SOSED       1947         RCHRES   1      INFLOW ISED   3
PERLND   2 SEDMNT SOSED          1.39      RCHRES   1      INFLOW ISED   1
PERLND   2 SEDMNT SOSED        98.3        RCHRES   1      INFLOW ISED   2
PERLND   2 SEDMNT SOSED       116.45       RCHRES   1      INFLOW ISED   3
PERLND   3 SEDMNT SOSED        6.32        RCHRES   1      INFLOW ISED   1
PERLND   3 SEDMNT SOSED       445.2        RCHRES   1      INFLOW ISED   2
PERLND   3 SEDMNT SOSED       527.7        RCHRES   1      INFLOW ISED   3
PERLND   4 SEDMNT SOSED         5.48       RCHRES   1      INFLOW ISED   1
PERLND   4 SEDMNT SOSED       386.8        RCHRES   1      INFLOW ISED   2
PERLND   4 SEDMNT SOSED       458.5        RCHRES   1      INFLOW ISED   3
END NETWORK
EXT TARGETS
<-volume-> <-GRP> <-MEMBER_><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name> ###        <NAME> # #<-factor->strg <Name> ### <Name> #  tem strg strg***
```

```
RCHRES   1 HYDR    RO              1.0 AVER WDM   2060 MFLO     ENGL AGGR REPL
RCHRES   1 HYDR    RO              1.0 AVER WDM   2064 MFLO     ENGL      REPL
RCHRES   1 SEDTRN ROSED  4         1.0 SAME WDM   2500 SFLO     ENGL      REPL
RCHRES   1 SEDTRN SSED   4         1.0 AVER WDM   2510 SSED     ENGL      REPL
END EXT TARGETS
PERLND
  ACTIVITY
    #THRU# ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC***
    1    4    0    1    1    1    0    0    0    0    0    0    0    0
  END ACTIVITY
  PRINT-INFO
 ***#THRU# ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC PIVL  PYR
    1    4    6    5    5    5    6    6    6    6    6    6    6    6    6    9
  END PRINT-INFO
  GEN-INFO
                                     1=ENGL 2=METR PRINT FILES ***
    #THRU#<-----NAME--------->NBLKS<----UNITS----> ENGL METR  ***
    1    4  POPLAR RUN             1    1    1    1    6    0
  END GEN-INFO
**************************************************************************************
***
***                                SNOW MELT CALCULATIONS
***
  SNOW-PARM1
     PLS       LAT        ELEV        SHADE    SNOWCF      COVIND    ***
    #  - #     ##.#       ####         #.#       #.#         ##       ***
    1          39.75      1800         0.9       1.3        0.1
    2    4     39.75      1800         0.1       1.3        0.1
  END SNOW-PARM1
  SNOW-PARM2
    PLS        RDCSN      TSNOW      SNOEVP     CCFACT     MWATER    MGMELT     ***
    #  - #     ##.#       ####         #.#        #.#         ##        ###      ***
    1    4     .15         32.0       0.05        0.5        .03      .0001
  END SNOW-PARM2
  PWAT-PARM1
    #thru# CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE                ***
    1    4    1    0    0    1    1    0    0    0    1
  END PWAT-PARM1
  PWAT-PARM2
    #THRU#FOREST       LZSN      INFILT      LSUR      SLSUR      KVARY     AGWR***
    1       0.2         6.00       .060       400.        .20         .00      .90
    2       0.1         5.00       .010       400.        .20         .00      .90
    3       0.1         8.00       .025       400.        .20         .00      .90
    4       0.0         6.00       .030       400.        .20         .00      .90
  END PWAT-PARM2


  PWAT-PARM3
    #THRU# ***PETMAX     PETMIN     INFEXP     INFILD     DEEPFR     BASETP     AGWETP
    1    4       39.        33.        1.0        1.0       0.02       .02        .01
  END PWAT-PARM3

  PWAT-PARM4
    #THRU# CEPSC       UZSN       NSUR      INTFW       IRC       LZETP    ***
    1    4              0.75       .150       2.5        0.15       0.20
  END PWAT-PARM4


  MON-INTERCEP
    #THRU#   JAN  FEB  MAR  APR  MAY JUNE JULY  AUG SEPT  OCT  NOV  DEC ***
    1        .01  .01  .01  .02  .04  .23  .33  .33  .33  .33  .10  .01
```

```
    2        .01  .01  .01  .01  .03  .15  .20  .20  .15  .15  .05  .01
    3    4   .01  .01  .01  .01  .03  .04  .04  .04  .03  .03  .01  .01
  END MON-INTERCEP

  MON-UZSN
    #THRU#   JAN  FEB  MAR  APR  MAY JUNE JULY  AUG SEPT  OCT  NOV  DEC ***
    1    4   .05  .05  .05  .09  0.1  1.0  1.3  1.3  1.5  1.5  .90  .25
  END MON-UZSN

  MON-LZETPARM
    #THRU#   JAN  FEB  MAR  APR  MAY JUNE JULY  AUG SEPT  OCT  NOV  DEC ***
    1        .02  .02  .03  .05  .07  .25  .75  .85  .85  .75  .20  .02
    2        .02  .02  .03  .04  .05  .20  .65  .75  .75  .55  .02  .02
    3    4   .02  .02  .03  .04  .05  .20  .45  .55  .50  .25  .07  .02
  END MON-LZETPARM

  PWAT-STATE1
    #THRU#  CEPS      SURS      UZS      IFWS       LZS      AGWS  *** GWVS
    1       0.00      0.00      0.40     0.00       4.00     1.00       0.00
    2       0.00      0.00      0.40     0.00       4.00     1.00       0.00
    3    4  0.00      0.00      0.40     0.00       4.00     1.00       0.00
  END PWAT-STATE1

