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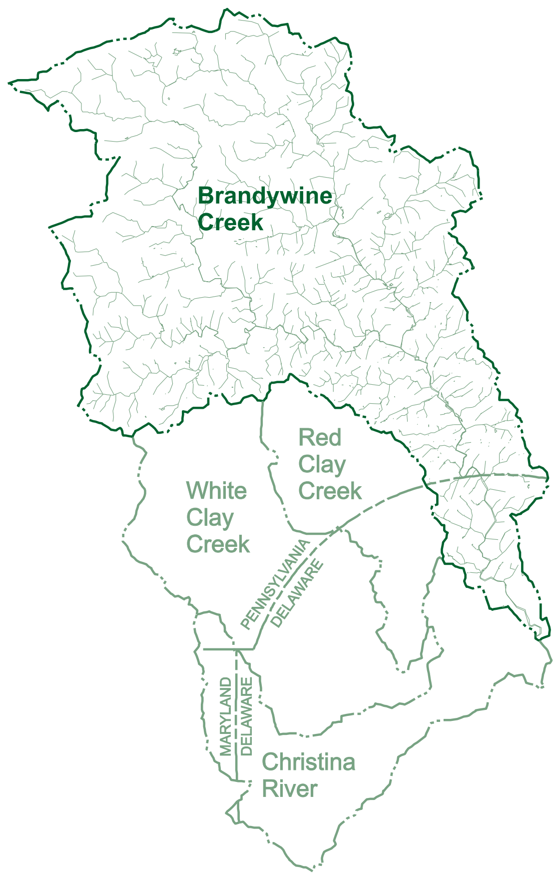
SIMULATION OF STREAMFLOW AND WATER QUALITY IN THE BRANDYWINE CREEK SUBBASIN OF THE CHRISTINA RIVER BASIN, PENNSYLVANIA AND DELAWARE, 1994-98

Water-Resources Investigations Report 02-4279



In cooperation with the

DELAWARE RIVER BASIN COMMISSION,

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL, *and the*

PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION

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by Lisa A. Senior and Edward H. Koerkle

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New Cumberland, Pennsylvania
2003

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CONVERSION FACTORS, DATUMS, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre	4,047	square meter
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
ounce, fluid (fl. oz)	0.02957	liter
gallon (gal)	3.785	liter
gallon (gal)	0.003785	cubic meter
million gallons (Mgal)	3,785	cubic meter
cubic inch (in^3)	0.01639	liter
cubic foot (ft^3)	0.02832	cubic meter
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer
cubic foot per day (ft^3/d)	0.02832	cubic meter per day
gallon per day per square mile [$(gal/d)/mi^2$]	0.001461	cubic meter per day per square kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second
million gallons per day per square mile [$(Mgal/d)/mi^2$]	1,461	cubic meter per day per square kilometer
inch per hour (in/h)	0.0254	meter per hour
inch per year (in/yr)	25.4	millimeter per year
	Mass	
ounce, avoirdupois (oz)	28.35	gram
pound, avoirdupois (lb)	0.4536	kilogram
ton, short (2,000 lb)	0.9072	megagram
ton, long (2,240 lb)	1.016	megagram
ton per day (ton/d)	0.9072	metric ton per day
ton per day per square mile [$(ton/d)/mi^2$]	0.3503	megagram per day per square kilometer
ton per year (ton/yr)	0.9072	metric ton per year
	Density	
pound per cubic foot (lb/ft^3)	16.02	kilogram per cubic meter
pound per cubic foot (lb/ft^3)	0.01602	gram per cubic centimeter

CONVERSION FACTORS, DATUMS, AND ABBREVIATED WATER-QUALITY UNITS—Continued

Multiply	By	To obtain
	Application rate	
pounds per acre per year [(lb/acre)/yr]	1.121	kilograms per hectare per year
	Temperature	
degree Fahrenheit (°F)	°C=5/9.(°F-32)	degree Celsius

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29); horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Abbreviated water-quality units used in report:

- L, liter
- mg/L, milligrams per liter
- µg/L, micrograms per liter
- mL, milliliter
- µm, micrometer
- µS/cm, microsiemens per centimeter at 25 degrees Celsius

SIMULATION OF STREAMFLOW AND WATER QUALITY IN THE BRANDYWINE CREEK SUBBASIN OF THE CHRISTINA RIVER BASIN, PENNSYLVANIA AND DELAWARE, 1994-98

By Lisa A. Senior and Edward H. Koerkle

ABSTRACT

The Christina River Basin drains 565 mi^2 (square miles) in Pennsylvania and Delaware. Water from the basin is used for recreation, drinking-water supply, and to support aquatic life. The Christina River Basin includes the major subbasins of Brandywine Creek, Red Clay Creek, White Clay Creek, and Christina River. The Brandywine Creek is the largest of the subbasins and drains an area of 327 mi^2. Water quality in some parts of the Christina River Basin is impaired and does not support designated uses of the streams. A multi-agency water-quality management strategy included a modeling component to evaluate the effects of point and nonpoint-source contributions of nutrients and suspended sediment on streamwater quality. To assist in nonpoint-source evaluation, four independent models, one for each of the four main subbasins of the Christina River Basin, were developed and calibrated using the model code Hydrological Simulation Program—Fortran (HSPF). Water-quality data for model calibration were collected in each of the four main subbasins and in small subbasins predominantly covered by one land use following a nonpoint-source monitoring plan. Under this plan, stormflow and base-flow samples were collected during 1998 at six sites in the Brandywine Creek subbasin and five sites in the other subbasins.

The HSPF model for the Brandywine Creek Basin simulates streamflow, suspended sediment, and the nutrients, nitrogen and phosphorus. In addition, the model simulates water temperature, dissolved oxygen, biochemical oxygen demand, and plankton as secondary objectives needed to support the sediment and nutrient simulations. For the model, the basin was subdivided into 35 reaches draining areas that ranged from 0.6 to 18 mi^2. Three of the reaches contain a regulated reservoir. Eleven different pervious land uses and two impervious land uses were selected for simulation. Land-use areas were determined from 1995 land-use data. The predominant land uses in the basin are forested, agricultural, residential, and urban.

The hydrologic component of the model was run at an hourly time step and calibrated using streamflow data for eight U.S. Geological Survey (USGS) streamflow-measurement stations for the period of January 1, 1994, through October 29, 1998. Daily precipitation data for three National Oceanic and Atmospheric Administration (NOAA) gages and hourly data for one NOAA gage were used for model input. The difference between observed and simulated streamflow volume ranged from -2.7 to 3.9 percent for the nearly 5-year period at the eight calibration sites. Annual differences between observed and simulated streamflow generally were greater than the overall error. For example, at a site near the bottom of the basin (drainage area of 237 mi^2), annual differences between observed and simulated streamflow ranged from -14.0 to 18.8 percent and the overall error for the 5-year period was 1.0 percent. Calibration errors for 36 storm periods at the eight calibration sites for total volume, low-flow-recession rate, 50-percent lowest flows, 10-percent highest flows, and storm peaks were within the recommended criteria of 20 percent or less. Much of the error in simulating storm events on an hourly time step can be attributed to uncertainty in the rainfall data.

The water-quality component of the model was calibrated using monitoring data collected at six USGS streamflow-measurement stations with variable water-quality monitoring periods ending October 1998. Because of availability, monitoring data for suspended-solids concentrations were used as surrogates for suspended-sediment concentrations, although suspended-solids data may underestimate suspended sediment and affect apparent accuracy of the suspended-sediment simulation. Comparison of observed to simulated loads for two to six individual storms in 1998 at each of the six monitoring sites indicate that simulation error is commonly as large as an order of magnitude for suspended sediment and nutrients. The simulation error tends to be smaller for dissolved nutrients than for particulate nutrients. Errors of 40 percent or less for monthly or annual values indicate a fair to good water-quality calibration according to recommended criteria, with much larger errors possible for individual events. Assessment of the water-quality calibration under stormflow conditions is limited by the relatively small amount of available water-quality data in the basin. Duration curves for simulated and reported sediment concentration at Brandywine Creek at Wilmington, Del., are similar, indicating model performance is better when evaluated over longer periods than when evaluated on individual storm events.

Users of the Brandywine Creek HSPF model should be aware of model limitations and consider the following if the model is used for predictive purposes: flow and water quality for individual storm events may not be well simulated, but the model performance is reasonable when measured over longer periods of time; the observed flow-duration curve for the simulation period is similar to the long-term flow-duration curve at Brandywine Creek at Chadds Ford, Pa., indicating that the calibration period is representative of all but the highest 1 percent of flow at that site; relative errors in flow and water-quality simulations are greater for smaller drainage areas than for larger areas; and calibration for water quality was based on limited data.

INTRODUCTION

The Christina River Basin (fig. 1), which includes White Clay Creek (drainage area of 108 mi^2), Red Clay Creek (54 mi^2), and Brandywine Creek (327 mi^2), drains approximately 565 mi^2 in southeastern Pennsylvania, northern Delaware, and a small part of northeastern Maryland. The Christina River and its tributaries provide drinking water for more than 40 percent of the residents of Chester County, Pa., and more than 50 percent of the residents of New Castle County, Del.

Stream waters of the Christina River Basin are used for public water supply and recreation and to support aquatic life. Some of these uses are threatened because of water-quality impairment caused by point and nonpoint sources of contamination. Causes of impairment have been identified as sediment, nutrients, and bacteria (Greig and others, 1998). In addition, some agricultural areas of the basin are undergoing urbanization, and the effects of land-use changes on water quality and quantity are unknown. The states of Delaware and Pennsylvania need tools to evaluate alternative approaches for addressing existing water-quantity and water-quality problems and for forecasting future conditions.

A 5-year water-quality management strategy for the Christina River Basin starting in 1995 was conceived and directed by the Delaware Department of Natural Resources and Environmental Control (DNREC), Pennsylvania Department of Environmental Protection (PADEP), Chester County Conservation District, Water Resources Agency of New Castle County, Chester County Water Resources Authority, New Castle County Conservation District, Delaware River Basin Commission (DRBC) U.S. Environmental Protection Agency (USEPA), watershed groups, and other concerned organization, groups, and individuals. To assist with the water-quality management process, the U.S. Geological Survey (USGS) developed a nonpoint-source monitoring plan and constructed a hydrologic and water-quality model of the basin to estimate sediment and nutrient contributions from nonpoint sources. USGS conducted the Christina River Basin nonpoint-source monitoring and modeling in cooperation with DRBC, DNREC, and PADEP.

A widely used computer model, Hydrological Simulation Program—Fortran (HSPF), was selected to meet the water-resources planning and management needs for the Christina River Basin. The watershed modeling program, HSPF, can be used to simulate the delivery of nonpoint-source contaminants to main-stem streams. The model can simulate hydrologic processes, physical transport of nonpoint-source contaminants, and in-stream chemical reactions. This model also can be used to evaluate options for managing contaminants from nonpoint and point sources and provide a comprehensive method of calculating nonpoint-source loads to meet total maximum daily load requirements. Data required for calibration of the HSPF model include concentrations of contaminants of interest over a range of hydrologic conditions from various land-use areas that are expected to differ in hydrologic response and contribution of nonpoint-source contaminants.

The nonpoint-source water-quality sampling plan, executed in 1997-98, provided streamflow, nutrient, and suspended solids data that were used to (1) estimate concentrations and loads of the selected constituents from various land uses in the Christina River Basin; and (2) calibrate an HSPF model for each major subbasin for these selected constituents. Because HSPF can be applied only to free-flowing, non-tidal streams, each of the four major subbasins in the Christina River Basin was modeled separately. The lower reaches of the Christina River and its tributaries, Brandywine Creek, White Clay Creek, and Red Clay Creek, are tide-affected. Nonpoint-source water-quality and streamflow data were collected at four main-stem sites on the lower free-flowing reaches of the Christina River and Brandywine, White Clay, and Red Clay Creeks and at seven subbasin sites selected principally for land-use characterization (fig. 1; table 1). All sites were equipped for continuous streamflow recording and automated water-

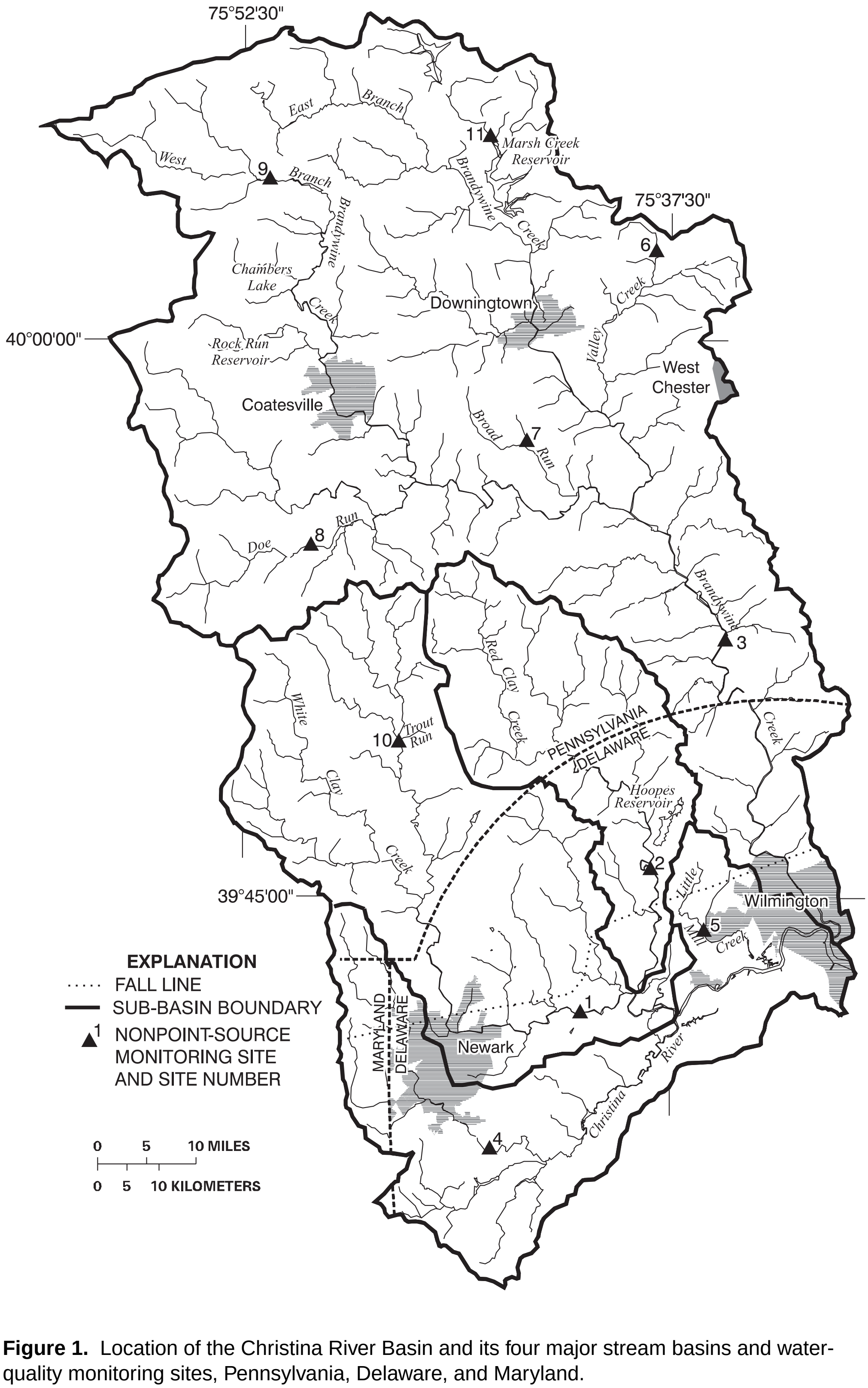


Figure 1. Location of the Christina River Basin and its four major stream basins and water-quality monitoring sites, Pennsylvania, Delaware, and Maryland.

Table 1. *Nonpoint-source water-quality monitoring sites, Christina River Basin, Pennsylvania and Delaware (See figure 1 for location of sites)*

Type of nonpoint-source water-quality sampling site	Site code on map	Location	U.S. Geological Survey streamflow-measurement station number	Drainage area (square miles)
Overall basin main-stem site				
White Clay Creek	1	White Clay Creek near Newark, Del.	01479000	89.1
Red Clay Creek	2	Red Clay Creek near Woodale, Del.	01480000	47.0
Brandywine Creek	3	Brandywine Creek at Chadds Ford, Pa.	01481000	287
Christina River	4	Christina River at Cooch's Bridge, Del.	01478000	20.5
Single land-use sampling sites				
Urban	5	Little Mill Creek near Newport, Del.	[1]01480095	5.24
Residential - sewered	6	Unnamed tributary to Valley Creek at Highway 30 at Exton, Pa.	[2]01480878	1.47
Residential - unsewered (on septic systems)	7	Little Broad Run near Marshallton, Pa.	[2]01480637	.60
Agricultural - row crop	8	Doe Run above tributary at Springdell, Pa.	[2]014806318	11.7
Agricultural - livestock	9	West Branch Brandywine Creek near Honey Brook, Pa.	01480300	18.7
Agricultural - mushroom	10	Trout Run at Avondale, Pa.	[2]01478137	1.31
Forested	11	Marsh Creek near Glenmoore, Pa.	01480675	8.57

[1] Streamflow-measurement station restarted for study.
[2] New streamflow-measurement station constructed for study.

quality sampling. Six sites were at existing USGS streamflow-measurement stations (gages), one site (01480095) was at a discontinued streamflow-measurement station recommissioned for the study, and four new streamflow / water-quality sites (01480878, 01480637, 014806318, 01478137) were constructed (table 1).

The HSPF model for the largest of the subbasins, the Brandywine Creek Basin, was developed first and is discussed in this report. A subsequent report details the model for the White Clay Creek subbasin (Senior and Koerkle, 2003). HSPF models also are being done for the Red Clay Creek and Christina River subbasins. The HSPF model may be used to evaluate options for managing contaminants from nonpoint and point sources and can provide a comprehensive method of calculating nonpoint-source loads to meet total maximum daily load (TMDL) requirements. Currently, TMDL assessments are ongoing in the Christina River Basin.

Purpose and Scope

This report describes the development of an HSPF model constructed for the Brandywine Creek subbasin of the Christina River and the subsequent hydrologic and water-quality simulations. The main objective of modeling was to create a tool to estimate nonpoint-source loads of selected constituents over a range of hydrologic conditions. The model description includes explanation of the general aspects, model structure, spatial segmentation, parameterization, and limitations. In addition, data used for model-input and calibration are described. The HSPF model for the Brandywine Creek subbasin was used to simulate streamflow, water temperature, suspended sediment, and nutrients on an hourly basis for the calibration period January 1, 1994, through October 29, 1998. Additionally, the model was used to simulate water temperature, dissolved oxygen, biochemical oxygen demand, and plankton as secondary objectives needed to support the sediment and nutrient simulations. Calibration results, analysis of the model's sensitivity to parameter variation, and model limitations are presented and discussed for simulations of streamflow and water-quality constituents. Examples of model applications are given, including quantification of nonpoint-source loads from selected areas of the Brandywine Creek subbasin.

Previous Studies

An analysis of the trend in sediment yield for Brandywine Creek at Wilmington, Del., for the period from December 1946 to September 1955 was done by Guy (1957). An assessment of continuous stream temperature, dissolved oxygen concentration, pH, and specific conductance data at three stream sites on Brandywine Creek for the period 1970-80 was done by Murphy and others (1982). Data on water quality and stream invertebrates collected at numerous sites in the Brandywine Creek Basin as part of a long-term monitoring effort in Chester County, Pa., were evaluated for the period 1969-80 by Moore (1987) and published for the period of 1981-94 by Reif (1999). Historical trends in fecal coliform bacteria data at three stream sites on Brandywine Creek and a 1998 assessment of concentrations of fecal coliform bacteria throughout the Brandywine Creek Basin was presented by Town (2001). Flippo and Madden (1994) applied the HSPF model to four large reaches in the Brandywine Creek as part of a streamflow-routing study for the Delaware River.

Acknowledgments

Water-use data were obtained with the assistance of Gerald Kauffman of the Water Resources Agency at the University of Delaware, Robert Struble of the Brandywine Valley Association, and Craig Thomas of the Chester County Water-Resources Authority. Water-quality data for PADEP monitoring sites in Pennsylvania were provided by William Goman of PADEP. Information about agricultural uses was obtained from Daniel Greig and others at the Chester County Conservation District and the New Castle County Conservation District. Overall guidance for the project was provided by the modeling technical committee of the Christina River Basin Water-Quality Management group, including David Pollison of DRBC, Richard Greene and Hassan Mirsajadi of DNREC, William Goman of PADEP, Janet Bowers of Chester County Water Resources Authority, Gerald Kauffman of Water Resources Agency, and Larry Merrill of USEPA. In addition to those mentioned above, those who helped identify the need for the project include Nancy Goggin and Jennifer McDermott of DNREC, and Niki Kasi and Russell Wagner of PADEP.

DESCRIPTION OF STUDY AREA

The Brandywine Creek drains 327 mi^2 in southeastern Pennsylvania and northern Delaware. The headwaters of Brandywine Creek are in Chester County, Pa., and the stream flows south into New Castle County, Del., where it is tributary to the Christina River (fig. 1). A small area in the easternmost part of the basin is in Delaware County, Pa. The largest population centers in the basin are the city of Wilmington, Del., and the boroughs of Downingtown, Coatesville, and West Chester, Pa.

Physical Setting

The Brandywine Creek Basin encompasses areas in the Piedmont Physiographic Province in southeastern Pennsylvania (Berg and others, 1989) and the Piedmont and Coastal Plain Physiographic Provinces in northern Delaware. The topography of the Piedmont Physiographic Province is characterized by gently rolling uplands dissected by narrow valleys, whereas the topography of the Coastal Plain Province is characterized by nearly flat terrain. Elevation of the land surface ranges from near sea level to about 1,040 ft above sea level. Most of the basin is in the Piedmont Physiographic Province, which is underlain predominantly by metamorphic rocks of igneous and sedimentary origin. A small part in the southern tip of the basin, below the Fall Line, is in the Coastal Plain Physiographic Province, which is underlain by unconsolidated sediments.

Climate

The Brandywine Creek Basin has a modified humid continental climate. Winters are mild to moderately cold and summers are warm and humid. Normal mean annual air temperatures at National Oceanic and Atmospheric Administration (NOAA) weather station near the center of the basin in West Chester, Pa. (fig. 1), for 1971-2000 is 52.8°F (11.6°C) (National Oceanic and Atmospheric Administration, 2000a). Normal mean annual air temperatures (1971-2000) are cooler in the northern part of the basin (51.5°F at Coatesville, Pa.) than in the southern part of the basin (54.4°F at Wilmington, Del.) (National Oceanic and Atmospheric Administration, 2000a, 2000b). In West Chester, the normal mean temperature (1971-2000) for January, the coldest month, is 30.1°F (-1.4°C), and normal mean temperature (1971-2000) for July, the warmest month, is 74.7°F (23.7°C). Normal mean annual precipitation (1971-2000) at West Chester is 47.89 in. Precipitation is distributed fairly evenly throughout the year. In southeastern Pennsylvania and northern Delaware, snowfall is mainly in the months of December, January, February, and March.

Geology

The Brandywine Creek Basin is underlain by Paleozoic-age and older metamorphosed sedimentary and igneous rocks. The metasediments include schist, quartzite, and carbonate rocks. The Paleozoic-age and older rocks have been folded, faulted, and metamorphosed several times during their history, resulting in a structurally complex assemblage. The primary structural trends are east-northeast. In the southernmost part of the basin, below the Fall Line, these rocks are overlain by Cretaceous-age and quaternary-age sands and gravels of the Coastal Plain. These Coastal Plain sediments were deposited on the older bedrock, forming beds that thicken to the southeast.

Soils

Nine soil associations and 13 soil series are found in the Brandywine Creek Basin (fig. 2) (Kunkle, 1963; Matthews and Lavoie, 1970). In general, the soils have developed in place and are derived from the underlying bedrock. Most of the soils are developed on schist, gneiss, and quartzite, with the exception of the Haferstown-Conestoga-Guthrie association, which is developed on carbonate rocks, and soils south of the Fall Line, which are developed on unconsolidated Coastal Plain sediments.

The principal soil association is Glenelg-Manor-Chester, which overlies greater than 60 percent of the basin. Soils in this association generally are gently to moderately sloping and well drained. Surface permeabilities of individual soil series range from 0.6 to 2.0 in / h except for the Aldino, Hagerstown, Manor, and Neshaminy series. Permeabilities in these four series, which are limited in extent, range from 2.0 to 6.3 in / h.

Hydrology

The metamorphosed sedimentary and igneous rocks that underlie most of the Brandywine Creek Basin form fractured-rock aquifers. The competent bedrock is overlain by weathered rock, saprolite, and soil. The bedrock and overlying materials are recharged by precipitation. Ground water flows through the secondary openings (fractures) in fractured-rock aquifers and discharges locally to streams and springs. The sands and gravels of the Coastal Plain in the southern tip of the basin also are recharged by precipitation. Recharge to these sedimentary beds may discharge locally to streams and also may recharge the individual beds that dip to the southeast. Ground water in the Coastal Plain sands and gravels flows through primary openings (pore spaces).

Approximately half of the annual input of precipitation to the Brandywine Creek Basin is discharged as streamflow. The remaining precipitation is lost to evapotranspiration. Streamflow is composed of, on average, about 65 percent base flow (ground-water discharge) and 35 percent surface runoff (Sloto, 1994) with between-year variations of 10 percent not uncommon. Streams in the Brandywine Creek Basin are mostly low to moderate gradient. Channel bottoms in higher gradient reaches and forested areas primarily are exposed bedrock, sand, and gravel. In low-gradient reaches and pools, extensive sediment coverage of the channel bottoms can be found particularly in the northwest area of the basin where rowcrop agriculture is fairly extensive.

A number of hydraulic structures are located throughout the Brandywine Creek Basin (fig. 1). The primary purposes of these structures are flood control and impoundment. In the upper West Branch drainage, Chambers Lake and Rock Run Reservoirs, on tributaries to the West Branch, impound 1,170 and 770 acre-feet, respectively. Chambers Lake is regulated actively to augment West Branch flows in response to withdrawals by the City of Coatesville Authority and prevailing flow conditions. Rock Run is not regulated actively and serves as a water-supply reservoir. In the upper East Branch drainage, Marsh Creek Reservoir impounds 14,400 acre-feet and actively regulates releases on the basis of water-use withdrawals in the East Branch and average flows at Chadds Ford. Other hydraulic structures in the upper East Branch include Barneston and Beaver Creek flood-control structures and Struble Lake. In addition, a number of historic low-head dams are situated in the lower Brandywine Creek Basin.

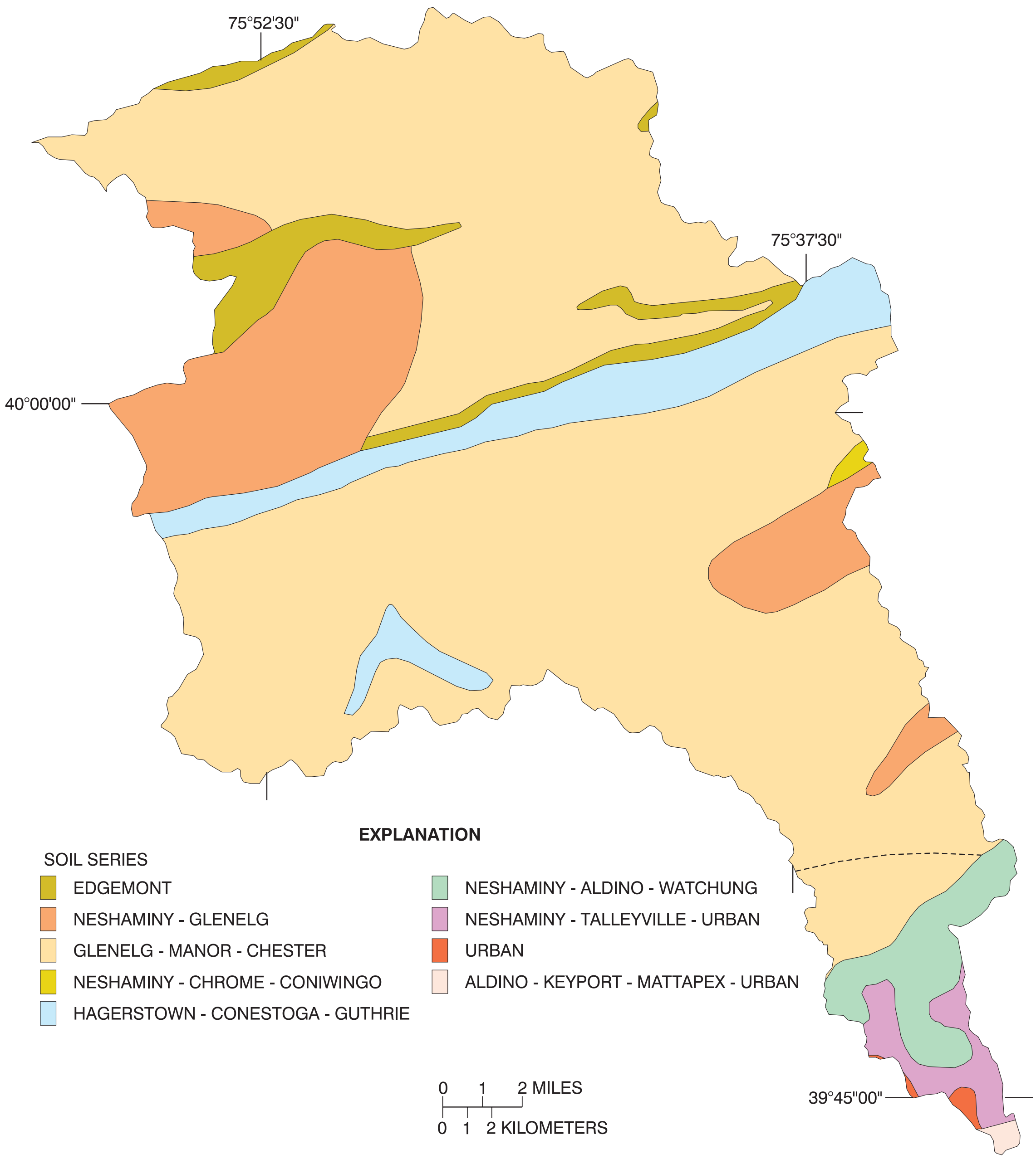


Figure 2. Mapped soil associations in the Brandywine Creek Basin, Pennsylvania and Delaware.

Land Use

Land use in the Brandywine Creek Basin in 1993-95 (Greig and others, 1998) was predominantly agricultural, forested, and residential, with lesser amounts of open and urban land, including industrial and commercial uses. From data compiled for the 1993-95 period, estimated land use in the basin is about 39 percent agricultural, 32 percent forested, 17 percent residential, 6 percent urban, 4 percent open, and 2 percent other.

Water Use

Water use in the Brandywine Creek Basin consists of withdrawals and discharges of surface water and ground water for residential, commercial, and industrial consumptive and non-consumptive uses. Typically, water from a surface-water intake or ground-water well is withdrawn, used as needed, and returned to the source as waste flow minus consumptive losses. Waste flows return to surface waters through wastewater treatment facilities and industrial discharges. In the less urbanized parts of the basin, ground water is the primary water supply through wells on individual properties. Wastewater in these non-sewered areas typically is discharged and infiltrates to ground water mainly through septic systems on individual properties. In and near population centers, public water suppliers use surface water as the main water source but may augment with ground water. A few public water systems rely on ground water for supply. Wastewater in urban areas generally is carried by sewers to treatment facilities that typically discharge to streams.

Some of the larger public water systems maintain complex withdrawal, distribution, and discharge facilities that allow water redistribution within or between basins. For example, the City of Coatesville Authority (CCA) withdraws from the West Branch Brandywine Creek Basin but has the option to import water from the West Branch Octoraro Creek in the Susquehanna River Basin, which borders the northwest side of the Brandywine Creek Basin. In addition, the CCA can distribute water such that allotments go to users in the East Branch Brandywine drainage, the Octoraro Creek drainage, Susquehanna River Basin, as well as the West Branch Brandywine drainage. The city of Wilmington, Del., is the largest water user in the Brandywine Creek Basin. Wilmington is permitted to withdraw up to 36 Mgal/d (U.S. Environmental Protection Agency, 2000a) or about 65 percent of all permitted withdrawals within the Brandywine Creek Basin.

In the Christina River Basin, impaired water quality has been linked to water-use processes such as wastewater treatment, industrial discharges, and septic systems (Greig and others, 1998). The effects of these processes on streamflow and water quality in the Brandywine can vary depending on their location and volumes.

DESCRIPTION OF MODEL

The numerical model HSPF includes a set of computer codes for algorithms used to simulate the hydrologic response of land areas to precipitation and flow through stream channels in a basin. The algorithms used to simulate these processes are described in detail by Bicknell and others (1997). The rainfall-driven simulation of streamflow includes response from pervious and impervious land areas and routing of water in the stream channel. Pervious and impervious land areas are assigned hydrologic-response parameters on the basis of land use and other characteristics such as slope. Streamflow routing is controlled by channel characteristics of model reaches. The HSPF model can be used to simulate free-flowing streams and well-mixed reservoirs but cannot be used to simulate tidal streams.

The HSPF model structure requires dividing the basin into multiple elements whose number and size reflect the range of selected hydrologic characteristics and the scope of available input data. A first step in structuring the model is segmenting the basin. Segmentation commonly is delimited by climatological or physical characteristics that would determine specific hydrologic response to precipitation. When little differences are apparent in physical characteristics, segmentation may be determined by the number and location of precipitation stations available for input. The basin also is subdivided into characteristic pervious (PERLND) and impervious (IMPLND) land-use types. Within each segment, each PERLND and IMPLND is assigned hydrologic-response parameters. These parameters control the partitioning and magnitude of hydrologic outputs in response to input precipitation. The stream channel is then partitioned into reaches (RCHRES). A RCHRES generally is delimited by major flow inputs (tributaries, etc.), calibration locations (streamflow gages, water-quality sites), and time-of-travel considerations. Each RCHRES receives flow from land area draining to that reach and from upstream RCHRES. Runoff, interflow, and ground water from each PERLND and IMPLND is directed to a RCHRES. Point-source withdrawals and discharges can be specified for the RCHRES where they are located. The overall model structure including assignment of time-series data (meteorological, streamflow, point-source withdrawals and discharges), reach connections, land-area to reach relations, channel characteristics, and land-use category response parameters are described in the user control input (UCI) file.

The hydrologic response of PERLNDs and IMPLNDs is handled by their respective modules. The water budget, or predicted total runoff, for pervious land is simulated using the section PWATER of the PERLND module. Total runoff is the sum of base flow (ground-water discharge to streams), interflow, and surface runoff. The hydrologic processes modeled by PWATER include infiltration of precipitation, interception by plant materials, evapotranspiration, surface runoff, interflow, and ground-water flow. Precipitation may be evaporated from, move through, and (or) remain in storage in surface interception, surface detention, interflow, upper soil zone, lower soil zone, and active ground water. Predicted total runoff for impervious land is simulated using the section IWATER of the IMPLND module. The hydrologic processes modeled by IWATER include retention, routing, and evaporation of water from impervious areas.

Runoff derived from snowfall, snow accumulation, and snow melt is simulated using the module SNOW. Meteorological data are used to determine when precipitation is rain or snow, calculate an energy balance for the snow pack, and determine the effect of heat fluxes on the snow pack. The amount of precipitation that occurs as snow in the Brandywine Creek Basin is highly variable. Some years have no snow; others may have snow and snow cover for most of the winter months. The assumption was made that simulating snow would result in a more accurate streamflow simulation. However, periods cold enough to have substantial snowfall also are likely to suffer from poor observed streamflow record because of channel ice at stream-gaging locations.

The routing of water in the stream channel is simulated by the section HYDR of the module RCHRES. Routing is based on kinematic-wave or storage-routing methods, where flow is assumed to be unidirectional. HYDR calculates rates of outflow and change in storage for a free-flowing reach or completely mixed reservoir. RCHRES inflows include runoff from PERLND and IMPLND land areas draining to that reach, water from upstream RCHRES, precipitation falling directly on the RCHRES surface area, and other discharges to the reach. RCHRES outflows include flow to the downstream reach, withdrawals from the reach, and evaporation. A series of reaches are used to represent the actual network of stream channels.

For each RCHRES, a relation between depth, surface area, volume, and outflow (discharge) is assigned and specified in an F-TABLE. When available, data for the F-TABLEs were derived from stage-discharge ratings for stream-gaging stations at RCHRES endpoints. For reaches that do not end at a stream-gaging station, data for the F-TABLE were generated using the computer program XSECT. XSECT calculates depth-discharge relations for a hypothetical stream channel, assuming a trapezoidal shape and using specified stream length, stream slope, channel width, channel depth, floodplain slope, Manning’s n for the stream channel, and Manning’s n for the floodplain.

The water-quality component of HSPF simulates contributions from pervious and impervious land areas and accounts for chemical reactions in the stream reaches. The model includes algorithms to describe the transport of constituents from the land to the stream reach, chemical reactions affecting constituents in the reach, sediment exchange between channel bed and water column, and the temperature of runoff to and water in a reach. Contributions of constituents from land areas may vary by land-use category in the model. Water-quality simulation requires a calibrated hydrodynamic model.

Water temperature, dissolved oxygen, and carbon dioxide in surface runoff, interflow, and ground-water outflows from pervious land areas are simulated in the PWTGAS section of the PERLND module and from impervious lands in the IWTGAS section of the IMPLND module. Water temperature in each reach is simulated by the HTRCH section of the module RCHRES and includes heat transported by PERLND and IMPLND outflows and point-source discharges. The main heat-transfer processes considered are transfer by advection, where water temperature is treated as a thermal concentration, and transfer across the air-water interface. Heat gain and loss by radiation also is simulated. Meteorological data, such as air temperature and wind speed, are used in the simulation of stream temperature. Dissolved oxygen in each reach is simulated by the OXRX section of the RCHRES module. Effects of reaeration, advection, benthal oxygen demand, and oxygen depletion due to the decay of biochemical oxygen demand are included in the dissolved oxygen simulation.

The simulation of sediment includes transport of sediment from land areas and transport within the stream channel. Sediment release from pervious areas is simulated in the SEDMNT module. Sediment available for transport is generated by detachment associated with rainfall. Detached sediment is transported to the stream as washoff. Scour also may be simulated for pervious areas. Sediment release for impervious areas is simulated in the SOLIDS module. Buildup of solids on impervious areas is transported to the stream in surface runoff. Sediment transport in the stream channel is simulated in the SEDTRN module. The channel simulation includes scour and deposition of bed material but not bank material.

The transport of nutrients from the land to the stream is simulated in the PQUAL module for pervious areas and IQUAL module for impervious areas. For pervious areas, nutrients associated with soil are transported with sediment in surface runoff. Nutrients also enter the stream in interflow and ground-water discharge. For impervious areas, nutrients accumulate on the surface and are washed into the stream during storm events. Once in the stream, the transport and chemical interactions of nutrients are simulated by the modules NUTRX and PLANK. The NUTRX module includes physical transport and inorganic chemical reactions affecting nutrients. The PLANK module simulates the role of phytoplankton in the stream and includes uptake and release of nutrients.

DATA FOR MODEL INPUT AND CALIBRATION

HSPF requires a large amount of data to characterize effectively the hydrologic and water-quality response of the watershed to precipitation and other inputs (Donigian and others, 1984). Data used in creating and defining the model structure and parameters were derived principally from spatial analysis of basin characteristics and previously published information. Spatial data analyzed for model construction includes land use, land-surface slope, and soil associations. Time-series input for streamflow and water-quality simulation includes meteorologic, precipitation quality, water-use, and discharge quantity and quality data. Calibration data consisted of observed streamflow for the hydrodynamic simulation and observed water temperatures and laboratory analyses of grab and composite stream samples for the water-quality simulation.

Time-series data for model input and model output were processed and stored in the binary format Watershed Data Management (WDM) database. The WDM format is the standard format for input to and output from HSPF. The computer programs ANNIE (Flynn and others, 1995), IOWDM (Lumb and others, 1990), METCMP (U.S. Geological Survey, in preparation), WDMUtil (U.S. Environmental Protection Agency, 1999), and GenScn (Kittle and others, 1998) were used in the processing of WDM time-series data. Parameter and model-structure data were processed independently of the time-series data and are defined in the UCI, an ascii text file.

Model-Input Data

The types, resolution, and quantity of the data needed for input are determined by (1) the hydrologic and water-quality processes to be included in the model; (2) the time step selected for simulation; (3) the length of the simulation period; and (4) the spatial scale of interest. For example, simulation of streamflow requires time-series inputs of precipitation, potential evaporation, withdrawals from streams, and discharges from streams. Simulation of stream water quality requires, in addition to parametric estimates of chemical inputs from pervious and impervious land areas, time-series inputs of water-temperature data and constituent loads in point-source discharges. Observed water-temperature time-series may be supplied as input, but because only a limited amount of recorded water-temperature data were available for the Brandywine Creek Basin, water temperature was simulated. The simulation of water temperature requires input of additional meteorological data.

The Brandywine Creek model was run on a 1-hour time step. Time-series data available only at time intervals greater than hourly required disaggregation. For the simulation period of January 1, 1994, through October 1998, nearly 5 years of reported or estimated hourly values were needed for the time-series input data sets.

Meteorologic Data

Simulation of mean hourly streamflow in HSPF required inputs of hourly precipitation and potential evapotranspiration. Daily potential evapotranspiration data were disaggregated at the time of simulation. Daily precipitation data from four NOAA meteorological gages in the Brandywine Creek Basin, Honey Brook 1 S, Coatesville 2 W, Glenmoore, and Wilmington Porter Reservoir (fig. 3), were disaggregated using METCMP into hourly data based on hourly precipitation recorded at the NOAA gage at the Wilmington, Del., Airport. Data from the Honey Brook 1 S and Glenmoore gages were shifted back 24 hours to partially compensate for differences in the reporting time of daily observations that otherwise would introduce a lag in the hydrograph response to precipitation.

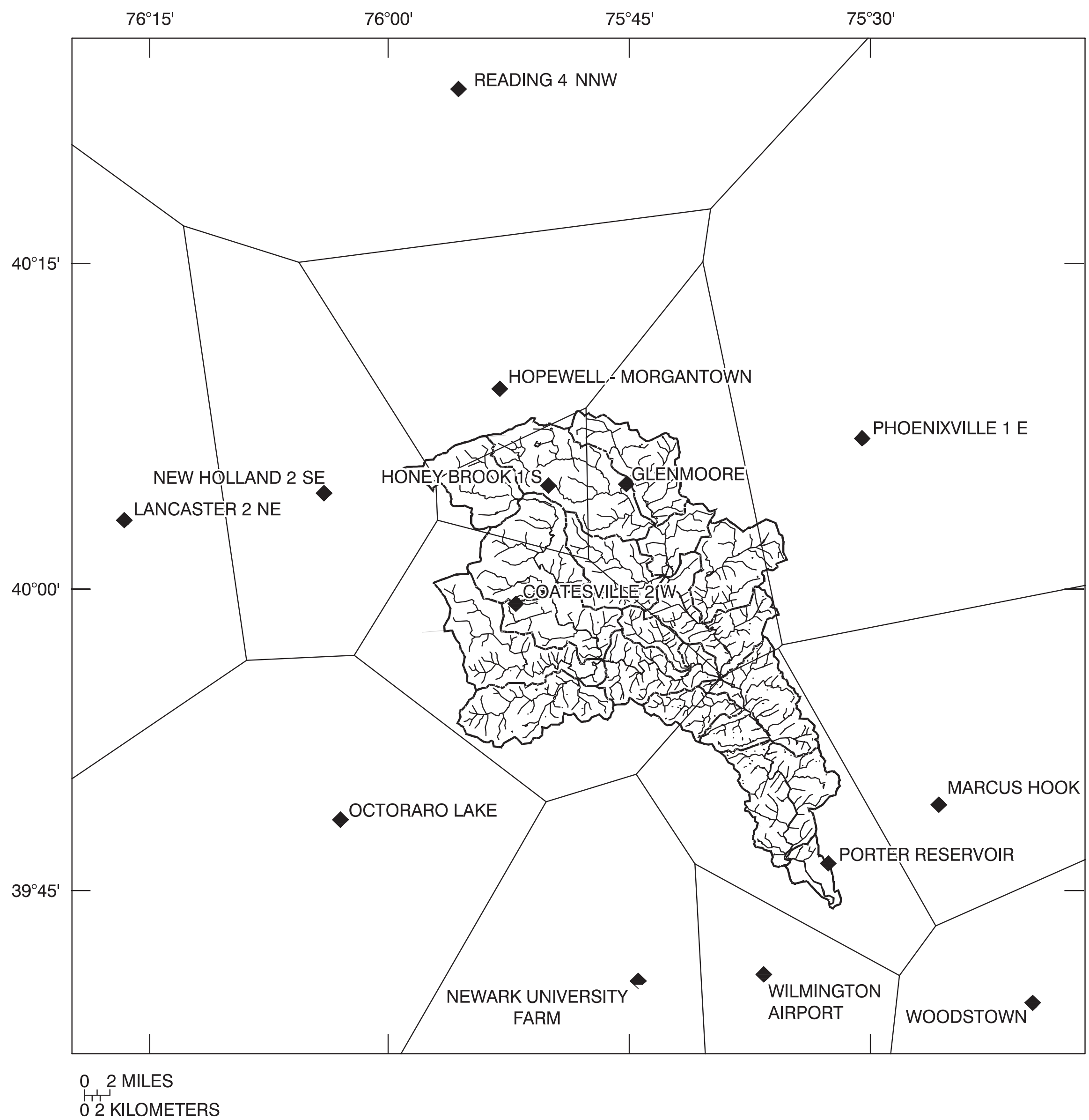


Figure 3. Location of National Oceanic and Atmospheric Administration meteorological stations and calculated Thiessen polygons in the vicinity of the Brandywine Creek Basin, Pennsylvania and Delaware.

The 1994-98 period of simulation spanned relatively normal, dry, and wet years of precipitation. For example, the long-term (1961-99) "normal" annual precipitation at Glenmoore is 46.5 in. (National Oceanic and Atmospheric Administration, 1999). In comparison to the normal annual precipitation, the year 1994 was similar, the years 1995 and 1997 were drier, and the years 1996 and the 10-month period of 1998 were wetter at Glenmoore (table 2). The greatest departure was in 1996 when annual precipitation was 48 percent above normal.

Comparison of the period-of-simulation precipitation totals shows differences (table 2) between raingages. For the 4-year 10-month period, Coatesville 2 W reported 24 percent more precipitation than Honey Brook 1 S, which is just 7.5 mi to the north, but just 6 percent and 3 percent more than the more distant Glenmoore and Porter Reservoir raingages, respectively. The difference between Coatesville 2 W and Honey Brook 1 S appears to result from a consistent recording bias (fig. 4). Although some disagreement in total precipitation can be expected, a review of numerous raingage network studies in the Eastern United States showed that annual differences at adjacent gages averaged 5 percent or less (Winter, 1981). Differences over a 5-year period can be expected to be smaller than annual differences. The monthly distribution of precipitation (fig. 5) indicates that differences of 30 percent or more between at least two of the four raingages used for model input

Table 2. *Raingage weighting factors and annual and total precipitation*

Raingage	Weighting factor[1]	Precipitation, in inches					
		1994	1995	1996	1997	1998[2]	Total
Honey Brook 1 S	1.16	44.3	37.4	59.9	30.5	33.3	205.4
Coatesville 2 W	.90	50.2	47.2	75.1	39.3	42.6	254.4
Glenmoore	1.03	47.2	41.7	68.7	38.2	44.7	240.5
Porter Reservoir	1.05	57.4	45.1	68.9	38.9	37.1	247.4

[1] Raingages used in computation of weighting factor:

Honey Brook 1 S -- Reading 4 NNW, Lancaster 2 NE, New Holland 2 SE, Octoraro Lake, Glenmoore, Coatesville 2 W.

Coatesville 2 W -- Lancaster 2 NE, New Holland 2 SE, Octoraro Lake, Glenmoore, Newark University Farm, Porter Reservoir, Honey Brook 1 S.

Glenmoore -- Reading 4 NNW, Lancaster 2 NE, New Holland 2 SE, Coatesville 2 W, Honey Brook 1 S, Newark University Farm, Porter Reservoir.

Porter Reservoir -- Coatesville 2 W, Octoraro Lake, Conowingo Dam, Chestertown, Dover, Porter Reservoir, Wilmington Airport.

[2] Precipitation for January 1 through October 29.

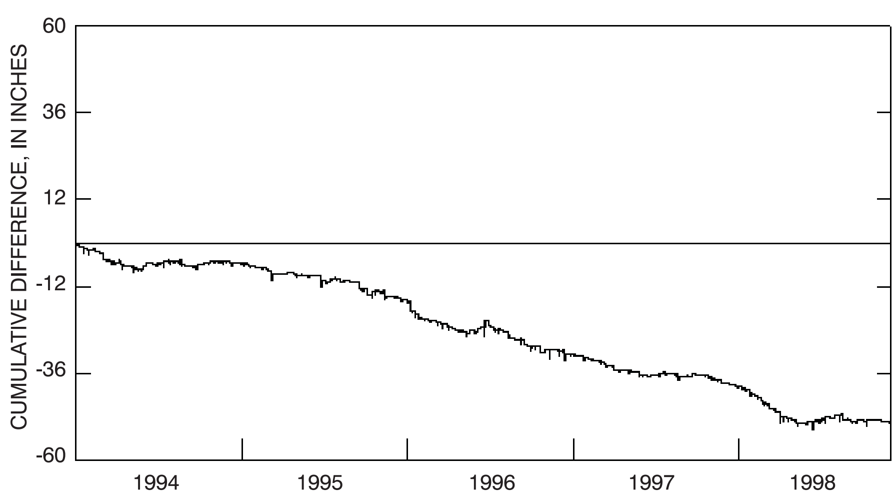


Figure 4. Cumulative difference in precipitation, Coatesville 2 W minus Honey Brook 1 S, for the period January 1, 1994, through November 30, 1998.

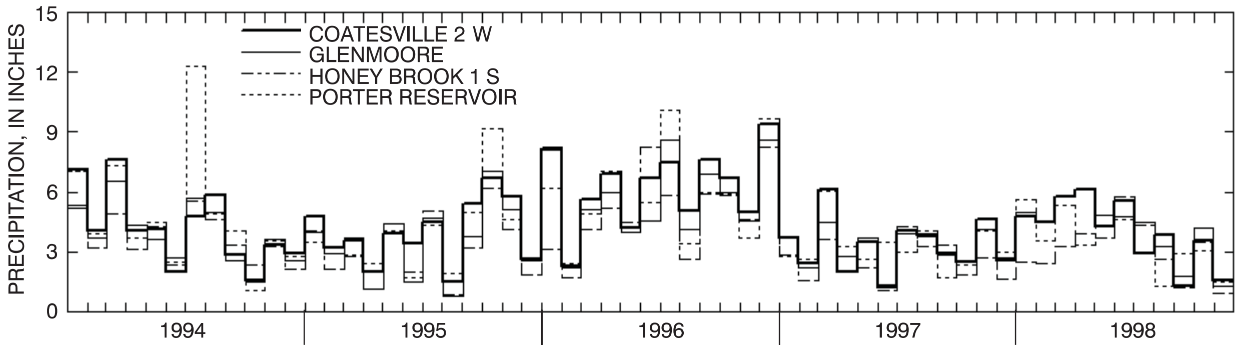


Figure 5. Monthly precipitation measured at four National Oceanic and Atmospheric Administration raingages in the Brandywine Creek Basin, Pennsylvania and Delaware.

were not unusual. Further comparison to NOAA raingages outside the Brandywine Creek Basin shows precipitation totals for the period to be greater at Coatesville 2 W than at adjacent gages and less at Honey Brook 1 S than at adjacent gages.

A weighting factor (table 2) was applied to improve estimates of actual area-weighted rainfall across the land segments. Given the large variance among and possible bias in precipitation amounts reported for raingages used in the Brandywine model, the use of a single raingage, whose data are point specific, to represent segment wide rainfall would likely introduce serious errors. The weighting factor was computed as the mean inverse-distance-weighted ratio of total precipitation at the raingage of interest to total precipitation at surrounding raingages. Inverse distance weighting (Shepard, 1968) is a classical method of interpolating scattered precipitation data over an area of interest (Tabios and Salas, 1985). Weights for the Brandywine HSPF raingages were computed using equation 1:

$$Rw = \sum_{1}^{n}\left[R1\cdot\left(\frac{\frac{1}{d1}}{\sum_{1}^{n}\frac{1}{di}}\right)+R2\cdot\left(\frac{\frac{1}{d2}}{\sum_{1}^{n}\frac{1}{di}}\right)+Rn\cdot\left(\frac{\frac{1}{dn}}{\sum_{1}^{n}\frac{1}{di}}\right)\right] \quad (1)$$

where

n is number of raingages used in weighting;

R_w is weighted ratio (weighting factor);

R_n is the ratio of total rainfall at nearby raingage to total rainfall at raingage of interest; and

d_n is the distance between nearby raingage and raingage of interest.

Small final adjustments to these factors were made if necessary to complete a satisfactory water balance for the simulation period (Donigian and others, 1984).

Precipitation data may contain a number of errors. Measurement errors, while known in general, are not specifically known for the gages used in the Brandywine Creek model. These errors may include malfunctioning equipment, incorrect calibration, and environmental influences (Winter, 1981). Precipitation data from NOAA raingages adjacent to the raingages selected for the model show departures as great as 15 percent over the simulation period whereas individual storm events exhibit departures as much as several hundred percent. Applying an inverse distance weighting reduced total departures for the overall simulation period but does not eliminate problems with individual storms. Some individual storm events are still poorly represented by the weighted data. Thus, storms with substantial precipitation in one part of the basin may appear to result in little or no streamflow response. Disaggregation of daily precipitation values to hourly values by applying the hourly distribution of precipitation at the Wilmington, Del., airport excludes the spatial and temporal variations in rainfall distribution across the Brandywine Creek Basin. Disaggregation errors can appear as timing shifts in storm hydrographs.

Potential evapotranspiration at the Wilmington, Del., Airport gage was used for model input. The daily estimates of potential evapotranspiration for Wilmington were calculated by the Northeast Regional Climate Center using a method described by DeGaetano and others (1994). Monthly totals of potential evapotranspiration are shown in figure 6. Disaggregation of daily potential evapotranspiration was done automatically by HSPF. Daily potential evapotranspiration totals were divided into 24 equal hourly values during an HSPF run.

Snow simulation requires precipitation, air temperature, solar radiation, dewpoint, and windspeed data. Hourly air temperature, solar radiation, dewpoint, and windspeed from Wilmington, Del., Airport were compiled and used as input to the model.

Simulation of stream water temperature requires air temperature, dewpoint, windspeed, cloud cover, and solar radiation. Hourly air temperature, dewpoint, windspeed, and cloud cover from the Wilmington, Del., Airport were used as input to the model. In the northern parts of the basin, air temperatures for input to the model were derived from data at the Coatesville 2 W NOAA meteorological gage. Minimum and maximum daily air temperatures for the Coatesville 2 W gage were disaggregated to hourly air temperature with METCMP, using the Wilmington Airport hourly data. Hourly estimates of solar radiation for Wilmington, Del., were calculated by the Northeast Regional Climate Center using a method described by DeGaetano and others (1993).

Water-Use Data

Simulation of streamflow and water quality requires information about stream withdrawals and discharges. Water withdrawal and discharge data were obtained from Chester County Water Resources Authority, Water Resources Agency at the University of Delaware, DNREC, and the Brandywine Valley Association who compiled water-use information from various sources including PADEP, DNREC, and individual water users. Much of these data were reported on a monthly or annual basis, and in many cases, were available for only 1, 2, or 3 years of the 1994-98 simulation period. Where at least 1 year of acceptable monthly withdrawal data were available, the remaining years missing information was filled by copying data from the most recent year prior to the missing period. Where no monthly withdrawal data were available, missing monthly data were filled with values equal to 75 percent of permitted withdrawal maximums. Missing discharge data were filled using the same method as withdrawals.

The discharges and withdrawals included in the simulation are presented in table 3. Isolated single-family residential discharges were not included in the streamflow simulation. Monthly-to-hourly disaggregation of water-use data was done by the HSPF model at the time of simulation. Inputs from point sources include water-quality constituent loads, discharge temperature, and rate of discharge. Point-source discharge-quality data, typically available as monthly or yearly values, were disaggregated to an hourly time step by dividing monthly or yearly values by the number of time steps in those periods during simulation. Withdrawals from Brandywine Creek by the City of Wilmington (table 3) were not included in the

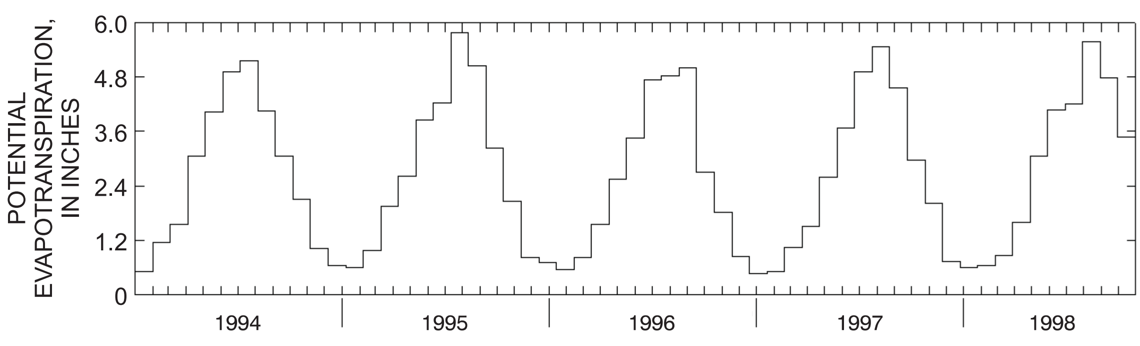


Figure 6. Estimates of monthly potential evapotranspiration for Wilmington Airport, Delaware.

Table 3. *Stream withdrawals and discharges of flow and ammonia and phosphorus loads included in the Hydrological Simulation Program—Fortran (HSPF) model of the Brandywine Creek Basin, Pennsylvania and Delaware*

[Mgal/d, million gallons per day; lb/d, pounds per day; DW, drinking water; IND, industrial; IRR, irrigation; STP, sewage treatment plant; --, not applicable or no information]

Subbasin	Name	Type	Flow volume (Mgal/d)		1994-98 Average discharge load (lb/d)	
			Capacity or flow limit	1994-98 Average	Ammonia	Phos-phorus
	Withdrawals					
West Branch	City of Coatesville Authority - W. Branch Brandywine Creek	DW	1.0	0.354	--	--
West Branch	City of Coatesville Authority - Rock Run	DW	3.0	2.68	--	--
West Branch	Lukens Steel	IND	4.760	1.35	--	--
West Branch	Sealed Air Corporation	IND	.278	.034	--	--
West Branch	Embreeville Center	DW	.20	.149	--	--
East Branch	Downingtown Municipal Authority	DW	2.5	1.02	--	--
East Branch	Sonoco Products	IND	1.320	1.60	--	--
East Branch	Milestone Materials	IND	.620	.420	--	--
East Branch	Whitford Country Club	IRR	.643	.026	--	--
East Branch	Philadelphia Suburban Water Co. - Ingrams Mill	DW	6.0	.646	--	--
East Branch	Brandywine Paperboard	IND	.024	.019	--	--
Main stem	Radley Run County Club	IRR	.100	.020	--	--
Main stem	Brandywine Country Club	IRR	.510	.022	--	--
Main stem	Wilmington Country Club	IRR	1.800	.165	--	--
Main stem	Dupont Country Club	IRR	.720	.019	--	--
Main stem	Wilmington Finishing	IND	1.000	.046	--	--
Main stem	City of Wilmington	DW	48.0		--	--
	Discharges					
West Branch	Northwest Chester County	STP	.600	.433	12.18	2.83
West Branch	Tel Hai Rest Home	STP	.055	.044	1.26	.72
West Branch	Coatesville City Authority - water plant	IND	.14	.073	--	--
West Branch	Lukens Steel no. 1 and no. 16	IND	1.00	.760	--	--
West Branch	Coatesville City Authority - sewage treatment plant	STP	3.85	2.87	10.15	27.76
West Branch	South Coatesville Borough	STP	.390	.224	.95	2.96
West Branch	Parkesburg Borough Authority	STP	.700	.263	8.45	3.06
West Branch	Lincoln Crest Mobile Home Park	STP	.036	.038	.28	--
West Branch	Embreeville Center	STP	.200	.059	.75	.70
East Branch	Indian Run Mobile Home Park	STP	.0375	.0370	.18	.16
East Branch	Little Washington Waste Water Company	STP	.0531	.0420	.88	.80
East Branch	Eaglepoint Development	STP	.015	.001	.08	.01
East Branch	Pennsylvania Turnpike Service Plaza	STP	.050	.014	.06	.06
East Branch	Uwchlan Township Municipal Authority	STP	.475	.033	.32	.18
East Branch	Pepperidge Farm	IND	.144	.021	--	--
East Branch	Downingtown Area Regional Authority	STP	7.134	5.40	13.51	64.63
East Branch	Sonoco Products	IND	1.028	.806	3.67	1.23
East Branch	Broad Run Sewer Company	STP	.400	.260	3.51	5.21
East Branch	West Chester Borough - Taylor Run sewage treatment plant	STP	1.800	1.27	12.37	15.74
East Branch	Philadelphia Suburban Water Co. - Ingrams Mill	WTP	.369	.137	--	--
Main stem	Radley Run Mews sewage treatment plant	STP	.032	.017	.09	.30
Main stem	Radley Run Country Club	STP	.017	.008	.12	.12
Main stem	Birmingham / TSA	STP	.04	.0107	.15	--
Main stem	Birmingham Township	STP	.15	.050	.17	2.46
Main stem	Knights Bridge / Village at Painters	STP	.045	.021	.06	.75
Main stem	Mendenhall Inn	STP	.022	.011	.03	--
Main stem	Unionville - Chadds Ford Elementary School	STP	.0063	.0027	--	--
Main stem	Winterthur	STP	.025	.011	--	--

model because the intakes are downstream of the lowermost streamflow-measurement station 014815000 Brandywine Creek at Wilmington, Del.

Spatial Data

Spatial data input to the HSPF model are used primarily to define the structure and "fixed" characteristics of the model. The principal structural unit of the HSPF model is the hydrologic response unit (i.e. PERLND and IMPLND). Hydrologic-response units for the basin were determined from analysis of digital spatial data consisting of land use, elevation, geology, soil association, and sanitary-sewer service area data. The digital spatial data were compiled from multiple sources by the Water Resources Agency for New Castle County for this study (Greig and others, 1998). These data were processed with a geographic information system (GIS) and compiled for model input. Non-digital data such as information regarding the location of specific agricultural practices also were used. Fifteen land-use categories were delineated in the original digital database. These categories were simplified and reclassified into 10 pervious and 2 impervious land-use categories that were expected to have distinct nonpoint-source water-quality signatures (table 4). The spatial distribution of the simplified pervious land-use categories is shown in figure 7. Areas of undesignated land use were considered to have characteristics of areas with open land use.

Agricultural land use, principally in the western part of the basin, was divided into three characteristic subtypes for the model. Agricultural-livestock land use identifies relatively small acreage farms with high animals-per-acre densities, limited pasture areas, and rowcrops. Small acreage dairy operations typify this land-use type. Agricultural-rowcrop land use identifies farms with lower animals-per-acre densities (typically beef cattle and horses) and substantial pasture and crop acreage. Agricultural-mushroom land use is the third type of agriculture land use delimited, but mushroom production operations are much more prevalent in the adjacent Red Clay Creek and White Clay Creek Basins than in the Brandywine Creek Basin. Land areas of each type of agricultural land were not available in digital-spatial format and were estimated based on knowledge of the area and discussions with the Chester County Conservation District.

Residential land use is distributed throughout the basin and is divided into two types: sewered and non-sewered. Sewered residential areas tend to have higher housing densities and are nearer to urban / suburban areas than non-sewered area. Non-sewered residential areas tend to have lower densities and are more rural. Urban land use in the basin generally is concentrated in an east-west trending band in central Chester County, Pa., underlain by carbonate rocks and traversed by the state highway Route 30 and in the cities of Newark and Wilmington, Del., on the Fall Line. Other urban land use is in small boroughs and along major roadways. Forested land is distributed throughout the basin and tends to be along stream channels, especially in the southern and northern parts of the basin (fig. 7).

Table 4. *Land-use categories used in the Hydrological Simulation Program—Fortran model of the Brandywine Creek Basin, Pennsylvania and Delaware*

Land-use category for model		Description of land use
Pervious land area[1]	residential-septic	Includes all residential land not within a sewer service area
	residential-sewer	Includes all residential land within a sewer service area
	urban	Includes commercial, industrial, institutional, transportation uses
	agricultural-livestock	Predominantly mixed agricultural activities of dairy cows, row crop, pasture, and other livestock operations
	agricultural-rowcrop	Predominantly row crop cultivation (corn, soybean, alfalfa), may include some hay or pasture
	agricultural-mushroom	Mushroom-growing activities including compost preparation, mushroom-house operations, spent compost processing
	open	Recreational and other open land not used for agriculture
	forested	Predominantly forested land
	wetlands / water	Wetlands and open water
	undesignated	Land use not defined
Impervious land area[2]	residential	Impervious residential land
	urban	Impervious commercial, industrial, and other urban land

[1] Pervious land area is designated as PERLND in model.
[2] Impervious land area is designated as IMPLND in model.

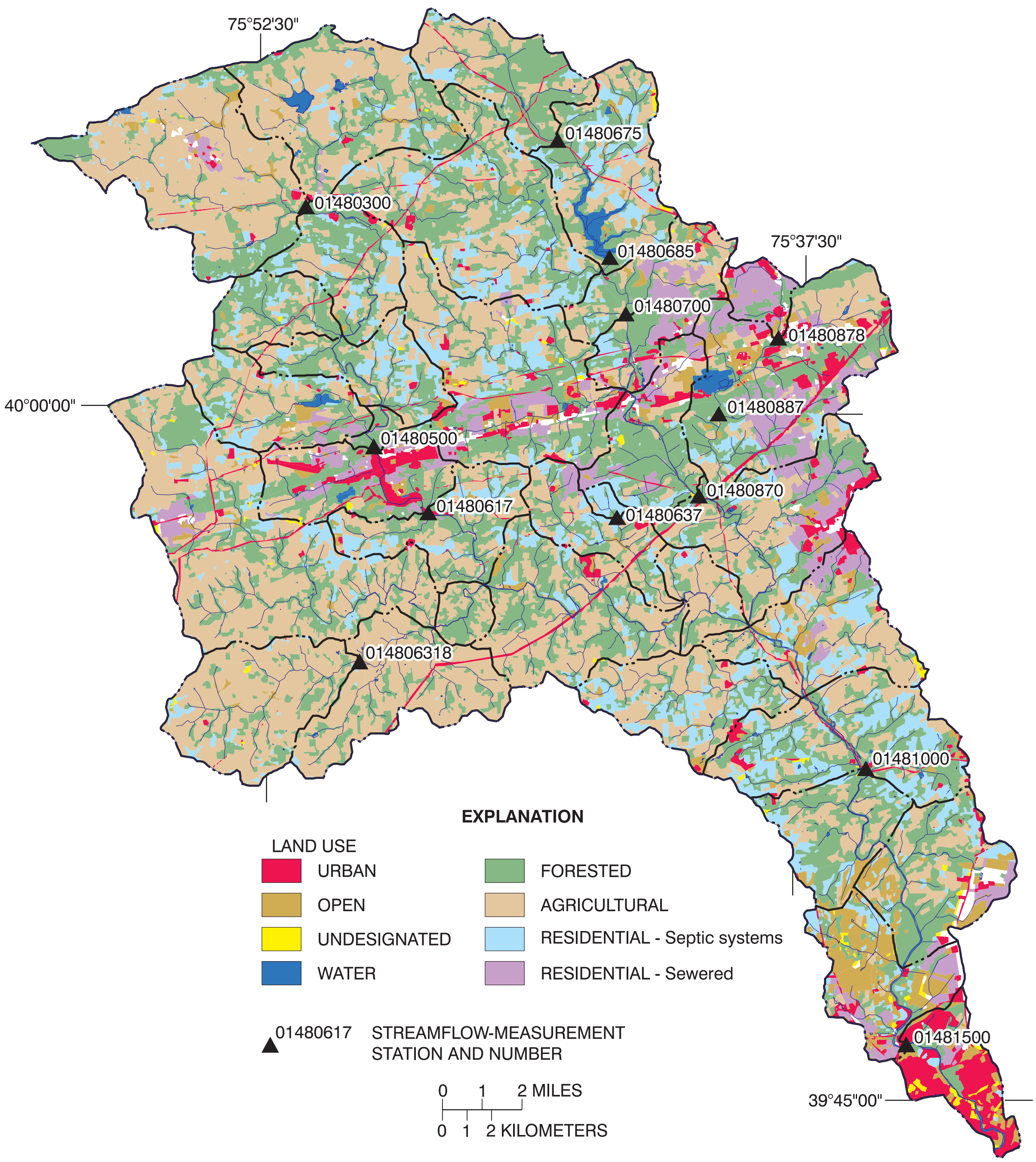


Figure 7. Generalized 1995 land-use map for the Brandywine Creek Basin, Pennsylvania and Delaware.

Model-Calibration Data

Observed streamflow and water-quality data are needed to calibrate the hydrologic and water-quality components of the HSPF model, respectively. These data are available at streamflow-measurement stations (gages) and water-quality monitoring sites established in the basin for this study and for other purposes. The period of record and frequency of observations differ among these gages and monitoring locations. In general, fewer water-quality data are available than streamflow data.

Hydrologic Data

Data from USGS streamflow-measurement (gaging) stations operating in the Brandywine Creek Basin during the 1994-98 simulation period were used for the hydrologic calibration (table 5; fig. 8) (Durlin, 1995; Durlin and Schaffstall,1997a, 1997b, 1998, 1999). Of the 14 stations listed in table 5, data from 10 were used for model calibration. Three of the 10 stations (014806318, 01480637, 01480878) were established in small subbasins of the Brandywine Creek Basin specifically for a limited 1-year period of storm monitoring. Data from these three stations were not used as primary calibration data but as ancillary information during the calibration process. Data from Marsh Creek near Downingtown, Pa. (01480685), were not used for calibration but to specify the discharge from Marsh Creek Reservoir during the basin simulation. This station is downstream of the Marsh Creek Reservoir dam and records the regulated streamflow from the dam.

Streamflow data at all the sites were recorded at time steps smaller than the 1-hour time step used in the model. Because of the shorter time steps, no disaggregation was needed for the streamflow data. However, periods of missing data and periods of poor-quality data because of freezing conditions are numerous in the hourly streamflow record. Periods of missing data were estimated by interpolation or regression. During periods of relatively steady base flow, missing data were interpolated. During periods of rapidly changing flow (generally stormflow), missing data were estimated by linear regression. A regression equation was generated using data from the nearest upstream or downstream gaging station, and which bounded the period of missing record. Poor-quality data because of freezing conditions were more problematic in that data from nearby stations also were usually affected. As a result, these data were used as recorded unless data of better quality were available from a nearby gaging station.

Table 5. *Streamflow-measurement stations in the Brandywine Creek Basin, Pennsylvania and Delaware*

U.S. Geological Survey station identification number	Station name	Drainage area (square miles)	Period of record
01480300	West Branch Brandywine Creek near Honey Brook, Pa.	18.7	6/60 - current
01480400	Birch Run near Wagontown, Pa.[1]	4.55	2/95 - current
01480500	West Branch Brandywine Creek at Coatesville, Pa.	45.8	10/43 - 12/51 1/70 - current
01480617	West Branch Brandywine Creek at Modena, Pa.	55.0	1/70 - current
014806318	Doe Run above tributary at Springdell, Pa.	11.2	8/97 - 9/98
01480637	Little Broad Run near Marshallton, Pa.	.6	10/97 - 9/98
01480675	Marsh Creek near Glenmoore, Pa.	8.57	7/66 - current
01480685	Marsh Creek near Downingtown, Pa.[1]	20.3	6/73 - current
01480700	East Branch Brandywine Creek near Downingtown, Pa.	60.6	10/65 - current
01480870	East Branch Brandywine Creek below Downingtown, Pa.	89.9	2/72 - current
01480878	Unnamed tributary to Valley Creek at highway 30 at Exton, Pa.	2.64	7/97 - 9/98
01480887	Valley Creek at Ravine Road near Downingtown, Pa.[1]	14.5	10/89 - 9/97
01481000	Brandywine Creek at Chadds Ford, Pa.	287	8/11 - 9/53 10/62 - current
01481500	Brandywine Creek at Wilmington, Del.[2]	314	10/46 - current

[1] Not used as a model calibration location.
[2] Because of missing record, the period of October 1,1994 - October 30, 1998, was used for calibration.

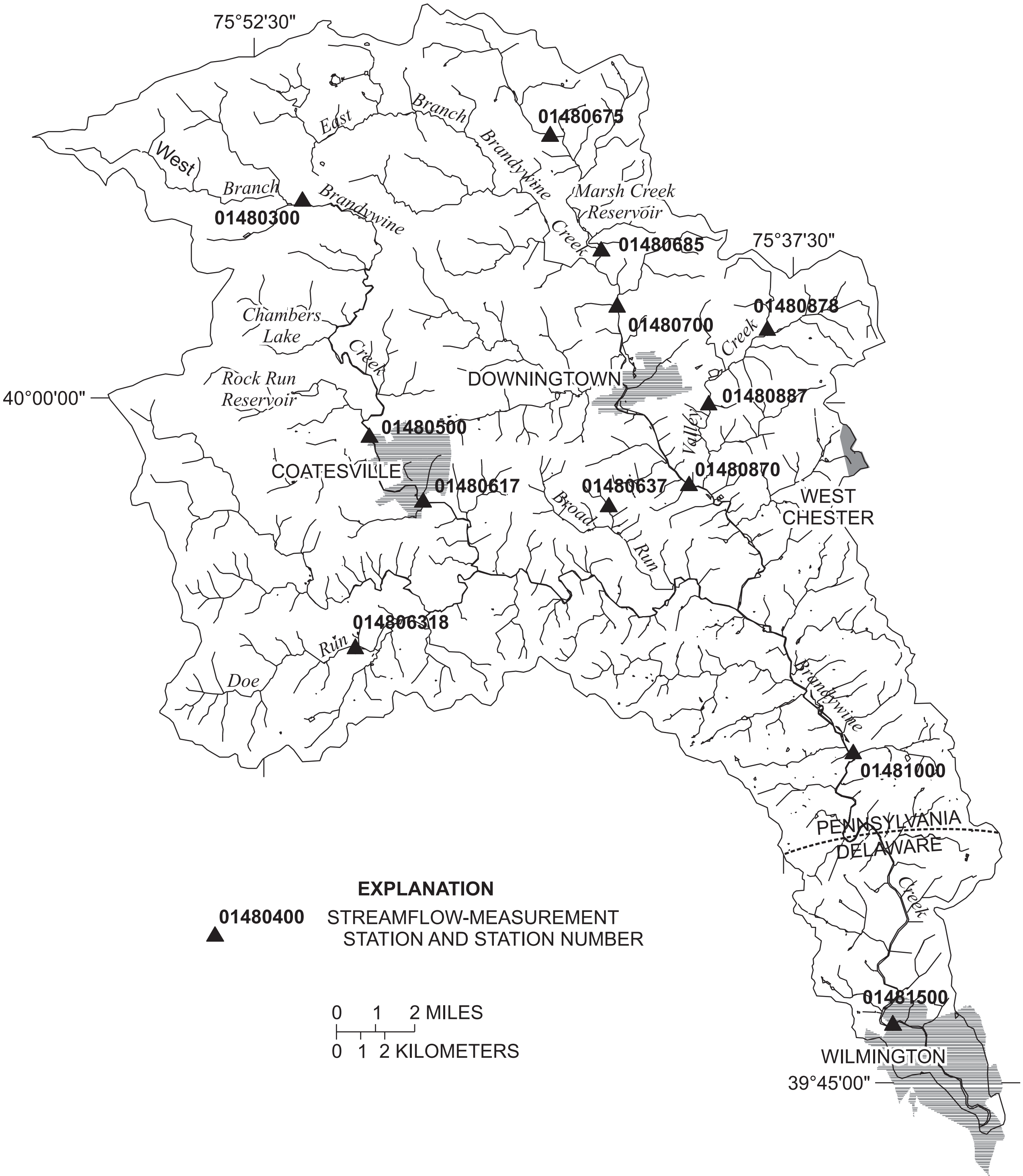


Figure 8. Location of streamflow-measurement stations and water-quality monitoring sites, Brandywine Creek Basin, Pennsylvania and Delaware, and streamflow-measurement stations in the Red Clay Creek, White Clay Creek, and Christina River Basins.

Observed snowfall and snow-on-ground at the Coatesville 2 W NOAA gage were used to assess the need for using the snowfall and snowmelt simulation module (SNOW) and for calibration of the snow module parameters. The days of snowfall and days that snow covered the ground at the Coatesville 2 W gage for the years 1994-98 are listed in table 6. Snow accumulation and snowmelt were more important processes in the years 1994 and 1996 than for other years in the simulation period. Snow was on the ground for most of January, February, and March 1994 and for all of January and 2 weeks of February 1996. In 1994, 1996, and 1997, snow cover of 2 in. or greater lasted no longer than 2 weeks.

Table 6. *Days of snowfall and snow-on-ground at the National Oceanic and Atmospheric Administration weather station Coatesville 2 W, 1994-98*

Year	Days of snowfall (maximum in inches)		Days of snow-on-ground (maximum in inches)[1]		Days of greater than 2 inches[1] of snow on ground
1994	27	(8.6)	72	(16)	69
1995	10	(9.1)	16	(10)	13
1996	27	(22.8)	52	(29)	39
1997	21	(11.4)	23	(11)	6
[2]1998	7	(1.4)	2	(1)	0

[1] Inches of snow, not inches of water equivalent.
[2] Through October 1998.

Water-Quality Data

Water-quality data at stream-monitoring sites were used in model calibration. Water-quality data for the simulation period 1994-98 were collected by PADEP, DNREC, and USGS as part of several monitoring efforts in the Brandywine Creek Basin (fig. 8). The period of record at monitoring sites varied from 1 to 5 or more years, and the sampling interval varied from hourly or less for storms to annually (table 7). The chemical analyses of samples collected as part of these monitoring efforts varied. Other water-quality data used for model calibration include continuous temperature and dissolved-oxygen concentration at three USGS streamflow-measurement stations (01480500, 01480870, 01481000) and continuous temperature at one USGS streamflow-measurement station (01480400). Continuous water-quality stations are typically operated from March to December of each year. Annual base-flow nutrients data at eight sites sampled by USGS as part of the stream conditions of Chester County biological monitoring program also were available for use in assessing model calibration.

Two of the monitoring programs were designed specifically to assist in the current assessment of water quality in the Brandywine Creek: (1) monthly and bi-monthly monitoring efforts were conducted by DNREC and PADEP from 1995 to 1998; and (2) a hydrologically based sampling scheme was done by USGS, PADEP, and DNREC in 1998. The monthly and bi-monthly monitoring effort included analyses for metals, nutrients, suspended solids, and other constituents in samples collected at nine stream sites in the Brandywine Creek Basin and was done to support an assessment of water quality during low-flow conditions and target point-source contributions. The hydrologically based sampling scheme included analyses for nutrients, suspended solids, and organic carbon at six sites in the Brandywine Creek Basin and five sites in other parts of the Christina River Basin and was done to support an assessment of these constituents under base-flow and stormflow conditions throughout the year and assist in the evaluation of nonpoint-source contributions to the stream. The nonpoint-source water-quality monitoring in 1997-98 was designed to provide data on the concentrations and loads of nutrients and suspended solids seasonally under various hydrologic conditions for the whole basin and for five small areas predominantly covered by one land use. Samples were collected during four base-flow and six stormflow events at the six sites. Continuous data collected at the nonpoint-source monitoring sites included streamflow and water temperature. Samples collected at the Brandywine Creek at Chadds Ford, Pa., site (01481000) provided information about the water quality of the whole basin. Samples collected in the five small subbasins predominantly covered by one land use (table 7) were used to provide information about the relation between land use and water quality. The predominant land uses in the small-basin sites include various types of agricultural, residential, forested, and urban land use.

Table 7. *Water-quality monitoring sites in the Brandywine Creek Basin during 1994-98*

[--, no data; WQN, Water-Quality Network; Abbreviations: P, Pennsylvania Department of Environmental Protection; D, Delaware Department of Natural Resources and Environmental Control; U, U.S. Geological Survey; Temp, water temperature; DO, dissolved oxygen; TSS, total suspended solids]

U.S. Geological Survey station identification number	State site number	Drainage area (square miles)	Location (predominant land use)	Monitoring agency	Period of record	Chemical analyses
Monthly and bi-monthly monitoring sites						
01480500	--	45.8	West Branch at Coatesville	P	1995-98	Nutrients, TSS
01480617	--	55.0	West Branch at Modena	P	1995-98	Nutrients, TSS
01480640	--	134	West Branch at Wawaset	P	1995-98	Nutrients, TSS
01480700	--	60.6	East Branch near Downingtown	P	1995-98	Nutrients, TSS
01480870	--	89.9	East Branch below Downingtown	P	1995-98	Nutrients, TSS
01480950	--	123	East Branch at Wawaset	P	1995-98	Nutrients, TSS
01481000	WQN105	287	Chadds Ford	P	1995-98	Nutrients, TSS
--	104051	--	Smiths Bridge	D	1995-98	Nutrients, TSS
--	104021	314	Rd. 279 Bridge, DuPont Exp. Station[1]	D	1995-98	Nutrients, TSS
Base flow and stormflow nonpoint-source monitoring small and whole basin sites						
01480300	--	18.7	West Branch at Honey Brook (agricultural-mixed animal and crop)	U, P, D	1998	Nutrients, TSS
014806318	--	11.2	Doe Run (agricultural-rowcrop)	U, P, D	1998	Nutrients, TSS
01480637	--	.6	Little Broad Run (residential-unsewered)	U, P, D	1998	Nutrients, TSS
01480675	--	8.57	Marsh Creek (forested)	U, P, D	1998	Nutrients, TSS
01480878	--	2.64	Unnamed trib. to Valley Creek (residential-sewered)	U, P, D	1998	Nutrients, TSS
01481000	--	287	Chadds Ford (mixed-whole basin)	U, P, D	1998	Nutrients, TSS
Continuous monitoring site (15-minute or 30-minute time interval, March-December)						
01480500	--	45.8	West Branch at Coatesville	U	1995-current	Temp
01480617	--	55.0	West Branch at Modena	U	1971-current	Temp, DO
01480870	--	89.9	East Branch below Downingtown	U	1972-current	Temp, DO
01481000	--	287	Chadds Ford	U	1971-current	Temp, DO
Annual biological monitoring sites						
01480653	--	16.5	East Branch at Glenmoore	U	1971-95, 1998	Nutrients
01480700	--	60.6	East Branch near Downingtown	U	1970-96	Nutrients
01480903	--	20.4	Mullsteins Meadow, Valley Creek	U	1971-97	Nutrients
01480950	--	123	East Branch at Wawaset	U	1971-97	Nutrients
01480640	--	134	West Branch at Wawaset	U	1971-97	Nutrients
01480629	--	22.6	Buck Run	U	1971-98	Nutrients
01480632	--	11.8	Doe Run near Springdell	U	1971-97	Nutrients
01481000	--	287	Chadds Ford	U	1970-98	Nutrients

[1] Site is just upstream of U.S. Geological Survey station 01481500.

The stormflow and base-flow events were selected as representative of the range of seasonal, hydrologic, and land-use conditions in the basin. Timing for the six stormflow events was as follows: two storms in mid to late winter (February 4-5 and March 8-9, 1998), one storm in early spring after pre-planting tillage (May 2-3, 1998), one storm in late spring/early summer after planting of crops (June 12-13, 1998), one storm in midsummer (July 8-9, 1998), and one storm in fall after harvest (October 8-9, 1998). Sampling was delayed because of dry conditions in the fall of 1997. No samples were collected from frozen-ground runoff and snow-melt events because of the mild winter of 1998. Sampled storms resulted from precipitation events that ranged from about 0.4 to 3.3 in. For Brandywine Creek at Chadds Ford, Pa., these precipitation events resulted in peak flows with a 1-year or less recurrence interval. Base flow was sampled in January, April, July, and September 1998.

Base-flow and stormflow samples collected from January to October 1998 were analyzed for concentrations of dissolved and total nitrogen and phosphorus species and suspended solids (table 8). Other constituents, such as dissolved organic carbon (DOC) and chlorophyll *a*, and properties, such as chemical oxygen demand (COD) and biological oxygen demand (BOD), also were analyzed to better understand and simulate the chemical processes involving the fate and transport of nutrients.

Table 8. *Constituents in nonpoint-source monitoring samples to be determined by laboratory chemical analysis[1], Brandywine Creek Basin, Pennsylvania and Delaware*

[mg/L, milligrams per liter; EPA, U.S. Environmental Protection Agency; STDMTD, Standard Methods (American Public Health Association, 1995); µS/cm, microsiemens per centimeter]

Constituent	STORET code	Method	Reporting limit (mg/L)
Required constituents or properties for all samples			
Ammonia nitrogen, dissolved	00608	EPA 350.1	0.004
Ammonia nitrogen, total	00610		.004
Kjehldahl nitrogen, dissolved	00623	EPA 351.2	.05
Kjehldahl nitrogen, total	00625		.05
Nitrite plus nitrate nitrogen, dissolved	00631	EPA 353.2	.05
Orthophosphorus, dissolved	00671	EPA 365.1	.005
Phosphorus, dissolved	00666	EPA 365.1	.005
Phosphorus, total	00665		.005
Chloride	00940	EPA 325.2	1
Specific conductance	90095	EPA 120.1	1 µS/cm
Total suspended solids-concentration	80154	EPA 160.2	1
Biological oxygen demand (BOD_{20})	00308	EPA 405.1	2.4
Dissolved organic carbon	00681	EPA 415.1	1
Chlorophyll *a* in phytoplankton[2]	32211	92 STDMTD,	.001
Pheophytin in phytoplankton	32218	92 STDMTD	.001
Additional constituents-Mainstem site at Chadds Ford, Pa.			
Copper, dissolved	01040	EPA 220.2	.005
Copper, total	01042		.005
Lead, dissolved	01049	EPA 239.2	.003
Lead, total	01052		.003
Zinc, dissolved	01090	EPA 200.7	.010
Zinc, total	01092		.010
Chemical oxygen demand	00340	EPA 410.1, 410.2, 410.3	5.0
Total organic carbon	00680	EPA 415.1	1

[1] Specifications for analytical method, reporting limit, holding time, sample volume and preservation provided by the Delaware Department of Natural Resources and Environmental Control laboratory.

[2] First storm sampling event, all grab sampling events.

Chloride was measured to provide data on the concentrations of a conservative solute. Samples collected at the monitoring site 01481000 Brandywine Creek at Chadds Ford, Pa., also were analyzed for total organic carbon, COD, and dissolved and total concentrations of copper, lead, and zinc, as requested by DNREC for their use. Stormflow samples were collected by USGS and the University of Delaware. Base-flow samples were collected by PADEP and by DNREC. DNREC's laboratory in Dover, Del., performed all laboratory chemical analyses. Results of laboratory analyses for all stormflow and base-flow samples are listed in Appendix 1.

Two types of samples, discrete and composite, were collected by an automatic sampler during storm events. Discrete samples, collected at fixed-time intervals during the storm event, represent instantaneous concentrations. Composite samples can be used to estimate loads for a storm event. The automatic sampler was programmed prior to each storm event to start sampling at a pre-determined change in stage and to collect one series of fixed-interval discrete samples and another series of flow-weighted aliquots (250 mL each) for the composite sample. The fixed-interval series consisted of up to six 2-L samples, collected from 1.5 to 3 hours apart. The flow-weighted series consisted of up to 48 250-mL samples. The intake for the automatic sampler was set in mid-stream and stage was determined by a transducer set in the stilling well and linked to the automatic sampler. Streams were assumed to be well mixed. The automatic sampler was programmed to collect a sample at fixed-time intervals and after each time that a pre-determined flow volume, calculated using an established rating between stage and streamflow, had passed by the monitoring site. Composite samples were obtained by mixing the series of flow-weighted aliquots. Because the automatic sampler was programmed in advance of storms for which the intensity and duration were unknown, the amount of the actual storm periods covered by samples varied.

The measured concentration of constituents in discrete storm samples was, in general, related to streamflow (figs. 9-14). The concentration of total suspended solids, ammonia nitrogen plus organic-nitrogen (Kjehldal nitrogen), total phosphorus, and DOC tended to increase with increasing streamflow whereas the concentration of dissolved nitrite plus nitrate nitrogen decreased with increasing streamflow. Orthophosphate concentrations increased with streamflow except at Chadds Ford where there was a slight decreasing relation. The concentration-streamflow relation was not discernible in all cases. Marsh Creek in particular exhibits almost no relation between constituent concentrations and streamflow whereas at Chadds Ford it is evident for all constituents. Little Broad Run also exhibits weak relations between concentration and streamflow, which can be attributable in part to the limited number of data points for this site.

Concentrations of suspended solids and nutrients in stream samples differed at the six monitoring locations and in relation to hydrologic conditions. Base-flow concentrations primarily are controlled by ground-water discharge and stormflow concentrations by runoff and interflow processes. The distribution of constituent concentrations at the six nonpoint-source monitoring sites are shown in figures 15-17. Under stormflow conditions, concentrations of suspended solids, nitrate, ammonia, and total phosphorus generally were higher at the two sites in predominantly agricultural subbasins than at sites in subbasins with predominantly residential or forested land uses with a few exceptions. Under stormflow conditions, concentrations of suspended solids also were relatively high at the site in the predominantly non-sewered residential basin that has one farm property in its headwaters areas and where the stream has a relatively steep gradient. Concentrations of nitrate under base-flow conditions also commonly were higher at the two sites in predominantly agricultural subbasins than at sites in subbasins with other land uses. Concentrations of suspended sediment, nitrate, and total phosphorus under base-flow and stormflow conditions were greater at the site in the predominantly non-sewered residential subbasin than at the sites in the predominantly forested and sewered residential subbasins. Concentrations of dissolved orthophosphate in base flow and stormflow were greatest at the site in the agricultural subbasin with livestock and crops (01480300, West Branch Brandywine Creek at Honey Brook). Although elevated orthophosphate may be related to the land use in the subbasin, some orthophosphate may be associated with discharge from a small sewage treatment plant a short distance upstream of the site.

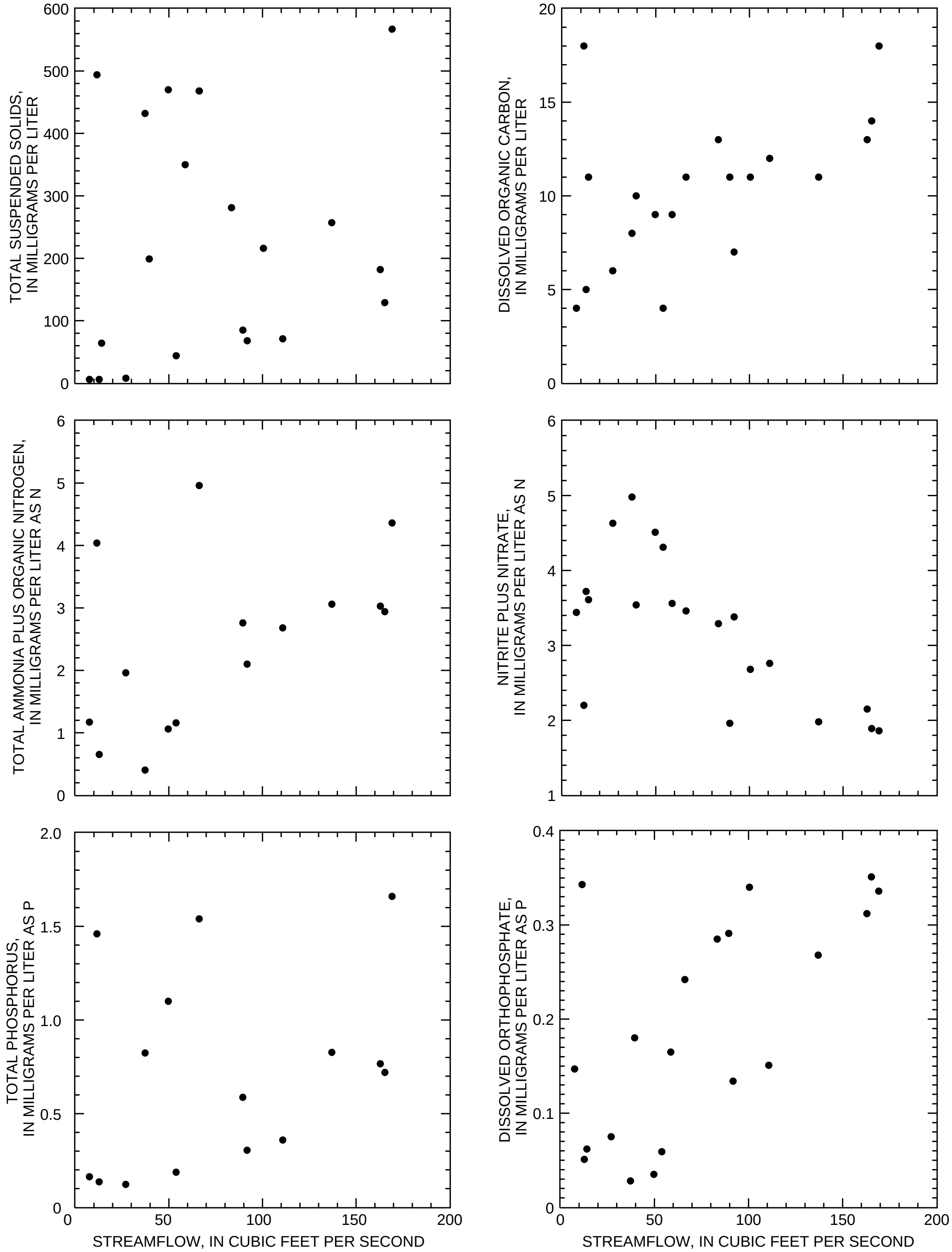


Figure 9. Relation between water-quality constituents and streamflow for stormflow and base-flow samples collected in 1998 at streamflow-measurement station 01480300, West Branch Brandywine Creek at Honey Brook, Pa.

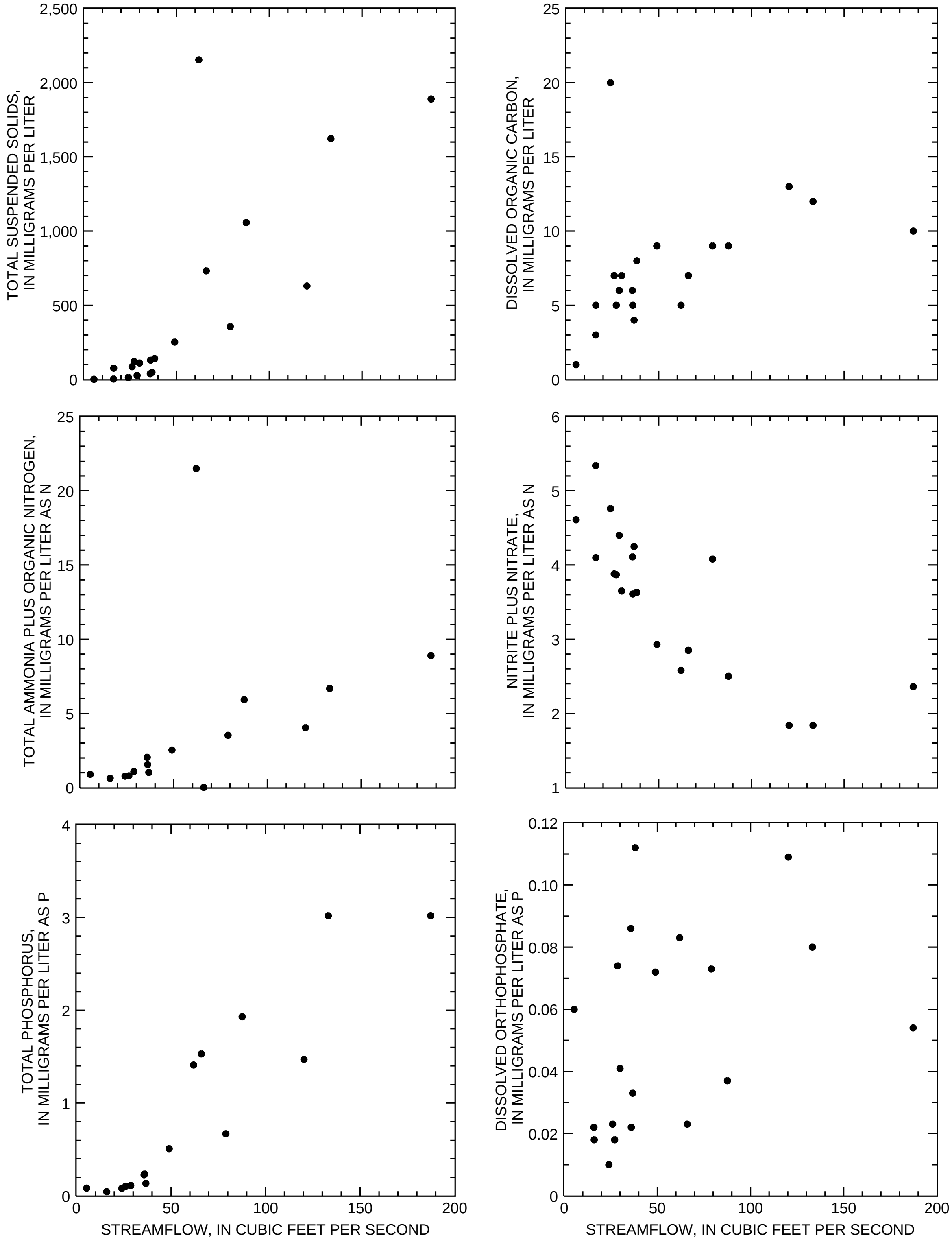


Figure 10. Relation between water-quality constituents and streamflow for stormflow and base-flow samples collected in 1998 at streamflow-measurement station 014806318, Doe Run at Springdell, Pa.

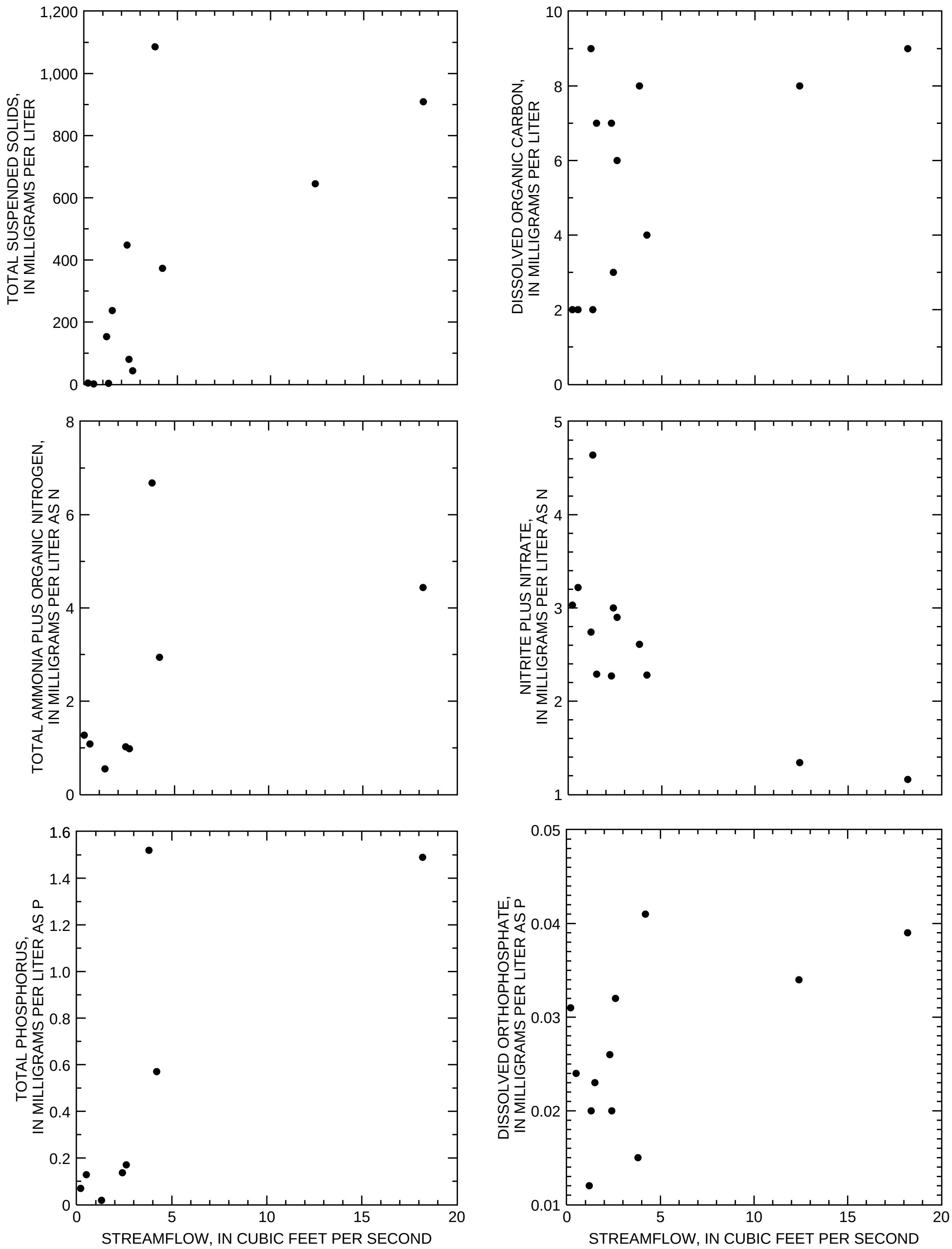


Figure 11. Relation between water-quality constituents and streamflow for stormflow and base-flow samples collected in 1998 at streamflow-measurement station 01480637, Little Broad Run near Marshallton, Pa.

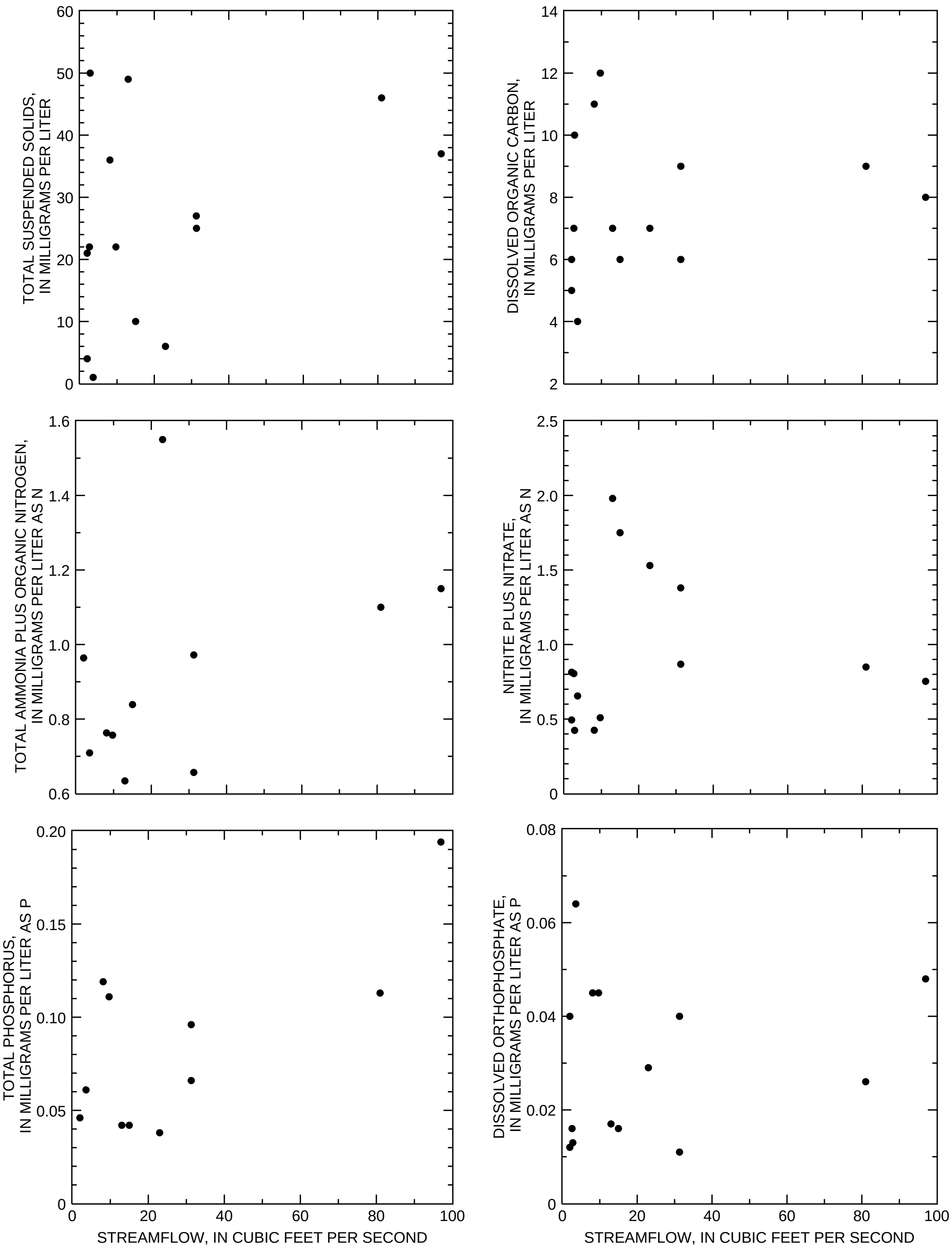


Figure 12. Relation between water-quality constituents and streamflow for stormflow and base-flow samples collected in 1998 at streamflow-measurement station 01480675, Marsh Creek near Glenmoore, Pa.

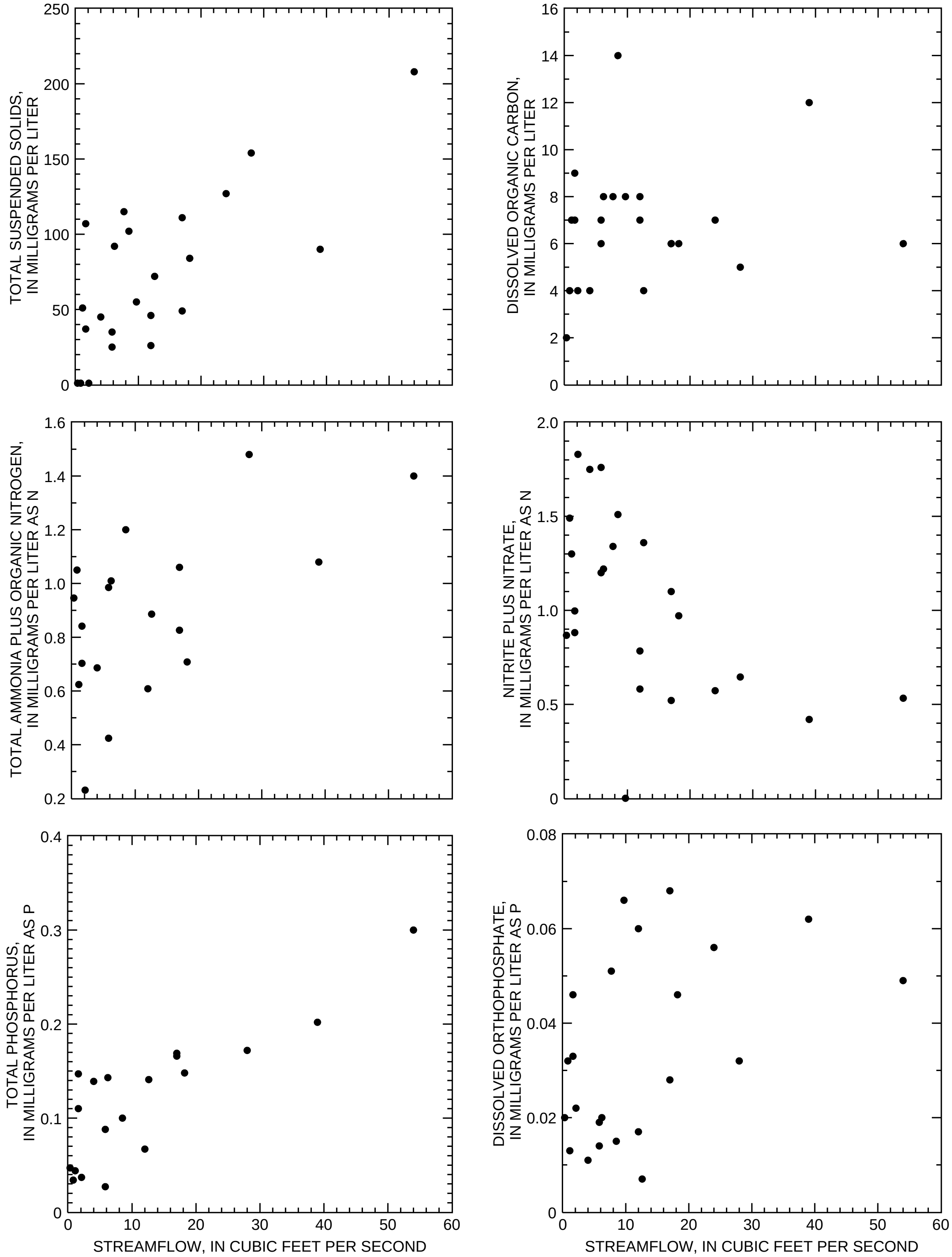


Figure 13. Relation between water-quality constituents and streamflow for stormflow and base-flow samples collected in 1998 at streamflow-measurement station 01480878, Unnamed tributary to Valley Creek near Exton, Pa.