  SED-PARM1
   <PLS>***
   #  - #       CRV  VSIV SDOP ***
   1             0    0    1
   2             1    0    1
   3             0    0    1
   4             0    0    1
  END SED-PARM1
  SED-PARM2
    <PLS>***
    # - #          SMPF      KRER       JRER       AFFIX      COVER    NVSI***
    1              1.00      0.60       3.00       0.50       0.98     0
    2              0.50      0.60       1.50       0.25       0.50     0
    3              0.50      0.60       1.25       0.10       0.50     0
    4              1.00      0.60       3.00       0.50       0.98     0
  END SED-PARM2

  SED-PARM3
    <PLS>***
    # - #         KSER       JSER       KGER       JGER***
    1             0.60       3.00        .50       3.0
    2             0.60       1.50        .50       2.0
    3             0.60       1.50        .50       2.0
    4             0.60       2.50        .50       3.0
  END SED-PARM3

  MON-COVER
    <PLS>  MONTHLY VALUES FOR EROSION RELATED COVER***
    # - #    JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC***
    2        .35  .35  .35  .00  .10  .45  .95  .90  .80  .55  .35  .35
  END MON-COVER

END PERLND

RCHRES
  ACTIVITY
    RCHRES  ACTIVE SECTIONS ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
```

```
  1         1    1    0    0    1    0    0    0    0    0
END ACTIVITY
GEN-INFO
  RCHRES        NAME         NEXITS   UNIT SYSTEMS   PRINTER ***
                                    USER T-SERIES  ENGL METR LKFG ***
  # -  #                                   IN  OUT               ***
  1      POPLAR      RUN          1    1    1    1    6         0
END GEN-INFO
PRINT-INFO
 # - #   HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR ***
  1         5    6    6    6    5    6    6    6    6    6    0    9
END PRINT-INFO
HYDR-PARM1
  RCHRES  FLAGS FOR HYDR SECTION ***
  # -  #  VC A1 A2 A3  ODFVFG FOR EACH *** ODGTFG FOR EACH     FUNCT  FOR EACH
          FG FG FG FG  POSSIBLE   EXIT *** POSSIBLE   EXIT     POSSIBLE   EXIT
  1        0  1  1  1    4  0  0  0  0       0  0  0  0  0       2  0  0  0  0
END HYDR-PARM1
HYDR-PARM2
  RCHRES ***
  # -  #    FTABNO      LEN    DELTH     STCOR        KS      DB50 ***
  1              1     2.00    200.        0.0       0.0      0.01
END HYDR-PARM2
HYDR-INIT
  RCHRES  INITIAL CONDITIONS FOR HYDR SECTION ***
  # -  # ***   VOL     INITIAL  VALUE  OF COLIND     INITIAL  VALUE  OF OUTDGT
         *** AC-FT     FOR EACH  POSSIBLE    EXIT     FOR EACH  POSSIBLE    EXIT
  1           0.07       4.0  4.0  4.0  4.0  4.0       0.0  0.0  0.0  0.0  0.0
END HYDR-INIT
ADCALC-DATA
  RCHRES          ***
  # -  #    CRRAT      VOL       ***
  1           3.5     0.0
END ADCALC-DATA
SANDFG
  RCHRES        ***
  # -  #  SNDFG     ***
  1         3
END SANDFG
SED-GENPARM
  RCHRES    BEDWID     BEDWRN        POR ***
  # -  #      (FT)       (FT)            ***
  1           10.0       3.00       0.35
END SED-GENPARM
SAND-PM
  RCHRES          D          W       RHO      KSAND     EXPSND ***
  # -  #       (IN)   (IN/SEC) ***
  1           0.01        1.2      2.50         1          1
END SAND-PM
SILT-CLAY-PM
  RCHRES          D          W       RHO      TAUCD      TAUCS          M ***
  # -  #       (IN)   (IN/SEC)              (LB/FT2)   (LB/FT2)(LB/FT2-D) ***
  1          0.001       .001      2.40
END SILT-CLAY-PM
SILT-CLAY-PM
  RCHRES          D          W       RHO      TAUCD      TAUCS          M ***
  # -  #       (IN)   (IN/SEC)              (LB/FT2)   (LB/FT2)(LB/FT2-D) ***
  1        0.00004      .0001      2.30
END SILT-CLAY-PM

SSED-INIT
```

```
    RCHRES      SUSPENDED SED CONCS (MG/L) ***
    # - #        SAND       SILT      CLAY  ***
    1             0.0       1.00      6.
  END SSED-INIT
  BED-INIT
    RCHRES    BEDDEP  INITIAL BED COMPOSITION     ***
    # - #      (FT)       SAND      SILT      CLAY ***
    1           0.5       0.80      0.15      0.05
  END BED-INIT
END RCHRES
FTABLES
  FTABLE    1
ROWS COLS ***
  16    4
    DEPTH      AREA   VOLUME   DISCHARGE ***
     (FT)     (ACRE)  (ACRE-FT)  (FT3/S)   ***
      0.0       0.0       0.0       0.0
      0.3      25.0      3.50       0.3
      0.4      29.0      4.10       1.4
      0.6      31.0      4.40       6.0
      0.8      35.0      4.90      13.0
      1.1      38.0      5.60      27.0
      1.3      40.0      6.30      45.0
      1.6      45.0      6.90      68.0
      1.8      50.0      8.10      90.0
      2.2      60.0     10.00     120.0
      2.4      75.0     12.50     140.0
      2.8     100.0     16.20     206.0
      3.3     125.0     25.00     300.0
      4.1     150.0     40.00     450.0
      5.0     300.0     80.00     700.0
      6.0     500.0    150.00    1000.0
  END FTABLE1
END FTABLES
END RUN
```


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