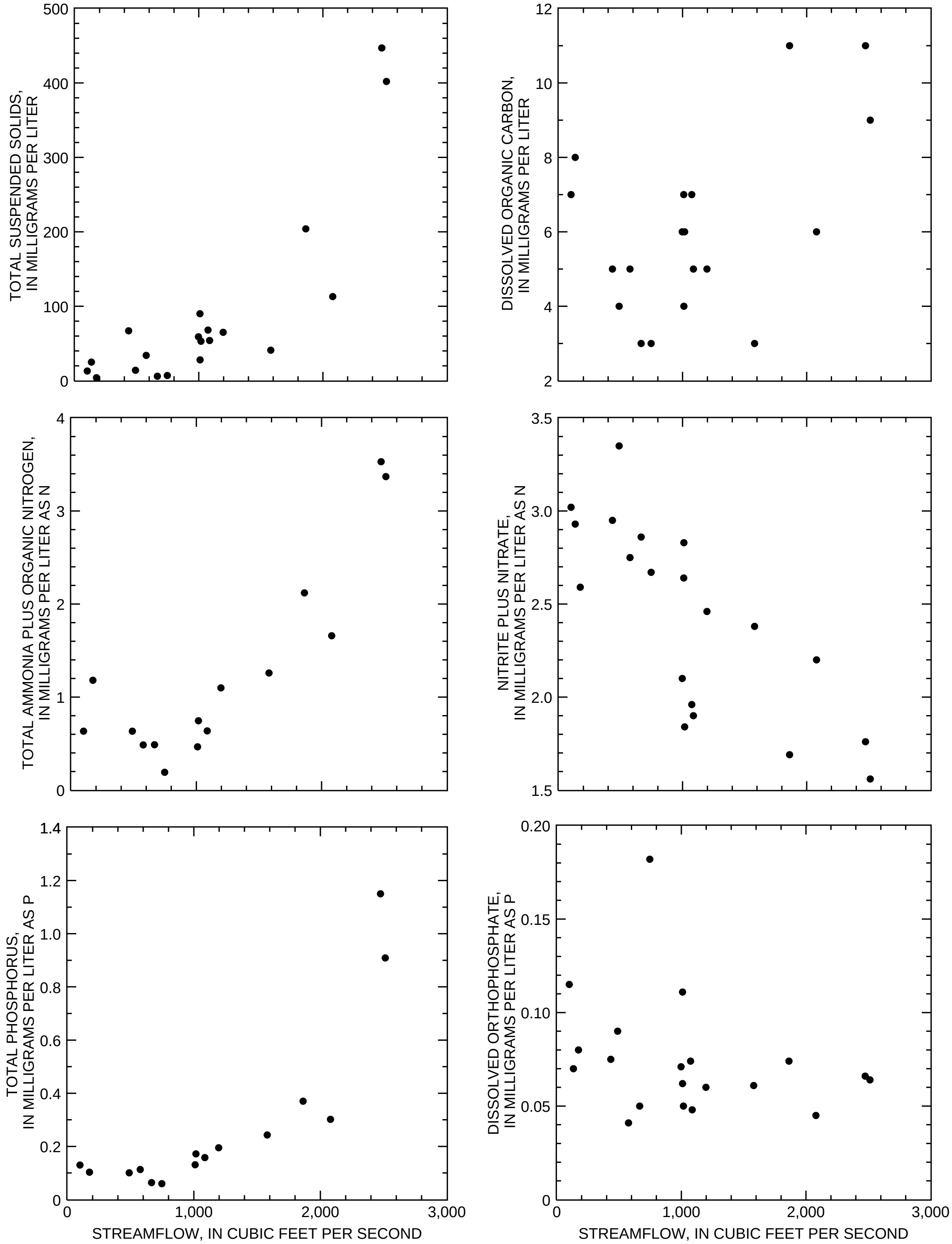
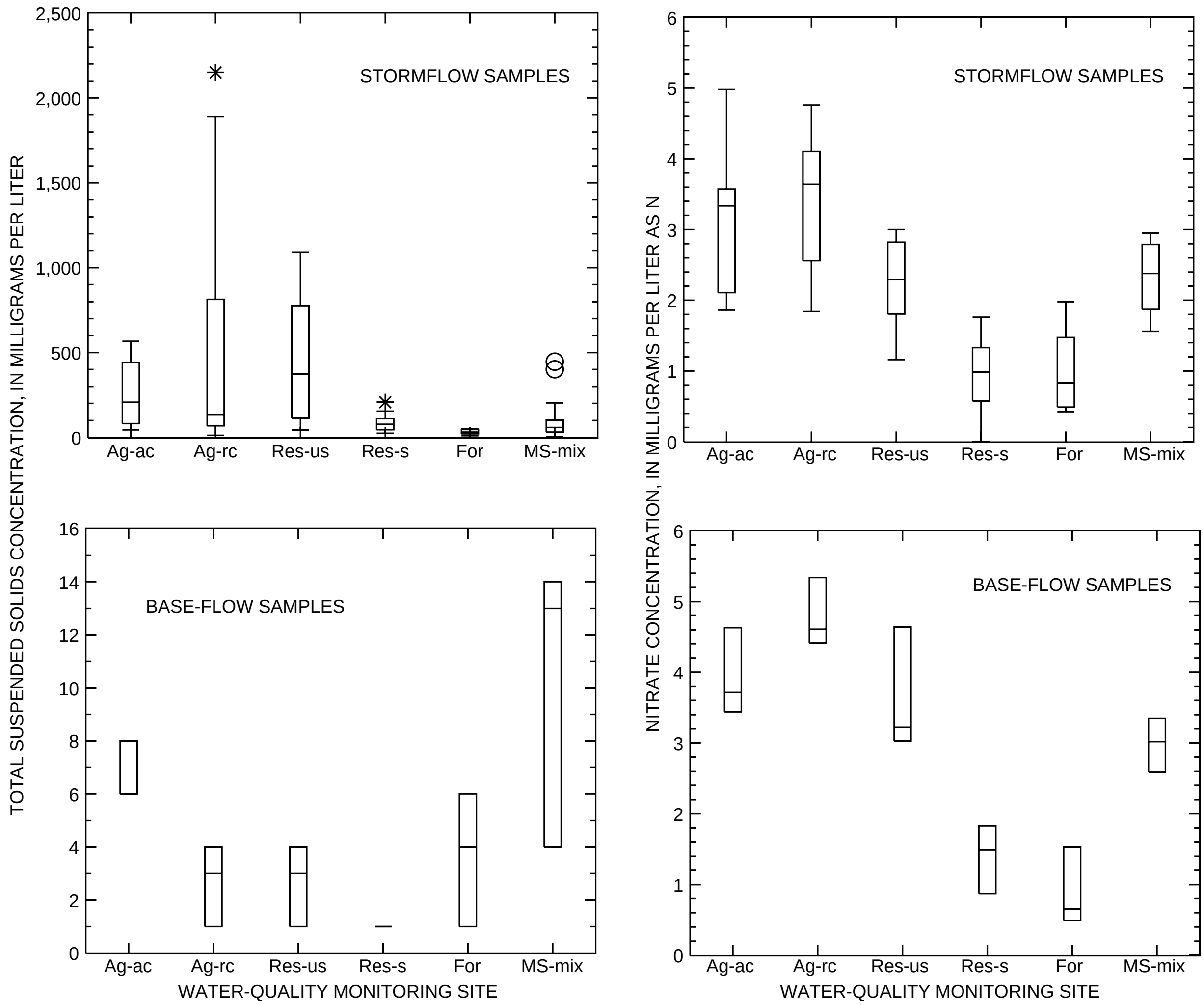
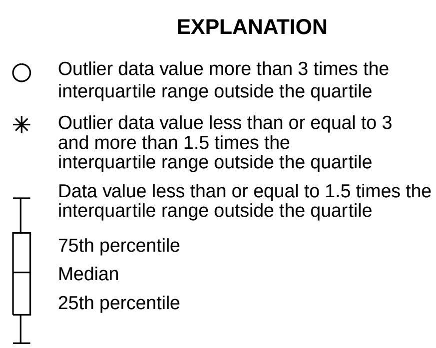


Figure 14. Relation between water-quality constituents and streamflow for stormflow and base-flow samples collected in 1998 at streamflow-measurement station 01481000, Brandywine Creek at Chadds Ford, Pa.





Site	Land use	Station number
Ag-ac	Agricultural - animals, crops	01480300
Ag-rc	Agricultural - row crop	014806318
Res-us	Residential - unsewered	01480637
Res-s	Residential - sewered	01480878
For	Forested	01480675
MS-mix	Main stem - mixed use	01481000

Figure 15. Distribution of concentrations of suspended solids and nitrate in samples collected under stormflow and base-flow conditions at six monitoring sites in the Brandywine Creek Basin, 1998. [See figure 8 for location of and table 7 for description of monitoring sites.]

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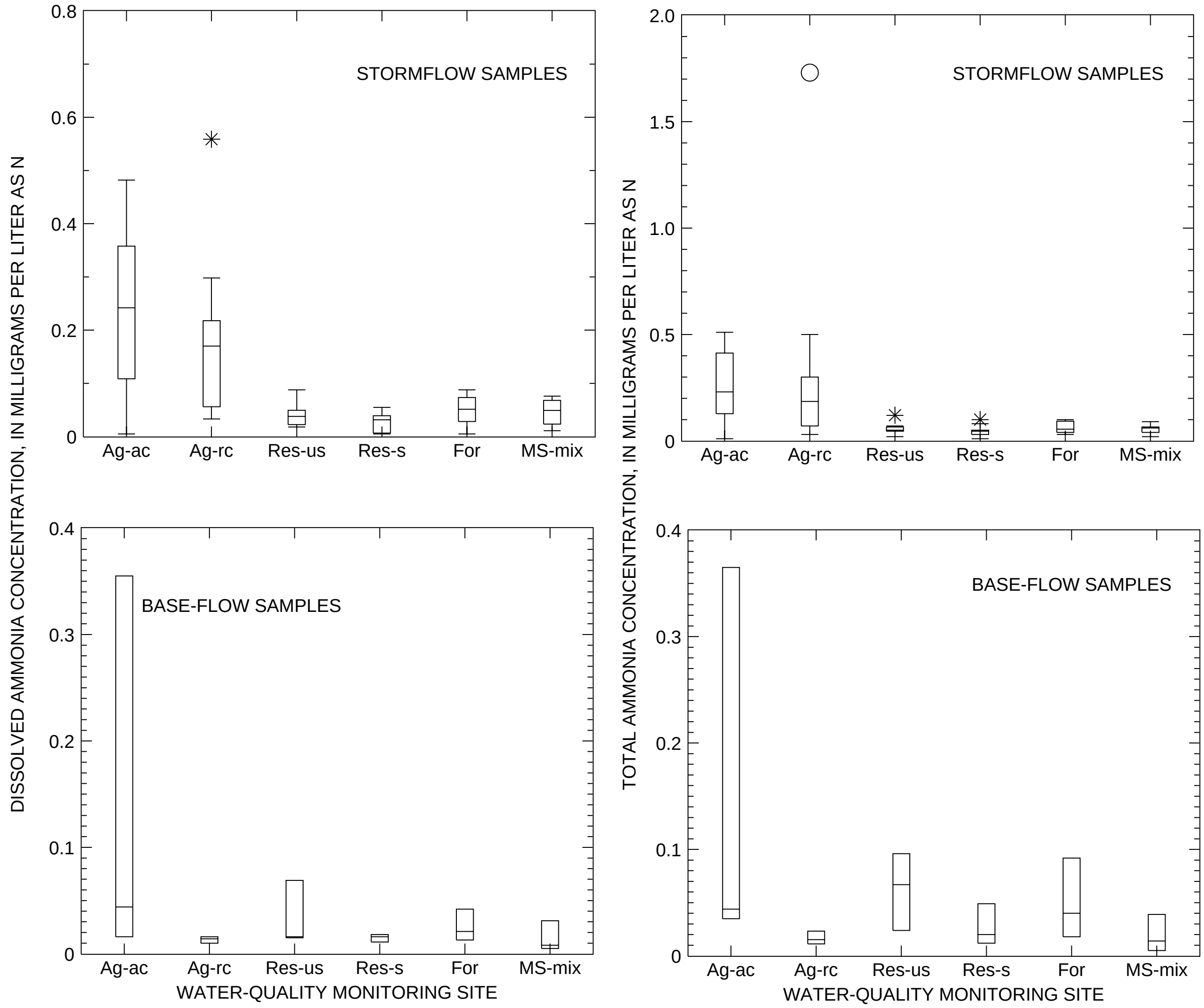
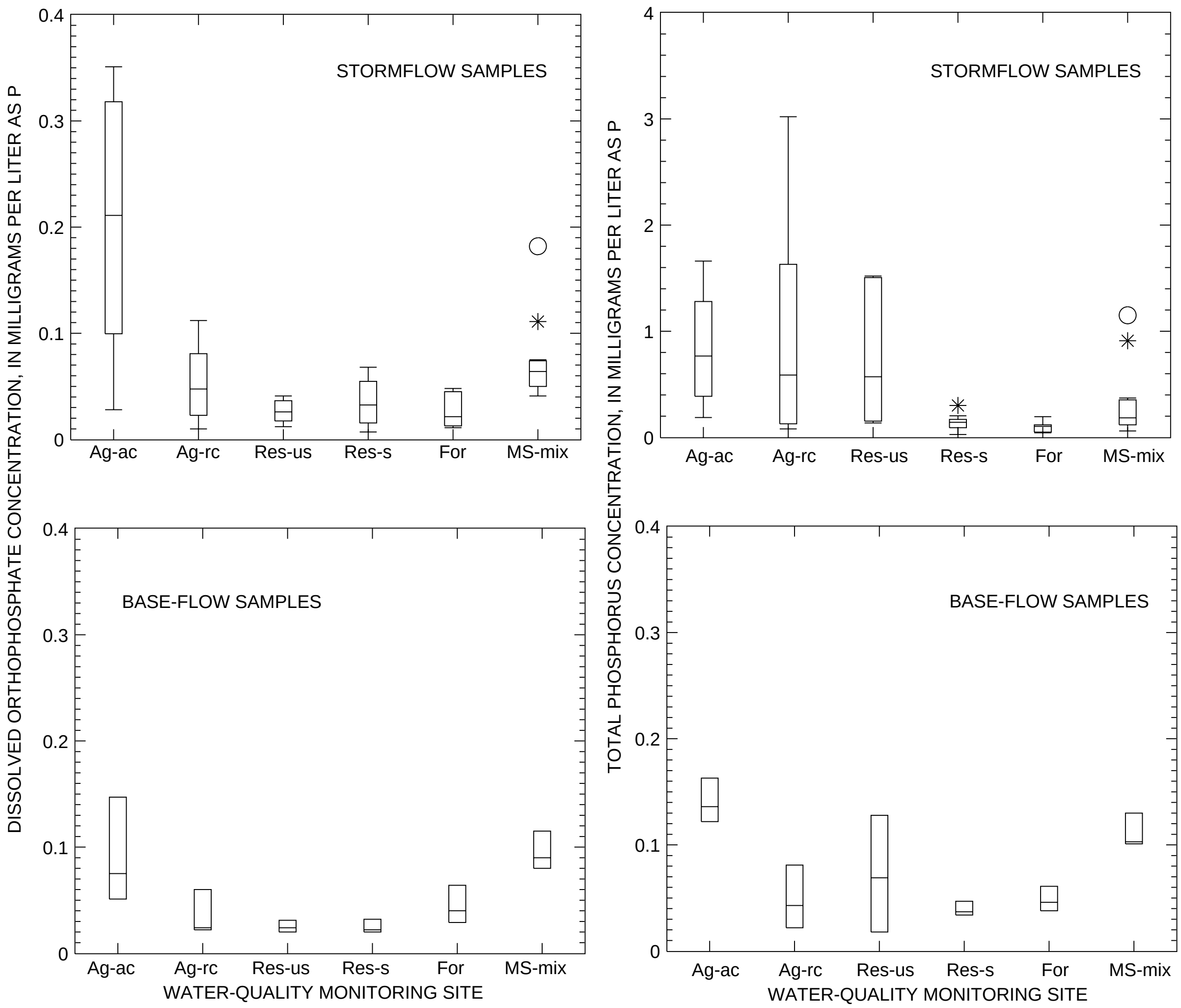


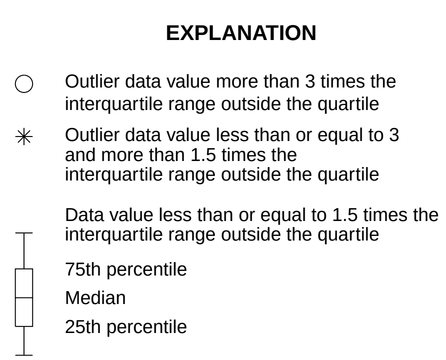
EXPLANATION

- Outlier data value more than 3 times the interquartile range outside the quartile
- Outlier data value less than or equal to 3 and more than 1.5 times the interquartile range outside the quartile
- Data value less than or equal to 1.5 times the interquartile range outside the quartile
- 75th percentile
- Median
- 25th percentile

Site	Land use	Station number
Ag-ac	Agricultural - animals, crops	01480300
Ag-rc	Agricultural - row crop	014806318
Res-us	Residential - unsewered	01480637
Res-s	Residential - sewered	01480878
For	Forested	01480675
MS-mix	Main stem - mixed use	01481000

Figure 16. Distribution of concentrations of dissolved and total ammonia in samples collected under stormflow and base-flow conditions at six monitoring sites in the Brandywine Creek Basin, 1998. [See figure 8 for location of and table 7 for description of monitoring sites.]





Site	Land use	Station number
Ag-ac	Agricultural - animals, crops	01480300
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Res-us	Residential - unsewered	01480637
Res-s	Residential - sewered	01480878
For	Forested	01480675
MS-mix	Main stem - mixed use	01481000

Figure 17. Distribution of concentrations of dissolved orthophosphate and total phosphorus in samples collected under stormflow and base-flow conditions at six monitoring sites in the Brandywine Creek Basin, 1998. [See figure 8 for location of and table 7 for description of monitoring sites.]

Concentrations of suspended sediment were higher by as much as three orders of magnitude in stormflow samples compared to base-flow samples. Concentrations of nitrate generally were greater in base-flow samples.

SIMULATION OF STREAMFLOW

Streamflow in the Brandywine Creek Basin was simulated for the period January 1994 to October 29, 1998, or just under 5 years. Donigian and others (1984) suggest a 3-year to 5-year simulation period as optimal for HSPF because a greater variety of climatic conditions will be included.

The Brandywine Creek Basin was divided into four segments for the model. Segments of the basin area were defined primarily on the basis of spatial distribution of precipitation. Within each segment, the hydrologic response of land areas was assumed to differ principally by land use because soils within each segment were similar. The segment areas are bounded approximately by Thiessen polygons generated for the four NOAA meteorological gages. Each segment receives precipitation input from one of the four NOAA meteorological gages, Honey Brook 1 S, Glenmoore, Coatesville 2 W, or Porter Reservoir (figs. 4 and 18). The land-based hydrologic response in each segment was characterized spatially by subdividing the area into a total of 12 land-use categories that consist of 10 pervious and 2 impervious land-use types (table 9). These simplified land-use categories represent the predominant land uses in the basin. Initial hydrologic-response parameters were assigned to the land-use categories and were modified as needed during model calibration. Parameters do not vary within a segment but may vary from segment to segment.

The amount of impervious land was calculated from the residential and urban pervious land uses using factors modified from Water Resource Agency for New Castle County values in Greig and others (1998). Because the HSPF model simulates no infiltration in impervious areas and some runoff from impervious areas such as roofs and roads does infiltrate, the amount of effectively impervious area is expected to be lower than impervious areas estimated by land-use maps. Thus, the amount of effectively impervious area was reduced from the amount of impervious area estimated from land-use maps. This type of modification has been employed in HSPF models in other study areas (Zarriello, 1999). The proportion of effectively impervious land was estimated as 0.1 in residential areas without sewers, 0.3 in residential areas with sewers, 0.5 for urban areas. and 0.1 for undesignated lands in sewered areas.

Thirty-five RCHRES were specified for the Brandywine model (fig. 18). RCHRES lengths ranged from 0.87 to 12.1 mi in length; the median length was 3.2 mi. Selection of RCHRES lengths was guided by the confluences of major tributaries, the location of calibration points, the location of dams and impoundments, and major changes in land use contributing to a stream reach. Length measurements were taken from topographic maps. Sixteen RCHRES are in the West Branch, 12 RCHRES in the East Branch, and 7 in the main stem below the confluence. Each of the three reservoirs in the basin was simulated as a reach. The area of each land-use category draining directly to each reach was calculated and ranged from 0.6 to 25.54 mi^2 (table 9).

Snowfall, snow accumulation, and snow melt were simulated throughout the basin initially because hydrologic and meteorologic records indicated substantial snow, ice, and sub-freezing temperatures during the winters of 1993-94 and 1995-96. In the coldest periods, sub-freezing temperatures resulted in stream channel icing at the calibration sites. During both winters, only estimated daily streamflows were available during much of December, January, and February. Hourly streamflow values for these periods are considered poor and published daily streamflows are reported as estimated. Final calibration included the simulation of snow only in the northwestern part of the basin corresponding to segment 1. Streamflow for segment 1 was calibrated from data collected at the streamflow-measurement station on West Branch Brandywine Creek at Honey Brook, Pa. Although snow and ice probably accumulated in other parts of the basin during the winters of 1993-94 and 1995-96, an improved calibration was obtained by excluding the simulation of snow elsewhere. Possible physical reasons for this may include 1) the northwestern part of the basin has higher elevation and is colder than other parts of the basin; and 2) poor winter-time record at the streamflow-measurement stations.

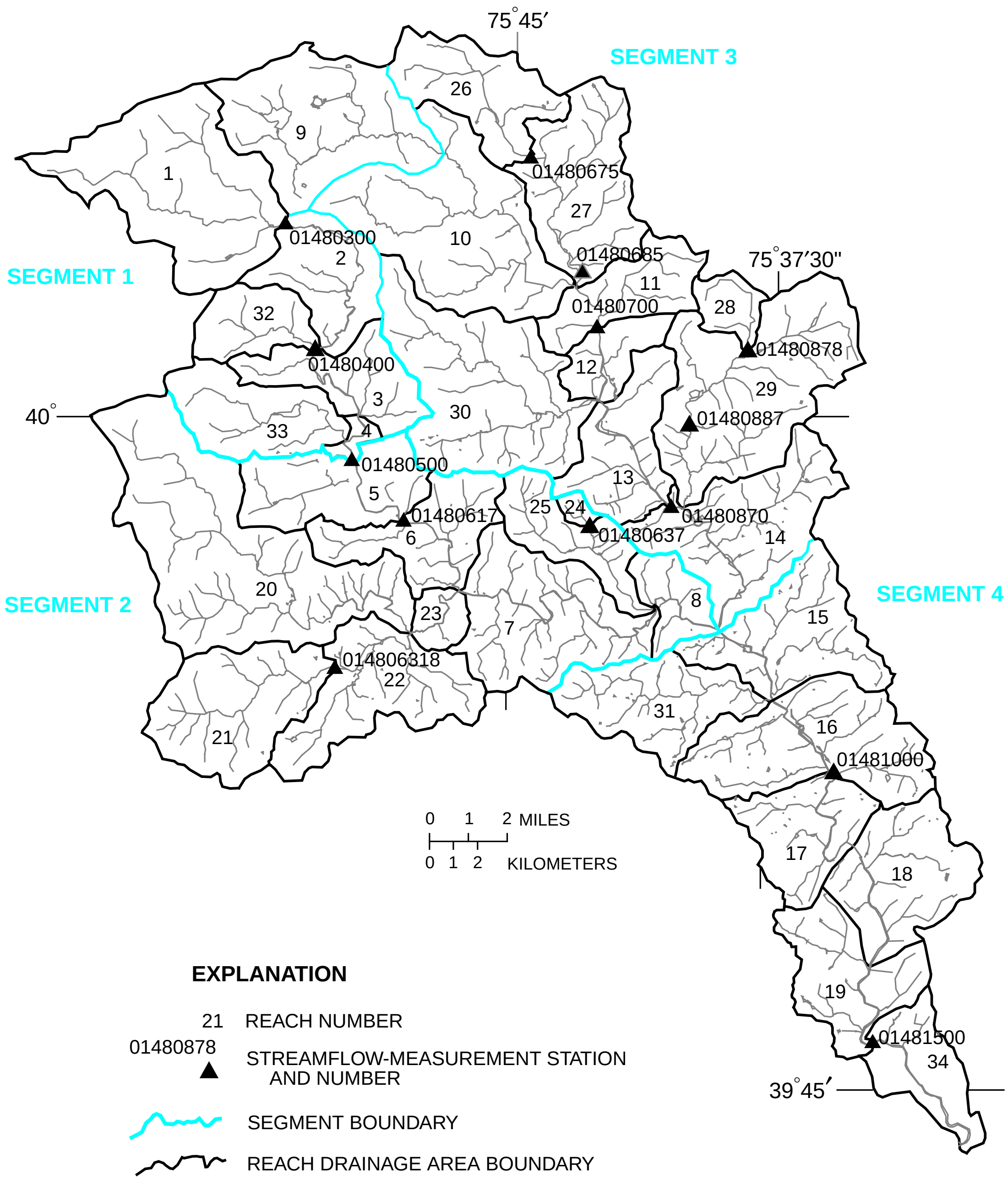


Figure 18. Location of segments, reach drainage areas, and stream reaches (RCHRES) delineated for HSPF model of the Brandywine Creek Basin, Pennsylvania and Delaware.

Table 9. *Reach number, length, drainage area, segment number, and percentage of land-use category in drainage area for Brandywine Creek model*

[mi, miles; mi^2, square miles]

Reach number	Reach length (mi)	Reach drainage area (mi^2)	Segment number	Land-use category, in percent											
				Residential - septic	Residential- sewer	Urban	Agricultural - livestock	Agricultural - row crop	Agricultural - mushroom	Forested	Open	Wetland.water	Undesignated	Impervious - residential	Impervious - urban
1	6.60	18.39	1	4.1	1.4	0.6	45.6	22.5	0	20.1	2.7	0.5	0.9	1.1	0.7
2	7.60	7.38	1	17.3	.6	1.8	9.4	19.0	0	46.4	.5	.8	.2	2.2	1.8
3	2.94	6.76	2	22.3	.3	1.2	7.5	22.6	0	39.8	2.0	.5	.03	2.6	1.2
4	1.85	.80	2	0	7.1	2.1	0	14.9	0	68.8	.1	1.7	.2	3.0	2.1
5	2.91	8.82	2	1.5	11.0	10.5	0	19.1	0	34.8	3.6	1.5	2.4	4.9	10.7
6	2.93	8.06	2	17.1	.5	1.5	4.0	35.6	0	35.4	1.8	.5	.01	2.1	1.5
7	7.80	13.46	2	5.9	0	1.5	0	49.0	0	38.2	1.9	1.2	.1	.7	1.5
8	2.19	3.62	2	9.2	0	.6	0	62.6	0	24.9	0	1.2	.1	1.0	.6
9	7.10	14.68	1	6.1	.5	.4	27.0	27.0	0	32.6	2.2	2.8	.2	.9	.4
10	12.10	18.31	3	17.0	.2	1.2	0	36.0	0	40.3	1.2	.6	.2	2.0	1.2
11	1.79	6.31	3	4.7	11.6	1.9	0	33.1	0	35.6	4.7	.5	.6	5.5	1.9
12	2.02	3.70	3	8.4	18.7	4.4	0	11.4	0	38.9	2.2	1.3	1.3	8.9	4.5
13	3.86	7.94	3	6.5	10.1	4.3	0	14.3	0	47.9	3.1	1.4	2.7	5.1	4.6
14	4.86	12.92	3	8.8	10.8	3.5	0	31.9	0	30.2	3.2	1.0	1.4	5.6	3.6
15	2.49	10.36	4	17.6	7.2	1.9	0	40.7	0	16.8	6.9	1.0	1.0	5.0	1.9
16	2.88	14.06	4	25.0	0	2.4	0	25.7	0	38.7	1.6	.9	.5	2.8	2.4
17	4.15	7.51	4	12.2	0	.1	0	27.0	0	48.6	6.1	1.3	.4	4.1	.3
18	3.39	10.37	4	9.2	3.5	1.6	2.1	19.1	0	38.2	14.6	1.1	5.8	2.5	2.2
19	2.71	8.64	4	10.6	10.3	3.4	0	4.1	0	16.5	40.3	1.0	4.6	5.6	3.6
20	8.66	25.54	2	7.7	1.8	1.1	5.9	52.9	0	25.5	1.3	.4	.8	1.6	1.1
21	6.73	11.05	2	3.5	0	.4	7.6	68.6	0	17.3	1.1	.1	.5	.4	.4
22	3.18	10.96	2	.7	0	.9	7.9	71.3	0	17.7	0	.3	.2	.1	.9
23	.87	1.95	2	0	0	.01	4.9	44.4	0	49.4	0	1.3	0	0	.01
24	3.14	.60	2	73.2	4.9	0	0	3.5	0	8.2	0	0	0	10.3	0
25	3.14	5.83	2	15.2	3.7	2.3	0	40.7	0	30.4	1.7	.1	.3	3.3	2.3
26	1.60	2.61	3	8.1	0	2.2	6.5	19.6	0	59.5	.3	.5	.1	.9	2.2
27	4.80	11.54	3	21.5	.1	.9	8.9	20.6	0	33.9	2.4	7.4	1.1	2.4	.9
28	2.00	2.40	3	.1	37.6	6.5	0	3.0	0	20.5	5.7	.03	3.6	16.1	6.7
29	7.20	18.21	3	4.3	12.9	3.5	0	20.9	0	35.1	5.0	2.5	3.2	6.0	6.7
30	4.09	18.08	3	12.2	6.6	4.7	0	32.4	0	30.0	2.2	.2	2.7	4.2	5.0
31	4.09	9.19	4	22.7	0	.8	0	48.8	0	22.1	1.8	.3	.3	2.5	.8
32	2.00	4.66	1	11.3	0	.8	15.8	15.8	0	52.9	.9	.1	.3	1.3	.8
33	2.75	8.03	2	12.2	3.5	1.3	4.2	38.0	0	29.8	4.5	2.1	.4	2.9	1.3
34	4.46	6.05	4	1.9	2.5	28.0	0	1.6	0	13.9	12.9	2.6	7.3	1.3	28.2
35	4.00	5.80	3	6.3	0	1.1	12.1	36.3	0	34.1	.3	7.8	.2	.7	1.1
Total	144.88	324.62	--	10.5	3.9	2.7	6.3	32.7	0	31.8	3.8	1.2	1.3	2.9	2.8

Assumptions

The simulation of streamflow in Brandywine Creek was done under the following assumptions: (1) inputs of hourly precipitation would be estimated reasonably well by disaggregated 24-hour precipitation data; (2) the average precipitation over a given land segment would be represented adequately by weighted data from a single precipitation gage; (3) a simplified set of PERLNDs and IMPLNDs would not unduly limit a satisfactory hydrologic calibration of the Brandywine model.

Model Calibration

The basin hydrology model was calibrated using HSPEXP (Lumb and others, 1994), an expert system, and the calibration guidelines in Donigian and others (1984). Because transport of many nonpoint-source constituents is greatest at high flows, the model calibration effort was directed at the full range of observed streamflow with some focus on higher streamflows. Prior to calibration, initial estimates of the hydrologic calibration parameters were determined. The initial values were derived from known watershed characteristics where possible, from the HSPFParm database (Donigian and others, 1998), and from published sources such as Donigian and Davis (1978) and the USEPA (2000b). During calibration with HSPEXP, simulated streamflow is compared to observed streamflow through statistical and graphical methods and suggestions are given as to which parameter(s) needs modified. HSPEXP also includes default criteria for determination of a satisfactory hydrologic calibration (table 10). The criteria are maximum allowable differences (errors) between observed and simulated streamflow expressed as percent error. These criteria are not fixed in HSPEXP and can be modified depending on the users' needs. Donigian and others (1984) offer the following error criteria for calibration: annual and monthly values less than 10 percent difference (Very Good); 10 to 15 percent difference (Good); 15 to 25 percent difference (Fair). Calibrated hydrologic parameter values are listed in the Brandywine UCI in Appendix 3.

The Brandywine model was calibrated at gaged locations along the East and West Branches and main stem of Brandywine Creek in downstream order. For example, the part of the basin above West Branch Brandywine Creek at Honey Brook, Pa. (01480300), was calibrated before the part of the basin draining to the next gage downstream, West Branch Brandywine Creek at Coatesville, Pa. (01480500). The period of calibration was January 1, 1994, to October 30, 1998, except for the Wilmington, Del. (01481500), site. The period of calibration for Wilmington was October 1, 1994, to October 30, 1998, because of missing hourly streamflow record for most of 1994. Calibration errors (table 10) could not be computed for the

Table 10. *Calibration criteria and errors for HSPF simulated streamflow at eight gaging sites in the Brandywine Creek Basin for the period January 1, 1994, through October 29, 1998*

	Calibration error criteria, in percent[1]						
	Total volume	Low flow recession rate	50-percent lowest flows	10-percent highest flows	Storm peaks	Seasonal volume error	Summer storm volume error
	10.0	**0.03**	**10.0**	**15.0**	**20.0**	**30.0**	**50.0**
Calibration site[2]	**Calibration errors from HSPEXP, in percent**						
01480300	0.9	-0.04	-2.1	-1.4	7.0	12.8	15.1
01480500	1.2	-.01	10.2	-.7	-1.4	17.6	28.1
01480617	-1.3	.01	2.1	-1.2	14.3	20.3	31.7
01480675	.2	.04	17.8	-6.6	1.4	19.9	.5
01480700	-2.7	-.01	-6.1	-.4	10.5	1.2	13.8
01480870	2.2	0	-2.1	2.8	2.8	.6	13.7
01481000	1.0	0	4.9	6.6	14.3	4.6	10.4
[3]01481500	3.9	0	-.5	15.0	8.4	3.5	-1.4

[1] Default criteria for satisfactory hydrologic calibration in HSPEXP.
[2] Streamflow-measurement station number.
[3] Errors for the period October 1, 1994, through October 29, 1998.

three smallest drainage sites (Doe Run above tributary at Springdell, Pa., Little Broad Run near Marshallton, Pa., and Unnamed tributary to Valley Creek at Highway 30 at Exton, Pa.) because of excessive periods of poor or missing streamflow record.

Stormflow hydrograph calibration consisted of comparing stormflow volume, average simulated peak flows, and recession rates of selected storms with observed data in HSPEXP and visual examination of simulated and observed stormflow hydrographs. Thirty-six storm events were selected from the simulation period. Storms were selected using the following criteria as a guide: (1) total storm precipitation will be equal to 1 in. or more and cover a broad area of the drainage basin in order that all / most segments of the basin exhibit a hydrologic response to the storm; and (2) all storms during which water-quality data were collected. The summary statistics—error in total storm volume, error in the mean of peak stormflows for all selected storms, and error in total summer storm volume—were calculated for the 36 selected stormflow periods collectively. For the Brandywine Creek sites and Marsh Creek, these statistics indicate simulation errors less than the default HSPEXP error criteria (table 10), indicating a good calibration for the model. However, these statistics are not indicative of the errors for individual storm simulations.

In general, errors in individual storm simulations vary widely and tend to increase with decreasing drainage area. An example of this behavior is shown for errors in simulated peak stormflows for selected storms at all streamflow-measurement sites, in order of increasing drainage area, for the August 8, 1997, through October 29, 1998, period (fig. 19). Peak stormflow errors varied about an order of magnitude at most sites and when compared to the default 20 percent error criteria from HSPEXP, relatively few errors in peak stormflows were equal to or less than the criteria. The largest errors in simulation of stormflow appear to result from incorrectly specified precipitation. For example, poor simulations at two of the water-quality calibration sites (fig. 20) had identifiable problems with the specified rainfall. These problems include incorrect total rainfall across the drainage basin, incorrect dissagregation, and shifts in rainfall timing. Incorrect total rainfall is shown most clearly for an August 17, 1998, storm event at Little Broad Run near Marshallton, Pa. (fig. 20C). During that storm, 1.65 in. of rainfall recorded in 1 hour at Coatesville 2 W were applied to the basin during simulation and generated a peak stormflow of about 85 ft^3/s whereas the observed streamflow increased by less than 1 ft^3/s. Data from a short-term raingage closer to the site recorded a maximum of 0.2 in. of rainfall in 1 hour. A disaggregation error resulted in the under-simulated stormflow at Chadds Ford on August 12-14, 1996 (fig. 20A). Because no rain fell at Wilmington Airport, where the data used for hourly rainfall disaggregation was recorded, the 2.65 in. of rainfall reported at Porter Reservoir was disaggregated into 48 (0.08 in. maximum) hourly amounts. Maximum rainfall intensity and therefore peak stormflows were reduced correspondingly. Shifts in the overall timing of stormflow hydrographs was a third problem related to precipitation and can be seen in the October 4-5, 1995, stormflow event at Chadds Ford (fig. 20B). Typically, a time discrepancy between the simulated and observed stormflow hydrographs has no effect on the HSPEXP error statistics except when the time shift moves the simulated hydrograph beyond the established storm event time boundaries. These boundaries are set at whole day increments (for individual storms) or seasonal periods (June, July, August for the summer). However, a time-shifted event can cause difficulties with the evaluation of a water-quality calibration; the temporal mismatch between observed and simulated streamflows produces a corresponding mismatch between observed and simulated water quality. Use of inverse distance weighting of rainfall also has the potential to result in incorrectly specified rainfall for individual storm events, but examination of the data show this effect to be of minor significance.

Stormflow simulations with the least error tended to result from storms that produced the most uniform rainfall distribution across a drainage basin. Examples of simulations having more uniform rainfall are shown for each of the six water-quality sites in figure 21.

Time-series comparison of simulated and observed daily mean streamflow at West Branch Brandywine Creek at Modena (01480617), East Branch Brandywine Creek below Downingtown (01480870), and Brandywine Creek at Chadds Ford (01481000) (figs. 22, 23, and 24) indicates a tendency toward undersimulation during low-flow conditions. The undersimulation is noticeable most at the East Branch Brandywine Creek below Downingtown site. Oversimulation of the lowest flows at West Branch Brandywine Creek at Modena

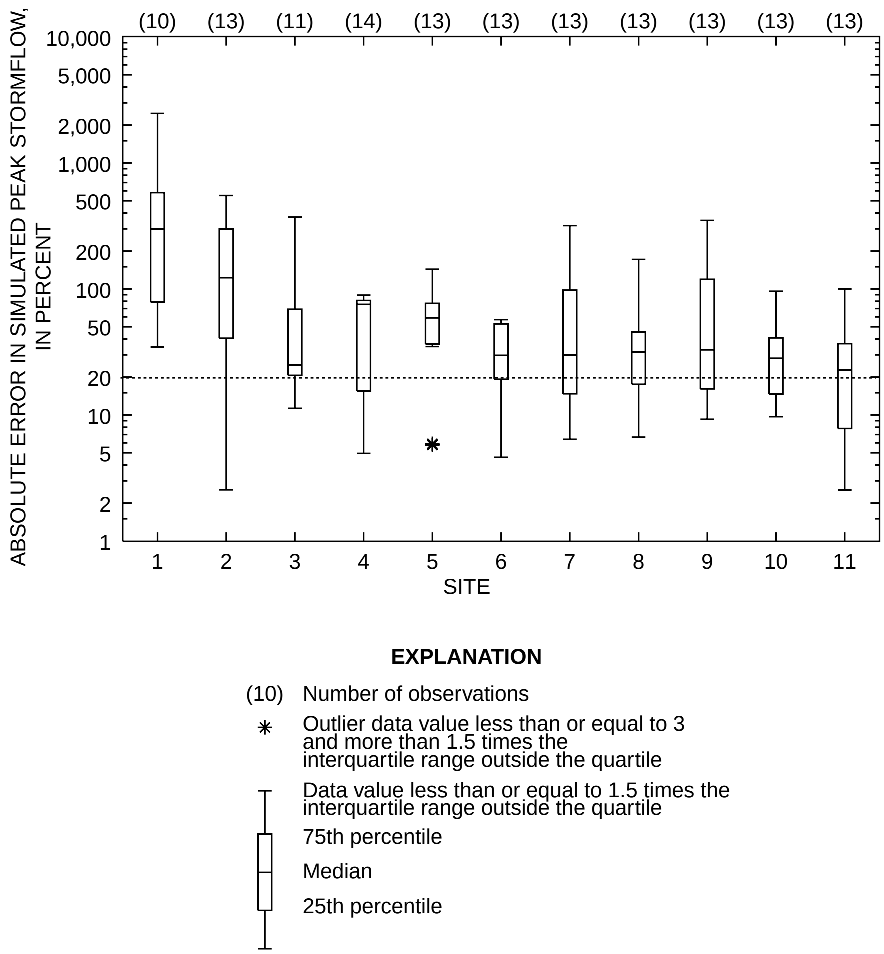


Figure 19. Summary of errors in simulated peak stormflows for selected storms in the period August 8, 1997, through October 29, 1998, at the sites in the Brandywine Creek Basin (in order of increasing drainage area).

1. Little Broad Run near Marshallton, Pa. (0.6 mi^2)
2. Unnamed tributary to Valley Creek at highway 30 at Exton, Pa. (2.6 mi^2)
3. Marsh Creek near Glenmoore, Pa. (8.6 mi^2)
4. Doe Run above tributary at Springdell, Pa. (11.2 mi^2)
5. West Branch Brandywine Creek near Honey Brook, Pa. (18.7 mi^2)
6. West Branch Brandywine Creek at Coatesville, Pa. (45.8 mi^2)
7. West Branch Brandywine Creek at Modena, Pa. (55.0 mi^2)
8. East Branch Brandywine Creek near Downingtown, Pa. (60.6 mi^2)
9. East Branch Brandywine Creek below Downingtown, Pa. (89.9 mi^2)
10. Brandywine Creek at Chadds Ford, Pa. (287 mi^2)
11. Brandywine Creek at Wilmington, Del. (314 mi^2)

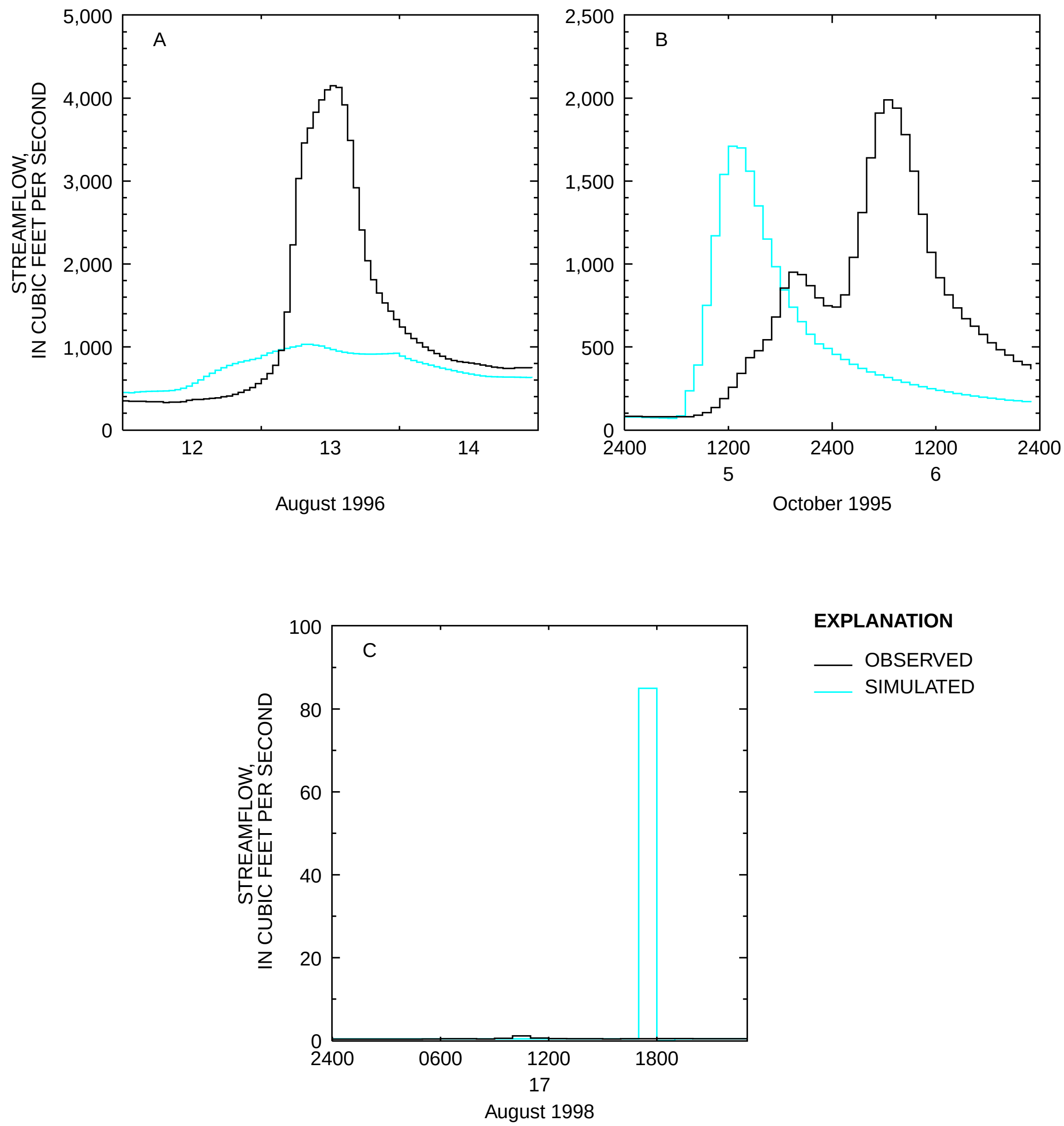


Figure 20. Observed and simulated stormflow for Brandywine Creek at Chadds Ford, Pa., on (A) August 12-14, 1996, (B) October 5-6, 1995, and (C) for Little Broad Run near Marshallton, Pa., on August 17, 1998.

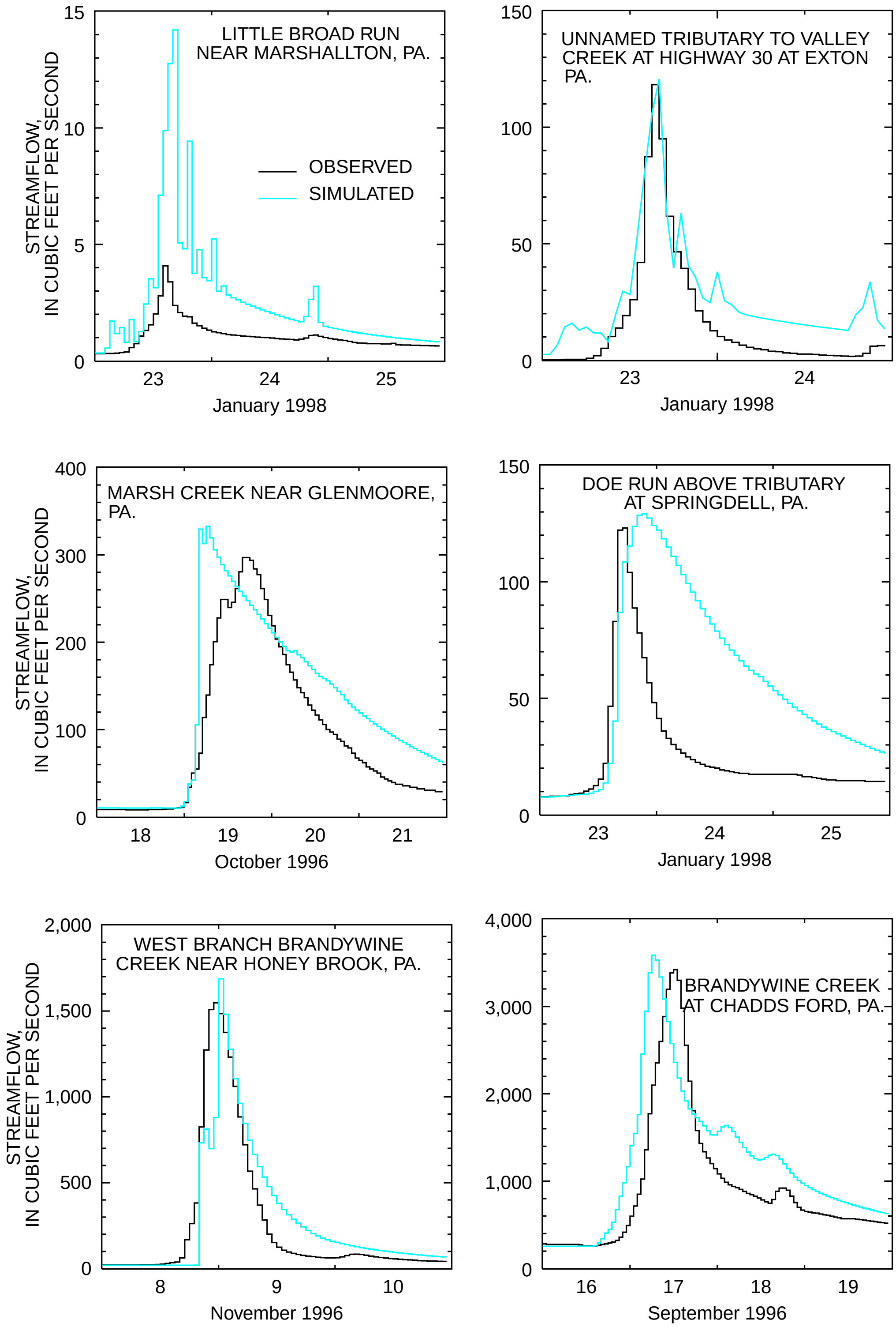


Figure 21. Simulated and observed stormflow hydrographs at six water-quality sites in the Brandywine Creek Basin.

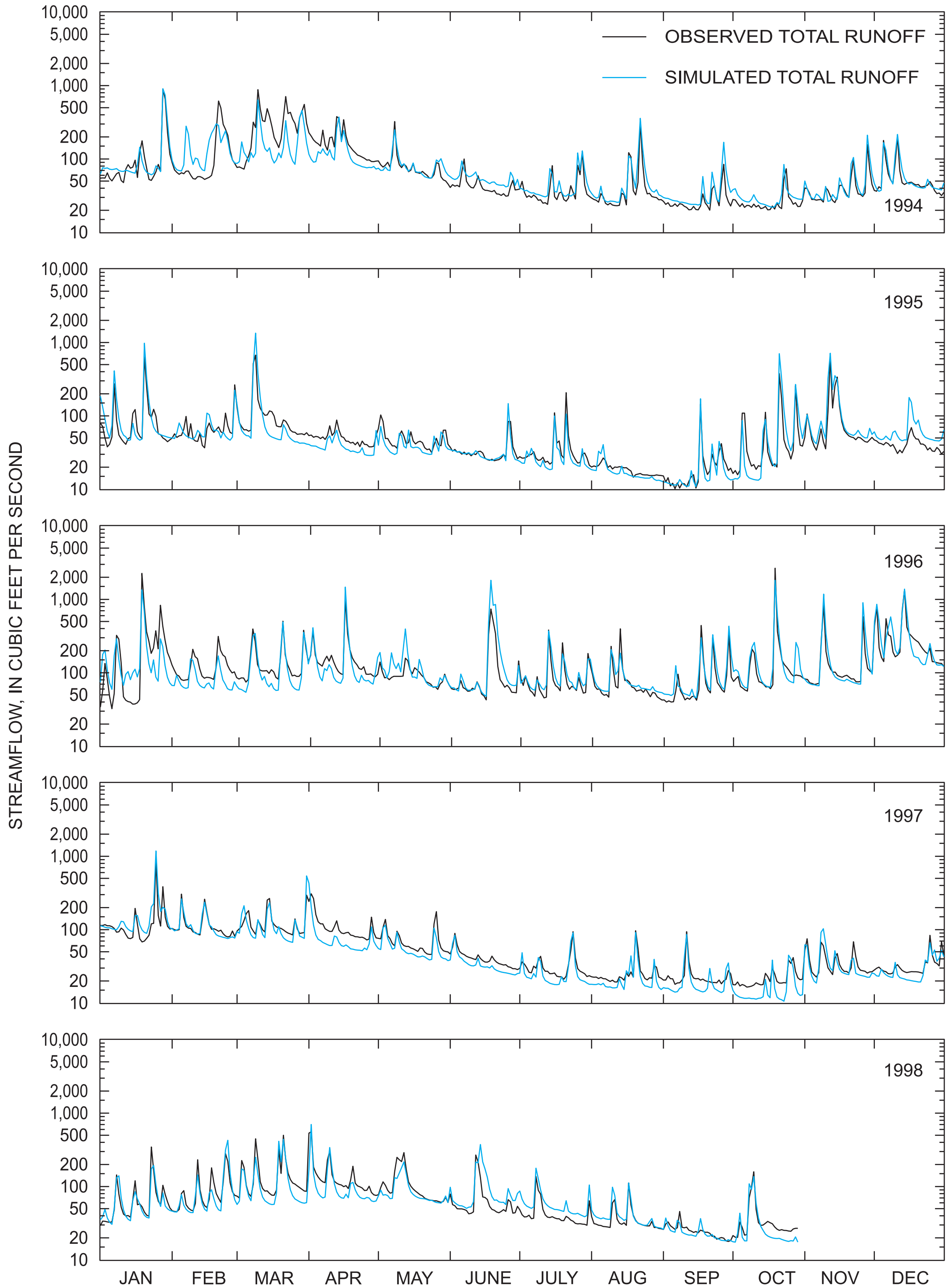


Figure 22. Simulated and observed daily mean streamflow at streamflow-measurement station 01480617, West Branch Brandywine Creek at Modena, Pa., for the period January 1, 1994, through October 29, 1998.

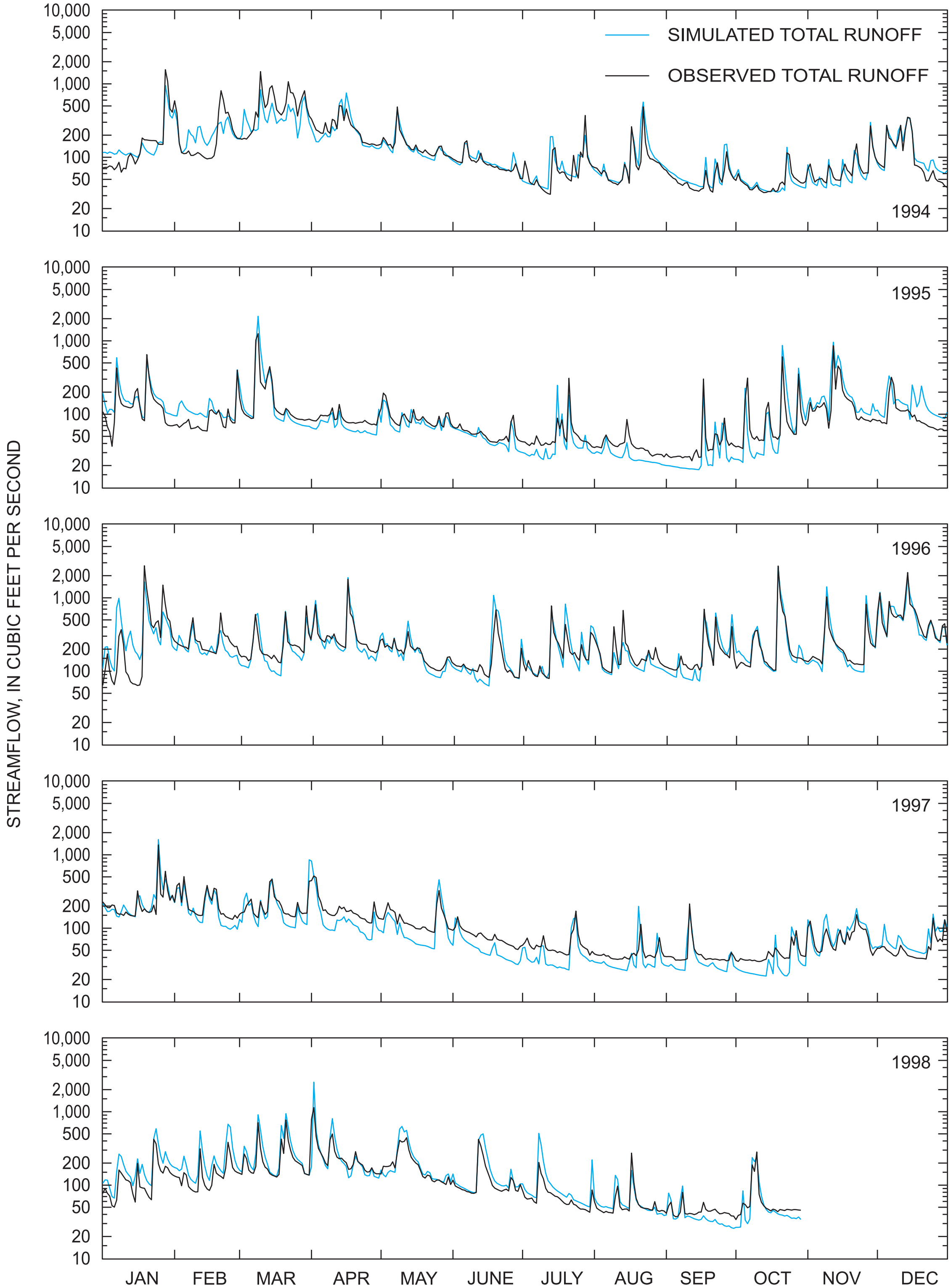


Figure 23. Simulated and observed daily mean streamflow at streamflow-measurement station 01480870, East Branch Brandywine Creek below Downingtown, Pa., for the period January 1, 1994, through October 29, 1998.

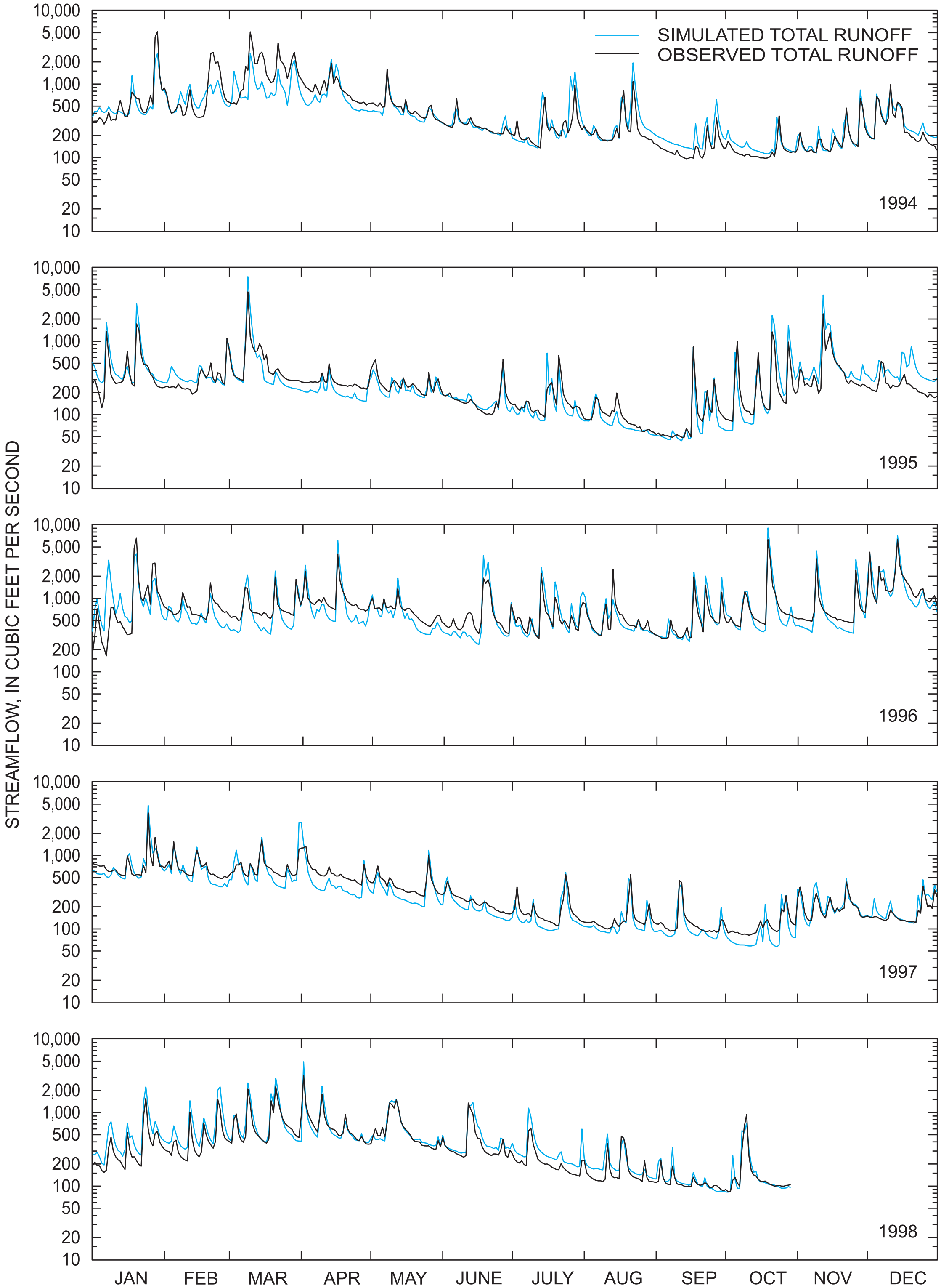


Figure 24. Simulated and observed daily mean streamflow at streamflow-measurement station 01481000, Brandywine Creek at Chadds Ford, Pa., for the period January 1, 1994, through October 29, 1998.

probably is caused by poor estimation of an intermittent upstream withdrawal. Because withdrawal data were available only on a monthly basis and lacking other information, those withdrawals were estimated for input as uniform hourly values.

Time series comparison of simulated and hourly streamflow at five of six water-quality sites, which include the three small-basin sites, for the period October 1, 1997, through October 29, 1998, are shown in figure 25. The Unnamed tributary to Valley Creek at Highway 30 at Exton, Pa., and Doe Run above tributary at Springdell, Pa., show definite oversimulation over their period of record. Marsh Creek near Glenmoore, Pa., also shows oversimulation although not as pronounced during the period shown. Little Broad Run near Marshallton, Pa., was undersimulated for the fall and winter of 1997-98 and oversimulated for the summer of 1998. The West Branch Brandywine Creek near Honey Brook, Pa., simulation errors were, percentage wise, the smallest of the five water-quality sites and similar in pattern to those at Little Broad Run.

Flow-duration curves of simulated and observed hourly streamflow for the streamflow sites on the main branches of Brandywine Creek and Marsh Creek indicate generally good agreement (figs. 26, 27, and 28). Overall, the simulated durations of the highest flows, those that transport the bulk of nonpoint-source constituents, generally occur either as frequently or somewhat more frequently than observed high flows except at the East Branch below Downingtown site. Simulated low flows do not match observed flows as well. The lowest 20 percent of streamflows generally are undersimulated at sites on the Brandywine Creek except at Marsh Creek near Glenmoore. At Marsh Creek near Glenmoore, the lowest 50 percent of flows are oversimulated. This site has a large wetland area in the headwaters area that likely contributes greater ground-water discharge to stream base flow than the other sites.

Flow-duration curves at the three small-basin sites (fig. 29), including Doe Run above tributary at Springdell, Pa., Little Broad Run near Marshallton, Pa., and Unnamed tributary to Valley Creek at Exton, Pa., show considerably greater simulation errors than those at the main branches of Brandywine Creek and Marsh Creek sites do. However, because the period of record is less at the small-basin sites (1+ year) than for main-stem sites (4-5 years), flow-duration curves for these two groups of sites cannot be compared directly. High-flow and low-flow simulations at the Doe Run site are oversimulated and undersimulated, respectively. This simulation could be improved by increasing the infiltration rate for PERLNDs in segment 2, but this change would result in poorer high-flow simulations at West Branch Brandywine Creek at Coatesville and West Branch Brandywine Creek at Modena. The over-then-under simulation characteristic of the 50-percent highest flows at the Little Broad Run site may indicate uncharacterized storage in a number of ponds above the calibration site affects the routing of water in that reach; the highest flows are reduced because of water storage while flows occurring 5 to 45 percent of the time are increased because of the release of stored water. The Unnamed tributary to Valley Creek at Exton site exhibited oversimulation throughout the range of streamflows. Reduced observed streamflow may explain, in part, the oversimulation. Approximately 1 mi of the stream just upstream of the site is underlain by carbonate rocks, and loss of water from the stream channel to ground water is not uncommon in carbonate areas. In addition, the pumping of public supply wells in the drainage area of the Exton site may reduce ground-water discharge to the stream.

The model performance in simulating hourly and daily streamflow was evaluated at six water-quality monitoring sites for 1998, the year of water-quality data collection, and at three sites for the calibration period of 1994-98. Statistical measures of the hourly and daily streamflow comparison are listed in table 11. Correlation and model-fit efficiency coefficients for the sites draining smaller areas (Little Broad Run, Unnamed tributary to Valley Creek) are lower than those for sites draining larger areas, indicating a poorer model fit for the smaller sites. The magnitude of mean errors relative to mean flow also are greater for sites draining smaller areas than larger areas. Unlike the flow-duration comparisons, the statistics for one-to-one comparison of observed and simulated values (table 11) are affected by errors in the timing of storms. Because errors in the timing of precipitation and consequent storms commonly occur in shifts on the order of hours, not days, they result in lower values of correlation and model-fit efficiency coefficients for hourly streamflow compared to those for daily streamflow (table 11). Errors in timing of precipitation on the order of hours affect simulated stormflow in small drainage areas to a greater extent than simulated stormflow in large

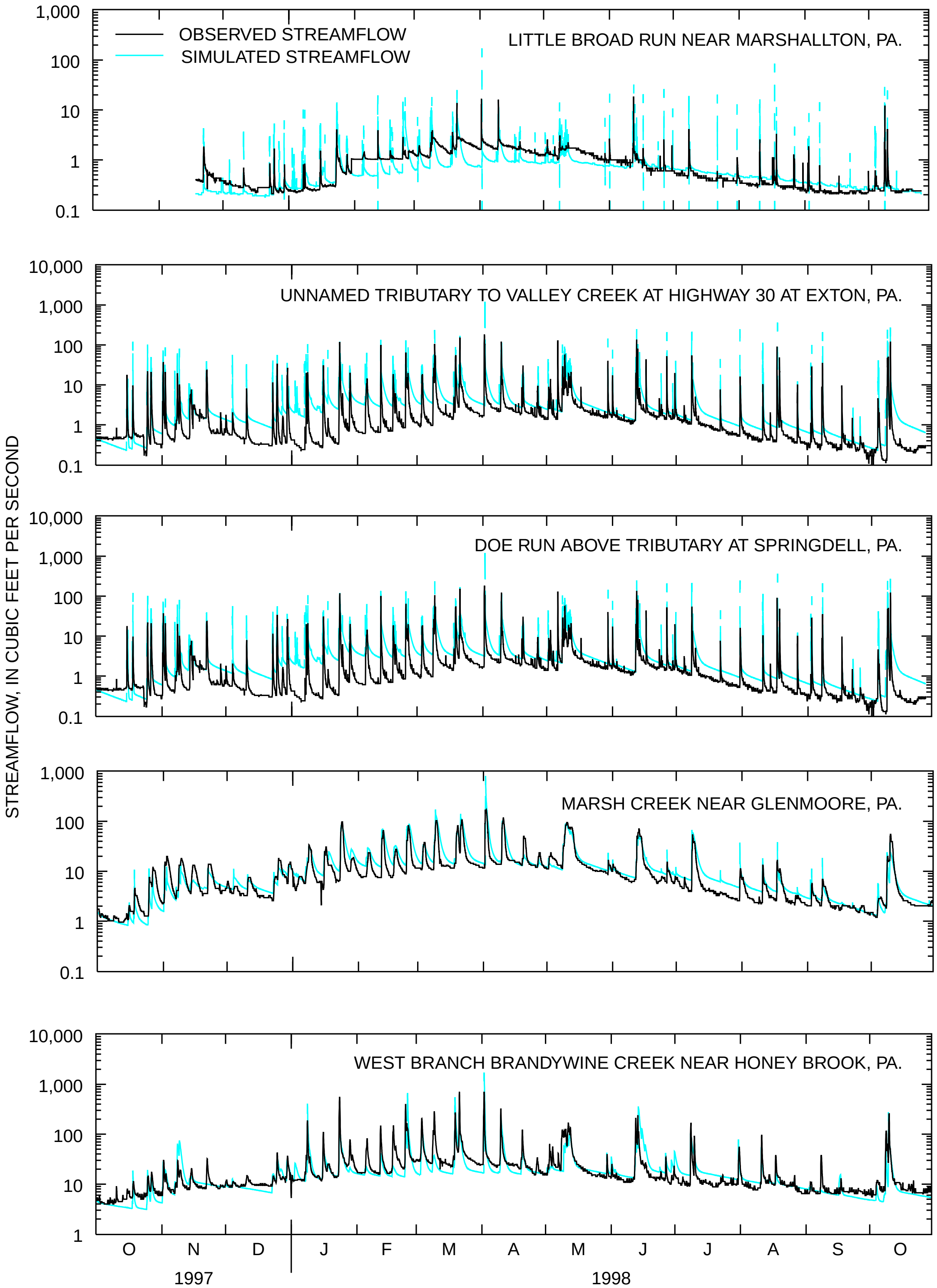


Figure 25. Simulated and observed streamflow at five water-quality sites in the Brandywine Creek Basin for the period October 1, 1997, through October 29, 1998.

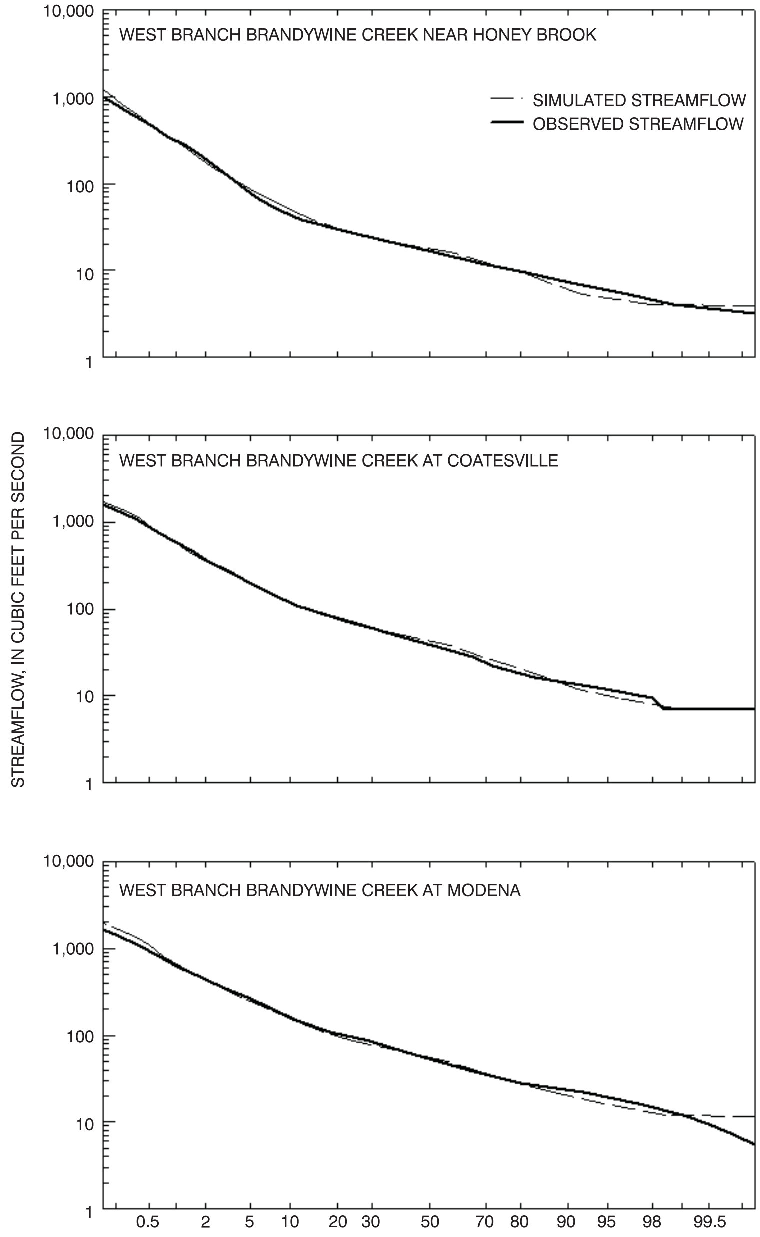


Figure 26. Duration curves of simulated and observed hourly mean streamflow for three sites on West Branch Brandywine Creek.

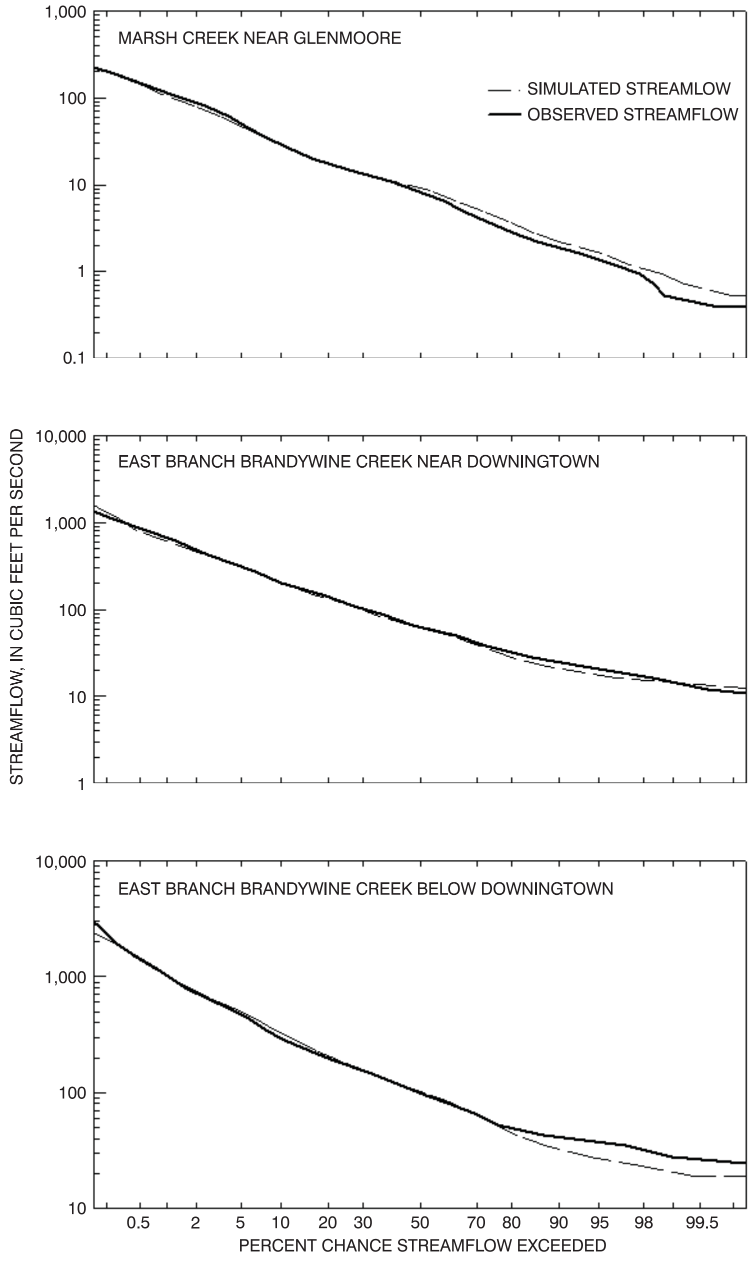


Figure 27. Duration curves of simulated and observed hourly mean streamflow for three sites on East Branch Brandywine Creek.

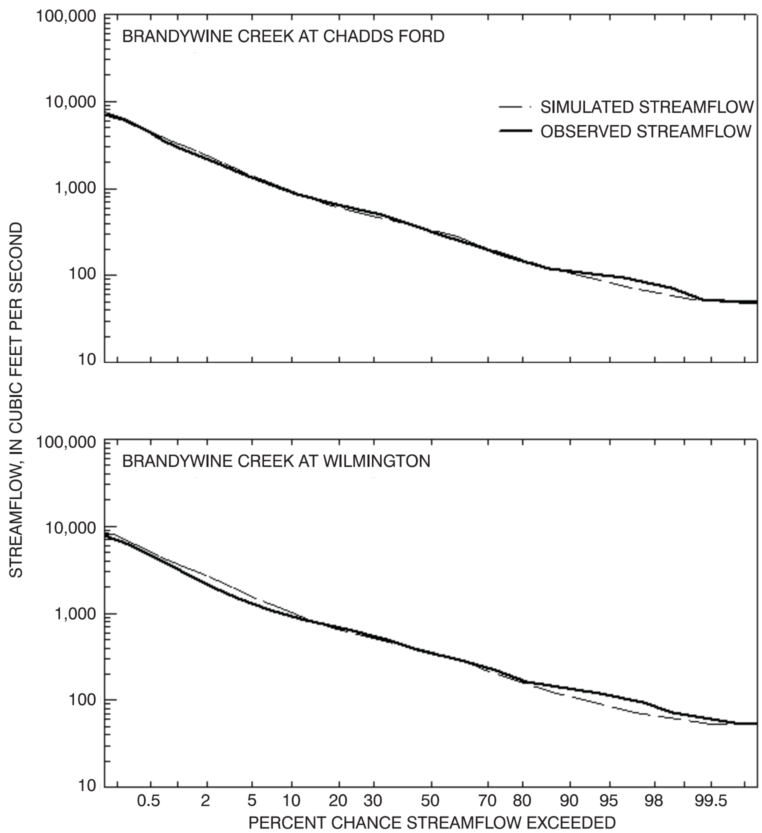


Figure 28. Duration curves of simulated and observed hourly mean streamflow for two sites on the main stem Brandywine Creek.

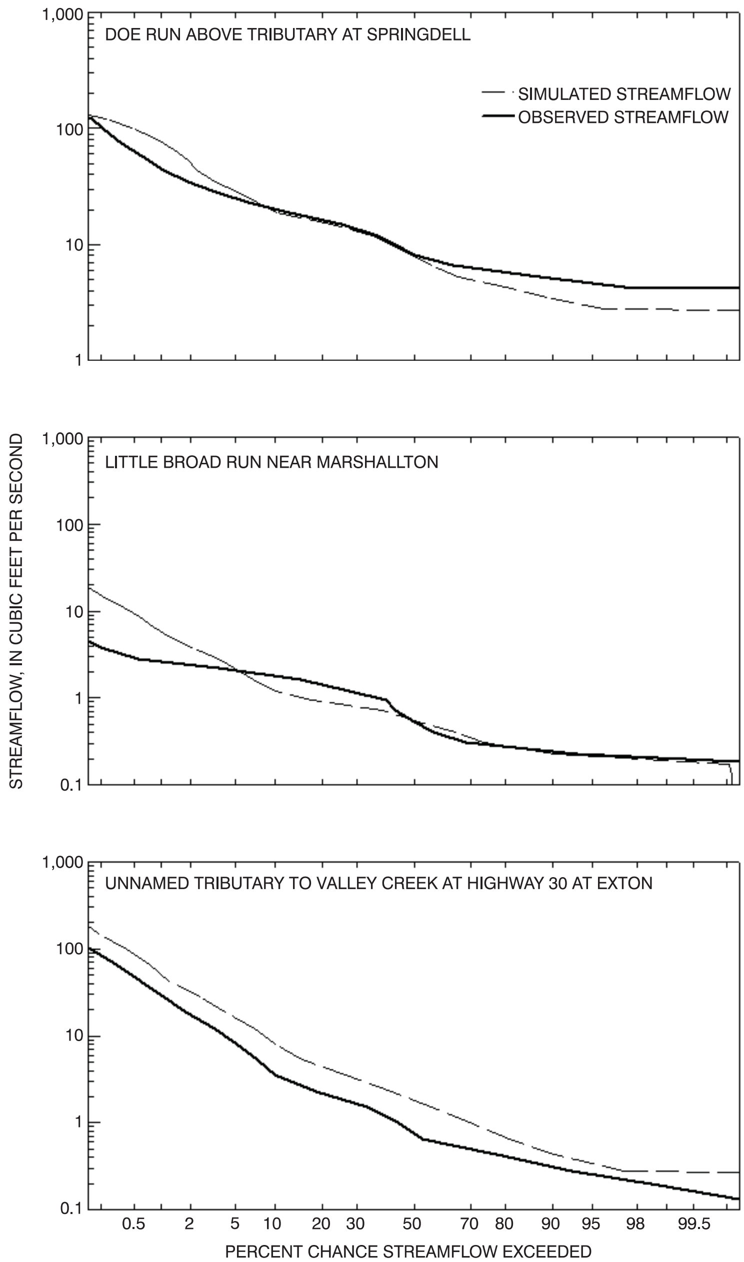


Figure 29. Duration curves of simulated and observed hourly mean streamflow for three sites on tributaries to the Brandywine Creek.

Table 11. *Statistics for comparison of observed and simulated hourly and daily mean streamflow at the six nonpoint-source water-quality monitoring sites during the January–October 1998 nonpoint-source monitoring period and at three nonpoint-source water-quality monitoring sites during the January 1994–October 1998 calibration period in the Brandywine Creek Basin*

Site	Type of mean values	Number of values	Streamflow, in cubic feet per second				Correlation coefficient	Model fit efficiency[1]
			Mean observed	Mean simulated	Mean error	Mean absolute error[2]		
Nonpoint-source monitoring period, January—October 1998								
Honey Brook	hourly	7,248	26.25	24.34	1.908	12.059	0.64	0.36
Honey Brook	daily	302	26.25	24.34	1.908	10.614	.71	.47
Doe Run	hourly	7,248	14.10	14.89	-.795	3.757	.64	.39
Doe Run	daily	302	14.10	14.89	-.795	3.468	.75	.54
Little Broad Run	hourly	7,248	.89	.90	-.009	.504	.24	.05
Little Broad Run	daily	302	.89	.90	-.009	.415	.66	.42
Marsh Creek	hourly	7,248	13.60	16.87	-3.277	5.136	.83	.67
Marsh Creek	daily	302	13.60	16.87	-3.277	4.912	.91	.78
Exton	hourly	7,248	2.79	5.67	-2.877	3.697	.42	.16
Exton	daily	302	2.79	5.67	-2.877	3.166	.75	.42
Chadds Ford	hourly	7,248	400.70	476.29	-75.588	110.559	.91	.79
Chadds Ford	daily	302	400.70	476.29	-75.588	102.574	.95	.85
Calibration period, January 1994—October 1998								
Honey Brook	hourly	42,312	31.77	31.48	.286	16.631	.61	.34
Honey Brook	daily	1,763	31.77	31.48	.286	14.116	.73	.54
Marsh Creek	hourly	42,312	14.43	14.45	-.023	5.783	.78	.53
Marsh Creek	daily	1,763	14.43	14.45	-.023	5.468	.82	.61
Chadds Ford	hourly	42,312	485.70	490.39	-4.65	151.669	.84	.69
Chadds Ford	daily	1,763	485.70	490.39	-4.65	141.311	.87	.75

[1] From Nash and Sutcliffe (1970) as described in Wicklein and Schiffer (2002).
[2] Mean absolute error = sum[|(simulated - observed)|/number of values].

drainage areas because the time to peak for storms generally increases with basin size. The evaluation indicates that the model-fit efficiency and correlation coefficients are similar and generally slightly better for 1998 than the calibration period of 1994-98 at the three sites where record was available. Model-fit efficiency coefficients greater than 0.97 indicate an excellent calibration (Martin and others, 2000; James and Burgess, 1982).

Simulated and observed streamflow, in inches, for Brandywine Creek at Chadds Ford, Pa., is listed by year and for the 5-year period of simulation in table 12. A plot of cumulative errors for Brandywine Creek at Chadds Ford, Pa. (fig. 30), shows the changes in cumulative error are during the winters of 1994 and 1996 when snowfall accumulation and snowmelt were important processes. The substantial oversimulation of 1998, which was primarily during the spring months, cannot be explained by unusual hydrologic conditions.

A well-calibrated model will simulate the surface runoff, interflow, and ground-water components of the total volume of water leaving the land areas and entering the streams. Simulation of components of flow is important because the transport of contaminants in surface runoff, interflow, and ground water is affected by the amount and rate of water leaving the land through each process. Water in an HSPF model reach can be subdivided into surface runoff (SURO), interflow (IFWO), and active ground-water flow (AGWO).

These components represent the volumes of water discharged to the stream from a pervious land segment (PERLND). Impervious land segments (IMPLNDs), by definition, have only a surface runoff (SURO) pathway. AGWO discharged to a stream is referred to as base flow in this report. For the 5-year period of simulation of Brandywine Creek at Chadds Ford, Pa., the surface runoff is 17.5 in. and 16 percent of total flow, interflow is 31.2 in. and 28 percent of total flow, and active

Table 12. *Observed and simulated streamflow for Brandywine Creek at Chadds Ford, Pa., 1994-98*

Year	Streamflow, in inches			Percent difference[1]
	Simulated	Observed	Simulated - observed	
1994	20.8	24.2	-3.4	-14.0
1995	15.7	13.5	2.2	16.3
1996	39.2	38.9	.3	.8
1997	16.1	17.0	-.9	-5.7
[2]1998	18.3	15.4	2.9	18.8
Total (1994-98)	110.1	109.0	1.1	1.0

[1] 100 x (Simulated - Observed) / Observed.
[2] Through October 29, 1998.

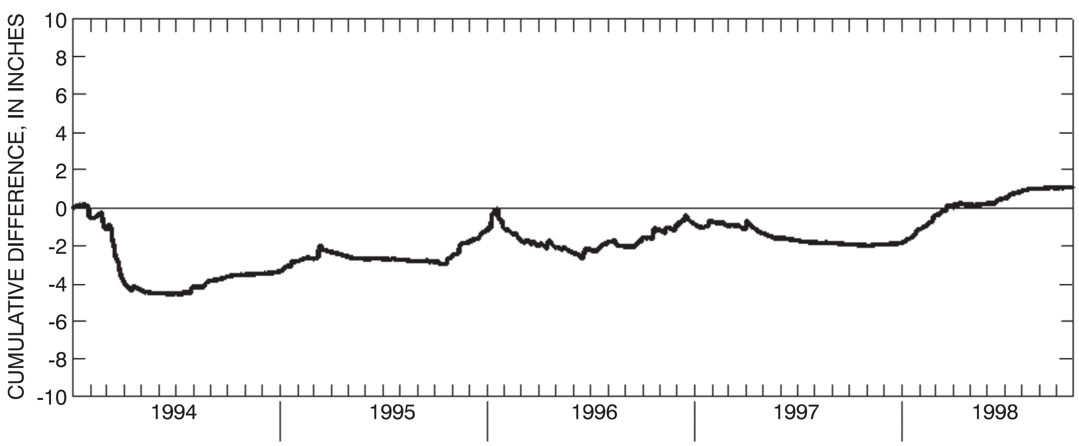


Figure 30. Cumulative difference between simulated and observed hourly mean streamflow at streamflow-measurement station 01481000, Brandywine Creek at Chadds Ford, Pa.

ground-water flow is 61.4 in. and 56 percent of total runoff. For the same period, base flow determined by commonly used fixed-interval or local-minimum base-flow-separation techniques (Sloto and Crouse, 1996; Pettyjohn and Henning, 1979) is 63.5 and 63.7 percent, respectively, of total flow for Brandywine Creek at Chadds Ford. The percentage of total flow as base flow determined by HSPF and base-flow-separation techniques for the simulation period is similar, although values of active ground-water flow calculated by HSPF cannot be compared exactly to those calculated by fixed-interval or local-minimum base-flow-separation techniques because of differences in methodology. The base-flow-separation techniques do not determine interflow as a separate component and it is likely that the techniques result in dividing the amount of IFWO, interflow calculated by HSPF, between the amounts of base flow and stormflow.

The partitioning of PERLND water among SURO, IFWO, and AGWO affects the stream hydrograph and, consequently, the simulation of nonpoint-source constituent transport (Fontaine and Jacomino, 1997). The monthly contributions from SURO, IFWO, and AGWO for a wet year (1996) and a dry year (1997) at the most downstream calibration point in each of the four calibration segments is presented in figure 31. In 1996, the greatest percent surface runoff of total runoff (28 percent SURO) was simulated at West Branch Brandywine Creek near Honey Brook and the least (16 percent) was simulated at East Branch Brandywine Creek below Downingtown and at Brandy-

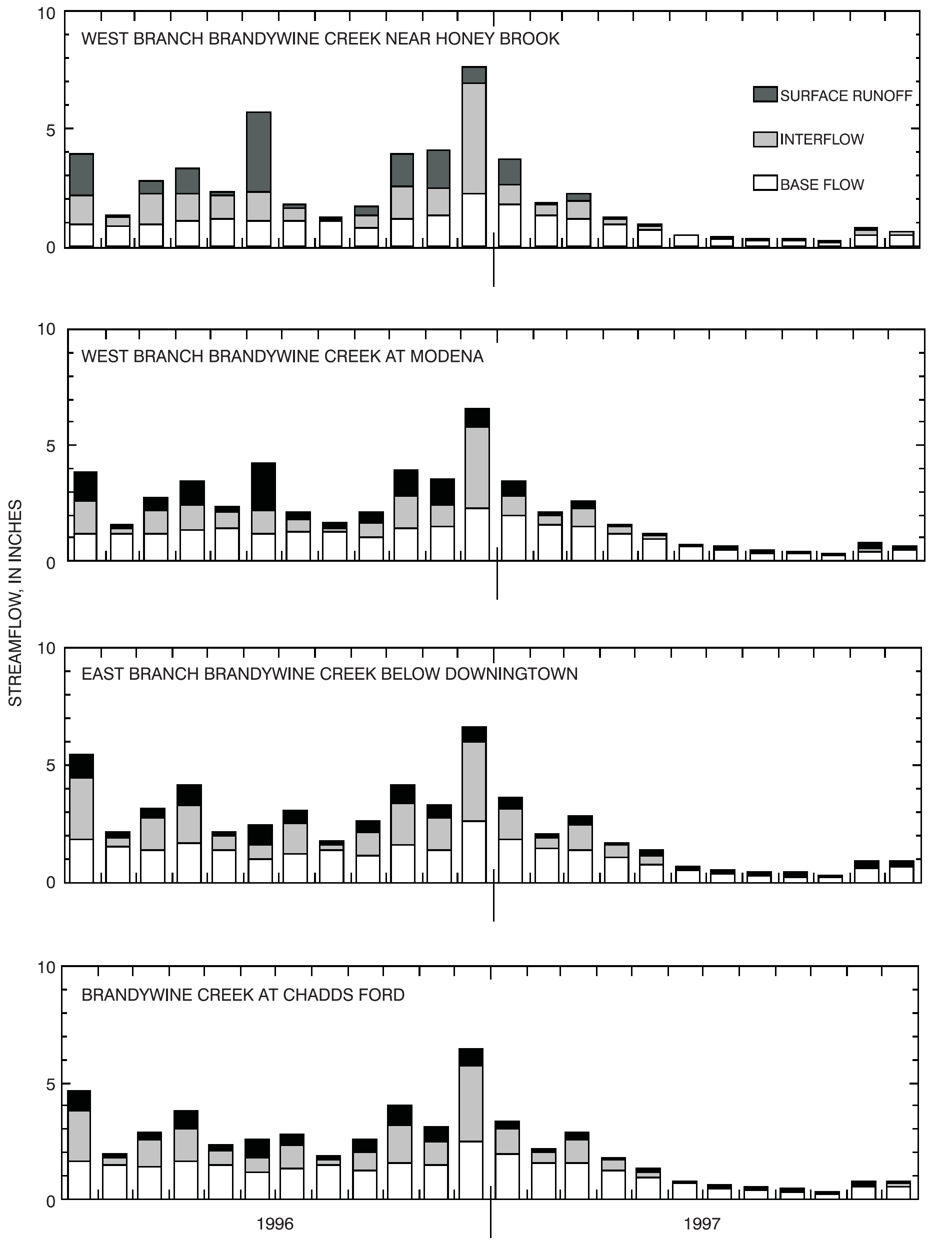


Figure 31. Simulated surface runoff, interflow, and base-flow contribution from pervious land segments (PERLNDs) at the most downstream calibration sites in each of the four model segments of the Brandywine Creek Basin.

wine Creek at Chadds Ford. In 1997, the simulated percent surface runoff was about equal at these three stream sites (13 percent SURO) and slightly greater (15 percent SURO) for West Branch Brandywine Creek at Modena. Over the full simulation period, the average SURO ranged from 15 percent at the below Downingtown site to 21 percent at the Honey Brook site. Sloto (1994) estimated an average 36 percent surface runoff from 1963 to 1988 at the Chadds Ford site and an average 44 percent surface runoff from 1974 to 1988 at the Honey Brook site.

Overall, the calibration of the hydrologic component of the HSPF model for the Brandywine Creek Basin generally is balanced over the full range of observed streamflows, even though more emphasis was placed on high-flow simulation. The Brandywine model simulates streamflow better at sites draining areas of the size used for calibration than at sites draining smaller areas. The model was calibrated at main-stem and headwater sites draining areas greater than 15 mi^2. As calibrated, the hydrologic component of the model has limitations for the application of simulating water quality under stormflow conditions. These limitations, related primarily to the regionalization of distant point-source precipitation data and differences in spatial scale relative to the calibration sites, tend to increase the range and magnitude of errors in the simulated hydrologic responses to individual storm events at many of the nonpoint-source water-quality monitoring sites. Because of the dependence of certain water-quality characteristics on streamflow conditions, limitations in the hydrologic simulations will affect water-quality simulations, particularly during stormflow conditions at sites draining relatively small areas. Errors in hourly stormflow simulation are due in part to errors in hourly rainfall estimated by disaggregating daily values and commonly are relatively greater at sites draining smaller areas (less than 10 mi^2) than at sites draining larger areas (more than 10 mi^2).

Sensitivity Analysis

A sensitivity analysis was performed to examine the influence of altering selected parameters on streamflow volume simulated by the Brandywine Creek HSPF model. For the analysis, parameters were altered one at a time. To a large extent, the relative sensitivities of the model result to changes in individual parameters are determined by the algorithm in which the parameters are used. However, relative sensitivities also are influenced by the calibrated values of other para-meters because of various degrees of interdependence. IMPLND and RCHRES parameters were not included in the sensitivity analysis because they proved to have minimal influence on streamflow volumes during the calibration process. Rather, variations in the timing of stormflow discharges are affected most by varying IMPLND and RCHRES parameters.

Selected PERLND parameter values were multiplied by a factor prior to running a simulation while holding all other parameters constant. Typically, application of the multiplication factors resulted in doubling or halving the initial parameter value. In some instances, limitations on the range of allowable values prevented doubling or halving the values. The lower zone evapotranspiration (LZETP) and ground-water recession (AGWRC) parameters are two examples. In addition, the AGWRC parameter was only decreased because its calibrated value is close to the maximum allowable value. Sensitivity analyses were completed for three sites: West Branch Brandywine Creek at Modena, East Branch Brandywine Creek below Downingtown, and Brandywine Creek at Chadds Ford. The response of simulated runoff characteristics is listed in tables 13, 14, and 15.

Total runoff volumes at the three sites show the greatest sensitivity to lower-zone storage (LZSN) and lower-zone evapotranspiration (LZETP). Both parameters control evapotranspiration that for the Brandywine Creek is estimated to account for about 55 percent of the hydrologic budget (Sloto, 1994). Upper-zone storage (UZSN) and interception storage (CEPSC) also affect total runoff but more moderately. As with the lower-zone parameters, UZSN and CEPSC influence the amount of water lost to evapotranspiration.

For parameters that were doubled or halved, the 10-percent highest flows are primarily sensitive to the infiltration rate (INFILT) and secondarily sensitive to LZSN and AGWRC except at East Branch Brandywine Creek below Downingtown where flows were primarily sensitive to the interflow recession rate (IRC). The 50-percent lowest flows are sensitive primarily to AGWRC and secondarily sensitive to INFILT. In addition to these parameters, the 10-percent highest flows and 50-percent lowest flows are very sensitive to AGWRC.

Table 13. *Sensitivity analysis of modeled runoff characteristics at West Branch Brandywine Creek at Modena, Pa. (01480617), to variations in selected pervious land (PERLND) parameters*

[AGWRC, active ground-water recession rate; INFILT, infiltration; LZSN, lower-zone storage; CEPSC, interception storage; UZSN, upper-zone storage; SLSUR, slope of overland flow; NSUR, Manning's n for overland flow; INTFW, interflow; IRC, interflow recession rate; LZETP, lower-zone evapotranspiration]

Parameter	Multiplier	Runoff errors (in percent)						Total inches			
		Total runoff volume	50-percent low flow	10-percent high flow	Seasonal runoff volume	Summer storm volume	Average storm peak	Total runoff	Surface runoff	Interflow	Total evapotrans-piration
Calibrated value	1	-1.3	2.1	-1.2	20.3	31.7	14.3	104.9	21.5	27.1	132
AGWRC	.75	.3	-48.1	22.1	20.4	33.5	15.3	106.6	21.4	27	131.7
INFILT	2	-.2	21.4	-16.5	36.0	33.9	-11.4	106.1	16.2	19.7	130.5
INFILT	.5	-1.9	-17.6	14.9	6.9	32.4	52.4	104.3	29.7	31.8	132.8
LZSN	2	-7.9	3.2	-12.7	36.0	43.2	3.0	97.9	19.4	22.2	135.4
LZSN	.5	5.0	1.5	12.3	.7	14.7	30.8	111.6	24.2	33.8	126.3
CEPSC	2	-2.9	-3.2	-.6	14.4	28.8	16.4	103.2	21.6	27.4	133.6
CEPSC	.5	-.3	5.9	-1.7	24.1	32.8	14.3	106	21.4	26.8	130.8
UZSN	2	-3.4	4.1	-6.4	23.9	33.3	9.1	102.7	20.8	25.4	133.5
UZSN	.5	.4	.7	4.2	19.2	36.4	23.6	106.8	22.4	29	130.2
SLSUR	2	-1.3	1.8	-.7	20.3	31.5	18.4	104.9	22.3	26.5	131.9
SLSUR	.5	-1.4	2.4	-1.7	20.3	31.8	10.2	104.8	20.7	27.7	132
NSUR	2	-1.4	2.6	-2.2	20.4	32	7.1	104.8	19.8	28.3	132
NSUR	.5	-1.3	1.6	-.3	20.3	31.3	20.5	104.9	23.0	25.9	131.9
INTFW	2	-1.3	1.5	-1.5	20.1	35.0	-4.2	105.0	16.4	33	131.8
INTFW	.5	-1.5	2.7	-.1	20.8	28.3	40.0	104.7	28.6	18.6	132.2
IRC	2	-1.4	5.5	-10.6	20.4	31.9	7.1	104.8	21.5	27.1	132
IRC	.5	-1.3	.9	2.7	20.2	30.2	21.5	104.9	21.5	27.1	132
LZETP	1.25	-3.2	-1.6	-2.7	18.8	29.4	12.2	102.9	21.3	26.4	134.3
LZETP	.75	2.1	8.6	2.0	22.4	34.8	22.5	108.6	22	28.5	127.5

Table 14. *Sensitivity analysis of modeled runoff characteristics at East Branch Brandywine Creek below Downingtown, Pa. (01480870), to variations in selected pervious land (PERLND) parameters*

[AGWRC, active ground-water recession rate; INFILT, infiltration; LZSN, lower-zone storage; CEPSC, interception storage; UZSN, upper-zone storage; SLSUR, slope of overland flow; NSUR, Manning's n for overland flow; INTFW, interflow; IRC, interflow recession rate; LZETP, lower-zone evapotranspiration]

Parameter	Multiplier	Runoff errors (in percent)						Total inches			
		Total runoff volume	50-percent low flow	10-percent high flow	Seasonal runoff volume	Summer storm volume	Average storm peak	Total runoff	Surface runoff	Interflow	Total evapotrans-piration
Calibrated value	1	2.2	-2.1	2.8	0.6	13.7	2.8	118.9	18.4	36.1	132
AGWRC	.75	2.4	-35	17.2	16.3	22.4	4.8	119.1	18.4	36.1	132
INFILT	2	2.8	12.2	-9.5	8.4	11.7	-22.4	119.6	14.8	24.1	130.9
INFILT	.5	2.1	-17.1	15.2	8.5	16.8	43.6	118.7	25.2	45.1	132.6
LZSN	2	-2.8	1.5	-6.2	15.4	25.3	-5.9	113	17.1	30.2	135
LZSN	.5	7.0	-5	12.0	20.1	-5.9	14.5	124.4	20	44.3	126.4
CEPSC	2	1.1	-5.8	3.0	5.5	9.6	3.8	117.6	18.5	36.3	133.6
CEPSC	.5	3.0	.3	2.6	2.2	15.5	2.8	119.8	18.3	35.9	131
UZSN	2	.4	-.6	-2.5	.6	10.0	-2	116.8	17.9	32.6	134
UZSN	.5	3.9	-3.4	7.5	.6	19.7	7.7	120.8	18.8	39.7	129.9
SLSUR	2	2.2	-2.2	3.1	.6	13.1	7.7	118.9	19.1	35.5	132
SLSUR	.5	2.2	-2.0	2.6	.6	14.3	-3	118.9	17.6	36.7	132
NSUR	2	2.1	-1.9	2.3	.6	14.7	-6.9	118.8	16.9	37.3	132.1
NSUR	.5	2.2	-2.4	3.3	.6	12.9	11.6	118.9	19.8	34.9	132
INTFW	2	2.3	-2.5	3	.7	16.8	-16.6	119	14.9	40.4	131.9
INTFW	.5	2.1	-1.6	3.2	.4	9.1	36.8	118.8	24.8	28.4	132.2
IRC	2	2.2	2.4	-11.4	.2	14.3	-6.9	118.9	18.4	36.1	132
IRC	.5	2.2	-3.1	7.7	.7	11.5	12.5	118.9	18.4	36.1	132
LZETP	1.25	.6	-5.7	1.7	2.6	10.8	.9	117	18.2	35	134.9
LZETP	.75	6.6	6.7	6.2	4.9	21.6	7.7	124	18.8	39.4	124.3

Table 15. *Sensitivity analysis of modeled runoff characteristics at Brandywine Creek at Chadds Ford, Pa. (01481000), to variations in selected pervious land (PERLND) parameters*

[AGWRC, active ground-water recession rate; INFILT, infiltration; LZSN, lower-zone storage; CEPSC, interception storage; UZSN, upper-zone storage; SLSUR, slope of overland flow; NSUR, Manning's n for overland flow; INTFW, interflow; IRC, interflow recession rate; LZETP, lower-zone evapotranspiration]

Parameter	Multiplier	Runoff errors (in percent)						Total inches			
		Total runoff volume	50-percent low flow	10-percent high flow	Seasonal runoff volume	Summer storm volume	Average storm peak	Total runoff	Surface runoff	Interflow	Total ET
Calibrated value	1	1.0	4.9	6.6	4.6	10.4	14.3	110.1	17.3	31.3	133.2
AGWRC	.75	2.0	-46.4	32.2	29.6	14.8	20.2	111.2	17.3	31.2	132.9
INFILT	2	1.9	23.9	-10.8	18.3	13.1	-13.9	111.1	13.9	20.2	131.9
INFILT	.5	.7	-15.7	24.8	8.0	11.0	54.3	109.8	23.6	40.2	133.9
LZSN	2	-5.6	7.7	-5.1	19.8	21.7	3.9	102.9	16.2	25.6	135.9
LZSN	.5	7.4	2.5	20.4	18	-9.7	29.1	117.1	18.8	39.2	127.3
CEPSC	2	-.5	-.4	7.2	1	6.6	15.8	108.5	17.4	31.7	134.9
CEPSC	.5	2.0	8.5	6.1	8.2	12.5	14.3	111.2	17.2	31	132
UZSN	2	-.8	6.4	1.4	5.2	8.8	9.8	108.2	16.9	28.9	134.8
UZSN	.5	2.6	3.7	11.6	5.5	15.3	21.7	111.9	17.7	34	131.5
SLSUR	2	1.0	4.7	7.0	4.7	10.5	18.7	110.1	18.0	30.7	133.2
SLSUR	.5	1.0	5.0	6.2	4.6	10.7	11.3	110.1	16.6	31.9	133.2
NSUR	2	1.0	5.2	5.8	4.6	11.0	8.3	110.1	16.0	32.3	133.2
NSUR	.5	1.1	4.5	7.3	4.8	10.4	21.7	110.2	18.6	30.3	133.2
INTFW	2	1.1	4.4	6.5	4.5	13.4	-.6	110.2	14.1	35.2	133.1
INTFW	.5	.9	5.4	7.1	5.1	6.9	41	110	23.0	24.4	133.3
IRC	2	1.0	9.6	-9.4	4.9	11.5	-2.1	110.1	17.3	31.3	133.2
IRC	.5	1.0	3.6	12.1	4.5	8.1	30.6	110.1	17.3	31.3	133.2
LZETP	1.25	-1.2	0	4.7	3.2	7.9	12.8	107.7	17.1	30.3	136.3
LZETP	.75	5.9	15.3	11.0	8.5	16.2	21.7	115.5	17.8	33.9	126.2

Seasonal runoff volumes are most sensitive to the ground-water recession parameter (AGWRC) at East Branch Brandywine Creek below Downingtown and Brandywine Creek at Chadds Ford and to the lower-zone storage parameter (LZSN) at West Branch Brandywine Creek at Modena. Seasonal runoff volume refers to the differences between summer (June, July, and August) runoff volumes and winter (December, January, and February) runoff volumes. Secondary sensitivity is greatest for the infiltration rate (INFILT) at Brandywine Creek at Chadds Ford and West Branch Brandywine Creek at Modena and greatest for LZSN at East Branch Brandywine Creek below Downingtown. The AGWRC determines how rapidly stream base flow diminishes over time after recharge to ground-water storage. Ground-water storage is controlled, in part, by infiltration and water loss to lower-zone storage and evapotranspiration. Recharge to ground-water storage typically exhibits seasonality. Stream base flow modeled with relatively high ground-water recession rates shows or even amplifies the seasonality in ground-water storage, whereas, base flow modeled with relatively low ground-water recession rates suppresses seasonal fluctuations in ground-water storage.

Summer storm volumes show primary sensitivity to LZSN at the three sites and secondary sensitivity to lower-zone evapotranspiration (LZETP) at East Branch Brandywine below Downingtown and at Brandywine Creek at Chadds Ford. LZSN and LZETP generally are not considered as having much influence over storm volumes. However, because HSPEXP calculates storm volumes over only whole 24-hour increments, storm volumes for short-duration events, which are more prevalent in the summer, will include more base flow. These base-flow periods are affected by the LZSN and LZETP parameters. In addition, HSPEXP analysis is limited to 36 storms. Eleven of the 36 storms selected for analysis were from the drier than average 1997-98 period that coincided with available water-quality data. Storms from this period tend to be smaller with the result that HSPEXP calculated storm volumes contain a large proportion of base flow. At West Branch Brandywine Creek at Modena, secondary sensitivity was to interflow (INTFW). INTFW may alter storm volumes by diverting a portion of surface runoff to interflow storage for release to stream runoff at a reduced rate and later time.

Peak stormflows at all three locations are most sensitive to INFILT. Infiltration rate affects stormflow through diversion of potential surface runoff into the soil storages. Surface runoff controls peak stormflows. Peak stormflow was next most sensitive to interflow (INTFW). INTFW diverts surface runoff into interflow storage. Interflow recession rates (IRC) and LZSN have a more moderate effect on peak stormflows. In addition to these PERLND parameters, peak stormflow also is affected by IMPLND parameters, if sufficient IMPLND area exists, and by RCHRES storages as defined in the F-Tables. As with storm volumes, the choice of storms selected for inclusion into HSPEXP has a substantial effect on the reported peak-stormflow statistics.

Model Limitations

The final calibration of the hydrology component of the HSPF model for Brandywine Creek satisfies most of the recommended calibration criteria, but has limitations. These limitations can be classified as either errors in the input and calibration data or errors in the model structure. Errors in the input data may result from the measurement, interpolation, and extrapolation of precipitation and other climatic data, and discharge and withdrawal rates. Errors in calibration data include those involved in the actual measurement of streamflow or in the transcriptions of streamflow data. Measurement errors result from equipment malfunction and other problems, including the presence of ice in the stream channel at or near the measurement site. Specific information required to evaluate random or transitory measurement errors is generally unavailable. Interpolation errors can occur when data are disaggregated to smaller time steps. Extrapolation errors can occur when spatial variations and timing in data are lost by applying local data to large areas.

Errors resulting from extrapolation, interpolation, and disaggregation of the precipitation data are probably the greatest limitation to achieving the best possible model calibration and simulations. Applying point location data from four raingages to the entire 327-mi^2 basin and disaggregating daily precipitation data to hourly data values introduces substantial errors; stormflow simulations, in particular, have errors in peak flows and total volumes regularly exceeding 100 percent. These errors will translate into the water-quality calibration of the model. In addition, temporal errors in stormflow simulations can be detrimental to the water-quality calibration even if stormflow peaks and volumes are well simulated. The overall effect of these errors is an increase in the average error as the time period of simulation is decreased. Other climatic data such as air temperature, solar radiation, and windspeed are subject to the same type of errors but are less influential factors than precipitation in the streamflow simulation.

Measurement errors in observed streamflow are known and corrected in some instances but unknown and roughly estimated in other instances, such as ice-affected streamflow data. In many cases, corrections are limited to daily values and hourly data are left uncorrected or missing. Periods of missing hourly streamflow record were filled with estimated data for the model to calculate statistics. However, the errors associated with this estimated data are unknown. The USGS (Durlin and others, 1999) rates periods of estimated record as poor and states that errors greater than 15 percent can be expected. Errors in observed streamflow data can be expected to affect the statistics used for calibration evaluation and, if severe, lead to incorrect selection of parameter values.

Errors in the model structure are mainly due to limited resolution of PERLND, IMPLND, and RCHRES spatial characteristics and incorrectly specified model parameters. In general, spatial errors result from the loss of local variation in spatial characteristics. Lack of data resolution and the need to limit the complexity of the model structure are the primary reasons for this loss. For example, in the Brandywine Creek model, the number of pervious land-use categories has been limited to 10. In actuality, more than 10 distinct land-use categories exist. Further, each of these PERLND categories is assigned individual calibration parameters that are selected to represent a composite average for that category. Because of this spatial averaging, the model has limited capability to resolve responses from land uses with limited areal extent or that differ greatly from the average.

Many HSPF parameters are not expressed in terms of known physical behavior, making selection of parameter values somewhat ambiguous and may lead to incorrect specification. For example, the parameter AGWRC is not defined in terms of established ground-water hydrologic characteristics. Also, in the case of the parameter INFILT, published soil permeability values cannot be used directly but only as a guide. Verification of the proper selection of parameters occurs in the calibration process but a satisfactorily calibrated model can be produced with more than one combination of parameters.

SIMULATION OF WATER QUALITY

Suspended sediment and nutrients were simulated for the Brandywine Creek Basin. The simulation included delivery of suspended sediment and nutrients from pervious and impervious land areas to stream reaches, and transport and chemical reactions in the stream reaches. The instream simulation of nutrients requires information about stream temperature and dissolved oxygen. Because environmental data describing stream temperature and dissolved oxygen were not available for most reaches, the model was also used to simulate those parameters. Stream temperature is an important variable in determining water quality because temperature affects saturation levels of dissolved oxygen and rates of chemical reactions. Dissolved-oxygen concentrations affect the extent of chemical reactions involving nutrients, such as nitrification. In HSPF, the simulation of water quality is based on and is an extension of the hydrologic simulation.

The simulation of water quality was undertaken with the following assumptions: (1) land-based contributions of sediment and nutrients could be simulated by a simplified set of land-use categories; (2) water quality could be represented by the condition where chemical transformation of nutrients are simulated explicitly in the stream channel but not in land processes; and (3) the contribution of sediment from bank erosion in the stream channel can be estimated by sediment from pervious land areas.

Model Calibration

Each land-use category is assigned parameters that affect interflow, ground-water temperature, sediment release, and nutrient contributions from land areas. Stream reaches are assigned parameters that affect the simulation of stream temperature, sediment transport, bed erosion and deposition, and chemical reactions in the stream channel. Individual parameters were adjusted until the simulated water quality was an acceptable match to observed water quality. The computer program GenScn (Kittle and others, 1998), a graphical interface to HSPF, was used for the water-quality calibration.

Suggested guidelines to evaluate sediment and water-quality calibration, including the nutrients nitrogen and phosphorus, in the HSPF model are given in percentage differences between observed and simulated monthly or annual values (table 16) (Donigian and others, 1984). Comparison of loads, rather than instantaneous concentrations, are considered more appropriate when evaluating water-quality simulations of nonpoint-source constituents (Donigian and others, 1984). Comparison of instantaneous concentrations may result in larger apparent differences between observed and simulated values than comparison of loads because of the effect of even small lags (errors) in the timing of storm events. In addition, simulation errors usually are larger for water-quality concentrations than for streamflow.

Water-quality calibration included stormflow and base-flow conditions. Because the hydrologic part of the model is integral to simulation of water quality, only well-simulated storms would, ideally, be used for calibration of suspended sediment and nutrients. In all cases, however, the simulated storm hydrograph does not replicate the observed storm hydrograph well, especially with respect to peak flows. Therefore, simulated concentrations of suspended sediment, nitrate, ammonia, and phosphorus cannot be expected to exactly replicate observed concentrations for all storms. Calibration was considered satisfactory when the general pattern of simulated streamflow and suspended sediment and nutrients was simulated and when, for better simulated storms, simulated concentrations and loads of suspended sediment and nutrients were within an order of magnitude of observed concentrations and loads. Individual storm errors considerably larger than the recommended criteria of 40 percent or less for monthly or annual values for fair to good water-quality calibration may occur and have little effect on the overall calibration (Donigian and others, 1984). Calibrated values for water-quality parameters are given in the UCI file for Brandywine Creek (Appendix 3).

Table 16. *Suggested criteria to evaluate water-quality calibration for an Hydrologic Simulation Program–Fortran (HSPF) model (from Donigian and others, 1984)*

[<, less than]

Constituent	Difference between observed and simulated monthly or annual values, in percent		
Quality of calibration	**Very Good**	**Good**	**Fair**
Sediment	<15	15-25	25-35
Water quality (includes nitrogen and phosphorus)	<20	20-30	30-40

Monthly and annual load data were not available to assess calibration errors. Simulated and observed load data for two to six storms in 1998 were used to provide estimates of calibration accuracy. Loads were calculated from measured discharge and constituent concentrations in flow-weighted composite samples collected during storms. However, these limited data do not provide a long-term measure of the accuracy of the model and may include one or more poorly simulated storms or questionable laboratory analyses, which can have a large effect on the apparent accuracy of the model. The calibration error, calculated as (simulated-observed) / observed for the total flow volume or constituent load for up to six storms, is listed in table 17. Calibration errors for

Table 17. *Cumulative calibration errors in flow volume and constituent loads for selected storms in 1998 at six monitoring sites in the Brandywine Creek Basin*

U.S. Geological Survey identification number	Site name	Number of storms	Cumulative calibration error for selected storm simulations in 1998, in percent[1]						
			Stream-flow volume	Suspended sediment load	Nitrate load	Dissolved ammonia load	Particulate ammonia load	Dissolved ortho-phosphate load	Particulate phos-phorus load[2]
01480300	Honey Brook	5	-63	-96	-52	-85	-98	-92	-98
014806318	Doe Run	4	-22	-79	21	-83	-90	-17	-76
01480637	Little Broad Run	3	113	149	-13	-55	-68	230	-95
01480675	Marsh Creek	2	14	269	231	91	876	220	1,633
01480878	Exton	6	90	279	16	79	-62	85	104
01481000	Chadds Ford	5	18	127	10	117	-30	63	64

[1] Percent calibration error = 100 x (simulated-observed)/observed.

[2] One fewer storm was available for comparison because total phosphorus was not analyzed in the October 1998 storm.

individual storms at the six monitoring sites are listed and discussed in more detail in subsequent sections describing calibration of suspended sediment, nitrogen, and phosphorus. Generally for these storm events, loads of suspended sediment, nitrogen, and phosphorus were undersimulated when streamflow was undersimulated and oversimulated when streamflow was oversimulated. Dissolved constituents were simulated better than particulate constituents.

Water Temperature

Simulated stream water temperature was calibrated against data collected at four continuous monitoring sites on the Brandywine Creek. About 1 year of continuous water-temperature data also was collected at the short-term small-basin sites but was not used for calibration. Comparison of simulated and observed daily mean water temperature at the four continuous monitoring sites (fig. 32) shows a good correlation between simulated and observed water temperature over the range of 6 to 20°C. Errors in the simulated water temperatures, excluding any overall bias, fall within plus or minus 4°C. Overall bias, up to about 20°C, is about -1°C or less. The exception is at Modena, where water temperature is undersimulated by about 2°C. The Modena site is about 2 mi downstream of point-source thermal discharges from Lukens Steel. For all sites, water temperatures above 20°C are progressively undersimulated up to a maximum of about 8°C. Observed data below 6°C is limited because temperature monitoring equipment at the sites was shutdown from November through March except at Coatesville.

At the three small-basin sites, simulated and observed daily mean water temperatures are less well correlated than at the Brandywine Creek sites. (fig. 33). At Little Broad Run near Marshallton, water temperatures above 16°C are progressively oversimulated and below 16°C are undersimulated. The Little Broad Run site is on a stream that drains a small, 0.6-mi^2 headwater area. Streamflow in a headwater location generally has a greater percentage of ground-water inflow than higher-order streams. The relatively constant temperature of this inflow moderates temperature fluctuations. Winter water temperatures are higher and summer water temperatures lower. The local topography and partially wooded land use further reduce summer solar heat gain at the Little Broad Run site. Errors in simulated daily mean water temperatures at the Doe Run site have a bias similar to the Little Broad Run site but more subdued. These two sites also show greater error variance than the four continuous monitoring sites. The Exton site shows little or no bias in simulated water temperatures. All three small-basin sites show none of the undersimulation at higher water temperatures exhibited at the four continuous monitor sites. Although the period-of-record for observed water temperature is limited for the small-basin sites, the data suggest that the accuracy of water temperature simulations varies with the drainage area. Because water temperature affects the rate of chemical reactions and biological processes involving nutrients in the stream, errors in the temperature simulation will affect calibration of the nutrient simulation to some degree.

Sediment

Calibration of suspended sediment in the stream channel largely is done by adjusting parameters affecting soil detachment, soil washoff, and soil scour processes for pervious land surfaces, solids build up and washoff processes for impervious land surfaces, and sediment transport in the channel, including deposition on and scour of the channel bottom controlled by setting shear stress regimes. Sediment in streams may be derived from land areas, streambanks, and beds. For the calibration, no net erosion of streambeds was assumed to occur over the simulation period and therefore the principal sources of sediment were assumed to be land areas and streambanks. Because the HSPF model does not include the process of bank erosion, sediment from streambanks was estimated by simulating scour in pervious land areas. Simulated concentrations of suspended sediment were evaluated against data collected by USGS in 1998 at the Brandywine Creek Basin monitoring sites as well as data collected by PADEP at sites in Pennsylvania (1995-98) and by DNREC at sites in Delaware (1994-98).

Instantaneous concentrations of suspended solids were measured for up to six storms and four base-flow events in 1998. Reported concentrations of suspended solids (nonfilterable material) were considered estimates for suspended-sediment concentrations. Suspended-solids concentrations are not always accurate estimates of suspended-sediment concentrations and tend to be biased low, especially for conditions when sand-sized particles represent more than 25 percent of suspended sediment (Gray and others, 2000). When suspended solids are used as a surrogate for suspended-sedi-

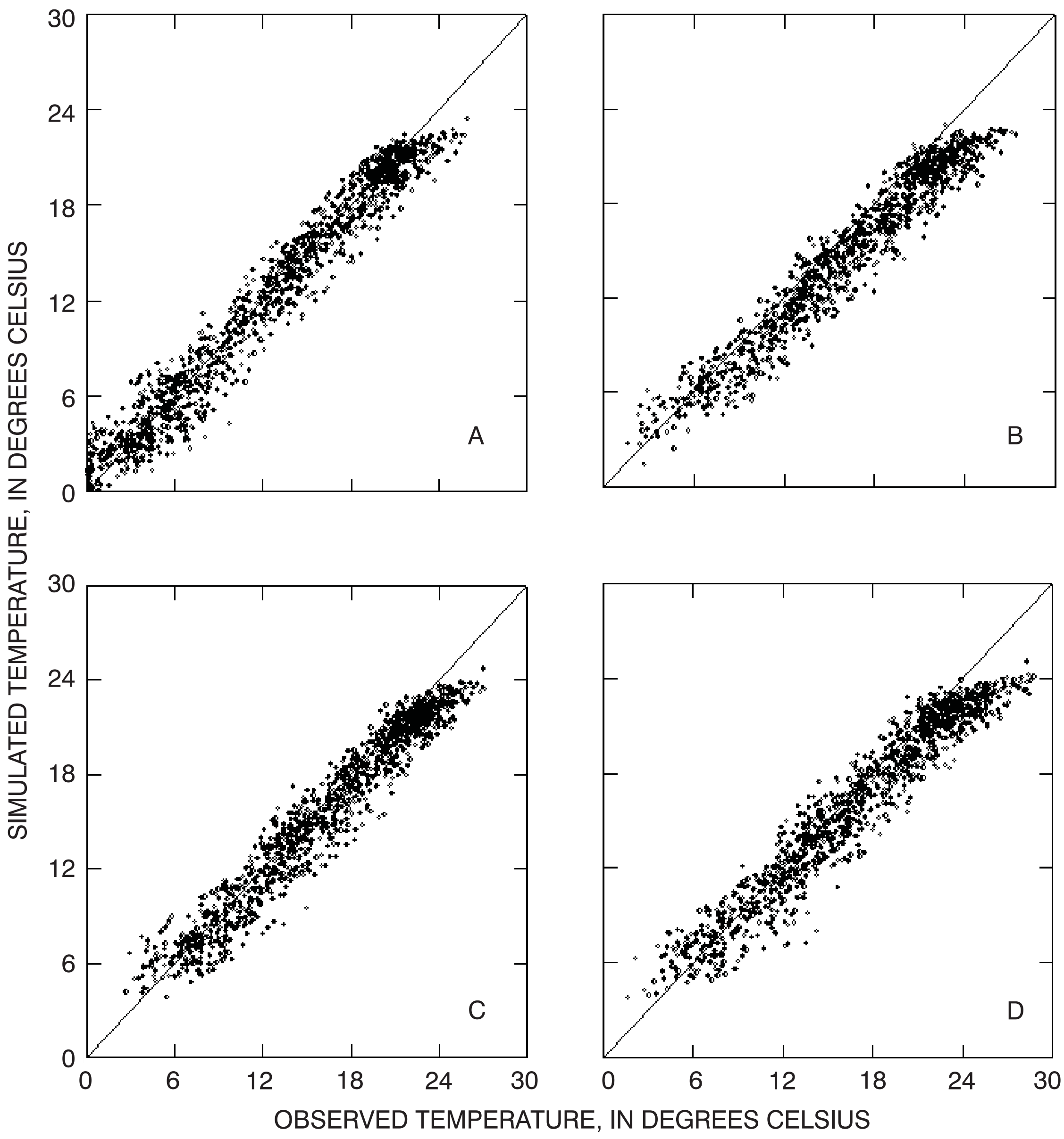


Figure 32. Relation between simulated and observed daily mean water temperature at (A) West Branch Brandywine Creek at Coatesville, Pa., and (B) Modena, Pa., at (C) East Branch Brandywine Creek below Downingtown, Pa., and at (D) Brandywine Creek at Chadds Ford, Pa.

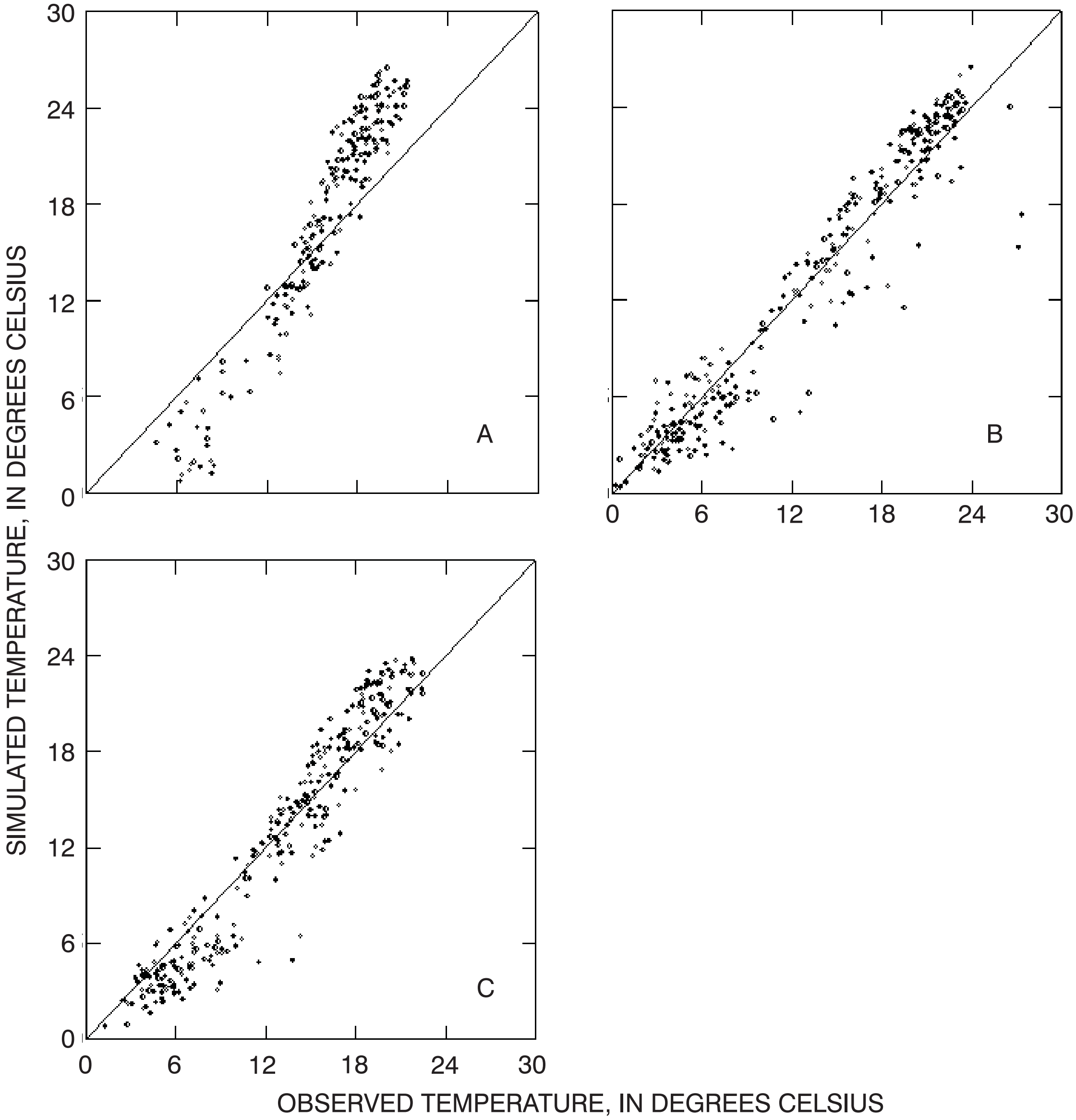


Figure 33. Relation between simulated and observed daily mean water temperature at (A) Little Broad Run near Marshallton, Pa., at (B) Unnamed tributary to Valley Creek at Highway 30 at Exton, Pa., and at (C) Doe Run above tributary at Springdell, Pa.

ment concentrations, the resulting errors in load computations can be as large as several orders of magnitude (U.S. Geological Survey, 2000). As noted earlier, only well-simulated storms (simulation error less than 20 percent for storm peaks, for example) would, ideally, be used for calibration of suspended sediment. In most cases, storms were not well simulated. Examples of five simulated storms and consequent sediment simulation at one site, West Branch Brandywine Creek at Honey Brook, are shown in figure 34. Of these five storm events, streamflow is best simulated during the July storm, although both streamflow and suspended-sediment concentrations are undersimulated. Simulations of suspended sediment for a storm that was relatively well replicated at each of the other five nonpoint-source monitoring sites are shown in figure 35. Simulated and observed streamflow and suspended-sediment concentrations for all sampled storms at six nonpoint-source monitoring sites in the Brandywine Creek Basin are shown in Appendix 2.

Composite samples collected during storms at six monitoring sites in the Brandywine Creek Basin in 1998 allow comparison of simulated and observed loads for the periods monitored. Peak flows were greatest in the March and June storms and least in the May and October storms (table 18). Streamflow and suspended sediment loads are undersimulated at the two sites in agricultural basins (West Branch Brandywine Creek at Honey Brook and Doe Run near Springdell) and oversimulated at the other sites (table 18), including the site in the forested basin (Marsh Creek near Glenmoore), two sites in residential basins (Little Broad Run near Marshallton and Unnamed tributary to Valley Creek at Exton), and the most-downstream site measuring loads in the whole basin (Brandywine Creek at Chadds Ford).

The results of suspended-sediment simulation at Brandywine Creek at Chadds Ford provides a measure of the overall model accuracy on a basin-wide scale (table 18). At Brandywine Creek at Chadds Ford, Pa., stormflow and suspended-sediment loads for storms tended to be oversimulated. The difference between observed and simulated streamflow ranged from -41 to 66 percent for individual storms and was 18 percent for the total of all storms. The difference between observed and simulated suspended-sediment loads ranged from -72 to >2,607 percent for individual storms and was 127 percent for the total of all storms. The May storm had the largest percentage difference between observed and simulated suspended-sediment load yet was the smallest in magnitude of the sampled storms. The less than 1 mg/L concentration of suspended solids reported in the composite sample for that storm is uncharacteristically small even for low-magnitude stormflow conditions and likely in error. The October storm has the best suspended-sediment simulation and the best stormflow simulation and demonstrates the importance of a good hydrologic calibration.

Comparison of simulated and observed values (table 18) for all sites indicate that when flow is undersimulated or oversimulated, loads of suspended sediment tend to be undersimulated or oversimulated, respectively, to a greater degree. For example, in a case of undersimulation, the cumulative error was -63 percent for simulated streamflow and -96 percent for simulated suspended-sediment load at West Branch Brandywine Creek at Honey Brook. For a case of oversimulation, the cumulative error was 113 percent for simulated streamflow and 149 percent for simulated suspended-sediment load at Little Broad Run near Marshallton. The non-linear relation between streamflow and sediment accounts for some of the differences in errors for streamflow and suspended-sediment simulations. The smallest error in simulation of suspended-sediment load (9 percent error) is associated with the best simulated storm in terms of flow volume (1 percent error), October 8-9, 1998, at Brandywine Creek at Chadds Ford (table 18). These results suggest that the suspended-sediment simulation is dependent on the flow simulation and has a large degree of variability.

Simulated concentrations of suspended sediment under base-flow conditions generally were within one order of magnitude of observed concentrations at the six monitoring stations (fig. 36) For these base-flow samples, streamflow was well simulated, as shown in figure 36. The average percentage difference between observed and simulated base flow was -15 percent, indicating slight oversimulation. Of the six sites, base flow for unnamed tributary to Valley Creek near Exton was oversimulated to the largest extent.

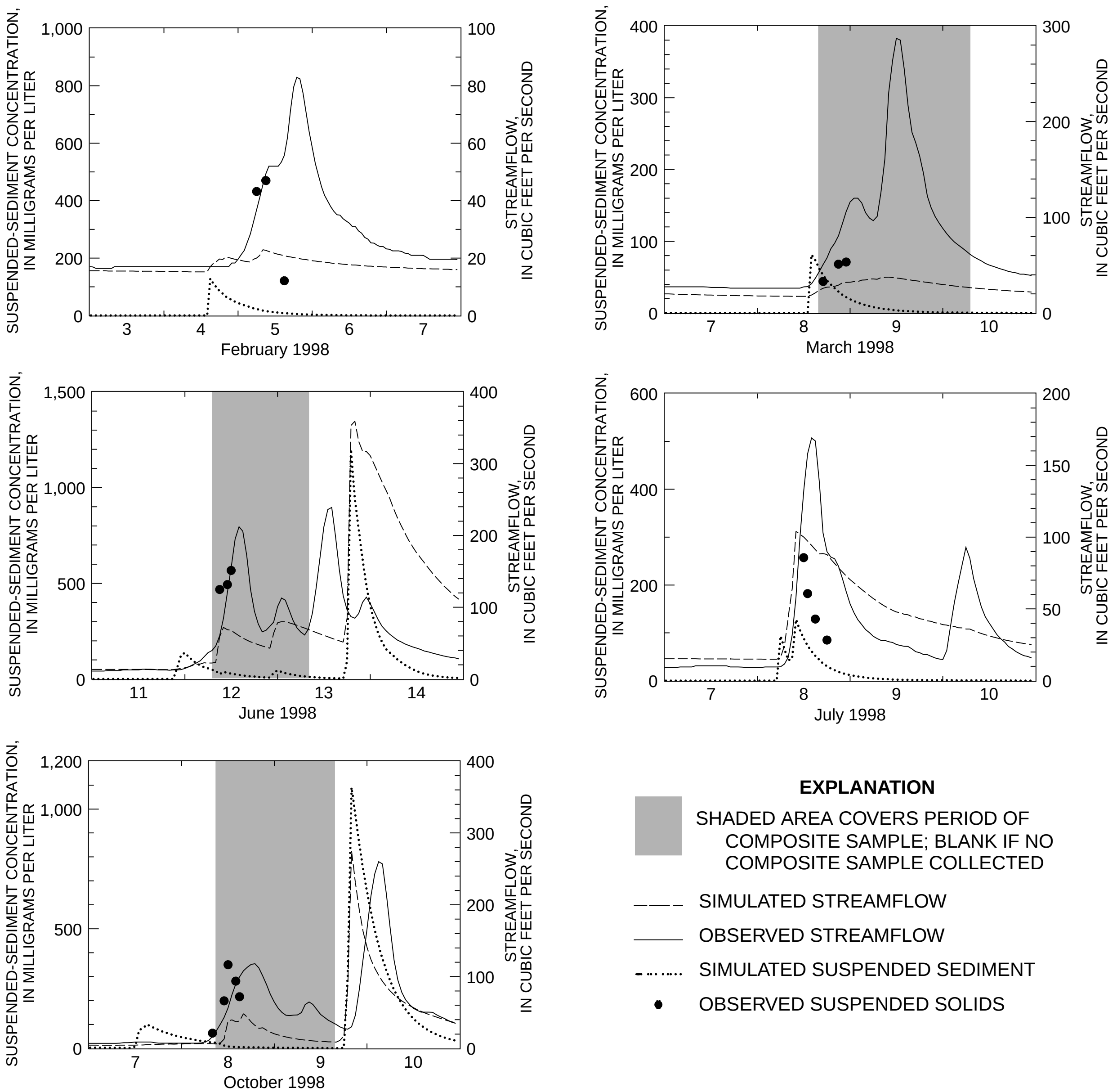


Figure 34. Simulated and observed streamflow and concentrations of suspended sediment during five storms in 1998 at streamflow-measurement station 01480300, West Branch Brandywine Creek at Honey Brook, Pennsylvania.

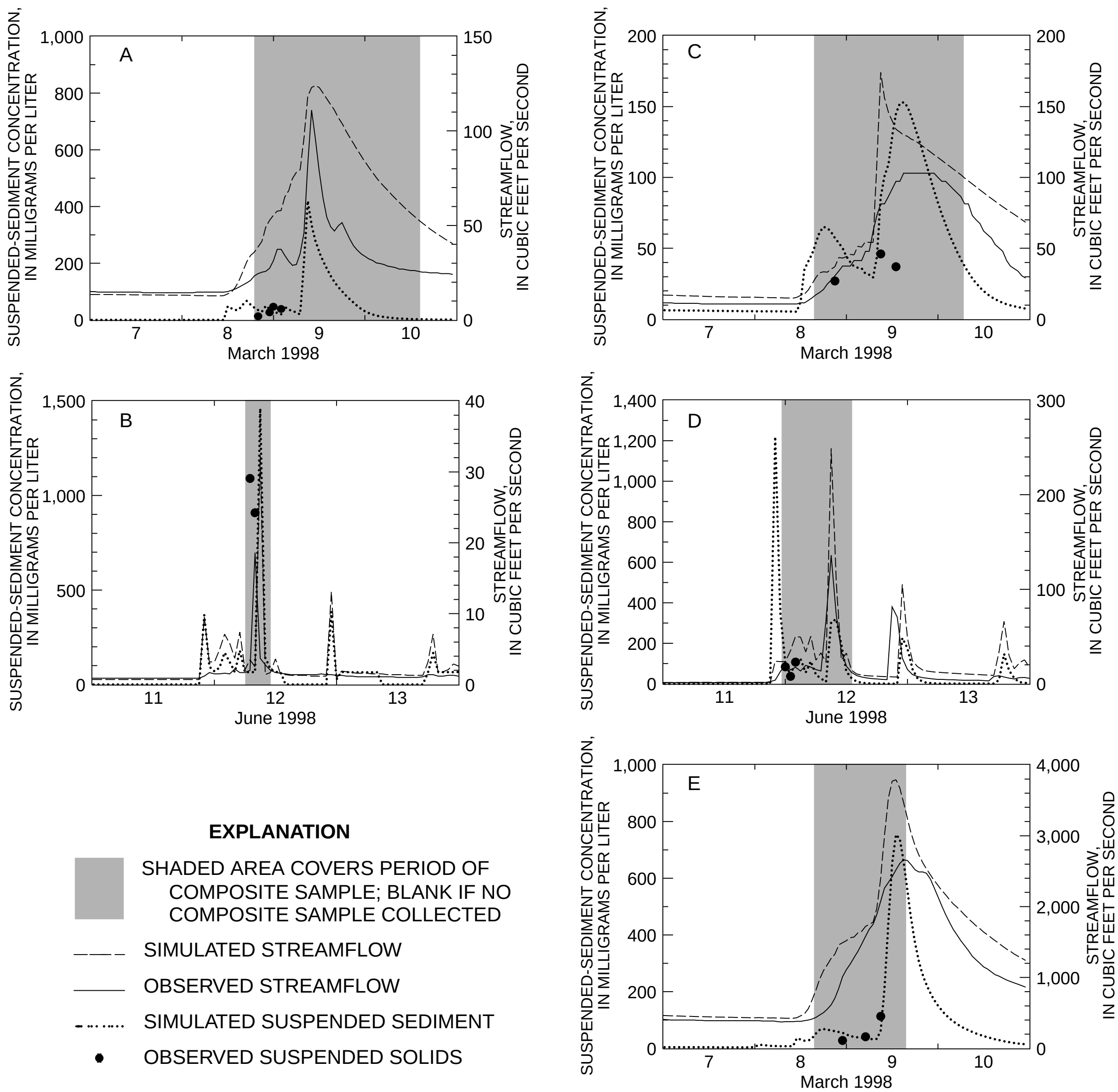


Figure 35. Simulated and observed streamflow and concentrations of suspended sediment and period of composite sample for a storm sampled in 1998 with a relatively well-simulated streamflow component at each of five nonpoint-source monitoring sites in the Brandywine Creek Basin, (A) 014806318 Doe Run near Springdell, Pa., (B) 01480637 Little Broad Run near Marshallton, Pa., (C) 01480675 Marsh Creek near Glenmoore, Pa., (D) 01480878 Unnamed tributary to Valley Creek near Exton, Pa., and (E) 01481000 Brandywine Creek at Chadds Ford, Pa.

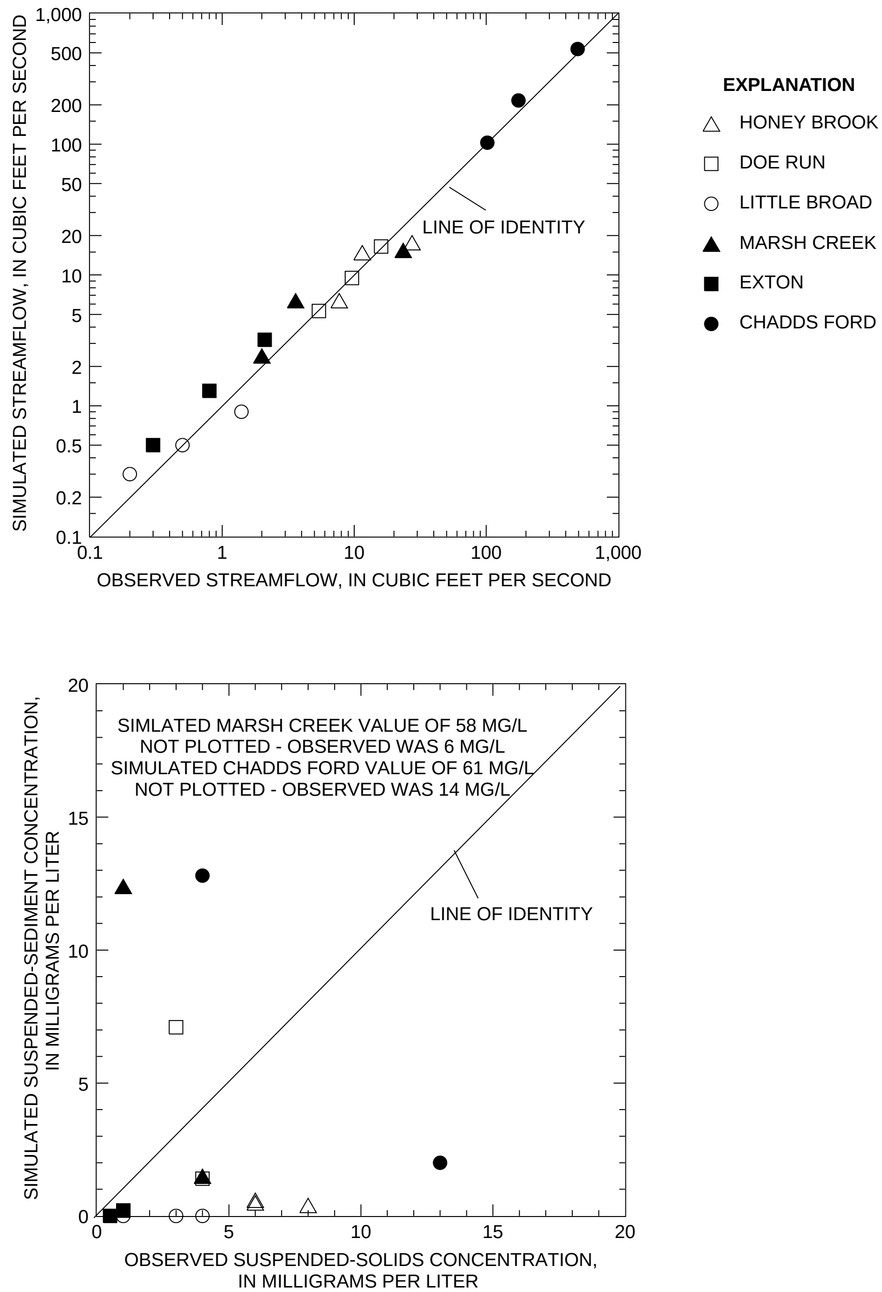


Figure 36. Simulated and observed streamflow and concentrations of suspended sediment under base-flow conditions at six monitoring sites in the Brandywine Creek Basin, 1998.

Table 18. *Simulated and observed streamflow and loads of suspended sediment for storms sampled in 1998 at six nonpoint-source monitoring sites in the Brandywine Creek Basin*

[ft^3/s, cubic feet per second; <, less than; >, greater than]

Dates of storm sampling	Peak streamflow[1] (ft^3/s)	Streamflow (millions of cubic feet)			Suspended sediment load (tons)		
		Simulated	Observed	Percentage difference[2]	Simulated	Observed	Percentage difference[2]
West Branch Brandywine Creek at Honey Brook, Pa.							
March 8-9	287	4.68	18.08	-74	1.64	61.13	-97
June 12	212	5.85	9.77	-40	4.64	70.41	-93
October 8-9	118	2.16	6.49	-67	.36	32.17	-99
Total - all storms		12.69	34.34	-63	6.64	163.71	-96
Doe Run near Springdell, Pa.							
March 8-9	96	5.49	3.27	68	25.90	20.79	25
June 12	194	1.33	3.40	-61	10.98	112.49	-90
July 8-9	79	.93	1.38	-33	1.08	12.00	-91
October 8-9	98	.82	2.91	-72	.46	36.73	-99
Total - all storms		8.57	10.96	-22	60.27	182.01	-79
Little Broad Run near Marshallton, Pa.							
March 8-9	3.7	.16	.07	142	1.67	.35	377
June 12	18.6	.14	.09	58	5.42	3.67	47
October 8-9	12.3	.24	.10	142	5.26	.94	464
Total - all storms		.53	.25	113	12.37	4.96	149
Marsh Creek near Glenmoore, Pa.							
March 8-9	103	11.75	9.03	30	35.57	7.42	379
June 12	60	3.15	4.07	-23	8.41	4.51	87
Total - all storms		14.90	13.11	14	43.98	11.93	269
Unnamed tributary to Valley Creek at Exton, Pa.							
February 4-5	11	.97	.41	137	1.56	1.83	-14
March 8-9	106	4.13	2.33	77	42.00	16.43	156
May 2-3	9	.54	.68	-22	.21	3.67	-94
June 12	136	2.79	1.75	60	17.21	11.84	45
July 8-9	54	3.33	.85	294	32.66	2.14	1,428
October 8-9	51	2.61	1.56	68	18.35	4.18	339
Total - all storms		14.38	7.58	90	112.00	40.07	279
Brandywine Creek at Chadds Ford, Pa.							
March 8-9	2,608	183.1	135.3	35	1,774	551.4	222
May 2-3	747	60.0	68.1	-12	58.2	<2.1	>2,607
June 12	2,623	26.7	45.0	-41	97.6	348.7	-72
July 8-9	1,211	118.8	71.5	66	543.5	104.0	423
October 8-9	1,098	58.3	59.1	-1	124.0	136.2	-9
Total - all storms		446.9	379.0	18	2,597	1,094.6	127

[1] Peak mean hourly streamflow during period of composite sampling.
[2] 100 × (simulated-observed)/observed.

Instantaneous loads, calculated from streamflows measured at gages and concentrations of suspended sediment measured in grab samples, also were used to evaluate model calibration. At the streamflow-measurement stations, 01481000 Brandywine Creek at Chadds Ford and 10481500 Brandywine Creek at Wilmington, most simulated suspended-sediment instantaneous loads were within an order of magnitude (or factor of 10) of observed loads, and in general are only moderately well simulated (fig. 37). The largest number of grab samples was collected at Chadds Ford, Pa., where 56 grab samples were collected by both PADEP and USGS under a range of hydrologic conditions from July 1995 through October 1998. Although simulated loads were both greater and smaller than observed loads, the net difference between the sum of simulated fluxes [193 lb / s)] was about 17 percent less than the sum of observed loads (233 lb / s). Although data on monthly and annual loads of suspended sediment are not available, the sum of instantaneous loads at Chadds Ford provides an estimate of the adequacy of the sediment calibration as 'good' using guidelines described by Donigian and others (1984) (table 16).

Comparison of concentration duration curves can be used to estimate statistical reliability of the simulation. Duration curves of observed concentrations of suspended sediment from September 1947 to September 1955 (Guy, 1957) and simulated concentrations for the period of January 1994 to October 1998 for Brandywine Creek at Wilmington, Del., are plotted in figure 38. Although the time periods differ, the duration curves compare well except for low-frequency, high-flow conditions for which the HSPF simulated concentrations of suspended sediment are several times greater than the observed concentrations. One explanation for the oversimulation of suspended sediment at high flow is an inaccurate simulation of hydrodynamic shear stress in that reach. Simulated shear stress and subsequent bed scour in the reach ending at Wilmington is relatively large compared to shear stress in other reaches. Other possible explanations for differences in the concentration duration curves include changes in flow duration (fig. 34), storm intensity, and land use between the two time periods.

In summary, the quality of the suspended-sediment calibration ranges from less than 'fair' (more than 35 percent error) to 'very good' (less than 15 percent error) for individual storms using criteria from Donigian and others (1984). Simulated instantaneous suspended-sediment loads at two long-term fixed-time-interval sites generally were within one order of magnitude of observed loads. These results indicate the range of variability that might be expected in simulating individual storms or instantaneous values. Comparison of the observed and simulated suspended-sediment concentration duration curves suggests that over relatively long time periods (5 years or more) the model results are statistically similar to observed data.

Simulated yields of sediment differ by land use and vary with precipitation from year to year (table 19). Simulated yields of sediment by land use (tables 19 and 20) are within the ranges reported for equivalent land-use types by Dunne and Leopold (1978, p. 520-522). Most of the simulated sediment yield was from land areas. Using pervious-land scour as an estimate of bank erosion, the average simulated amount of sediment removed by scour for the years 1994-97 differed among land uses and ranged from 0 to 29 percent of the total sediment yield. The highest percentage of sediment yield produced by scour was in urban and sewered residential land uses (median values of 18 and 17 percent, respectively) and the lowest was in forested and wetland land uses (median values of 1 and 0 percent, respectively). In areas of agricultural land use, the range of average simulated scour (bank erosion) was about 6 to 9 percent of total sediment yield for 1994-97 and appears to be similar to estimates obtained elsewhere. In a study of sediment sources in two agricultural basins in the United Kingdom, bank erosion was estimated to contribute about 10 percent or less of the sediment yield (Russell and others, 2001).

Dissolved Oxygen and Biochemical Oxygen Demand

Dissolved oxygen and biochemical oxygen demand (BOD) must be simulated in order to simulate nutrients in the stream. The simulation of dissolved oxygen included setting oxygen concentrations in land-surface runoff, interflow, and ground water and the in-stream effects of air and water temperature, reaeration, advection, and algal activity (photosynthesis and respiration). Dissolved-oxygen concentration data collected continuously at three monitoring sites in the Brandywine Creek Basin were used to evaluate the dissolved-oxygen simulation. The simulation of BOD from nonpoint sources included transport of BOD from land to streams and in-stream processes of BOD decay,

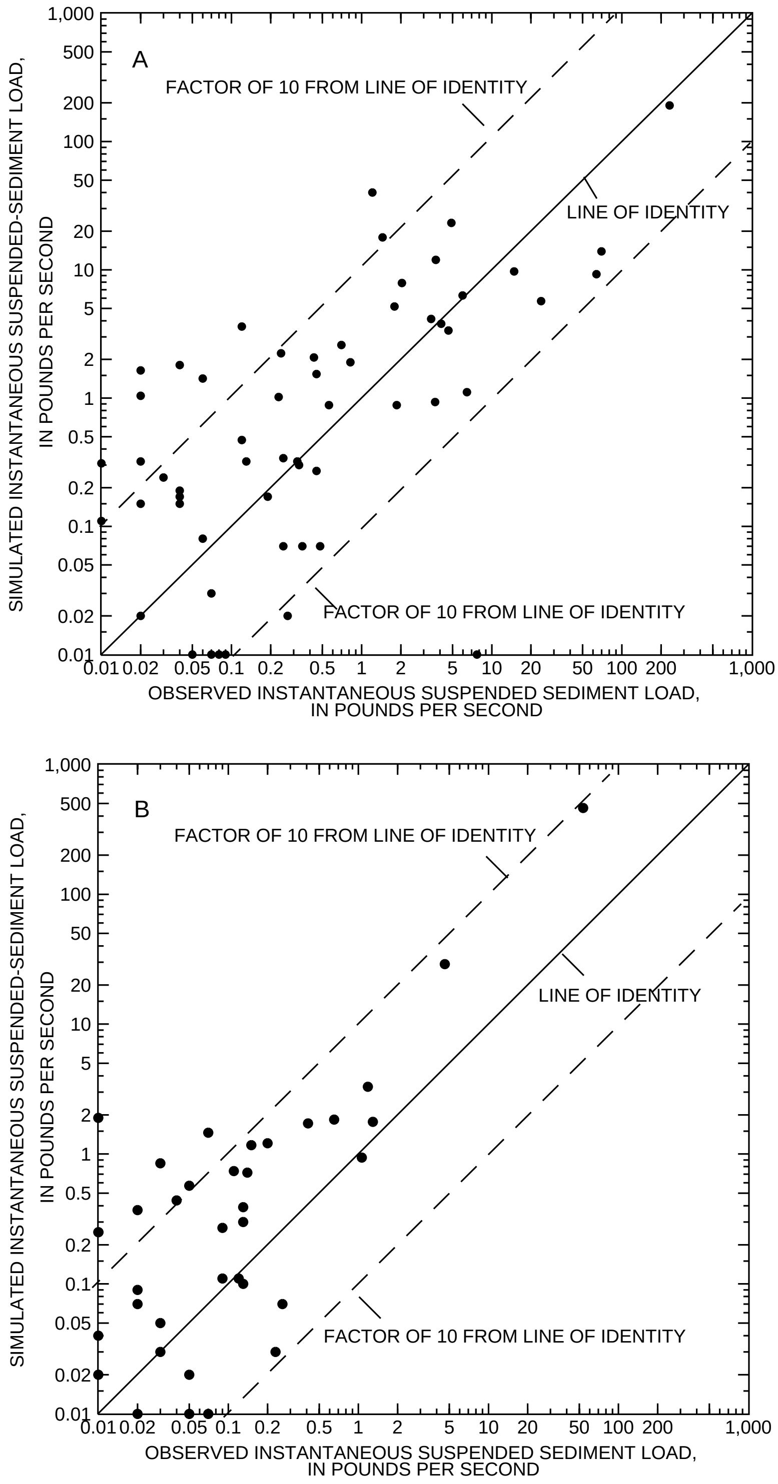
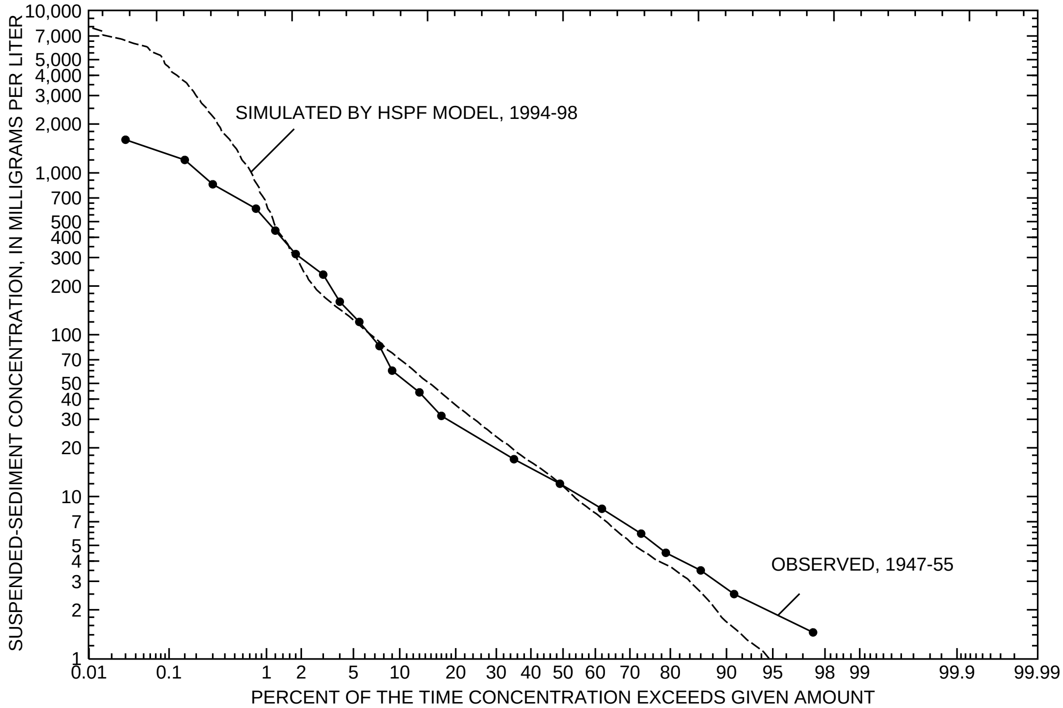


Figure 37. Simulated and observed loads of suspended sediment at streamflow-measurement stations (A) 01481000, Brandywine Creek at Chadds Ford, Pa., and (B) 01481500, Brandywine Creek at Wilmington, Del., 1995-98. (Data at Chadds Ford from PADEP and USGS; data at Wilmington from DNREC.)



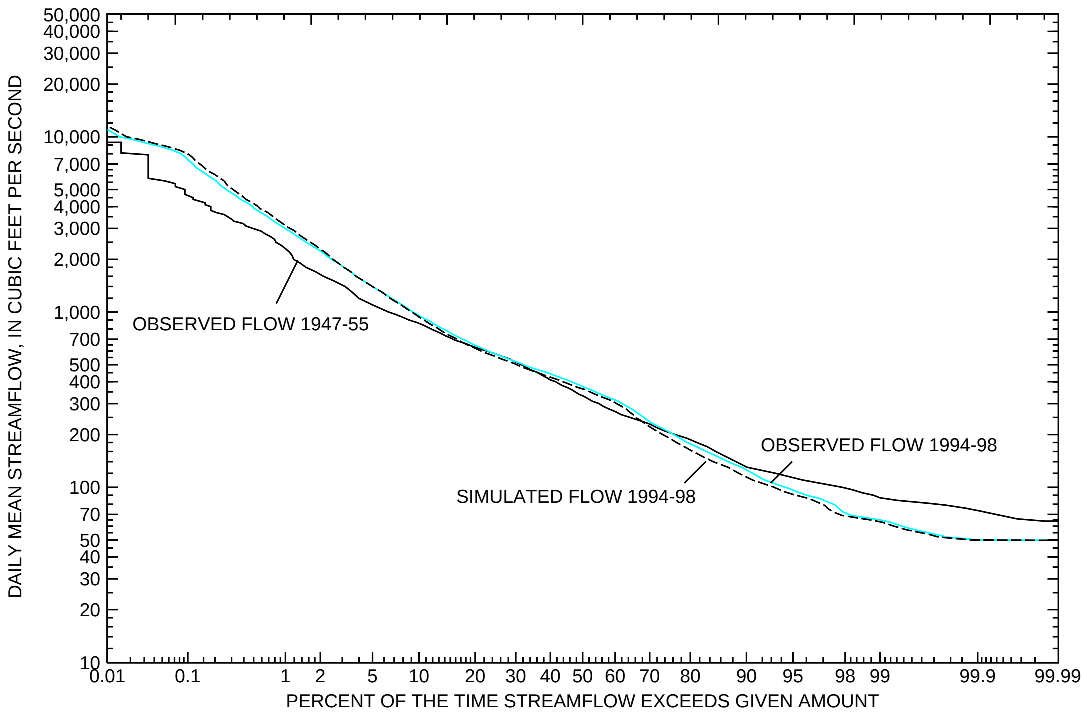


Figure 38. Sediment concentration and streamflow duration plots for Brandywine Creek at Wilmington, Del.

Table 19. *Annual precipitation and simulated annual sediment yields by land use for four segments of Hydrological Simulation Program–Fortran (HSPF) model for Brandywine Creek Basin, 1994-97*

[Yields are in tons per acre per year]

Precipitation/ Land-use category[1]	Seg-ment	Simulated annual sediment yield (tons per acre per year)									
		1994	1995	1996	1997	1994-97 average	Seg-ment	1994	1995	1996	1997	1994-97 average
Observed precipitation (inches)	1	51.68	41.96	70.18	34.97	49.70	2	45.17	42.47	67.50	35.33	47.62
Simulated sediment yields												
Residential - unsewered	1	.037	.077	.581	.028	.181	2	.003	.136	.571	.004	.179
Residential - sewered	1	.052	.108	.865	.041	.267	2	.004	.151	.604	.005	.191
Urban	1	.102	.207	1.120	.069	.375	2	.006	.324	.780	.008	.280
Agricultural - animal/crop	1	.634	1.760	6.940	.522	2.464	2	.194	3.610	6.590	.150	2.636
Agricultural - row crop	1	.634	1.760	6.940	.522	2.464	2	.194	3.610	6.590	.150	2.636
Agricultural - mushroom	1	.457	1.060	5.840	.352	1.927	2	.141	2.900	5.940	.114	2.274
Forested	1	.004	.020	.177	.015	.054	2	.001	.028	.177	.002	.052
Open	1	.088	.174	.829	.061	.288	2	.005	.133	.592	.009	.185
Wetlands/water	1	.034	.032	.083	.015	.041	2	.018	.500	.103	.017	.160
Undesignated	1	.094	.184	.851	.067	.299	2	.007	.144	.663	.009	.206
Impervious - residential	1	.134	.110	.105	.118	.117	2	.142	.117	.114	.115	.122
Impervious - urban	1	1.118	1.078	1.045	1.156	1.099	2	1.214	1.136	1.121	1.130	1.150
Observed precipitation (inches)	3	48.92	42.65	70.71	39.33	50.40	4	60.30	47.36	72.31	40.85	55.21
Simulated sediment yields												
Residential - unsewered	3	.009	.051	.292	.029	.095	4	.723	.059	.205	.003	.248
Residential - sewered	3	.012	.073	.390	.039	.129	4	.737	.077	.247	.003	.266
Urban	3	.052	.241	.839	.098	.308	4	1.430	.249	.635	.010	.581
Agricultural - animal/crop	3	.158	.638	2.510	.340	.912	4	3.610	1.270	2.810	.173	1.966
Agricultural - row crop	3	.158	.638	2.510	.340	.912	4	3.610	1.270	2.810	.173	1.966
Agricultural - mushroom	3	.075	.383	1.750	.196	.601	4	3.080	.399	1.360	.029	1.217
Forested	3	.006	.030	.147	.017	.050	4	.125	.007	.042	.001	.044
Open	3	.027	.102	.465	.053	.162	4	.475	.064	.141	.003	.171
Wetlands/water	3	.013	.026	.091	.014	.036	4	.620	.033	.550	.017	.305
Undesignated	3	.024	.104	.491	.055	.169	4	.344	.063	.196	.003	.152
Impervious - residential	3	.145	.108	.115	.113	.120	4	.164	.121	.113	.121	.130
Impervious - urban	3	1.173	1.073	1.136	1.113	1.124	4	1.216	1.156	1.146	1.200	1.180

[1] In pervious areas, unless noted.

Table 20. *Observed 1994-97 annual precipitation and simulated 1994-97 average annual sediment yield by land use for pervious and impervious land areas in four segments of Hydrological Simulation Program–Fortran (HSPF) model for Brandywine Creek Basin*

Precipitation/ Land-use category[1]	Mean sediment yield, 1994-97 (tons per acre per year)				
	Segment 1	Segment 2	Segment 3	Segment 4	All segments
Observed precipitation (inches)	49.70	47.62	50.40	55.21	50.731
Simulated sediment yields					
Residential - unsewered	.181	.179	.095	.248	.175
Residential - sewered	.267	.191	.129	.266	.213
Urban	.375	.280	.308	.581	.386
Agricultural - animals/crops	2.464	2.636	.912	1.966	1.994
Agricultural - row crop	2.464	2.636	.912	1.966	1.994
Agricultural - mushroom	1.927	2.274	.601	1.217	1.505
Forested	.054	.052	.050	.044	.050
Open	.288	.185	.162	.171	.201
Wetlands/water	.041	.160	.036	.305	.135
Undesignated	.299	.206	.169	.152	.206
Impervious - residential	.117	.122	.120	.130	.122
Impervious - urban	1.099	1.150	1.124	1.180	1.138

[1] In pervious areas, unless noted.

settling, and advection. Concentrations of BOD in the soil (sediment), interflow, and ground water were fixed in amounts that differed by land use. Estimates of BOD in soil, interflow, and ground water were derived from an HSPF model of the Pautuxent River Basin in northeastern Maryland (Steve Preston, U.S. Geological Survey, written commun., 1995). BOD concentration data from the analysis of grab and composite samples collected at six monitoring sites were used to evaluate the BOD simulation.

The general pattern of seasonal changes in dissolved-oxygen concentrations was simulated by the model, as shown in fig. 39 for Brandywine Creek at Chadds Ford, Pa. Daily mean concentrations of dissolved oxygen for Brandywine Creek at Chadds Ford, Pa., tended to be oversimulated especially in the summer months (fig. 39). The diurnal fluctuation in concentrations of dissolved oxygen attributed to processes of algal photosynthesis and respiration becomes more pronounced in the summer months than at other times of the year. In order to reproduce the temporal pattern of diurnal fluctuations in dissolved-oxygen concentrations, simulation of plankton was needed and included in the model. Comparison of simulated and observed concentrations of dissolved oxygen under base-flow conditions in 1998 at three sites on the Brandywine Creek show that the simulation better characterizes the smaller diurnal fluctuations during the cool, March period than the larger fluctuations common during the warm, August period (fig. 40). In general, the daily mean concentrations of dissolved oxygen tend to be oversimulated in the lowest range of observed concentrations that typically occur in the summer (fig. 41).

Overall, the simulation provides a reasonable estimate of dissolved-oxygen concentrations that are needed for the in-stream simulation of nutrients. At Brandywine Creek at Chadds Ford, the difference between simulated and observed mean daily oxygen concentrations ranged from -28 to 63 percent [100 × (simulated - observed)/observed], and the average difference was 9 percent for monitored periods from April 1994 through October 1998. Dissolved-oxygen concentrations for these sites are not monitored during the winter. For 95 percent of the observations, the difference between simulated and observed mean daily oxygen concentrations ranged from -10 to 31 percent.

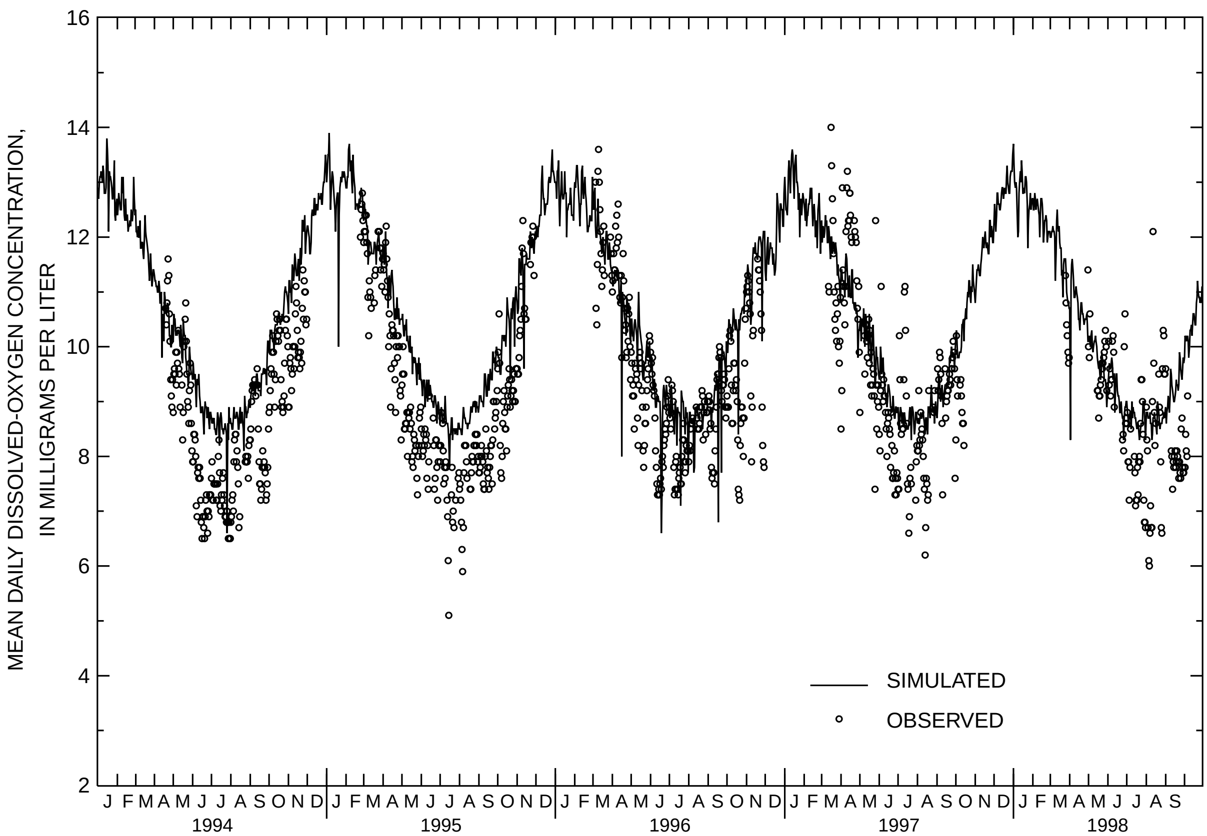


Figure 39. Simulated and observed daily mean concentrations of dissolved oxygen at streamflow-measurement station 01481000, Brandywine Creek at Chadds Ford, Pa., for the period January 1, 1994, through October 29, 1998.

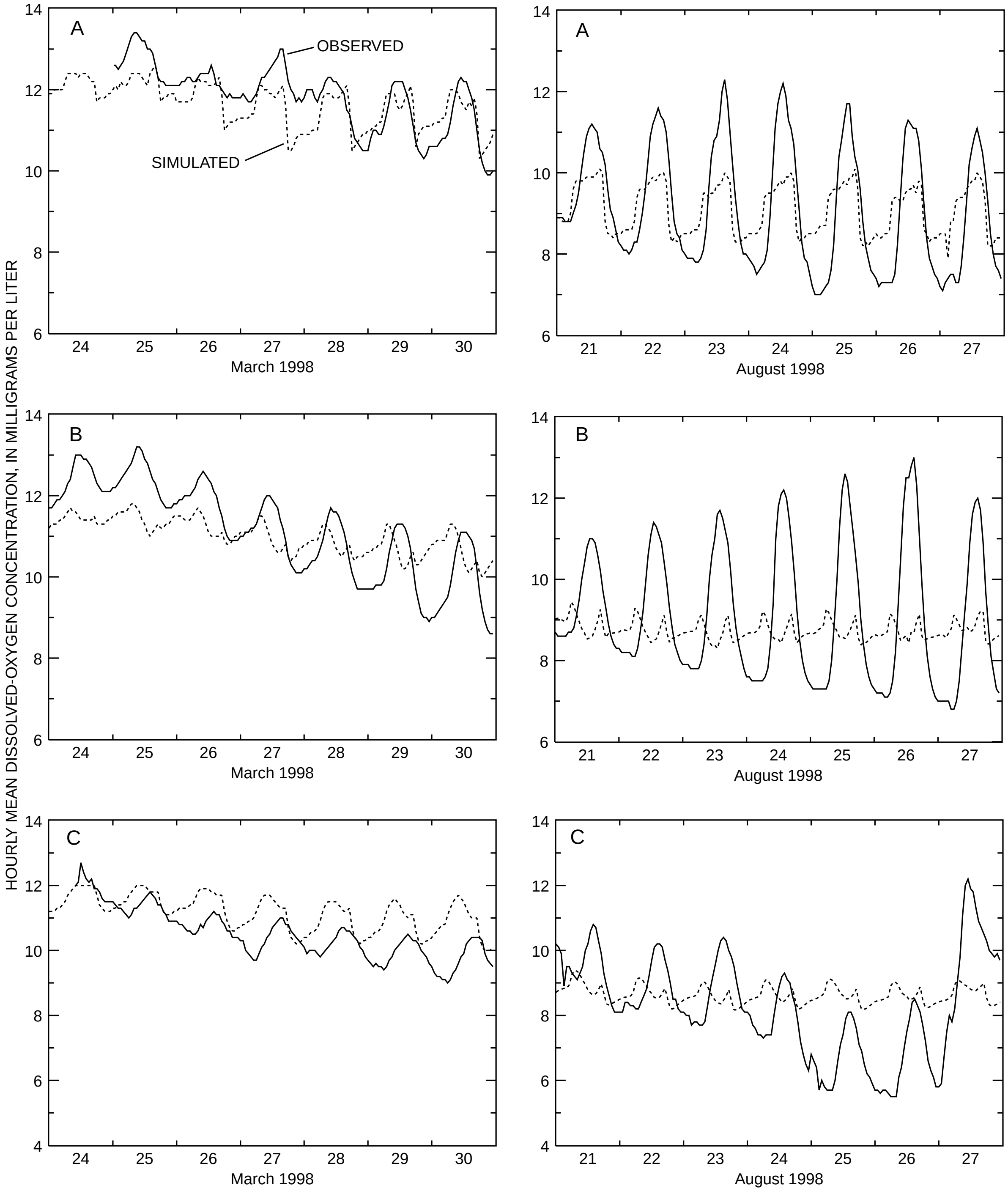


Figure 40. Simulated and observed hourly mean concentrations of dissolved oxygen at streamflow-measurement station (A) 01480617, West Branch Brandywine Creek at Modena, Pa., (B) 01480870, East Branch Brandywine Creek below Downingtown, Pa., and (C) 01481000, Brandywine Creek at Chadds Ford, Pa., for spring conditions, March 24-30, and summer conditions, August 21-27, 1998.

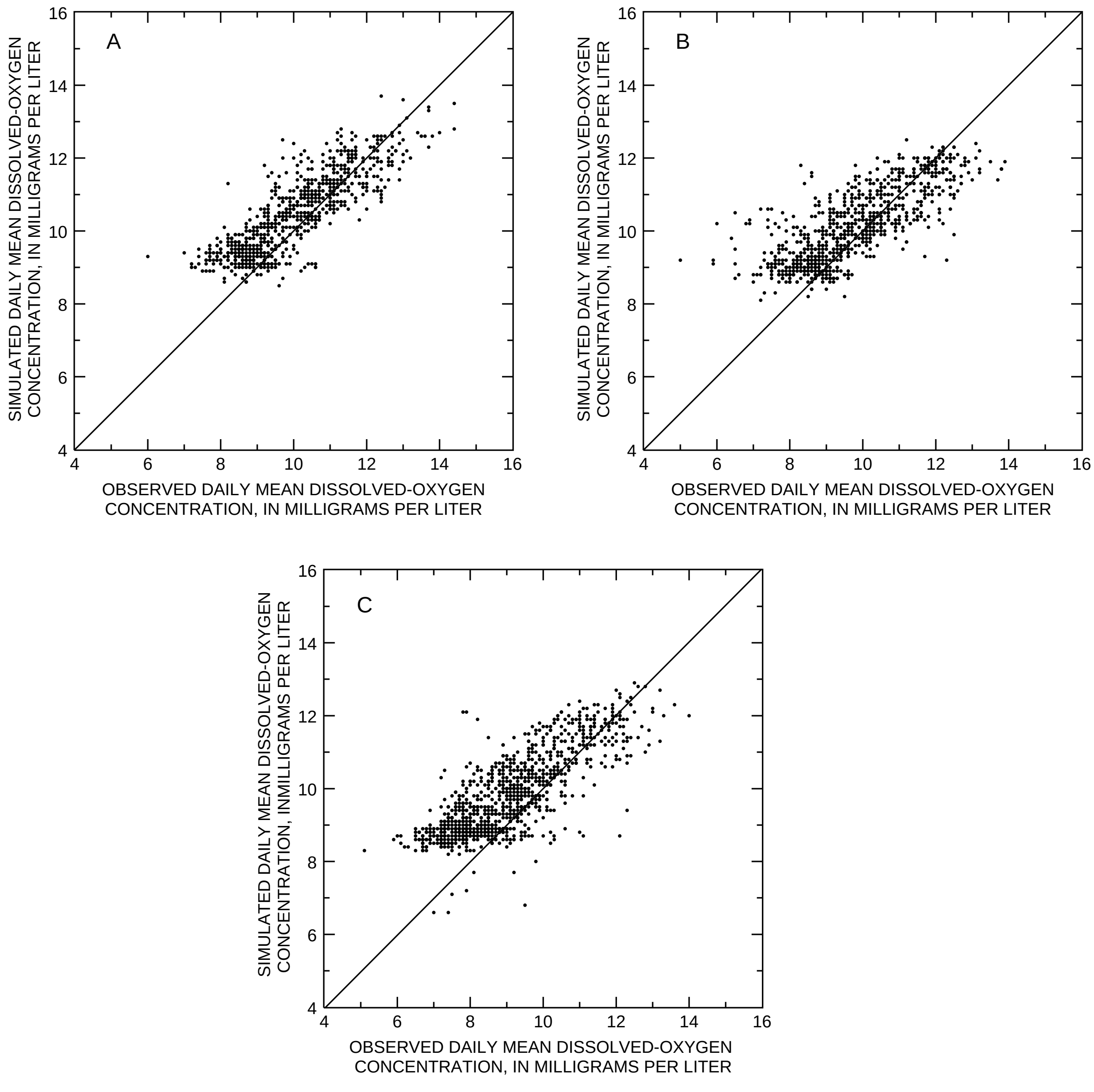


Figure 41. Relation between simulated and observed daily mean concentrations of dissolved oxygen at (A) West Branch Brandywine Creek at Modena, Pa., (B) East Branch Brandywine Creek below Downingtown, Pa., and (C) Brandywine Creek at Chadds Ford, Pa., for the period January 1 through October 29, 1998.

Although BOD and chlorophyll *a* were not main constituents of interest, the comparison of simulated and observed results is provided to help evaluate the dissolved-oxygen simulation. Comparison of simulated and observed BOD concentrations under stormflow and base-flow conditions (fig. 42) indicates that BOD commonly is undersimulated by as much as an order of magnitude or

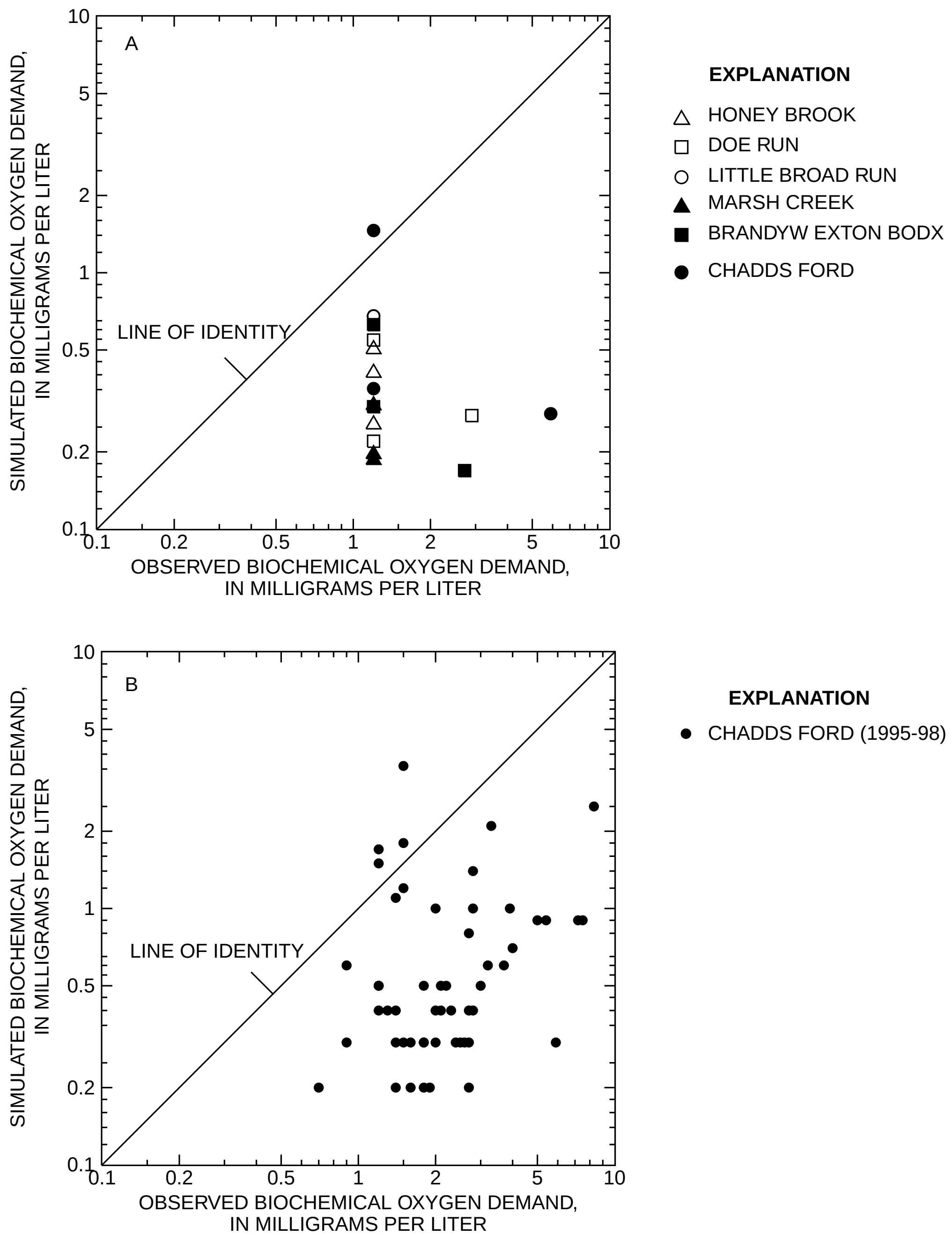


Figure 42. Simulated and observed concentrations of biological oxygen demand in (A) base-flow samples at six monitoring sites in the Brandywine Creek Basin, 1998 and (B) samples collected and analyzed by the Pennsylvania Department of Environmental Protection under a range of flow conditions at Brandywine Creek at Chadds Ford, Pa., 1995-98.

more. Many of the samples collected in 1998 for BOD analysis under base-flow conditions were reported as less than the detection level of 2.4 mg/L and are shown as 1.2 mg/L (0.5 times the detection level) in figure 43. Simulated BOD appears to under-represent observed BOD concentrations during stormflow. Undersimulation of BOD may result in undersimulation of BOD decay and consequent oxygen depletion. The amount of oxygen in the stream reach can affect the extent of nitrification and denitrification reactions.

Samples for chlorophyll-*a* analysis were collected quarterly under base-flow conditions in 1998 at the six monitoring sites in the Brandywine Creek Basin. Comparison of simulated and observed chlorophyll-*a* concentrations under base-flow conditions (fig. 43) indicates that chlorophyll-*a* concentrations commonly are simulated within a factor of two or better at four sites and tend to be undersimulated at the site draining a predominantly forested area (Marsh Creek near Glenmoore) and the site draining the predominantly sewered residential area (Unnamed tributary to Valley Creek near Exton). Undersimulation of chlorophyll-*a* concentrations may result in undersimulation of the magnitude of diurnal fluctuations in dissolved-oxygen concentrations.

Nitrogen

The two inorganic species of nitrogen, nitrate and ammonia, were simulated. Nitrogen loads from point and nonpoint sources were included in the simulation. Loads from point-source discharges were estimated from reported average monthly data for input on an hourly time step to the model. For most point-source discharges, nitrate was estimated from reported ammonia loads using the ratios specified in USEPA, Region 3 (2000a); nitrite was assumed to be negligible. The ratio of nitrate to ammonia in point-source effluent used for model data sets was 0.84 for small wastewater treatment plants (WWTPs), 314 for advanced secondary treatment type 1 WWTPs, 157 for advanced secondary treatment type 2 WWTPs, and 0.21 for industrial discharges. On the basis of monthly monitoring data in 1995-96 (H.J. Mays, Downingtown Area Regional Authority, written commun., 2001), the ratio of nitrate to ammonia for advanced secondary treatment type 2 plants was reduced by a factor of 0.6 to 94. For nonpoint sources, concentrations of nitrate and ammonia in sediment (soil), interflow, and ground water were estimated as fixed concentrations that differed by land use. Nitrate was assumed to be transported solely in the dissolved form. Ammonia was assumed to be transported in both dissolved and adsorbed forms.

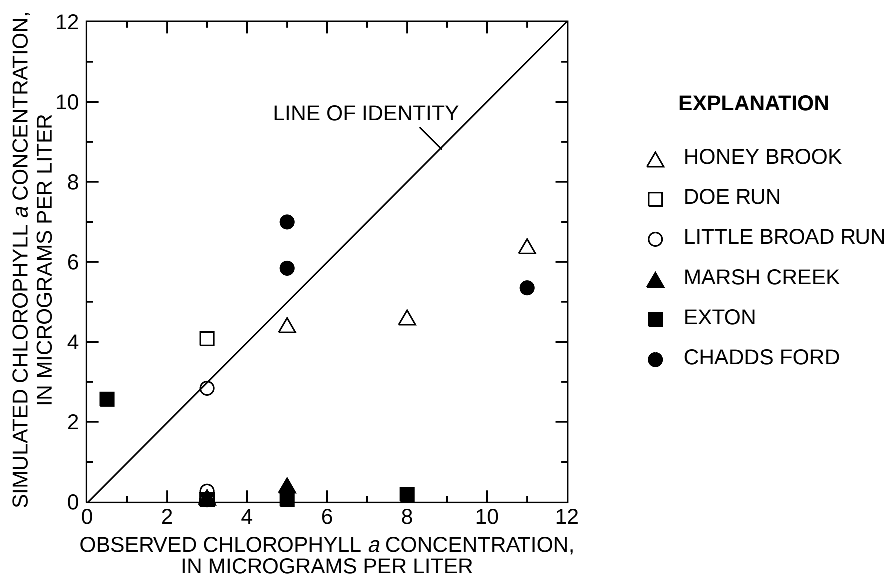


Figure 43. Simulated and observed concentrations of chlorophyll *a* in base-flow samples at six monitoring sites in the Brandywine Creek Basin, 1998.

Water-quality data from six monitoring stations were used in the calibration of concentrations of dissolved nitrate and dissolved and particulate ammonia nitrogen in stormflow and base flow. Simulated and observed concentrations of dissolved nitrate are shown in figure 44 for a storm with relatively well-simulated streamflow at each of the six nonpoint-source monitoring sites. Simulated and observed streamflow and concentrations of nitrate for all sampled storms at the six nonpoint-source monitoring sites in the Brandywine Creek Basin are shown in Appendix 2. Observed and simulated nitrate concentrations generally decrease as streamflow increases during storms.

Data from composite stormflow samples collected in 1998 were used in the calculation of loads of dissolved nitrate and dissolved and particulate ammonia nitrogen. Calculated loads served as the observed values in overall evaluation of nitrogen transport during storms. The error in simulated load is partially due to error in simulated streamflow. The error in the water-quality component of the load simulation can be estimated by adjusting for the error in streamflow simulation as follows, although this approach does not account for a nonlinear relation between flow and concentration: percentage error in water-quality component of load = $100 \times ([(Ls / Lo) / (Qs / Qo)] - 1)$, where Ls is simulated load, Lo is observed load, Qs is simulated streamflow, and Qo is observed streamflow.

Simulated and observed streamflow and load data for dissolved nitrate for sampled storm events are presented in table 21. Commonly, nitrate loads tend to be undersimulated when flow is undersimulated and oversimulated when flow is oversimulated. Both flow and nitrate load tend to be undersimulated at two sites in agricultural basins (West Branch Brandywine Creek at Honey Brook and Doe Run near Springdell) and oversimulated at the whole basin site (Brandywine Creek at Chadds Ford). At these three sites, the error in simulated nitrate component of load, adjusted for the error in simulated streamflow, ranges from -71 to 80 percent for storms in 1998 and typically is less than plus or minus 25 percent, indicating a ‘good’ calibration using monthly or yearly annual load criteria (Donigian and others, 1984). At the other three sites, the pattern between flow and nitrate simulations is less clear. At the two sites in predominantly residential basins (Little Broad Run near Marshallton and Unnamed tributary to Valley Creek at Exton), nitrate load is sometimes undersimulated when flow is oversimulated, but otherwise, the patterns between nitrate load and flow are similar to those at the agricultural and whole-basin sites. For these two sites, the error in the simulated nitrate component of load, adjusted for error in simulated streamflow, ranges from -88 to 21 percent for storms in 1998 and is less than plus or minus 25 percent for about half the storms. At the site in the forested basin (Marsh Creek near Glenmoore), nitrate is oversimulated in both undersimulated and oversimulated storms. Oversimulation of nitrate at the Marsh Creek site may be related to inaccurate characterization of nutrient uptake in wetlands upstream of the sampling location and / or to the oversimulation of sediment, which contributes nitrate through soil erosion. Adjusting for error in streamflow, nitrate is oversimulated by about a factor of 3 at Marsh Creek for the two storms sampled in 1998.

Simulated concentrations of dissolved nitrate in base flow generally were within 0.5 mg / L of observed concentrations at four of the six monitoring stations (fig. 45). Streamflow was well simulated for all base-flow samples, as shown in figure 29. Nitrate concentrations were oversimulated for Marsh Creek near Glenmoore, Pa., and for Brandywine Creek at Chadds Ford, Pa. Excluding data at Marsh Creek near Glenmoore and Brandywine Creek at Chadds Fords, the average difference between observed and simulated concentrations of nitrate was 0.23 mg / L, and the average percentage difference was 3 percent. Poorly modeled denitrification and nitrate-uptake processes probably contribute most to the oversimulation at Marsh Creek, a predominantly forested basin with substantial wetland headwaters. Oversimulation of nitrate at the Chadds Ford site probably is related to inadequately estimated hourly nitrate concentrations in discharges from wastewater treatment plants upstream and perhaps to errors in the plankton simulation. Observed hourly concentrations of nitrate for point-source discharges were not available but were interpolated from reported average monthly concentrations of ammonia assuming a constant ratio of nitrate to ammonia. The ratio of nitrate to ammonia in effluent probably fluctuates from day to day and over any 24-hour period.

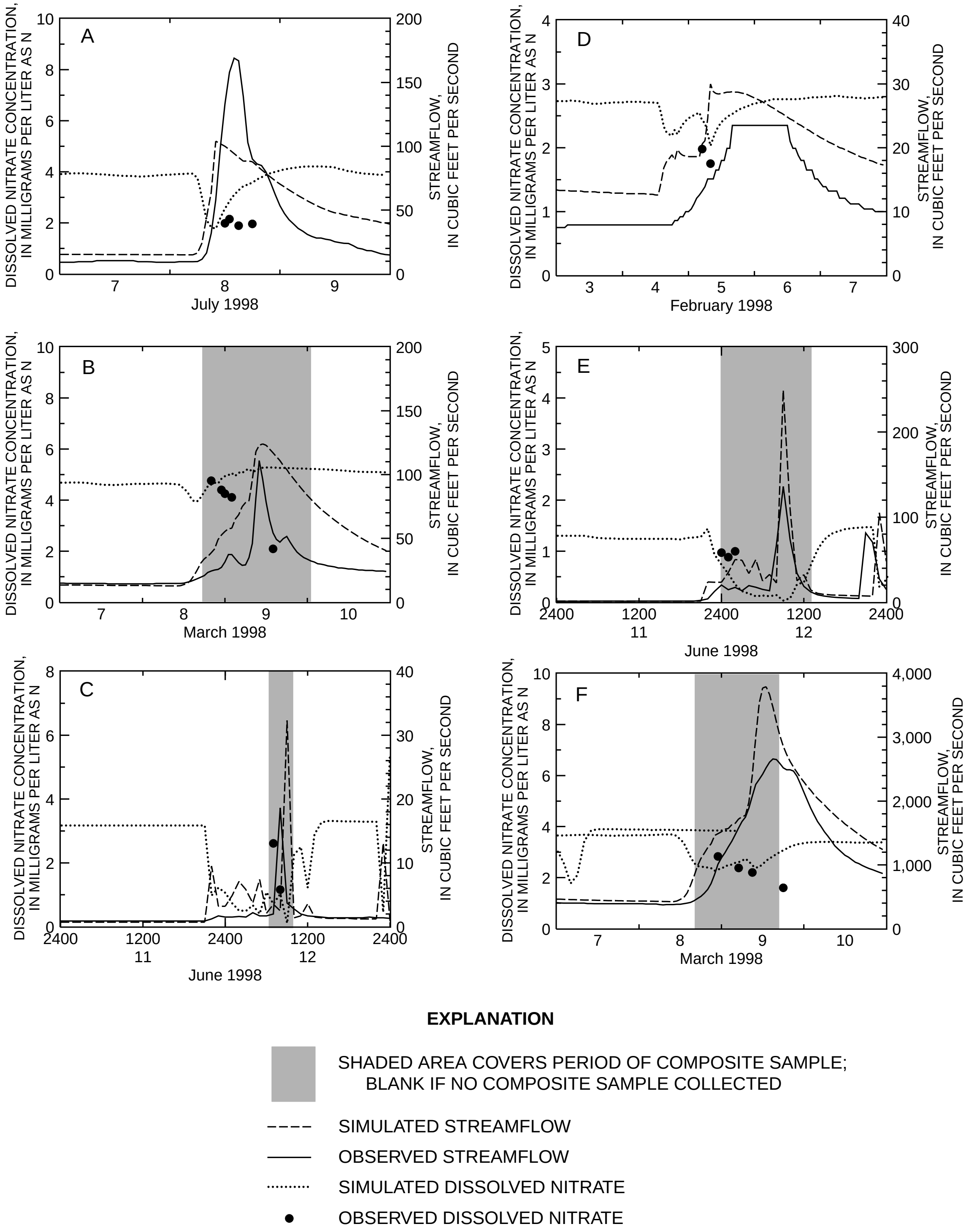


Figure 44. Simulated and observed streamflow and concentrations of dissolved nitrate and period of composite sample for a storm sampled in 1998 with a relatively well-simulated streamflow component at the nonpoint-source monitoring sites in the Brandywine Creek Basin, (A) 01480300 West Branch Brandywine Creek at Honey Brook, Pa., (B) 014806318 Doe Run near Springdell, Pa., (C) 01480637 Little Broad Run near Marshallton, Pa., (D) 01480675 Marsh Creek near Glenmoore, Pa., (E) 01480878 Unnamed tributary to Valley Creek near Exton, Pa., and (F) 01481000 Brandywine Creek at Chadds Ford, Pa.

Table 21. *Simulated and observed streamflow and loads of dissolved nitrate, dissolved ammonia, and particulate ammonia for storms sampled in 1998 at six nonpoint-source monitoring sites in the Brandywine Creek Basin*

[ft^3/s, cubic feet per second; Sim., simulated; Obs., observed; diff., difference; nd, not detected; --, not applicable]

Dates of storm sampling	Peak stream-flow[1] (ft^3/s)	Streamflow (millions of cubic feet)			Dissolved nitrate load (pounds as nitrogen)			Dissolved ammonia load (pounds as nitrogen)			Particulate ammonia load (pounds as nitrogen)		
		Sim.	Obs.	Percent diff.[2]	Sim.	Obs.	Percent diff.[2]	Sim.	Obs.	Percent diff.[2]	Sim.	Obs.	Percent diff.[2]
West Branch Brandywine Creek at Honey Brook, Pa.													
March 8-9	287	4.68	18.08	-74	1,278	2,696	-53	57.5	379	-85	0.79	46.8	-98
June 12	212	5.85	9.77	-40	1,128	1,581	-29	12.1	82.8	-85	.37	2.5	-85
October 8-9	118	2.16	6.49	-67	147	1,008	-85	4.3	19.7	-79	.03	5.3	-99
Total - all storms		12.69	34.34	-63	2,553	5,286	-52	73.9	482	-85	1.19	54.6	-99
Doe Run near Springdell, Pa.													
March 8-9	96	5.49	3.27	68	1,750	683	156	14.3	49.0	-71	2.8	14.5	-81
June 12	194	1.33	3.40	-61	308	535	-42	3.1	35.6	-91	1.2	21.3	-95
July 8-9	79	.93	1.38	-33	202	305	-34	.6	12.3	-95	.05	0	--
October 8-9	98	.82	2.91	-72	127	450	-72	2.3	20.2	-88	.03	3.5	-99
Total - all storms		8.57	10.96	-22	2,387	1,972	21	20.4	117	-83	4.1	39.2	-90
Little Broad Run near Marshallton, Pa.													
March 8-9	3.7	.16	.07	142	22.8	12.0	90	.14	.31	-55	.006	0	--
June 12	18.6	.14	.09	58	2.0	7.74	-75	.01	.40	-99	.003	0	--
October 8-9	12.3	.24	.10	142	3.6	12.8	-72	.23	.11	105	.029	.117	-75
Total - all storms		.53	.25	113	28.4	32.6	-13	.73	.82	-55	.038	.117	-68
Marsh Creek near Glenmoore, Pa.													
March 8-9	103	11.75	9.03	30	1,881	521	261	26.4	13.1	101	16.1	1.14	1,308
June 12	60	3.15	4.07	-23	383	163	134	4.6	3.1	49	.10	.51	-80
Total - all storms		14.90	13.11	14	2,264	684	231	33.9	16.2	91	16.2	1.66	876
Unnamed tributary to Valley Creek at Exton, Pa.													
February 4-5	11	.97	.41	137	37.3	24.2	54	1.68	.57	195	.06	.57	-90
March 8-9	106	4.13	2.33	77	175	81.6	115	6.48	6.48	0	2.15	3.24	-34
May 2-3	9	.54	.68	-22	33.0	56.1	-41	1.15	.69	67	.02	.17	-86
June 12	136	2.79	1.75	60	35.8	62.1	-42	6.38	5.31	20	1.62	4.98	-68
July 8-9	54	3.33	.85	294	79.8	39.8	100	11.2	2.24	398	6.40	.53	1,094
October 8-9	51	2.61	1.56	68	18.3	63.3	-71	3.41	1.57	116	.71	19.2	-96
Total - all storms		14.38	7.58	90	379	327	16	30.3	16.9	79	11.0	28.7	-62
Brandywine Creek at Chadds Ford, Pa.													
March 8-9	2,608	183.1	135.3	35	29,682	18,635	59	437	231	89	153	nd	--
May 2-3	747	60.0	68.1	-12	11,669	12,946	-10	137	9	1,497	5.6	94.6	-94
June 12	2,623	26.7	45.0	-41	2,362	4,924	-52	27	122	-78	3.3	48.4	-93
July 8-9	1,211	118.8	71.5	66	13,974	9,449	48	299	95	215	42.6	45.2	-6
October 8-9	1,098	58.3	59.1	-1	2,459	8,547	-71	115	11	931	6.5	112	-94
Total - all storms		446.9	379.0	18	60,145	54,501	10	1,015	468	117	211	300	-30

[1] Peak mean hourly streamflow during period of composite sampling.
[2] 100 x (simulated-observed)/observed.

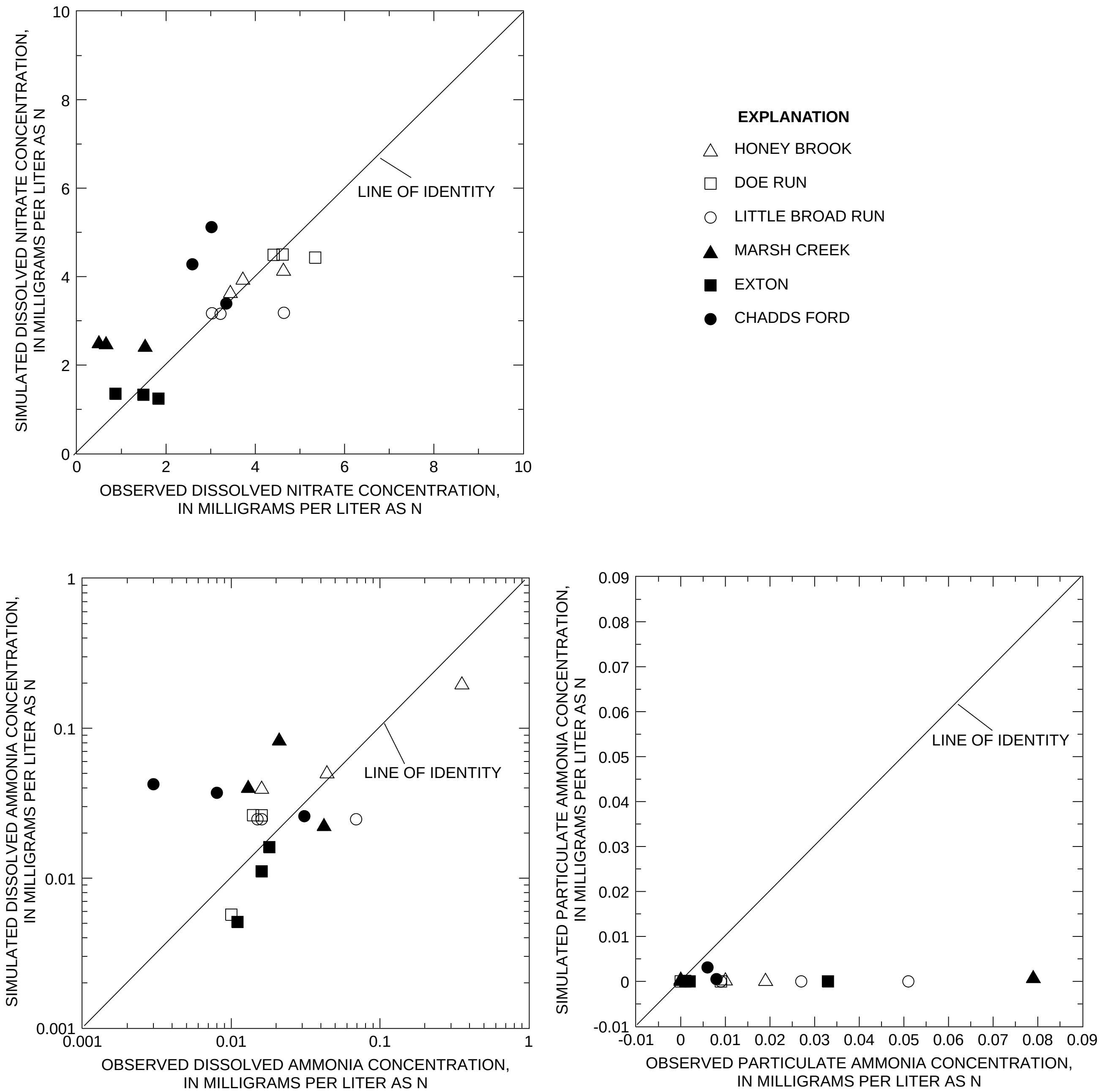


Figure 45. Simulated and observed concentrations of nitrate and dissolved and particulate ammonia during base-flow conditions in 1998 at six monitoring sites in the Brandywine Creek Basin.

To further illustrate effects of wastewater discharges, simulated and observed concentrations and loads of nitrate at main-stem sites upstream of major discharges were compared to those at Chadds Ford, Pa., a site downstream of most major discharges (fig. 46). Data at sites upstream of discharges on the main branches of Brandywine Creek were obtained from PADEP and do not include any data collected by USGS in 1998. Nitrate concentrations and loads generally are better simulated at the two main-stem sites above major dischargers (West Branch Brandywine Creek at Coatesville and East Branch Brandywine Creek near Downingtown, Pa.) than at Chadds Ford, Pa. At all sites, simulated nitrate loads generally were within a factor of five or less of observed loads (fig. 46). Comparison of estimated loads of total nitrate from point-source discharges and simulated nitrate concentrations for Brandywine Creek at Chadds Ford, Pa., indicates a strong temporal correlation in fluctuations (fig. 47), and therefore, errors in estimates of nitrate loads from point sources are likely to cause errors in the in-stream nitrate simulations downstream of those point sources.

Overall, the nitrate simulation under base flow and stormflow conditions appears to represent the observed patterns of nitrate concentration in response to flow conditions and defined land uses. Nitrate concentrations and loads are oversimulated at the forested basin site (Marsh Creek near Glenmoore) and this oversimulation partly may be related to inaccurate characterization of nitrate uptake upstream of the sampling site. Estimated nitrate loads from point sources appear to correlate with fluctuations in simulated nitrate concentrations at the whole-basin site downstream of most point sources. Nitrate loads at the whole-basin site (Brandywine Creek at Chadds Ford), where most data are available for 1995-98, are simulated within a factor of five or less of observed loads.

Simulated concentrations of dissolved and particulate ammonia were compared to observed concentrations of dissolved and particulate ammonia in stormflow and base-flow conditions where observed particulate ammonia concentrations were calculated by subtracting dissolved ammonia concentrations from total ammonia concentrations. Review of 1998 monitoring data indicates that, on average, dissolved ammonia represents about 83 percent of total ammonia concentrations in the Brandywine Creek Basin.

Simulated and observed concentrations of dissolved and particulate ammonia are shown in figures 48 and 49 for a storm with relatively well-simulated streamflow at each of the six nonpoint-source monitoring sites. Simulated and observed streamflow and concentrations of dissolved and particulate ammonia for all sampled storms at the six nonpoint-source monitoring sites in the Brandywine Creek Basin are shown in Appendix 2. Observed and simulated concentrations of dissolved and particulate ammonia generally tend to increase as streamflow increases during storms. Although the general pattern of observed dissolved and particulate ammonia concentrations during storms is simulated by the model, errors or differences between observed and simulated concentrations are apparent. Simulated dissolved ammonia concentrations were less than observed dissolved ammonia concentrations at some sites (West Branch Brandywine Creek at Honey Brook, Doe Run near Springdell, Marsh Creek near Glenmoore) and greater than observed dissolved ammonia concentrations at others (Little Broad Run, Unnamed tributary to Valley Creek, Brandywine Creek at Chadds Ford) (fig. 48). Simulated particulate ammonia concentrations were less than observed particulate ammonia concentrations at some sites (Little Broad Run, Marsh Creek near Glenmoore, Brandywine Creek at Chadds Ford) and greater than observed particulate ammonia concentrations at others (West Branch Brandywine Creek at Honey Brook, Doe Run near Springdell, Unnamed tributary to Valley Creek) (fig. 49). Errors or differences between observed and simulated concentrations are due in part to errors in flow simulation and timing of rainfall for particular storms.

Simulated and observed streamflow and loads of dissolved and particulate ammonia nitrogen for storm events occurring in 1998 are presented in table 21. Observed loads of dissolved ammonia commonly are greater than observed loads of particulate ammonia except for a few storms at a residential-basin site (Unnamed tributary to Valley Creek) and the whole-basin site (Brandywine Creek at Chadds Ford). Dissolved and particulate ammonia loads tend to be undersimulated when flow is undersimulated and oversimulated when flow is oversimulated. Flow and dissolved and particulate ammonia generally were undersimulated in the two agricultural basins (West Branch Brandywine Creek at Honey Brook and Doe Run near Springdell). Flow and dissolved

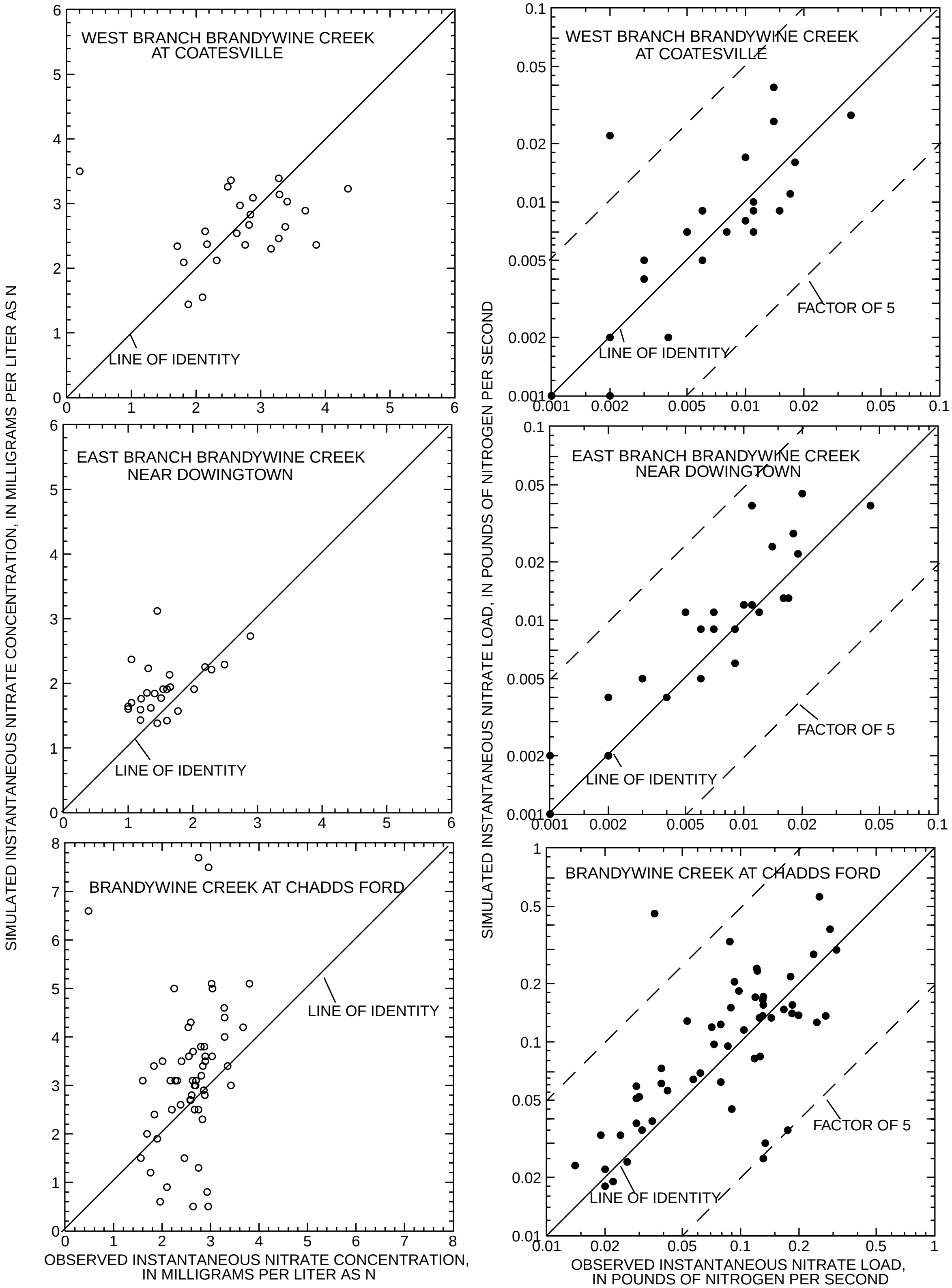


Figure 46. Simulated and observed concentrations and loads of nitrate at three main-stem monitoring sites on the Brandywine Creek.

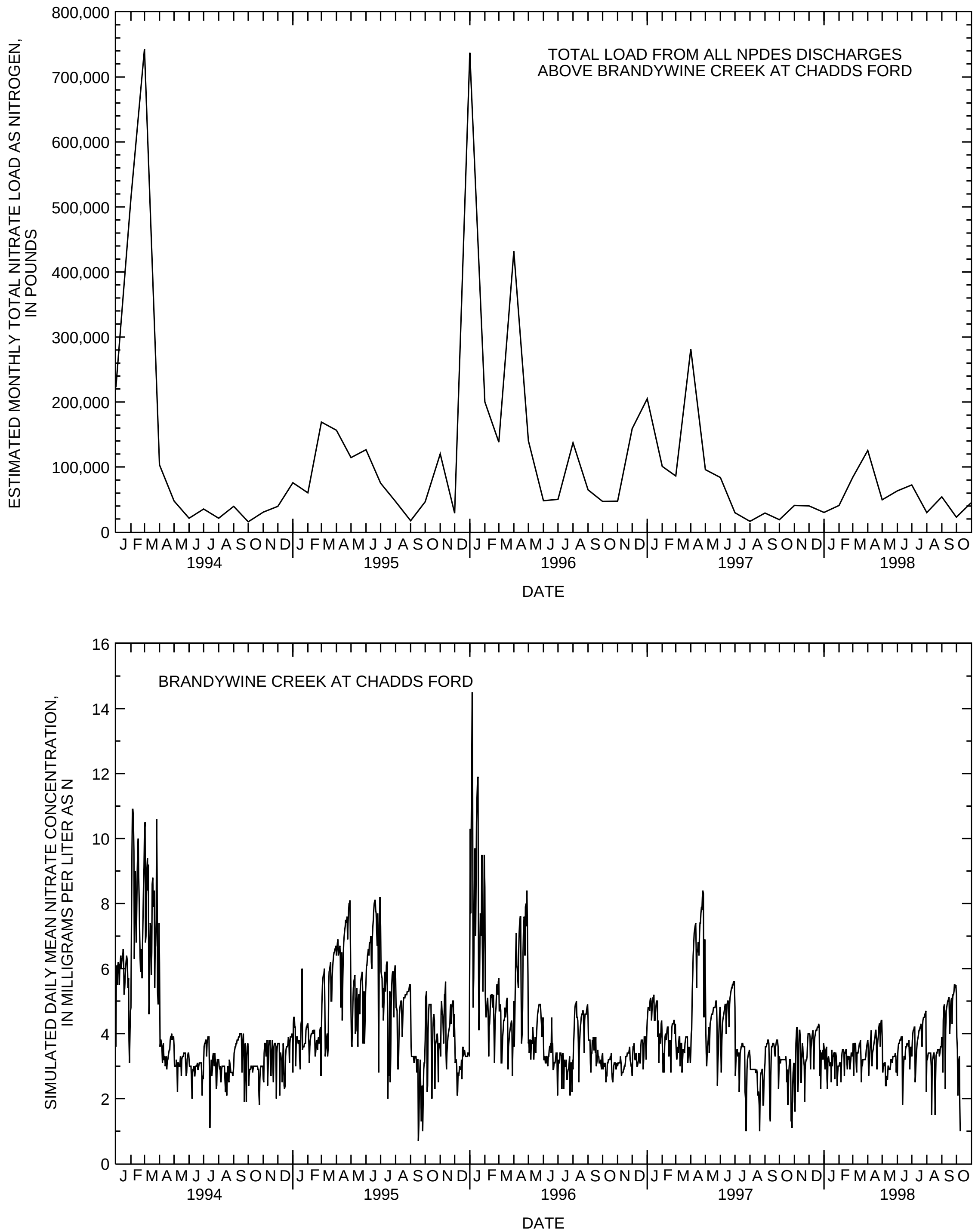


Figure 47. Estimated loads of total nitrate from point-source discharges to the Brandywine Creek and simulated nitrate concentrations for Brandywine Creek at Chadds Ford, Pa., 1994-98. (Nitrate loads were estimated from reported ammonia loads.)

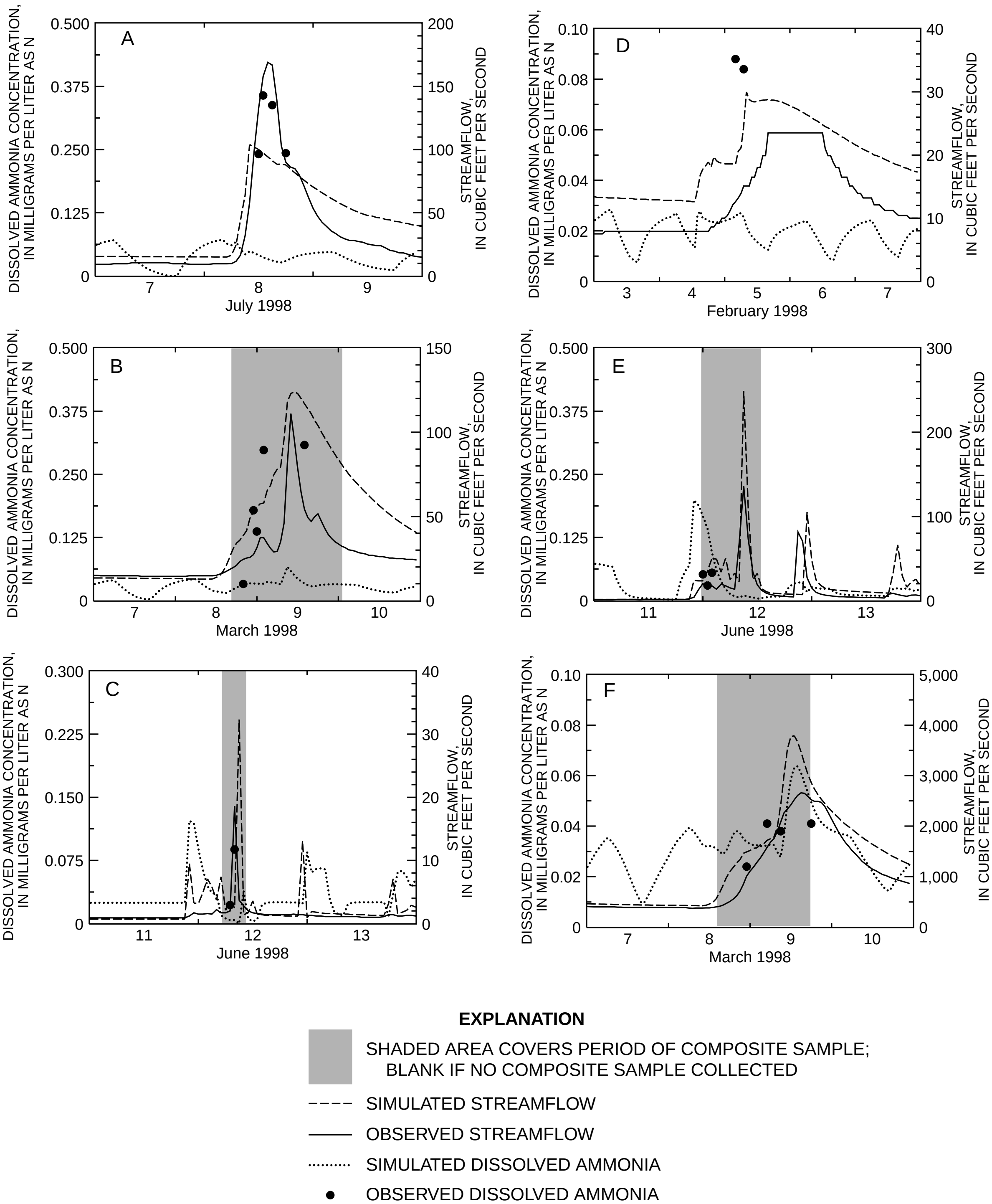


Figure 48. Simulated and observed streamflow and concentrations of dissolved ammonia for a storm sampled in 1998 with a relatively well-simulated streamflow component at the nonpoint-source monitoring sites in the Brandywine Creek Basin, (A) 01480300 West Branch Brandywine Creek at Honey Brook, Pa., (B) 014806318 Doe Run near Springdell, Pa., (C) 01480637 Little Broad Run near Marshallton, Pa., (D) 01480675 Marsh Creek near Glenmoore, Pa., (E) 01480878 Unnamed tributary to Valley Creek near Exton, Pa., and (F) 01481000 Brandywine Creek at Chadds Ford, Pa.

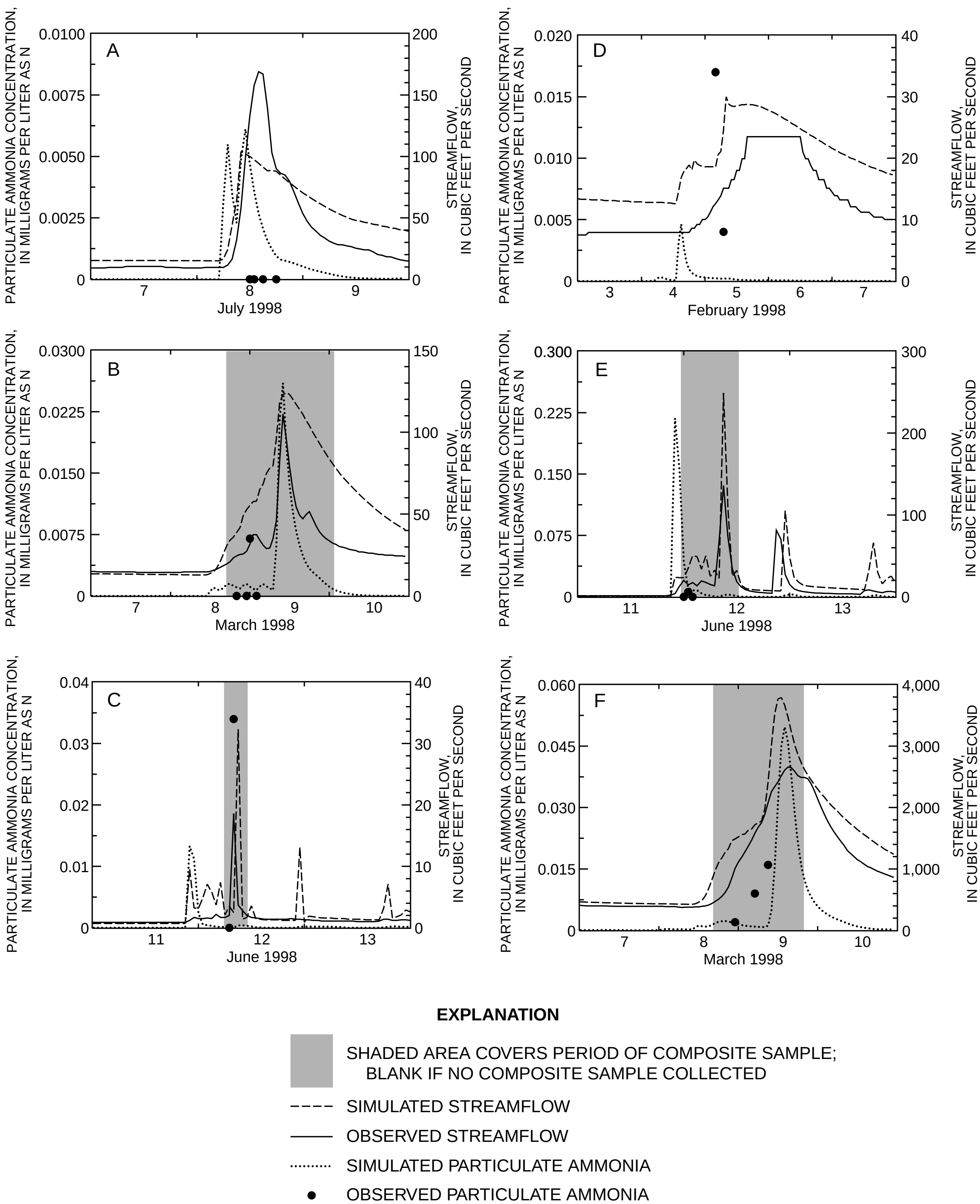


Figure 49. Simulated and observed streamflow and concentrations of particulate ammonia for a storm sampled in 1998 with a relatively well-simulated streamflow component at the nonpoint-source monitoring sites in the Brandywine Creek Basin, (A) 01480300 West Branch Brandywine Creek at Honey Brook, Pa., (B) 014806318 Doe Run near Springdell, Pa., (C) 01480637 Little Broad Run near Marshallton, Pa., (D) 01480675 Marsh Creek near Glenmoore, Pa., (E) 01480878 Unnamed tributary to Valley Creek near Exton, Pa., and (F) 01481000 Brandywine Creek at Chadds Ford, Pa.

and particulate ammonia were both undersimulated and oversimulated at the forested-basin (Marsh Creek near Glenmoore) and the whole-basin sites (Brandywine Creek at Chadds Ford). Flow generally was oversimulated at the two residential-basin sites; in these basins, dissolved ammonia also was oversimulated at one site (Unnamed tributary to Valley Creek near Exton) but sometimes undersimulated at the other (Little Broad Run near Marshallton). Particulate ammonia tended to be undersimulated at both residential-basin sites. Because some error in load simulation is due to error in streamflow simulation, the difference between the load error and the streamflow-volume error may be useful in evaluating the water-quality component of the overall load error. At the six sites, the error in the simulated dissolved ammonia component of load, adjusted for the error in simulated streamflow, ranges from -99 to 114 percent for storms in 1998. The error in the simulated particulate ammonia component of load, adjusted for error in simulated streamflow, ranges from -98 to 202 percent at the six sites for storms in 1998. Using monthly or yearly annual load criteria (Donigian and others, 1984) to evaluate errors due to the water-quality component of the ammonia simulation, the dissolved and particulate ammonia calibration ranges from ‘good’ to worse than ‘fair’ for cumulative and individual storm loads at the six sites.

The differences between observed and simulated loads of ammonia is partly due to errors in flow simulation. Because of the small number of storms sampled for the study, one poor storm simulation may have a large effect on the apparent overall differences between observed and simulated loads. Such is the case for the large error in load of particulate ammonia (1,308 percent high for the March storm at Marsh Creek near Glenmoore) (table 21).

Simulated concentrations of dissolved ammonia under base-flow conditions generally were within 0.02 mg/L as nitrogen (N) of observed concentrations at the six monitoring stations, with the exception of three values (fig. 45). As noted previously, streamflow was well simulated for all base-flow samples (fig. 32). Excluding the Marsh Creek and Chadds Ford sites, the average difference between observed and simulated concentrations of dissolved ammonia was 0.010 mg/L as N, and the average percent difference was -15 percent. Ammonia concentrations were oversimulated compared to observed data for two of three samples at Marsh Creek near Glenmoore and at Brandywine Creek at Chadds Ford, Pa. The oversimulation of dissolved ammonia at Marsh Creek probably is related to inadequate characterization of nutrient uptake in wetlands. The oversimulation of dissolved ammonia at the Chadds Ford site probably is related to the lack of temporal resolution in estimated ammonia concentrations in discharges from sewage treatment plants upstream and also to the lack of a plankton and algal simulation that includes ammonia uptake. Mean hourly ammonia loads for point-source discharges were estimated from reported average monthly ammonia values; however, hourly values probably vary within each month. Simulated concentrations of particulate ammonia were less than 0.005 mg/L as N at all six sites (fig. 45) and are less than the observed concentrations of particulate ammonia, which ranged from less than 0.002 to 0.08 mg/L as N. Most observed concentrations of particulate ammonia were less than 0.03 mg/L as N in base-flow samples and may partly represent laboratory error or uncertainty in the calculated particulate concentrations.

Overall, the dissolved and particulate ammonia simulation under base-flow and storm-flow conditions generally appears to represent the observed patterns of ammonia concentrations in response to flow conditions and defined land uses. Dissolved ammonia storm loads and base-flow concentrations tend to be oversimulated at the whole-basin site (Brandywine Creek at Chadds Ford) that is downstream of numerous point-source discharges; this oversimulation may be partly related to inaccurate characterization of ammonia uptake upstream of the sampling site and (or) inadequate characterization of ammonia in discharges. At all sites, errors expressed in percent are greater for particulate ammonia simulation than for dissolved ammonia simulation and are greater for the ammonia simulation than the nitrate simulation. Of the nitrogen species simulated, nitrate represents the greatest amount and particulate ammonia represents the least amount of the inorganic nitrogen load. In storms, nitrate loads are an order of magnitude greater than dissolved ammonia loads and two orders of magnitude greater than particulate ammonia loads (table 21).

Simulated annual yields of nitrogen varied by land use. Yields of nitrate and ammonia are presented per land-use category per segment per year in tables 22 and 24 and mean yields of nitrate and ammonia for the simulation period are presented per land-use category per segment in tables 23 and 25. For most land uses, simulated nitrate yields generally are at least one order of magnitude greater than simulated total ammonia yields.

Table 22. *Observed annual precipitation and simulated annual nitrate yields by land use for four segments of Hydrologic Simulation Program–Fortran (HSPF) model for Brandywine Creek Basin, 1994-97*

Precipitation/ Land-use category[1]	Segment	Simulated annual nitrate yield (pounds as nitrogen per acre)					Segment	Simulated annual nitrate yield (pounds as nitrogen per acre)				
		1994	1995	1996	1997	1994-97 average		1994	1995	1996	1997	1994-97 average
Observed precipitation (inches)	1	51.68	41.96	70.18	34.97	49.70	2	45.17	42.47	67.50	35.33	47.62
Simulated nitrate yields												
Residential - unsewered	1	16.40	11.10	24.90	9.28	15.42	2	11.90	8.99	26.20	12.00	14.77
Residential - sewered	1	8.54	5.82	13.40	4.82	8.15	2	6.12	4.72	13.80	6.18	7.71
Urban	1	8.32	5.63	12.80	4.68	7.86	2	6.12	4.81	13.70	6.17	7.70
Agricultural - animal/crop	1	28.90	21.40	49.40	16.00	28.93	2	21.60	21.50	53.20	19.20	28.88
Agricultural - row crop	1	28.90	21.40	49.40	16.00	28.93	2	21.60	21.50	53.20	19.20	28.88
Agricultural - mushroom	1	37.90	26.40	62.40	21.60	37.08	2	28.30	25.60	67.20	25.90	36.75
Forested	1	1.65	1.16	2.78	1.16	1.69	2	1.20	.91	2.64	1.37	1.53
Open	1	6.58	4.62	9.65	3.96	6.20	2	4.43	3.40	9.51	4.52	5.47
Wetlands/water	1	1.53	.91	1.62	.85	1.23	2	2.34	1.36	2.44	1.29	1.86
Undesignated	1	6.11	4.18	9.32	3.49	5.78	2	4.10	3.18	9.38	4.14	5.20
Impervious - residential	1	2.05	1.95	2.07	2.01	2.02	2	2.03	1.97	2.66	2.02	2.17
Impervious - urban	1	2.05	1.95	2.07	2.01	2.02	2	2.03	1.97	2.66	2.02	2.17
Observed precipitation (inches)	3	48.92	42.65	70.71	39.33	50.40	4	60.30	47.36	72.31	40.85	55.21
Simulated nitrate yields												
Residential - unsewered	3	14.40	12.10	31.40	11.40	17.33	4	23.00	14.00	32.10	13.50	20.65
Residential - sewered	3	7.41	6.29	16.40	5.91	9.00	4	12.20	7.29	16.70	6.96	10.79
Urban	3	7.72	6.67	16.60	6.16	9.29	4	12.30	7.67	16.90	7.02	10.97
Agricultural - animal/crop	3	24.70	21.30	55.40	21.30	30.68	4	44.10	25.90	58.10	23.00	37.78
Agricultural - row crop	3	20.70	17.80	46.90	17.80	25.80	4	37.70	21.90	49.20	19.20	32.00
Agricultural - mushroom	3	31.70	27.00	71.60	27.10	39.35	4	54.30	31.20	73.90	29.80	47.30
Forested	3	1.39	1.21	3.17	1.27	1.76	4	2.24	1.30	3.14	1.43	2.03
Open	3	5.29	4.59	11.20	4.58	6.42	4	8.40	5.20	11.40	4.91	7.48
Wetlands/water	3	1.42	1.24	2.54	1.12	1.58	4	2.47	1.50	2.72	1.42	2.03
Undesignated	3	.11	4.22	11.00	4.23	4.89	4	8.06	4.88	11.20	4.65	7.20
Impervious - residential	3	2.04	1.97	2.08	2.03	2.03	4	2.06	1.99	2.09	2.05	2.05
Impervious - urban	3	2.04	1.97	2.08	2.03	2.03	4	2.06	1.99	2.09	2.05	2.05

[1] For pervious areas unless other wise noted

Table 23. *Observed 1994-97 average annual precipitation and simulated 1994-97 average annual nitrate yield by land use for pervious and impervious land areas in four segments of Hydrologic Simulation Program–Fortran (HSPF) model for Brandywine Creek Basin*

Precipitation/ Land-use category[1]	Simulated mean annual nitrate yield, 1994-97 [pounds of nitrogen per acre per year]				
	Segment 1	Segment 2	Segment 3	Segment 4	All segments
Observed precipitation (inches)	49.70	47.62	50.40	55.21	50.73
Simulated nitrate yield					
Residential - unsewered	15.42	14.77	17.33	20.65	17.04
Residential - sewered	8.15	7.71	9.00	10.79	8.91
Urban	7.86	7.70	9.29	10.97	8.95
Agricultural - animals / crops	28.93	28.88	30.68	37.78	31.56
Agricultural - row crop	28.93	28.88	25.80	32.00	28.90
Agricultural - mushroom	37.08	36.75	39.35	47.30	40.12
Forested	1.69	1.53	1.76	2.03	1.75
Open	6.20	5.47	6.42	7.48	6.39
Wetlands / water	1.23	1.86	1.58	2.03	1.67
Undesignated	5.78	5.20	4.89	7.20	5.77
Impervious - residential	2.02	2.17	2.03	2.05	2.07
Impervious - urban	2.02	2.17	2.03	2.05	2.07

[1] In pervious areas, unless where noted.

Table 24. *Observed annual precipitation and simulated annual total ammonia yields by land use for four segments of Hydrologic Simulation Program–Fortran (HSPF) model for Brandywine Creek Basin, 1994-97*

Precipitation/ Land-use category[1]	Seg-ment	Simulated total annual ammonia yield (pounds as nitrogen per acre)					Seg-ment	Simulated total annual ammonia yield (pounds as nitrogen per acre)				
		1994	1995	1996	1997	1994-97 average		1994	1995	1996	1997	1994-97 average
Observed precipitation (inches)	1	51.68	41.96	70.18	34.97	49.70	2	45.17	42.47	67.50	35.33	47.62
Simulated ammonia yields												
Residential - unsewered	1	.13	.10	.28	.08	.15	2	.09	.09	.29	.09	.14
Residential - sewered	1	.08	.06	.17	.04	.09	2	.05	.05	.16	.05	.08
Urban	1	.08	.06	.18	.04	.09	2	.05	.07	.17	.05	.09
Agricultural - animal/crop	1	.34	.68	2.39	.25	.91	2	.16	1.05	2.02	.13	.84
Agricultural - row crop	1	.30	.59	2.06	.22	.79	2	.15	.89	1.71	.13	.72
Agricultural - mushroom	1	.22	.29	1.25	.14	.47	2	.13	.61	1.30	.11	.54
Forested	1	.05	.03	.07	.03	.05	2	.03	.02	.07	.04	.04
Open	1	.16	.12	.28	.09	.16	2	.10	.09	.26	.10	.14
Wetlands/water	1	.03	.02	.03	.02	.02	2	.04	.02	.04	.02	.03
Undesignated	1	.15	.11	.27	.08	.15	2	.07	.08	.26	.09	.13
Impervious - residential	1	.71	.67	.71	.69	.69	2	.70	.67	.70	.69	.69
Impervious - urban	1	.90	.86	.90	.90	.89	2	.92	.88	.91	.89	.90
Observed precipitation (inches)	3	48.92	42.65	70.71	39.33	50.40	4	60.30	47.36	72.31	40.85	55.21
Simulated ammonia yields												
Residential - unsewered	3	.11	.10	.29	.09	.15	4	.29	.12	.34	.11	.21
Residential - sewered	3	.06	.06	.17	.05	.08	4	.15	.07	.35	.06	.16
Urban	3	.07	.07	.20	.06	.10	4	.16	.08	.51	.06	.20
Agricultural - animal/crop	3	.14	.21	.70	.16	.30	4	.82	.34	1.70	.14	3.00
Agricultural - row crop	3	.14	.18	.59	.14	.26	4	.66	.28	1.70	.13	2.94
Agricultural - mushroom	3	.13	.16	.56	.13	.25	4	.71	.18	12.90	.11	3.47
Forested	3	.04	.03	.09	.03	.05	4	.06	.04	.05	.04	.05
Open	3	.12	.11	.29	.11	.16	4	.23	.12	.21	.11	.17
Wetlands/water	3	.02	.02	.04	.02	.03	4	.04	.03	.03	.02	.03
Undesignated	3	.11	.10	.29	.10	.15	4	.21	.12	.25	.11	.17
Impervious - residential	3	.70	.67	.71	.69	.69	4	.72	.68	.39	.70	.62
Impervious - urban	3	.91	.86	.92	.89	.90	4	.93	.89	1.94	.92	1.17

[1] For pervious areas, unless where noted.

Table 25. *Observed 1994-97 average annual precipitation and simulated 1994-97 average annual total ammonia yield by land use for pervious and impervious land areas in four segments of Hydrologic Simulation Program–Fortran (HSPF) model for Brandywine Creek Basin*

Precipitation/ Land use[1]	Simulated mean total ammonia yield, 1994-97 [pounds as nitrogen per acre per year]				
	Segment 1	Segment 2	Segment 3	Segment 4	All segments
Observed precipitation (inches)	49.70	47.62	50.40	55.21	50.73
Simulated ammonia yields					
Residential - unsewered	.15	.14	.15	.21	.16
Residential - sewered	.09	.08	.08	.16	.10
Urban	.09	.09	.10	.20	.12
Agricultural - animals/crops	.91	.84	.30	3.00	1.26
Agricultural - row crop	.79	.72	.26	2.94	1.18
Agricultural - mushroom	.47	.54	.25	3.47	1.18
Forested	.05	.04	.05	.05	.05
Open	.16	.14	.16	.17	.16
Wetlands/water	.02	.03	.03	.03	.03
Undesignated	.15	.13	.15	.17	.15
Impervious - residential	.69	.69	.69	.62	.68
Impervious - urban	.89	.90	.90	1.17	.96

[1] In pervious areas, unless where noted.

Phosphorus

Inorganic phosphorus was simulated. The model simulates dissolved inorganic phosphorus as orthophosphate and particulate inorganic phosphorus as adsorbed orthophosphate. Phosphorus loads from point and nonpoint sources are included in the simulation. Loads from point-source discharges were estimated from reported monthly average values for input on an hourly time step to the model. For nonpoint sources, dissolved and particulate phosphorus loads differed by land use and were estimated based on fixed concentrations in sediment (soil), interflow, and ground water. Phosphorus was assumed to be transported in both dissolved and adsorbed forms from the land surface and in the stream channel. Review of 1995-98 PADEP monitoring data collected commonly under moderate (non-storm) flow conditions indicates that, on average, dissolved orthophosphate represents about 79 percent of total phosphorus concentrations. For 1998 data collected at six monitoring stations in the basin under a range of flow conditions, dissolved orthophosphate represented about 62 percent of total phosphorus.

Water-quality data from six monitoring stations in the Brandywine Creek Basin were used in the calibration of dissolved and particulate (adsorbed) orthophosphate. Observed concentrations of particulate orthophosphate were estimated by subtracting concentrations of dissolved phosphorus from concentrations of total phosphorus and assuming the difference was particulate orthophosphate. For data at Chadds Ford, particulate orthophosphate was estimated by subtracting dissolved orthophosphate from total phosphorus to make use of the longer period of record covered by PADEP samples that included orthophosphate but not dissolved phosphate analysis. This approach may overestimate adsorbed or particulate orthophosphate because of the inclusion of organic or other forms of phosphorus. The accuracy of these estimated values also depends on the accuracy of laboratory methodology, which at low concentrations near detection levels, has substantial uncertainty.

Simulated and observed concentrations of dissolved and particulate orthophosphate are shown in figures 50 and 51 for a storm with relatively well-simulated streamflow at each of the six nonpoint-source monitoring sites. Simulated and observed streamflow and concentrations of dissolved and particulate orthophosphate for all sampled storms at the six nonpoint-source monitoring sites in the Brandywine Creek Basin are shown in Appendix 2. Observed and simulated concentrations of dissolved and particulate orthophosphate generally tend to increase as streamflow increases during storms. Although the general pattern of observed dissolved and particulate orthophosphate concentrations during storms is simulated by the model, errors or differences between observed and simulated concentrations are apparent. Simulated concentrations of dissolved orthophosphate were similar to observed concentrations of dissolved orthophosphate at some sites (Doe Run near Springdell, Little Broad Run, Unnamed tributary to Valley Creek), less than observed concentrations of dissolved orthophosphate at one site (West Branch Brandywine Creek at Honey Brook), and greater than observed concentrations of dissolved orthophosphate at other sites (Marsh Creek near Glenmoore, Brandywine Creek at Chadds Ford) (fig. 50). Simulated concentrations of particulate orthophosphate were similar to observed concentrations of particulate orthophosphate at most sites but less than observed concentrations of particulate orthophosphate at one site (West Branch Brandywine Creek at Honey Brook) (fig. 51). Errors or differences between observed and simulated concentrations are due in part to errors in flow simulation and timing of rainfall for particular storms.

Data from composite stormflow samples collected in 1998 were used in the calculation of loads of dissolved orthophosphate and particulate orthophosphate. Calculated loads served as the observed values in the evaluation of overall phosphorus transport during storms.

Simulated and observed streamflow and loads of dissolved and particulate orthophosphate during storms are presented in table 26. Observed loads of particulate orthophosphate commonly are greater than observed loads of dissolved orthophosphate. Dissolved and particulate orthophosphate loads tend to be undersimulated when flow is undersimulated and oversimulated when flow is oversimulated. Flow and dissolved and particulate orthophosphate tend to be undersimulated at the two sites in agricultural basins (West Branch Brandywine Creek at Honey Brook and Doe Run near Springdell) (table 26). Flow and dissolved and particulate orthophosphate tend to be oversimulated at the forested site (Marsh Creek near Glenmoore), a predominantly residential site with sewers (Unnamed tributary to Valley Creek at Exton), and the whole-basin site (Brandywine Creek at Chadds Ford) (table 26). At the site in the predominantly residential basin without sewers (Little Broad Run near Marshallton), flow and dissolved orthophosphate loads are oversimulated but particulate orthophosphate loads are undersimulated.

As discussed in the section on nitrate and ammonia, some error in load simulation is due to error in streamflow simulation and the difference between the load error and the streamflow-volume error may be useful in evaluating the water-quality component of the overall load error. At the six sites, the error in simulated dissolved orthophosphate component of load, adjusted for the error in simulated streamflow, ranges from -94 to 280 percent for storms in 1998 and is less than plus or minus 40 percent for about half the storms. The error in the simulated particulate orthophosphate component of load, adjusted for the error in simulated streamflow, ranges from -97 to 2,530 percent at the six sites for storms in 1998 and is less than plus or minus 40 percent for only two storms. The largest percentage error in particulate orthophosphate for an individual storm is associated with the March 8-9 storm at Marsh Creek near Glenmoore and is caused partly by the large error in the sediment simulation (table 18) and is an example of the importance of sediment calibration for particulate orthophosphate calibration. Using monthly or yearly annual load criteria (Donigian and others, 1984) to evaluate errors due to the water-quality component of the orthophosphate simulation, the dissolved and particulate orthophosphate calibration ranges from ‘very good’ to worse than ‘fair’ for cumulative and individual storm loads at the six sites.

Simulated concentrations of dissolved orthophosphate under base-flow conditions generally were within 0.03 mg/L as phosphorus (P) of observed concentrations at the six monitoring stations, with the exception of a few values (fig. 52). The mean difference between observed and simulated dissolved orthophosphate for base-flow conditions was 0.016 mg/L as P, and the average percentage difference was 33 percent (low). As noted previously, streamflow was well simulated

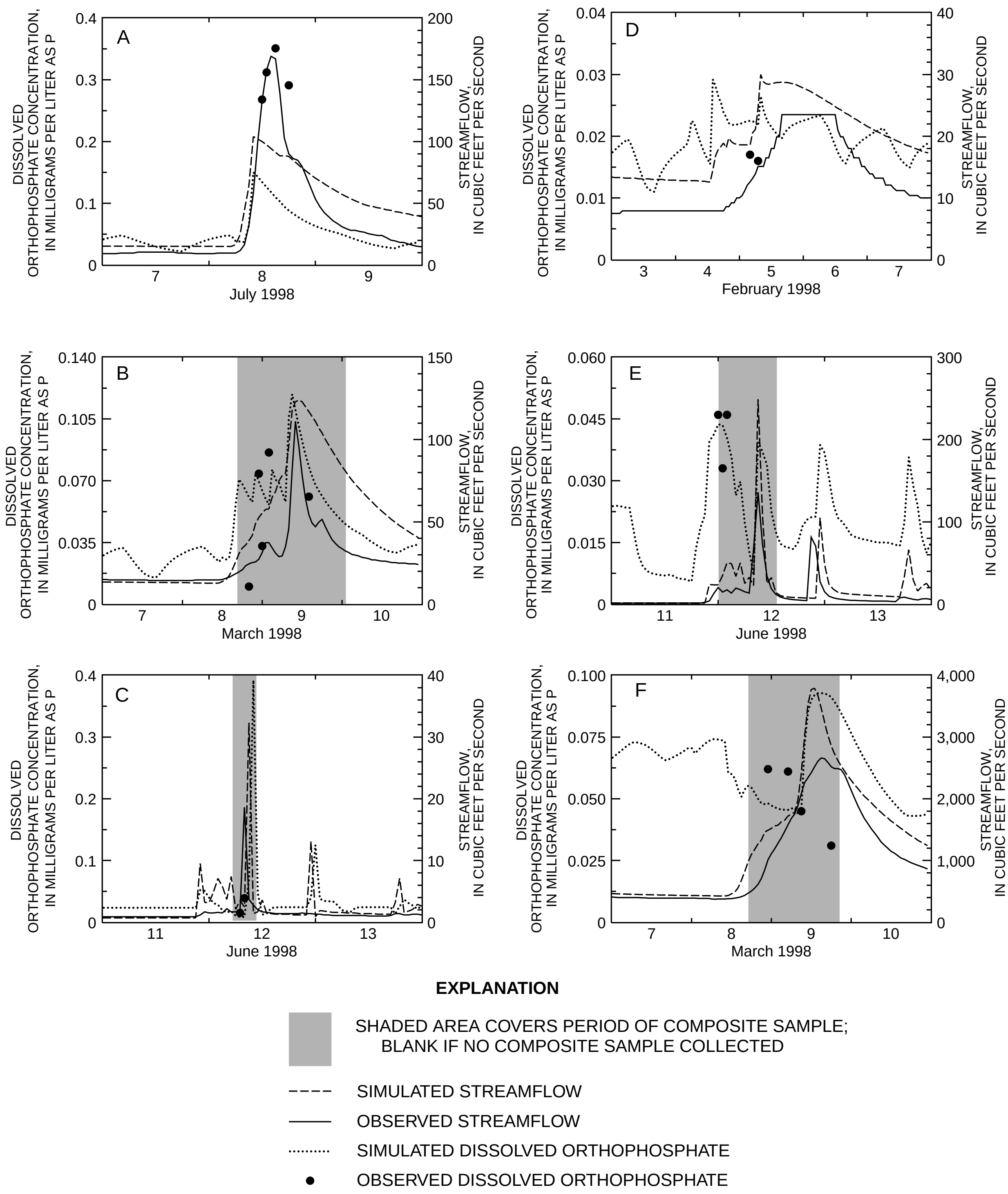
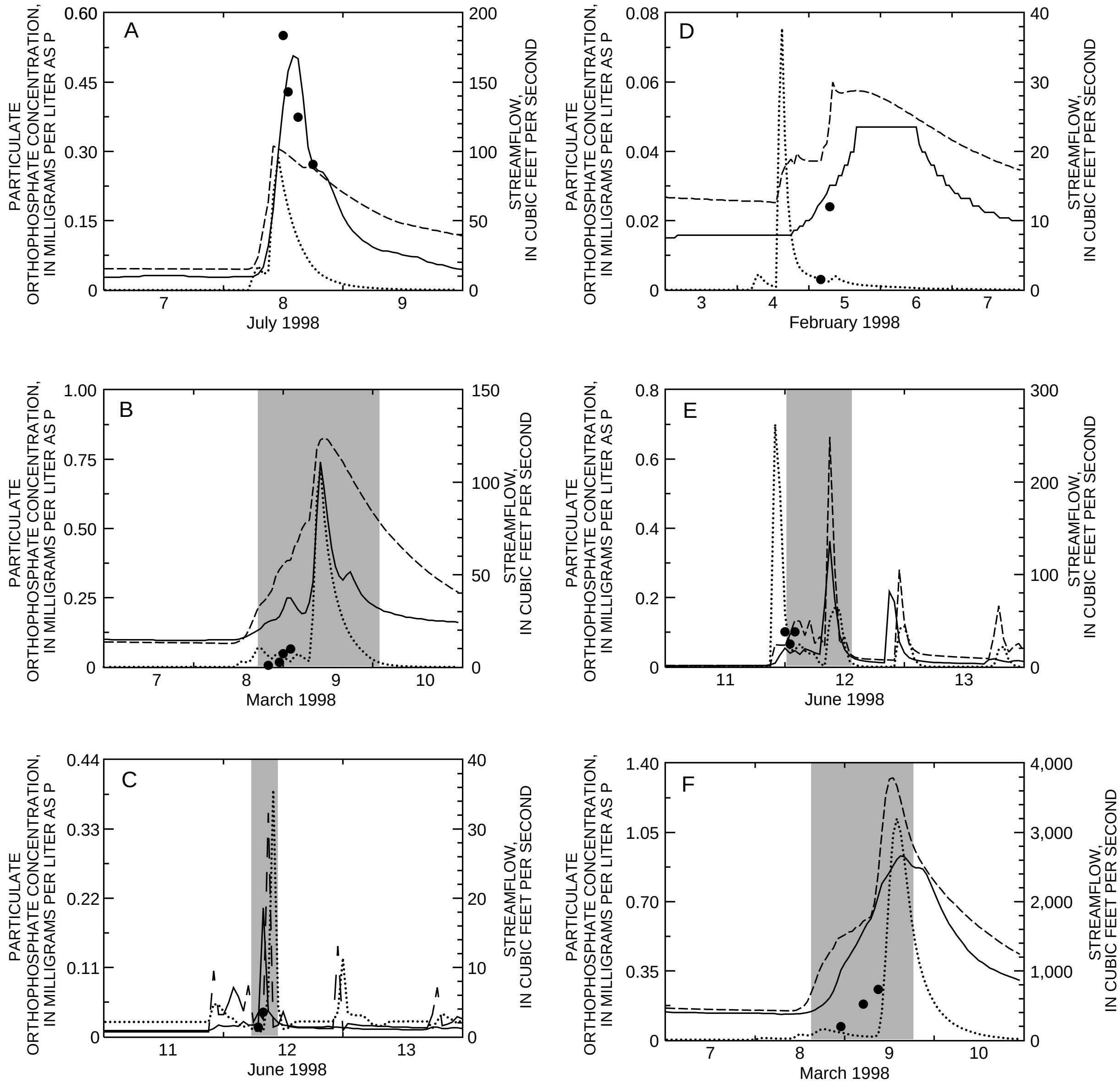


Figure 50. Simulated and observed streamflow and concentrations of dissolved orthophosphate for a storm sampled in 1998 with a relatively well-simulated streamflow component at the nonpoint-source monitoring sites in the Brandywine Creek Basin, (A) 01480300 West Branch Brandywine Creek at Honey Brook, Pa., (B) 014806318 Doe Run near Springdell, Pa., (C) 01480637 Little Broad Run near Marshallton, Pa., (D) 01480675 Marsh Creek near Glenmoore, Pa., (E) 01480878 Unnamed tributary to Valley Creek near Exton, Pa., and (F) 01481000 Brandywine Creek at Chadds Ford, Pa.



EXPLANATION

SHADED AREA COVERS PERIOD OF COMPOSITE SAMPLE; BLANK IF NO COMPOSITE SAMPLE COLLECTED

SIMULATED STREAMFLOW

OBSERVED STREAMFLOW

SIMULATED PARTICULATE ORTHOPHOSPHATE

OBSERVED PARTICULATE ORTHOPHOSPHATE

Figure 51. Simulated and observed streamflow and concentrations of particulate orthophosphate for a storm sampled in 1998 with a relatively well-simulated streamflow component at each of nonpoint-source monitoring sites in the Brandywine Creek Basin (A) 01480300 West Branch Brandywine Creek at Honey Brook, Pa., (B) 014806318 Doe Run near Springdell, Pa., (C) 01480637 Little Broad Run near Marshallton, Pa., (D) 01480675 Marsh Creek near Glenmoore, Pa., (E) 01480878 Unnamed tributary to Valley Creek near Exton, Pa., and (F) 01481000 Brandywine Creek at Chadds Ford, Pa.

Table 26. *Simulated and observed streamflow and loads of dissolved and particulate orthophosphate for storms sampled in 1998 at six nonpoint-source monitoring sites in the Brandywine Creek Basin*

[ft^3/s, cubic feet per second; Sim., simulated; Obs., observed; diff., difference; na, not applicable; nd, not done]

Dates of storm sampling	Peak streamflow[1] (ft^3/s)	Streamflow (millions of cubic feet)			Dissolved orthophosphate load (pounds as phosphorus)			Particulate orthophosphate load (pounds as phosphorus)		
		Sim.	Obs.	Percent diff.[2]	Sim.	Obs.	Percent diff.[2]	Sim.	Obs.	Percent diff.[2]
West Branch Brandywine Creek at Honey Brook, Pa.										
March 8-9	287	4.68	18.08	-74	14.3	261	-95	2.8	326	-99
June 12	212	5.85	9.77	-40	25.5	164	-84	11.4	328	-96
October 8-9	118	2.16	6.49	-67	3.1	141	-98	na	nd	na
Total - all storms		12.69	34.34	-63	42.9	566	-92	14.2	654	-98
Doe Run near Springdell, Pa.										
March 8-9	96	5.49	3.27	68	28.6	11.2	156	84.4	63.9	32
June 12	194	1.33	3.40	-61	8.1	14.0	-42	40.3	421	-90
July 8-9	79	.93	1.38	-33	2.2	4.6	-54	1.7	32	-95
October 8-9	98	.82	2.91	-72	1.1	18.6	-94	na	nd	na
Total - all storms		8.57	10.96	-22	39.9	48.3	-17	126	517	-76
Little Broad Run near Marshallton, Pa.										
March 8-9	3.7	.16	.07	142	.42	.11	272	.22	.41	-47
June 12	18.6	.14	.09	58	.51	.22	139	.40	10.8	-96
October 8-9	12.3	.24	.10	142	.64	.15	330	na	nd	na
Total - all storms		.53	.25	113	1.57	.48	230	.62	11.2	-95
Marsh Creek near Glenmoore, Pa.										
March 8-9	103	11.75	9.03	30	67.7	13.7	394	601	18.3	3,193
June 12	60	3.15	4.07	-23	7.3	9.8	-25	3.0	16.6	-82
Total - all storms		14.90	13.11	14	75.0	23.5	220	604	34.9	1,633
Unnamed tributary to Valley Creek at Exton, Pa.										
February 4-5	11	.97	.41	137	1.6	.3	445	1.3	3.8	-66
March 8-9	106	4.13	2.33	77	9.2	1.9	380	53.9	17.2	212
May 2-3	9	.54	.68	-22	.7	.6	15	.2	1.1	-80
June 12	136	2.79	1.75	60	6.0	6.0	1	19.8	28.0	-29
July 8-9	54	3.33	.85	294	7.5	2.2	233	39.3	5.9	562
October 8-9	51	2.61	1.56	68	5.6	5.5	1	na	nd	na
Total - all storms		14.38	7.58	90	30.4	16.5	85	114	56.1	104
Brandywine Creek at Chadds Ford, Pa.										
March 8-9	2,608	183.1	135.3	35	775	470	65	4,620	1,983	133
May 2-3	747	60.0	68.1	-12	189	120	57	91	34	164
June 12	2,623	26.7	45.0	-41	88	108	-18	154	1,050	-85
July 8-9	1,211	118.8	71.5	66	435	167	160	973	502	94
October 8-9	1,098	58.3	59.1	-1	153	142	8	na	nd	na
Total - all storms		446.9	379.0	18	1,640	1,008	63	5,838	3,570	64

[1] Peak mean hourly streamflow period of composite sampling.
[2] 100 x (observed-simulated)/observed.

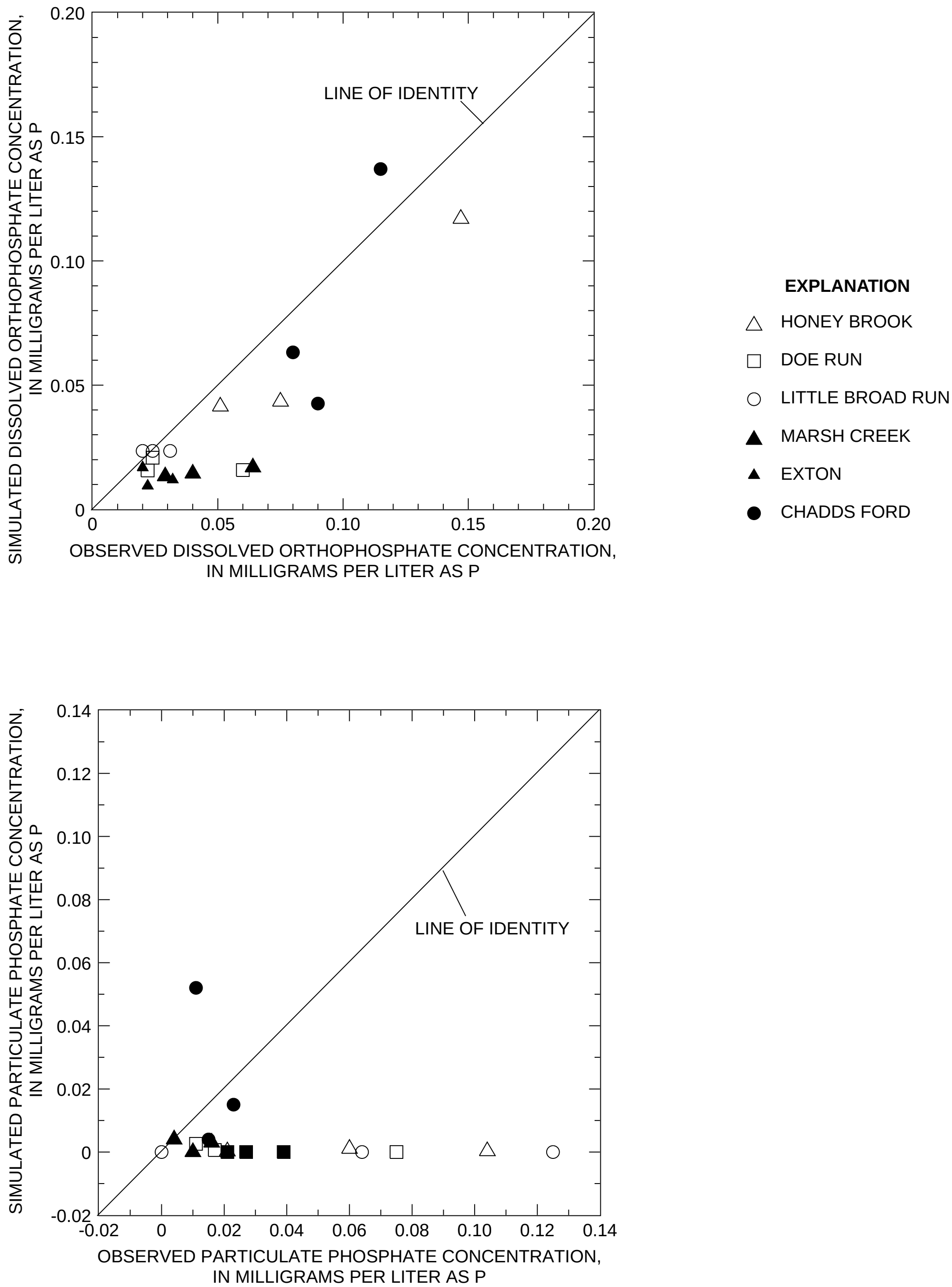


Figure 52. Simulated and observed concentrations of dissolved and particulate orthophosphate during base-flow conditions in 1998 at six monitoring sites in the Brandywine Creek Basin.

for all base-flow samples (fig. 36). Many simulated concentrations of particulate orthophosphate were <0.005 or 0 mg/L as P at all six sites and generally are less than the calculated observed concentrations of particulate orthophosphate concentrations, which ranged from 0 to 0.125 mg/L as P (fig. 52). Most observed concentrations of particulate orthophosphate were less than 0.06 mg/L as P in base-flow samples and may partly represent laboratory error or uncertainty in the calculated particulate concentrations. The mean difference between observed and simulated particulate orthophosphate for base-flow conditions was 0.03 mg/L as P, and the average percent difference was 55 percent.

Oversimulation at sites downstream of discharges may be caused partly by inadequate characterization of discharges or errors in the algal plankton simulation that results in nutrient uptake. To further investigate effects of discharges, simulated and observed concentrations and loads of dissolved orthophosphate at main-stem sites upstream of major discharges were compared to those at Chadds Ford, Pa. (fig. 53), a site that is downstream of most major discharges. The upstream data were obtained from PADEP and do not include any data collected by USGS in 1998. Observed orthophosphate concentrations and loads generally are lower but more poorly simulated at the two maim-stem sites above point-source dischargers (West Branch Brandywine Creek at Coatesville and East Branch Brandywine Creek near Downingtown, Pa.) than at the most downstream site below most point-source dischargers, Brandywine Creek at Chadds Ford, Pa. These results (fig. 48) suggest that relative errors associated with simulation of phosphorus from nonpoint sources probably are at least as great as errors associated with simulation of phosphorus from point sources. The increase in observed concentrations and loads of dissolved orthophosphate from the upstream sites to the downstream site is related in part to the contribution of phosphorus from point sources. At all three sites, simulated loads of dissolved orthophosphate generally were within a factor of 10 or less of observed loads (fig. 53).

Overall, the dissolved and particulate orthophosphate simulation under base-flow and stormflow conditions generally appears to represent the observed patterns of phosphorus concentrations in response to flow conditions and defined land uses. At all sites, errors expressed in percent are somewhat greater for particulate orthophosphate simulation than for dissolved orthophosphate simulation. In storms, loads of particulate orthophosphate commonly are from 2 to 10 times greater than loads of dissolved orthophosphate (table 26).

Simulated annual yields of phosphorus varied by land use. Yields of total phosphorus (dissolved plus adsorbed or particulate orthophosphate) are presented per land-use category per segment per year in table 27 and mean yields of total orthophosphate for the simulation period are presented per land-use category per segment in table 28.

Sensitivity Analysis

Calibration of water temperature is specified by 13 parameters; 5 for pervious land surfaces, 2 for impervious land surfaces, and 6 for stream reaches. For water-temperature simulation, the model is more sensitive to parameters in the reach modules than parameters in pervious and impervious modules. Water temperature in a reach is modeled as a function of the variables: upstream flow and land surface inflow temperatures; air temperature; and radiation, conduction, and convection gains or losses. Of these variables, radiation, conduction, and convection gains and losses have calibration parameters. Simulated water temperatures are most sensitive to the parameters CFSAEX, the solar radiation correction factor, and KCOND, the conduction-convection coefficient. Daily high temperatures are affected by CFSAEX and nighttime low temperatures by KCOND. In combination, CFSAEX and KCOND also influence daily mean water temperature.

The simulated sediment yield from pervious and impervious land areas is dependent on parameters affecting soil detachment, soil scour, and soil or sediment washoff and is sensitive to parameters affecting soil detachment (KRER, JRER), soil washoff (KSER, JSER), and soil scour processes (KGER, JGER) for pervious land surfaces, and solids build up (ACCSDP, REMDSP) and washoff processes for impervious land surfaces (KEIM, JEIM). Sediment washoff or transport capacity is dependent on surface runoff (SURO) and, therefore, the hydrologic component of the simulation. In addition, calibration of suspended sediment in the stream channel is sensitive to parameters controlling shear stress regimes (TAUD, TAUS) that determine deposition on and scour of the channel bottom. The sensitivity of sediment yield to

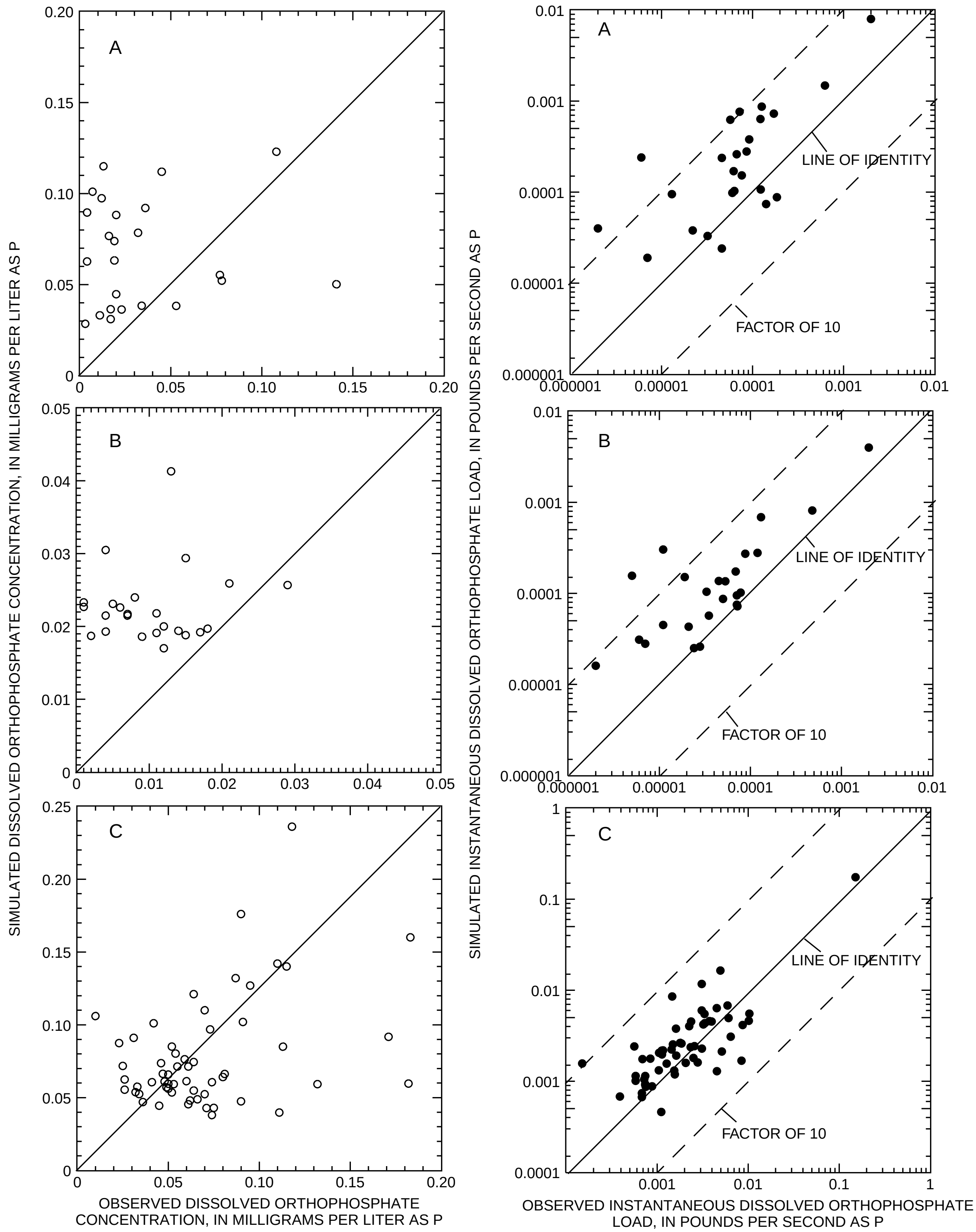


Figure 53. Simulated and observed concentrations and loads of dissolved orthophosphate at three main-stem monitoring sites on the Brandywine Creek, (A) West Branch Brandywine Creek at Coatesville, Pa., (B) East Branch Brandywine Creek near Downingtown, Pa., and (C) Brandywine Creek at Chadds Ford, Pa.

Table 27. *Observed annual precipitation and simulated annual yields of total phosphorus (dissolved plus adsorbed orthophosphate) by land use for four segments of Hydrologic Simulation Program–Fortran (HSPF) model for Brandywine Creek Basin, 1994-97*

Precipitation/ Land-use category[1]	Seg-ment	Simulated total annual phosphorus yield (pounds as phosphorus per acre)					Seg-ment	Simulated total annual phosphorus yield (pounds as phosphorus per acre)				
		1994	1995	1996	1997	1994-97 average		1994	1995	1996	1997	1994-97 average
Observed precipitation (inches)	1	51.68	41.96	70.18	34.97	49.70	2	45.17	42.47	67.50	35.33	47.62
Simulated phosphorus yield												
Residential - unsewered	1	.14	.12	.48	.08	.21	2	.09	.14	.50	.09	.20
Residential - sewered	1	.14	.13	.57	.09	.23	2	.09	.15	.51	.09	.21
Urban	1	.17	.18	.64	.10	.27	2	.09	.23	.58	.09	.25
Agricultural - animal/crop	1	4.80	13.5	50.6	4.06	18.2	2	.90	13.2	24.5	.71	9.83
Agricultural - row crop	1	3.65	10.1	38.0	3.07	13.7	2	.90	13.2	24.5	.71	9.83
Agricultural - mushroom	1	4.54	10.2	53.3	3.45	17.9	2	1.51	27.0	55.3	1.25	21.3
Forested	1	.02	.02	.04	.02	.02	2	.02	.01	.04	.02	.02
Open	1	.14	.21	.85	.09	.32	2	.04	.15	.66	.05	.23
Wetlands/water	1	.01	.01	.02	.01	.01	2	.02	1.25	.02	.01	.33
Undesignated	1	.14	.21	.87	.09	.33	2	.04	.17	.70	.04	.24
Impervious - residential	1	.40	.34	.37	.37	.37	2	.41	.36	.38	.36	.38
Impervious - urban	1	1.87	1.79	1.78	1.92	1.84	2	2.01	1.89	1.89	1.88	1.92
Observed precipitation (inches)	3	48.92	42.65	7.71	39.33	5.40	4	6.30	47.36	72.31	4.85	55.21
Simulated phosphorus yield												
Residential - unsewered	3	.11	.12	.38	.10	.18	4	.54	.13	.28	.10	.26
Residential - sewered	3	.11	.12	.42	.10	.19	4	.47	.14	.16	.10	.22
Urban	3	.13	.21	.60	.13	.27	4	.57	.22	.18	.10	.27
Agricultural - animal/crop	3	.76	2.51	9.60	1.40	3.57	4	13.1	4.67	.77	.81	4.84
Agricultural - row crop	3	.76	2.51	9.60	1.40	3.57	4	13.1	4.67	.64	.81	4.80
Agricultural - mushroom	3	.87	3.70	16.50	1.97	5.76	4	26.8	3.89	.50	.43	7.90
Forested	3	.02	.02	.04	.02	.02	4	.03	.02	.09	.02	.04
Open	3	.07	.12	.46	.08	.18	4	.44	.09	.27	.04	.21
Wetlands/water	3	.01	.01	.02	.01	.01	4	.02	.01	.05	.01	.02
Undesignated	3	.06	.12	.48	.08	.18	4	.33	.09	.27	.04	.18
Impervious - residential	3	4.12	.34	.39	.36	1.30	4	.45	.38	.38	.38	.40
Impervious - urban	3	1.96	1.79	1.92	1.86	1.88	4	2.03	1.93	1.94	2.00	1.98

[1] For pervious area, unless where noted.

Table 28. *Observed 1994-97 average annual precipitation and simulated 1994-97 average annual total orthophosphate yield by land use for pervious and impervious land areas in four segments of HSPF model for Brandywine Creek Basin*

Precipitation/ Land-use category[1]	Simulated mean total annual phosphate yield, 1994-97 [pounds as phosphorus per acre per year]				
	Segment 1	Segment 2	Segment 3	Segment 4	All segments
Observed precipitation (inches)	49.70	47.62	50.40	55.21	50.73
Simulated total orthophosphate yield					
Residential - unsewered	.21	.20	.18	.26	.21
Residential - sewered	.23	.21	.19	.22	.21
Urban	.27	.25	.27	.27	.26
Agricultural - animals / crops	18.24	9.83	3.57	4.84	9.12
Agricultural - row crop	13.71	9.83	3.57	4.80	7.98
Agricultural - mushroom	17.87	21.27	5.76	7.90	13.20
Forested	.02	.02	.02	.04	.03
Open	.32	.23	.18	.21	.23
Wetlands / water	.01	.33	.01	.02	.09
Undesignated	.33	.24	.18	.18	.23
Impervious - residential	.37	.38	1.30	.40	.61
Impervious - urban	1.84	1.92	1.88	1.98	1.90

[1] In pervious areas, unless where noted.

changes in parameters affecting pervious land-surface processes was investigated by varying parameters by selected multiplication factors. Results reported at Brandywine Creek at Chadds Ford, Pa., include the total effects in the four segments above the station (table 29).

The simulated yields of nitrate, ammonia, and phosphate from pervious and impervious land areas are dependent on parameters affecting concentrations of constituents on sediment (POTFW) and in interflow (IFLW-CONC) and ground water (GRND-CONC). The sensitivity of simulated total yields to changes in these parameters was investigated by varying the parameters by selected multiplication factors (table 30). The parameters affecting ground-water concentrations affect nitrate yields more than yields of ammonia and phosphorus because of differences in the main mechanisms that deliver these nutrients to the streams. Consequently, changes to parameters affecting concentrations of nutrients in soil (POTFW) and interflow (IFLW-CONC) affect yields of ammonia and phosphorus more than nitrate.

Model Limitations

The ability of the model to simulate the concentration of water-quality constituents depends on the adequacy of the hydrologic and physical process simulation and therefore will be limited by the accuracy of the hydrologic model. In addition, the water-quality calibration was based on relatively few available observed water-quality data; therefore, compared to a calibration with many water-quality data, greater uncertainty is associated with the simulation of water quality and assessment of the model performance is more difficult.

In-stream, temperature-dependent processes may be affected by the undersimulation of water temperature during periods when the water temperature is above 20°C. Typically, water temperatures are at or above 20°C during the months of June, July, August, and into September. Data from the small basins, however, suggest that the undersimulation of higher water temperatures changes progressively to oversimulation as upstream drainage area decreases.

Simulation of concentrations of suspended sediment, nitrate, ammonia, and phosphorus for individual storms or short periods of time may not be well simulated by the model because of hydrologic limitations related to accuracy of rainfall data. The timing and intensity of rainfall affect detachment processes for soil and soil-related constituents as well as transport of the solids from land to streams. The simulation of sediment was calibrated using measured concentrations of suspended solids in samples collected at one point in the stream. However, the suspended solids samples may not accurately represent suspended-sedi-

Table 29. *Sensitivity of model output for sediment yield at Brandywine Creek at Chadds Ford, Pa., to changes in selected parameters affecting sediment contributions from pervious land areas*

[KRER, coefficient in soil detachment equation; JRER, exponent in soil detachment equation; KSER, coefficient in detached-sediment washoff equation; JSER, exponent in detached-sediment washoff equation; KGER, coefficient in soil-matrix scour equation; JGER, exponent in soil-matrix scour equation]

Parameter	Multiplier	Sediment yield	
		Tons per acre	Percent difference[1]
Preliminary calibration value	1	4.372	0.0
Detachment processes			
KRER	.5	2.8607	-35
	2	5.5397	27
JRER	.5	5.5643	27
	1.5	3.8219	-13
Washoff processes			
KSER	.5	3.0024	-31
	2	5.1476	18
JSER	.75	5.2977	21
	1.5	3.1629	-28
KGER	.5	4.1792	-4
	2	4.7552	9
JGER	.5	5.1469	18
	1.5	4.2976	-2

[1] Percent difference from calibrated value = 100 x (changed result - calibrated result)/calibrated result.

Table 30. *Sensitivity of model output for total nutrients yield at Brandywine Creek at Chadds Ford, Pa., to changes in selected parameters affecting nutrient contributions from pervious land areas*

[POTFW, potency factor of sediment in washoff; IFLW-CONC, concentration in interflow; GRND-CONC, concentration in ground water]

Parameter	Multiplier	Nitrate as N		Ammonia as N		Phosphate as P	
		Pounds per acre	Percent difference[1]	Pounds per acre	Percent difference	Pounds per acre	Percent difference
Preliminary calibration value	1	72.718	0	1.1736	0	8.1363	0
POTFW	.5	72.718	0	0.80505	-31.40	4.5042	-44.64
	2	80.555	10.78	1.922	63.77	15.543	91.03
IFLW-CONC	.5	60.643	-16.61	1.09929	-6.33	8.0477	-1.09
	2	96.368	32.52	1.32984	13.31	8.322	2.28
GRND-CONC	.5	52.652	-27.59	1.03774	-11.58	7.9838	-1.87
	2	113.913	56.65	1.4506	23.60	8.4548	3.91

[1] Percent difference from calibrated value = 100 x (changed result - calibrated result)/calibrated result.

ment concentrations in the stream and streams may not be well mixed. Simulation of water quality may be less accurate for small-basin areas than for large-basin areas because of spatial resolution of the model. The hydrologic component of the model was calibrated at sites on the main branches and main stem of the Brandywine Creek rather than at small-basin sites.

The model probably does not fully describe the effects of in-stream biological processes on the concentrations of nutrients. The simulation of the nutrients, nitrogen and phosphorus included the biological processes of algal plankton and benthic algal nutrient uptake and release but not the role of zooplankton. The magnitude of diurnal fluctuations in concentrations of dissolved oxygen due to processes of in-stream photosynthesis and respiration may not be characterized fully by the simulation. The simulation of in-stream nutrient concentrations is further affected by the quality and quantity of information about nutrients in discharges from point sources. For example, although the model is run on an hourly time step, data on point-source discharges generally are available as monthly mean values for contributions of ammonia and phosphorus. Nitrate discharges are extrapolated from reported ammonia. The model, as configured, is better used to estimate loads of nonpoint-source nutrients from land areas than to predict concentrations at downstream sites after considerable in-stream transport and residence time.

The simulation of particulate orthophosphate was calibrated to an estimated value, calculated as observed total phosphorus minus observed dissolved phosphorus. This difference, however, may include forms of phosphorus other than orthophosphate. Because the model as configured only simulates orthophosphate, particulate phosphorus that includes forms of phosphorus other than orthophosphate may be undersimulated.

MODEL APPLICATIONS

The HSPF model for the Brandywine Creek Basin was developed to assist in the assessment of suspended sediment and nutrient loads from nonpoint sources to streams. The model load estimates may be used as part of an ongoing TMDL assessment for the Christina River Basin to indicate the possible location and magnitude of load reductions that might be needed to maintain or improve water quality where impaired. These load estimates are based on the land-use conditions during the period of calibration and do not reflect the effects of best-management practices put in place after 1998.

The model can be used to estimate loads from individual basins for the purposes of evaluating relative and absolute contributions of suspended sediment, nitrogen, and phosphorus. This information may be helpful in assessing areas that appear to generate elevated nonpoint-source loads of these constituents. For example, simulated total loads and loads per acre (yields) in 1995 for selected headwater areas in order of decreasing nitrate yields are listed in table 31. Precipitation in 1995 was similar to the long-term average, and yields in that year might be assumed to be similar to average. Results of model simulation indicate that for this time period, nitrate loads per acre are least in the predominantly residential subbasins and basins below reservoirs and greatest in the predominantly agricultural subbasins of Buck Run, Doe Run, and the West Branch Brandywine Creek above Honey Brook and in the mixed land use (residential with septic systems and agricultural) Pocopson Creek. Effluent from a sewage treatment plant is discharged to West Branch Brandywine Creek above Honey Brook. Nitrate yields from the predominantly forested Marsh Creek subbasin probably are overestimated by the model. Land use in the Marsh Creek subbasin is about 41 percent forested and about 42 percent agricultural. Total nitrate loads are least in the smallest subbasin, Little Broad Run, and greatest in the largest subbasin, Buck Run.

The HSPF model for the Brandywine Creek Basin can be used to compare simulated loads in the Brandywine Creek where monitoring data are limited to loads calculated from extensive observed data in nearby basins to the west that drain to the Chesapeake Bay. Evaluation of monitoring data from these nearby basins indicates a positive correlation between the percentage of land in agricultural use and calculated yields of nitrate,

Table 31. *Simulated total loads and loads per acre (yields) in 1995 for selected subbasins in the Hydrologic Simulation Program–Fortran (HSPF) model of the Brandywine Creek Basin (Subbasins listed in order of decreasing nitrate loads per acre. See figure for location of model reaches.)*

[lb, pounds; lb/acre, pounds per acre; tons/acre, tons per acre]

Model reach number	Subbasin stream name	Drainage area (acres)	Yield or relative load (mass per unit area)				Total load (mass)			
			Nitrate (lb/acre)	Ammonia (lb/acre)	Phosphate (lb/acre)	Sediment (tons/acre)	Nitrate (lb)	Ammonia (lb)	Phosphate (lb)	Sediment (tons)
32	Birch Run	2,982	3.37	0.81	2.86	0.53	10,060	2,413	8,540	1,567
28	Trib. to Valley Creek	1,538	4.42	.19	.42	.26	6,796	288	649	398
33	Rock Run	5,139	4.99	1.29	3.87	1.01	25,650	6,616	19,910	5,216
24	Little Broad Run	384	7.80	.15	.69	.75	2,997	58	265	287
30	Beaver Creek[1]	11,568	8.66	.17	1.17	.46	100,200	1,951	13,480	5,325
26	Marsh Creek	5,311	9.20	.14	.88	.21	48,880	740	4,670	1,120
9	Upper E. Br. Brandywine Creek	9,398	12.73	.47	6.44	1.02	119,600	4,444	60,520	9,621
20	Buck Run	16,349	13.62	1.01	8.02	2.06	222,600	16,560	131,100	33,750
31	Pocopson Creek[2]	5,883	14.27	.18	2.34	.61	83,940	1,087	13,750	3,561
1	Upper W. Br. Brandywine Creek[3]	11,767	15.76	.88	8.55	1.11	185,500	10,400	100,600	13,090
21	Doe Run	7,074	16.79	.97	10.20	2.59	118,800	6,889	72,190	18,310

[1] Equivalent to subbasin B-12.
[2] Equivalent to subbasin B-15.
[3] Upstream from Honey Brook, equivalent to subbasin B-1.

ammonia, phosphorus, and suspended sediment (Langland and others, 1995). Similar relations are indicated by results of the HSPF model for the Brandywine. Comparison of simulated and calculated yields suggests that the simulation provides reasonable results (figs. 54 and 55).

The HSPF model for the Brandywine Creek Basin also can be used to compare simulated loads from nonpoint-sources based in land areas to reported loads from point-source discharges to streams in the basin. For example, total nitrate, ammonia, and orthophosphorus loads as estimated by the HSPF model for the drainage area above Brandywine Creek at Wilmington, Del., are listed with estimated and reported loads from point-source discharges to the Brandywine in table 32. Simulated loads for ammonia and nitrate from nonpoint sources are about two to three times greater than the estimated loads for these constituents from point sources. Simulated phosphorus loads from nonpoint sources are about an order of magnitude greater than estimated phosphorus loads from point sources.

The simulated loads shown in table 32 are for the whole basin for the 4-year period (October 1994-September 1998) and include a range of hydrologic conditions. Using the model, simulated loads from the whole basin and selected subbasins in the Brandywine Creek Basin could be estimated under base-flow or stormflow conditions for an actual time period, such as 1996-97. Additionally, the HSPF model for the Brandywine Creek Basin may be used as a predictive tool to estimate loads under statistically identified flow conditions, such as based on some period of record. For example, the model could be used to estimate an average daily load of suspended particulate and dissolved phosphorus at Brandywine Creek at Chadds Ford at high-flow conditions for daily mean streamflows (800–1,300 ft^3/s) that occur between about 5 and 10 percent of the time based on the simulation period of 1994-98; under these conditions, the estimated combined load of phosphorus from both point and nonpoint sources is about 828 lb/d. Further, the model estimates that about 90 percent of the suspended and dissolved load of orthophosphate for the period 1994-98 is carried by daily mean streamflows (greater than 750 ft^3/s) that occur 10 percent or less of the time.

Successful application of the Brandywine Creek HSPF model to future scenarios or periods of record other than the calibration period will be best supported if the model was calibrated to a broad range of representative hydrologic conditions. The daily mean streamflow duration curve

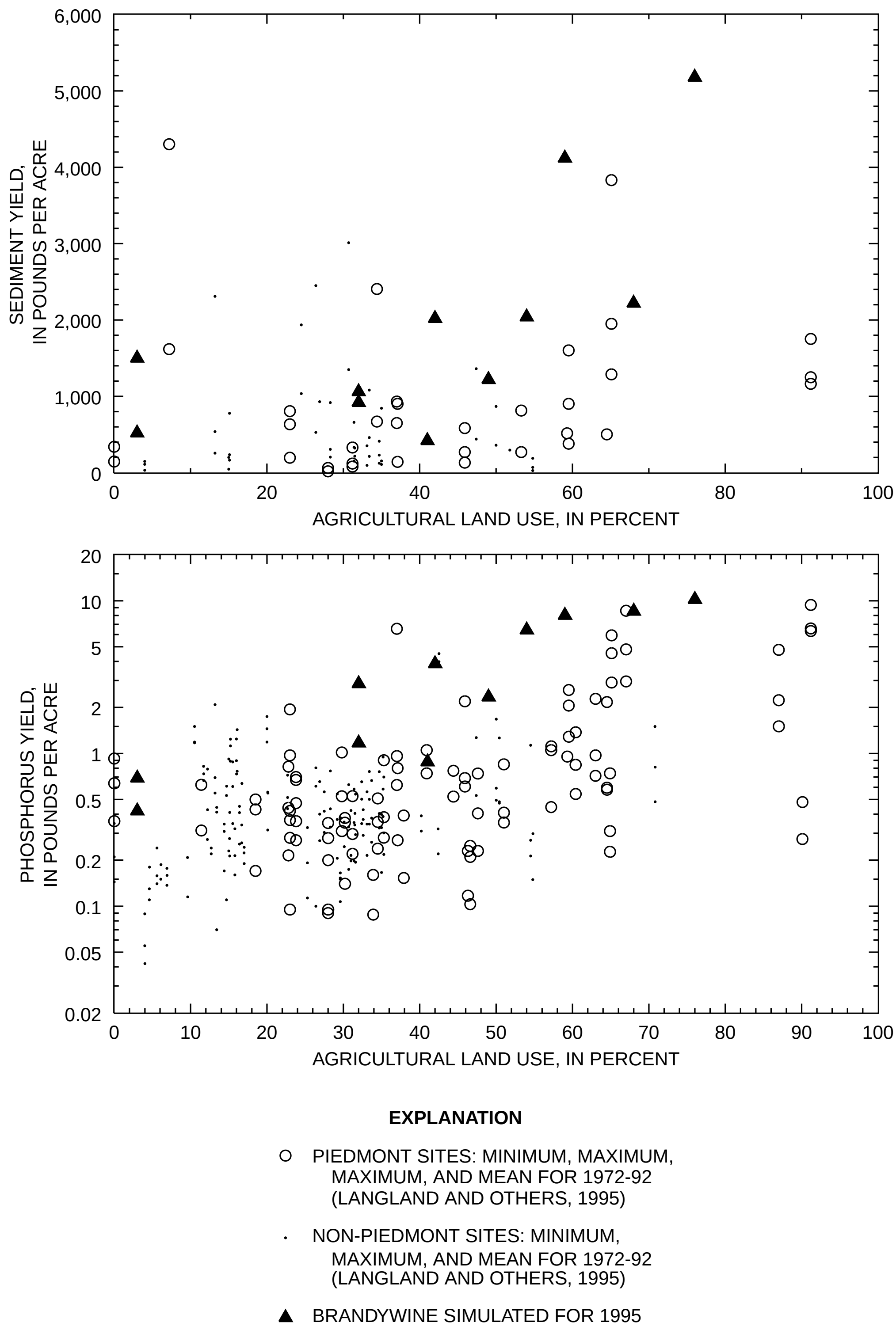


Figure 54. Sediment and phosphorus yields in relation to percent agricultural land use as calculated from observed data for subbasins in the Chesapeake Bay Watershed and as simulated by Hydrological Simulation Program–Fortran (HSPF) model for selected subbasins in the Brandywine Creek Basin.

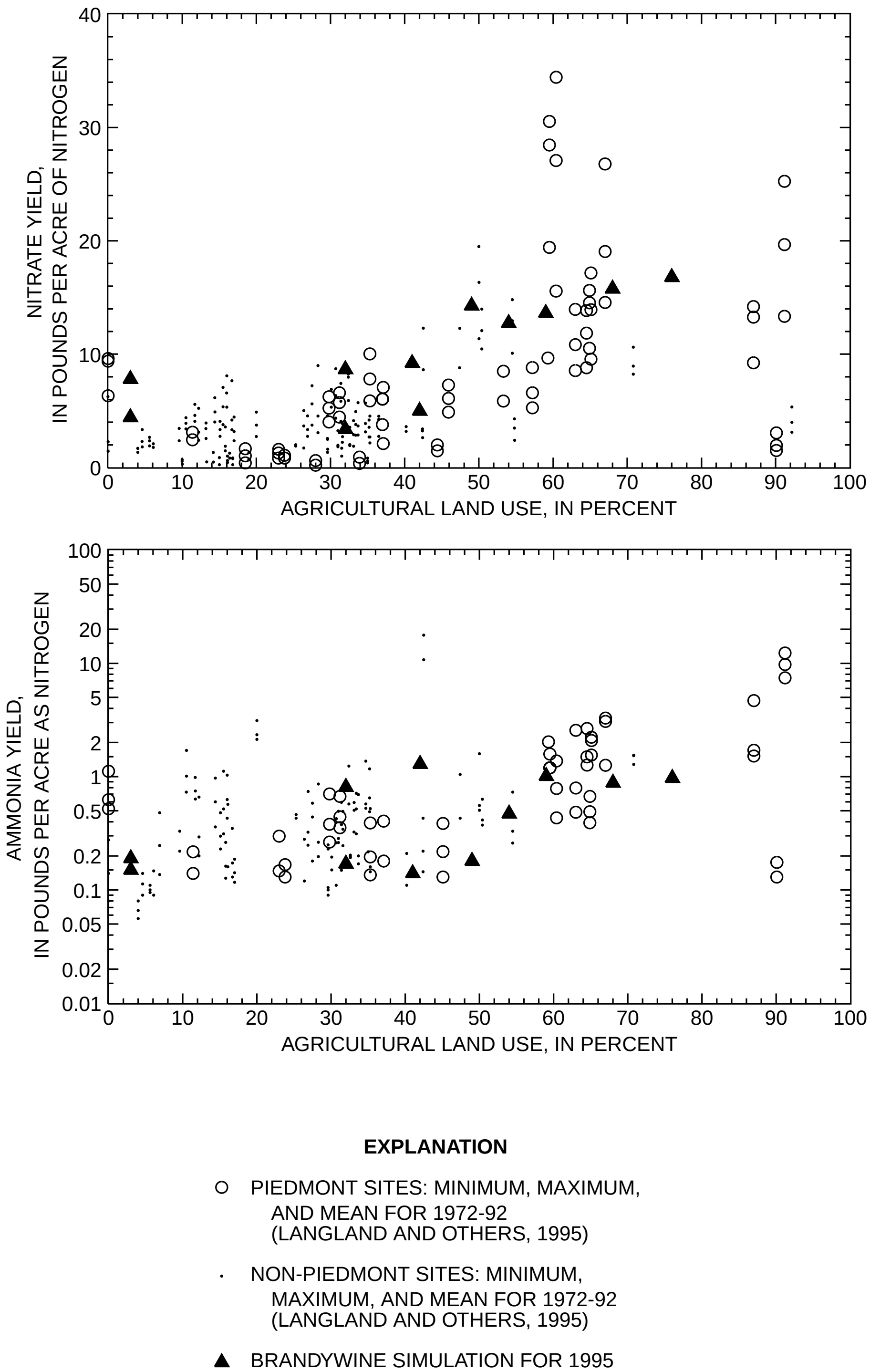


Figure 55. Yields of nitrate and ammonia in relation to percent agricultural land use as calculated from observed data for subbasins in the Chesapeake Bay Watershed and as simulated by Hydrologic Simulation Program–Fortran (HSPF) model for selected subbasins in the Brandywine Creek Basin.

Table 32. *Total simulated nonpoint-source and estimated point-source loads of nitrate, ammonia, and phosphorus for the 4-year period October 1994-September 1998, Brandywine Creek Basin*

	Total load, 1994-98, in tons		
	Nitrate	**Ammonia**	**Phosphorus**
Nonpoint source[1]	6,050	139	1,574
Point source[2]	[3] 2,555	50	97

[1] Calculated for drainage area above station 01481500 Brandywine Creek at Wilmington, Del.

[2] Includes all discharges above station 01481500 Brandywine Creek at Wilmington, Del.

[3] Estimated from reported ammonia loads.

for the simulation period at station 01481000 Brandywine Creek at Chadds Ford, Pa., was compared to the daily mean streamflow duration curve for the 39-year period October 1, 1962, to September 30, 2001 (fig. 56). In general, the duration curve of observed streamflow for the simulation period compares reasonably well with the longer 39-year duration curve over the full range of streamflows except above about 6,900 ft^3/s. Streamflows above 6,900 ft^3/s were not represented in the simulation period because of a lack of major storm events. Thus, the performance of the model simulations at these flows is unknown. Although these high streamflows generally produce the largest loads of suspended constituents, they are infrequent events. Daily mean streamflows greater than 6,900 ft^3/s have occurred only seven times in the 39-year period of record examined and only once since 1980. The Brandywine Creek model was calibrated to a range of streamflows that covered all but the most extreme high-flow events.

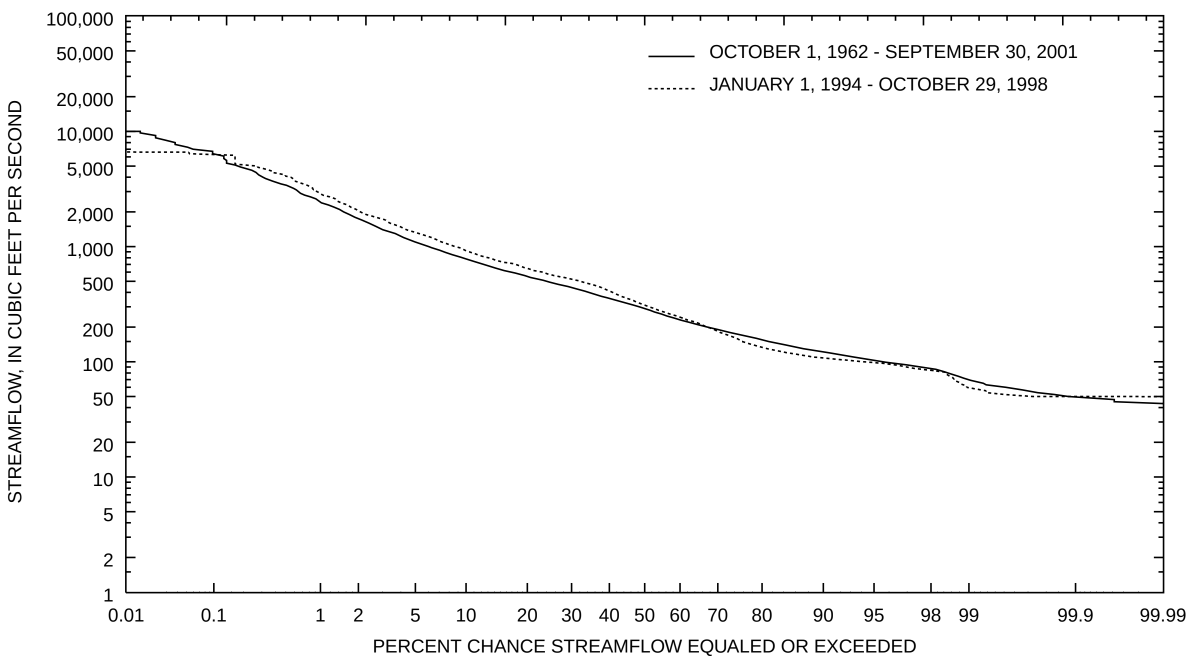


Figure 56. Duration curves of observed daily mean streamflow at 01481000 Brandywine Creek at Chadds Ford, Pa., for the period October 1, 1962, to September 30, 2001, and for the period of simulation, January 1, 1994, to October 29, 1998.

SUMMARY AND CONCLUSIONS

The Christina River Basin drains 565 mi^2 in Pennsylvania and Delaware and is used for recreation, drinking water supply, and support of aquatic life. The Christina River Basin includes the major subbasins of Brandywine Creek, Red Clay Creek, White Clay Creek, and the Christina River. The Brandywine Creek is the largest of the subbasins and drains an area of 327 mi^2. Monitoring data indicate that water quality in some parts of the Christina River Basin is impaired and does not support designated uses of the stream. A water-quality management strategy developed by a group of local, county, State, and Federal agencies to address water-quality problems included a modeling component to evaluate the effects of point and nonpoint-source contributions of nutrients and suspended sediment on stream water quality. The model selected for the nonpoint-source evaluation was HSPF. The HSPF model for the Christina River Basin was constructed and calibrated by the USGS in cooperation with the Delaware River Basin Commission, DNREC, and PADEP and consists of four independent models, one for each of the four main subbasins. This report covers the Brandywine Creek subbasin only.

The USGS also developed and executed a monitoring plan to collect water-quality data in each of the four main subbasins and in small areas predominantly covered by one land use for model calibration. Under this plan, stormflow and base-flow samples were collected during 1998 at six sites in the Brandywine Creek subbasin and five sites elsewhere in the Christina River Basin. Five of the six monitored stream sites in the Brandywine Creek subbasin drained areas, ranging in size from 0.6 to 18.7 mi^2, that were predominantly covered by one land use—animal / row crop, agricultural, row-crop agricultural, forested, sewered residential, unsewered residential, or urban. The sixth site was near the outlet of the Brandywine subbasin and drained 287 mi^2 of mixed land uses. Water samples were analyzed for dissolved and total nutrients and suspended solids. Because analyses of suspended sediment were not available, suspended-solids data were used as a surrogate for suspended-sediment data. Suspended solids and total phosphorus concentrations were higher in stormflow than in base-flow samples whereas dissolved nitrate concentrations tended to be higher in base-flow samples than in stormflow samples. Water quality varied among the six sites in the Brandywine Creek subbasin. Suspended solids and nutrient concentrations were higher in streams draining predominantly agricultural areas than in streams draining predominantly urban and sewered residential areas.

The HSPF model for the Brandywine Creek Basin was used to simulate streamflow, suspended sediment, and the nutrients of nitrogen and phosphorus. For the model, the basin was subdivided into 35 reaches draining areas that ranged from 0.6 to 25.5 mi^2. Three of the reaches contain a regulated reservoir. Eleven different pervious land uses and 2 impervious land uses were selected for simulation. Land-use areas were determined from 1995 land-use data. The predominant land uses in the basin are forested, agricultural, residential, and urban.

The hydrologic component of the model was run at an hourly time step and calibrated using streamflow data at eight USGS streamflow-measurement stations for the period of January 1, 1994, through October 29, 1998. Daily precipitation data at three NOAA gages in the Brandywine Creek Basin and hourly data at one NOAA gage near the southern tip of the basin were used for model input. The difference between observed and simulated streamflow volume ranged from -2.7 to 3.9 percent for the nearly 5-year period at the eight calibration sites. Annual differences between observed and simulated streamflow generally were greater than the overall error. For example, at the Brandywine Creek at Chadds Ford site near the bottom of the basin (drainage area of 237 mi^2), annual differences between observed and simulated streamflow ranged from -14.0 to 18.8 percent and the overall error for the 5-year period was 1.0 percent. At the eight streamflow-measurement stations, calibration errors for total flow volume, low-flow-recession rate, 50-percent lowest flows, 10-percent highest flows, storm peaks and other seasonal measures generally were within recommended criteria for a satisfactory calibration. Much of the error in simulating storm events on an hourly time step can be attributed to uncertainty in the rainfall data.

The water-quality component of the model was calibrated using monitoring data collected at six USGS streamflow-measurement stations with variable periods ending October 1998. The date for the start of water-quality monitoring ranged from July 1995 to January 1998. Monitoring data for concentrations of suspended solids were used as estimates for suspended sediment. Fewer data were available for water-quality calibration than for streamflow calibration. On the basis of limited water-quality data, the calibrated model simulates loads of suspended sediment, nitrate, dissolved and particulate ammonia, and dissolved orthophosphate and particulate phosphorus that are within an order of magnitude or less of observed loads for sampled storms in 1998 at most of the six sites. The error in water-quality loads typically is larger than and includes the error in stormflow simulation. Error in simulation of dissolved constituents generally was less than the error in simulation of particulate constituents. In storms, loads of particulate phosphorus generally are greater than loads of dissolved orthophosphate, and nitrate loads are about one order of magnitude greater than loads of dissolved ammonia and two orders of magnitude greater than loads of particulate ammonia.

Simulated yields of suspended sediment, nitrate, and ammonia for subbasins in the Brandywine Creek Basin were similar to yields calculated from monitoring data for subbasins in the nearby Chesapeake Bay drainage. Yields (expressed in pounds per acre) of these constituents tend to increase as the percentage of agricultural land increases.

Users of the Brandywine Creek HSPF model should be aware of model limitations and consider the following when predictive scenarios are desired: duration curves suggest the model simulates streamflow reasonably well when measured over a broad range of conditions and time although streamflow and the corresponding water quality for individual storm events may not be well simulated; streamflow duration curves for the simulation period compare well with duration curves for the 39-year period ending in 1998 at Chadds Ford, Pa., and include all but the extreme high-flow events; the magnitude of simulation errors tend to be inversely correlated to drainage area, with relative errors in flow and water-quality simulations for drainage areas less than 10 mi^2 typically larger than relative errors for drainage areas greater than 10 mi^2; and calibration for water quality was based on limited data, with the result of increasing uncertainty in the water-quality simulation.

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APPENDIX 1

RESULTS OF LABORATORY ANALYSES OF STORMFLOW AND BASE-FLOW SAMPLES

DATE	TIME	ENDING TIME	AGENCY ANALYZING SAMPLE (CODE NUMBER) (00028)	AGENCY COLLECTING SAMPLE (CODE NUMBER) (00027)	DISCHARGE, IN CUBIC FEET PER SECOND (00060)	DISCHARGE, INST. CUBIC FEET PER SECOND (00061)	SPECIFIC CONDUCTANCE LAB (US/CM) (90095)	SPECIFIC CONDUCTANCE (US/CM) (00095)	TEMPERATURE WATER (DEG C) (00010)	CHLORIDE, DISSOLVED (MG/L AS CL) (00940)	RESIDUE TOTAL AT 105 DEG. C, SUSPENDED (MG/L) (00530)	NITROGEN, AMMONIA DISSOLVED (MG/L AS N) (00608)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N) (00623)

01480300 WEST BRANCH BRANDYWINE CREEK NEAR HONEY BROOK, PA (LAT 40 04 22N LONG 075 51 40W)

DATE	TIME	ENDING TIME	(00028)	(00027)	(00060)	(00061)	(90095)	(00095)	(00010)	(00940)	(00530)	(00608)	(00623)
FEB 1998													
05...	0705	--	10003	--	--	37	268	--	--	22.0	432	.154	.37
05...	1005	--	10003	--	--	50	284	--	--	26.0	470	.356	.95
05...	1610	--	10003	--	--	58	273	--	--	--	121	.482	.30
MAR													
08-10	1530	0855	10003	--	148	--	205	--	--	12.9	107	.332	1.5
08...	1824	--	10003	--	--	54	233	--	--	16.4	44	.075	.75
08...	2224	--	10003	--	--	92	228	--	--	15.2	68	.358	1.7
09...	0024	--	10003	--	--	111	214	--	--	13.6	71	.422	1.8
JUN													
12-13	0549	0840	10003	--	91	--	177	--	--	11.6	228	.134	1.4
12...	1019	--	10003	--	--	66	189	--	--	14.7	468	.229	1.1
12...	1149	--	10003	--	--	12	167	--	--	11.2	494	.358	1.9
12...	1319	--	10003	--	--	169	157	--	--	9.1	567	.374	1.9
JUL													
08...	1303	--	10003	--	--	137	189	--	--	12.2	257	.241	1.4
08...	1433	--	10003	--	--	163	184	--	--	12.5	182	.357	2.1
08...	1603	--	10003	--	--	165	178	--	--	11.3	129	.338	1.7
08...	1903	--	10003	--	--	90	193	--	--	11.4	85	.243	1.5
OCT													
08...	0836	--	10003	--	--	14	274	--	--	27.0	64	<.005	--
08-09	0836	0928	10003	--	58	--	219	--	--	19.0	157	.048	--
08...	1135	--	1028	1028	--	20	--	265	16.0	--	--	--	--
08...	1136	--	10003	--	--	40	235	--	--	22.0	199	.063	--
08...	1306	--	10003	--	--	59	224	--	--	21.0	350	.053	--
08...	1436	--	10003	--	--	83	249	--	--	29.0	281	.120	--
08...	1606	--	10003	--	--	100	217	--	--	19.0	216	.207	--

014806318 DOE RUN ABOVE TRIBUTARY AT SPRINGDELL, PA (LAT 39 54 26N LONG 075 50 01W)

DATE	TIME	ENDING TIME	(00028)	(00027)	(00060)	(00061)	(90095)	(00095)	(00010)	(00940)	(00530)	(00608)	(00623)
MAR 1998													
08-09	1715	1427	10003	--	46	--	136	--	--	12.1	201	.237	1.2
08...	2124	--	10003	--	--	24	156	--	--	12.1	13	.033	.20
09...	0024	--	10003	--	--	29	150	--	--	12.6	27	.179	.38
09...	0154	--	10003	--	--	37	151	--	--	12.3	47	.137	.22
09...	0324	--	10003	--	--	36	156	--	--	13.5	39	.298	1.2
09...	1535	--	80020	1028	--	--	--	111	12.1	--	--	.308	.77
MAY													
02-03	1745	0916	10003	--	52	--	118	--	--	21.2	860	.222	1.1
02...	1915	--	10003	--	--	66	103	--	--	17.1	732	.094	.73
02...	2215	--	10003	--	--	62	108	--	--	52.5	2150	.559	1.8
JUN													
12-12	0734	1806	10003	--	101	--	167	--	--	9.1	1050	.166	.89
12...	1004	--	10003	--	--	88	109	--	--	8.6	1060	.161	.60
12...	1119	--	10003	--	--	187	109	--	--	8.9	1890	.209	.82
12...	1234	--	10003	--	--	133	95	--	--	6.6	1620	.191	.95
12...	1349	--	10003	--	--	120	100	--	--	7.5	630	.212	1.2
JUL													
08-08	0915	1938	10003	--	38	--	136	--	--	11.9	275	.141	.30
08...	1030	--	10003	--	--	26	142	--	--	9.9	86	.046	<.05
08...	1145	--	10003	--	--	36	131	--	--	9.9	130	.056	.55
08...	1300	--	10003	--	--	79	157	--	--	13.0	356	.235	.69
08...	1415	--	10003	--	--	49	147	--	--	13.3	252	.209	.54
OCT													
08...	1245	--	1028	1028	--	12	--	153	15.5	--	--	--	--
08-09	1308	0953	10003	--	45	--	121	--	--	13.0	400	.110	--
08...	1423	--	10003	--	--	16	122	--	--	11.0	76	.056	--
08...	1653	--	10003	--	--	27	142	--	--	13.0	121	.042	--
08...	1808	--	10003	--	--	30	141	--	--	13.0	111	.157	--
08...	1923	--	10003	--	--	38	145	--	--	14.0	141	.294	--

DATE	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N) (00613)	PHOS-PHORUS DIS-SOLVED (MG/L AS P) (00666)	PHOS-PHORUS ORTHO, DIS-SOLVED (MG/L AS P) (00671)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)	CARBON, ORGANIC DIS-SOLVED (MG/L AS C) (00681)	OXYGEN DEMAND, BIOCHEM CARBON. 20 (MG/L) (80087)
01480300 WEST BRANCH BRANDYWINE CREEK NEAR HONEY BROOK, PA (LAT 40 04 22N LONG 075 51 40W)									
FEB 1998									
05...	.40	.21	4.98	--	.066	.028	.824	8.0	13
05...	1.1	.41	4.51	--	.100	.035	1.10	9.0	>12
05...	1.4	.51	3.41	--	.170	.112	.414	12	--
MAR									
08...	2.6	.37	2.36	--	.306	.228	.513	11	9.7
08...	1.2	.08	4.31	--	.105	.059	.187	4.0	3.7
08...	2.1	.38	3.38	--	.171	.134	.305	7.0	5.5
09...	2.7	.42	2.76	--	.174	.151	.359	12	7.8
JUN									
12...	2.8	.14	2.56	--	.215	.266	.797	15	8.4
12...	5.0	.23	3.46	--	.175	.242	1.54	11	6.1
12...	4.0	.43	2.20	--	.333	.343	1.46	18	7.5
12...	4.4	.51	1.86	--	.304	.336	1.66	18	7.9
JUL									
08...	3.1	.23	1.98	--	.276	.268	.827	11	11
08...	3.0	.32	2.15	--	.337	.312	.766	13	14
08...	2.9	.30	1.89	--	.346	.351	.720	14	9.6
08...	2.8	.23	1.96	--	.315	.291	.587	11	7.2
OCT									
08...	--	.01	3.61	--	--	.062	--	11	14
08...	--	.06	2.46	--	--	.345	--	12	10
08...	--	--	--	--	--	--	--	--	--
08...	--	.09	3.54	--	--	.180	--	10	9.2
08...	--	.09	3.56	--	--	.165	--	9.0	8.1
08...	--	.14	3.29	--	--	.285	--	13	11
08...	--	.18	2.68	--	--	.340	--	11	11
014806318 DOE RUN ABOVE TRIBUTARY AT SPRINGDELL, PA (LAT 39 54 26N LONG 075 50 01W)									
MAR 1998									
08...	3.6	.31	3.30	--	.105	.054	.414	7.0	9.5
08...	.77	.03	4.76	--	.074	.010	.080	20	<2.4
09...	1.1	.18	4.40	--	.093	.074	.110	6.0	4.3
09...	1.0	.14	4.25	--	.084	.033	.132	4.0	4.0
09...	2.0	.29	4.11	--	.161	.086	.226	6.0	7.3
09...	--	--	2.09	.033	.072	.061	--	--	--
MAY									
02...	11	.52	2.84	--	.039	.039	1.95	7.0	6.7
02...	11	.25	2.85	--	.050	.023	1.53	7.0	4.7
02...	22	1.73	2.58	--	.086	.083	1.41	5.0	8.8
JUN									
12...	5.2	.27	2.49	--	.067	.065	2.03	11	6.3
12...	5.9	.19	2.50	--	.044	.037	1.93	9.0	3.2
12...	8.9	.33	2.36	--	.055	.054	3.02	10	6.1
12...	6.7	.50	1.84	--	.063	.080	3.02	12	4.1
12...	4.0	.36	1.84	--	.103	.109	1.47	13	6.5
JUL									
08...	2.5	.13	3.49	--	.047	.053	.419	10	12
08...	.79	.07	3.88	--	.009	.023	.102	7.0	3.5
08...	1.6	.07	3.61	--	<.005	.022	.234	5.0	3.4
08...	3.5	.24	4.08	--	.047	.073	.667	9.0	12
08...	2.5	.18	2.93	--	.044	.072	.507	9.0	12
OCT									
08...	--	--	--	--	--	--	--	--	--
08...	--	.13	2.45	--	--	.101	--	8.0	9.6
08...	--	.07	4.10	--	--	.018	--	5.0	3.4
08...	--	.06	3.87	--	--	.018	--	5.0	6.0
08...	--	.18	3.65	--	--	.041	--	7.0	6.3
08...	--	.27	3.63	--	--	.112	--	8.0	9.7

DATE	TIME	ENDING TIME	AGENCY ANA- LYZING SAMPLE (CODE NUMBER) (00028)	AGENCY COL- LECTING SAMPLE (CODE NUMBER) (00027)	DIS- CHARGE, IN CUBIC FEET PER SECOND (00060)	DIS- CHARGE, INST. CUBIC FEET PER SECOND (00061)	SPE- CIFIC CON- DUCT- ANCE LAB (US/CM) (90095)	SPE- CIFIC CON- DUCT- ANCE (US/CM) (00095)	TEMPER- ATURE WATER (DEG C) (00010)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL) (00940)	RESIDUE TOTAL AT 105 DEG. C, SUS- PENDED (MG/L) (00530)	NITRO- GEN, AMMONIA DIS- SOLVED (MG/L AS N) (00608)	NITRO- GEN,AM- MONIA + ORGANIC DIS. (MG/L AS N) (00623)
01480637 LITTLE BROAD RUN NEAR MARSHALLTON, PA (LAT 39 57 38N LONG 075 42 44W)													
MAR 1998													
09–09	0602	1248	10003	--	2.8	--	313	--	--	20.7	167	.074	.36
09...	0701	--	10003	--	--	2.4	186	--	--	22.2	80	.037	.53
09...	0831	--	10003	--	--	4.2	150	--	--	17.1	373	.055	.27
09...	1001	--	10003	--	--	2.6	183	--	--	20.7	43	.038	.34
09...	1435	--	80020	1028	--	--	--	173	12.3	--	--	.023	.18
JUN													
12...	0819	--	10003	--	--	3.8	108	--	--	19.1	1090	.022	.30
12–12	0819	1011	10003	--	8.0	--	143	--	--	9.5	1330	.072	.53
12...	0904	--	10003	--	--	18	897	--	--	9.0	909	.088	.21
OCT													
08...	1114	--	10003	--	--	1.2	196	--	--	25.0	153	.018	--
08–08	1114	2158	10003	--	<1.2	--	169	--	--	19.0	305	.018	--
08...	1159	--	10003	--	--	2.3	163	--	--	20.0	448	.044	--
08...	1315	--	1028	1028	--	2.1	--	165	16.5	--	--	--	--
08...	1329	--	10003	--	--	1.5	178	--	--	20.0	237	.023	--
08...	1459	--	10003	--	--	12	121	--	--	11.0	645	.043	--
01480675 MARSH CREEK NEAR GLENMOORE, PA (LAT 40 05 52N LONG 075 44 31W)													
FEB 1998													
05...	0548	--	10003	--	--	13	187	--	--	25.0	49	.088	.39
05...	0848	--	10003	--	--	15	180	--	--	25.0	10	.084	.36
MAR													
08–10	1602	0350	10003	--	75	--	130	--	--	13.9	26	.023	.66
08...	2220	--	10003	--	--	31	140	--	--	17.0	27	.036	.23
09...	1020	--	10003	--	--	81	117	--	--	17.2	46	.042	.57
09...	1420	--	10003	--	--	97	111	--	--	12.8	37	.040	.87
JUN													
12–13	1322	0856	10003	--	56	--	118	--	--	14.7	35	.012	.68
12...	1709	--	10003	--	--	31	125	--	--	14.5	25	.070	.57
13...	0309	--	10003	--	--	8.1	115	--	--	14.8	36	.061	.68
13...	0809	--	10003	--	--	9.7	114	--	--	12.9	22	.067	.73
OCT													
05...	1009	--	10003	--	--	2.8	208	--	--	24.0	50	<.005	--
07...	0933	--	10003	--	--	2.0	213	--	--	25.0	21	<.005	--
08...	0759	--	10003	--	--	2.6	176	--	--	22.0	22	<.005	--
01480878 UNN TRIB TO VALLEY CR AT HWY 30 AT EXTON, PA (LAT 40 01 35N LONG 075 38 11W)													
FEB 1998													
04...	1831	--	10003	--	--	1.1	610	--	--	100	51	.047	.34
04–05	1831	1110	10003	--	7.5	--	285	--	--	44.0	141	.022	.36
05...	0201	--	10003	--	--	5.8	283	--	--	42.0	25	.033	.35
05...	1446	--	10003	--	--	12	192	--	--	--	26	.016	.43
MAR													
08–09	1313	1411	10003	--	24	--	137	--	--	12.5	223	.044	.63
08...	1418	--	10003	--	--	4.0	350	--	--	44.7	45	.036	<.05
08...	1548	--	10003	--	--	13	236	--	--	28.2	72	.026	<.05
08...	2148	--	10003	--	--	28	147	--	--	14.0	154	.036	.54
MAY													
01–03	1941	0813	10003	--	5.8	--	263	--	--	29.4	170	.016	.71
02...	0006	--	10003	--	--	5.8	283	--	--	34.0	35	.025	.68
02...	0136	--	10003	--	--	8.5	254	--	--	28.0	102	.006	.70
JUN													
11–12	2329	1354	10003	--	31	--	102	--	--	9.3	214	.048	.53
12...	0129	--	10003	--	--	18	100	--	--	14.8	84	.052	.57
12...	0229	--	10003	--	--	1.6	148	--	--	13.6	37	.030	.45
12...	0329	--	10003	--	--	1.6	139	--	--	15.4	107	.055	.41
JUL													
08–09	0700	--	10003	--	--	6.2	235	--	--	26.4	92	.008	.32
08...	0800	--	10003	--	--	17	192	--	--	20.1	111	.035	.30
08...	1000	--	10003	--	--	54	92	--	--	7.0	208	.043	.31
08...	1100	--	10003	--	--	39	91	--	--	6.3	90	.040	.42

DATE	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	NITRO-GEN, NITRITE DIS-SOLVED (MG/L AS N) (00613)	PHOS-PHORUS DIS-SOLVED (MG/L AS P) (00666)	PHOS-PHORUS ORTHO, DIS-SOLVED (MG/L AS P) (00671)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)	CARBON, ORGANIC DIS-SOLVED (MG/L AS C) (00681)	OXYGEN DEMAND, BIOCHEM CARBON. 20 (MG/L) (80087)
01480637 LITTLE BROAD RUN NEAR MARSHALLTON, PA (LAT 39 57 38N LONG 075 42 44W)									
MAR 1998									
09...	1.8	.06	2.87	--	.161	.027	.259	5.0	3.7
09...	1.0	.05	3.00	--	.076	.020	.136	3.0	2.5
09...	2.9	.05	2.28	--	.088	.041	.570	4.0	4.3
09...	.98	.04	2.90	--	.098	.032	.170	6.0	3.1
09...	--	--	3.10	.029	<.010	<.010	--	--	--
JUN									
12...	6.7	.02	2.61	--	.028	.015	1.52	8.0	5.8
12...	6.8	.07	1.40	--	.041	.039	2.00	10	3.9
12...	4.4	.12	1.16	--	.053	.039	1.49	9.0	<2.4
OCT									
08...	--	.06	2.74	--	--	.012	--	9.0	12
08...	--	.04	2.09	--	--	.024	--	12	8.0
08...	--	.07	2.27	--	--	.026	--	7.0	8.1
08...	--	--	--	--	--	--	--	--	--
08...	--	.05	2.29	--	--	.023	--	7.0	7.0
08...	--	.06	1.34	--	--	.034	--	8.0	10
01480675 MARSH CREEK NEAR GLENMOORE, PA (LAT 40 05 52N LONG 075 44 31W)									
FEB 1998									
05...	.63	.10	1.98	--	.039	.017	.042	7.0	4.2
05...	.84	.09	1.75	--	.018	.016	.042	6.0	4.0
MAR									
08...	1.1	.03	.913	--	.092	.024	.090	8.0	5.5
08...	.97	.04	1.38	--	.053	.011	.066	6.0	2.5
09...	1.1	.05	.849	--	.087	.026	.113	9.0	3.2
09...	1.1	.05	.753	--	.061	.048	.194	8.0	3.4
JUN									
12...	.95	.01	.634	--	.053	.038	.110	12	4.6
12...	.66	.10	.868	--	.045	.040	.096	9.0	<2.4
13...	.76	.06	.425	--	.057	.045	.119	11	<2.4
13...	.76	.06	.509	--	.060	.045	.111	12	<2.4
OCT									
05...	--	.04	.424	--	--	.013	--	10	13
07...	--	.03	.814	--	--	.012	--	6.0	5.5
08...	--	.04	.805	--	--	.016	--	7.0	4.8
01480878 UNN TRIB TO VALLEY CR AT HWY 30 AT EXTON, PA (LAT 40 01 35N LONG 075 38 11W)									
FEB 1998									
04...	.62	.05	1.30	--	.013	.013	.044	7.0	6.8
04...	1.1	.04	.933	--	.010	.011	.156	7.0	7.1
05...	.42	.03	1.20	--	.015	.014	.027	6.0	4.4
05...	.61	.05	.582	--	.019	.017	.067	8.0	--
MAR									
08...	1.9	.07	.554	--	.119	.022	.236	7.0	6.1
08...	.69	.03	1.75	--	.140	.011	.139	4.0	3.8
08...	.89	.03	1.36	--	.124	.007	.141	4.0	4.5
08...	1.5	.03	.646	--	.080	.032	.172	5.0	5.0
MAY									
01...	1.1	.02	1.30	--	.024	.013	.050	6.0	4.7
02...	.98	.03	1.76	--	.025	.019	.088	7.0	<2.4
02...	1.2	.01	1.51	--	.013	.015	.100	14	<2.4
JUN									
11...	1.4	.09	.561	--	.052	.054	.307	9.0	3.2
12...	.71	.04	.971	--	.047	.046	.148	6.0	<2.4
12...	.70	.04	.882	--	.044	.033	.110	9.0	<2.4
12...	.84	.05	.997	--	.046	.046	.147	7.0	<2.4
JUL									
08...	1.0	.05	1.22	--	.010	.020	.143	8.0	9.2
08...	.83	.05	1.10	--	.024	.028	.166	6.0	5.7
08...	1.4	.10	.533	--	.040	.049	.300	6.0	6.1
08...	1.1	.06	.420	--	.053	.062	.202	12	5.5

DATE	TIME	ENDING TIME	AGENCY ANA- LYZING SAMPLE (CODE NUMBER) (00028)	AGENCY COL- LECTING SAMPLE (CODE NUMBER) (00027)	DIS- CHARGE, IN CUBIC FEET PER SECOND (00060)	DIS- CHARGE, INST. CUBIC FEET PER SECOND (00061)	OXYGEN, DIS- SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND- ARD UNITS) (00400)	SPE- CIFIC CON- DUCT- ANCE LAB (US/CM) (90095)	SPE- CIFIC CON- DUCT- ANCE (US/CM) (00095)	TEMPER- ATURE WATER (DEG C) (00010)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL) (00940)	RESIDUE TOTAL AT 105 DEG. C, SUS- PENDED (MG/L) (00530)
01480878 UNN TRIB TO VALLEY CR AT HWY 30 AT EXTON, PA (LAT 40 01 35N LONG 075 38 11W)													
JUL 1998													
08...	1200	--	10003	--	--	17	--	--	120	--	--	8.0	49
OCT													
08–09	0645	0658	10003	--	19	--	--	--	127	--	--	13.0	85
08...	0745	--	10003	--	--	7.7	--	--	279	--	--	38.0	115
08...	0945	--	10003	--	--	9.7	--	--	188	--	--	21.0	55
08...	1045	--	10003	--	--	12	--	--	146	--	--	16.0	46
08...	1145	--	10003	--	--	24	--	--	111	--	--	11.0	127
08...	1340	--	1028	1028	--	--	--	--	--	106	18.0	--	--
01481000 BRANDYWINE CREEK AT CHADDS FORD, PA (LAT 39 52 11N LONG 075 35 37W)													
MAR 1998													
05...	1050	--	1028	1028	--	501	12.2	7.3	--	225	6.5	--	--
08–09	1800	1645	10003	--	1630	--	--	--	191	--	--	17.9	129
09...	0000	--	10003	--	--	1010	--	--	235	--	--	23.9	28
09...	0600	--	10003	--	--	1580	--	--	209	--	--	20.8	41
09...	1000	--	10003	--	--	2080	--	--	185	--	--	18.2	113
09...	1915	--	80020	1028	--	2500	--	--	--	152	--	--	--
MAY													
02–03	0038	1105	10003	--	719	--	--	--	239	--	--	23.0	<1
03...	0322	--	10003	--	--	666	--	--	237	--	--	21.6	6
03...	0552	--	10003	--	--	747	--	--	236	--	--	21.0	7
04...	1142	--	1028	1028	--	480	9.8	7.4	--	255	16.1	--	--
JUN													
12–12	1553	2012	10003	--	2650	--	--	--	154	--	--	13.0	245
12...	1600	--	10003	--	--	2480	--	--	173	--	--	13.8	447
12...	1900	--	10003	--	--	2510	--	--	146	--	--	12.8	402
12...	2200	--	10003	--	--	1860	--	--	154	--	--	11.9	204
JUL													
07...	0920	--	1028	1028	--	195	8.3	7.5	--	300	21.9	--	--
08–09	1205	0109	10003	--	919	--	--	--	221	--	--	18.0	46
08...	1505	--	10003	--	--	576	--	--	258	--	--	22.0	34
08...	1805	--	10003	--	--	1200	--	--	254	--	--	22.2	65
08...	2105	--	10003	--	--	1090	--	--	224	--	--	17.8	54
09...	0305	--	10003	--	--	1020	--	--	197	--	--	15.2	53
OCT													
08...	1546	--	10003	--	--	135	--	--	279	--	--	27.0	25
08–09	1546	1057	10003	--	894	--	--	--	232	--	--	22.0	73
08...	1846	--	10003	--	--	434	--	--	296	--	--	31.0	67
08...	2146	--	10003	--	--	1010	--	--	265	--	--	25.0	90
09...	0046	--	10003	--	--	1070	--	--	220	--	--	20.0	68
09...	0646	--	10003	--	--	998	--	--	209	--	--	20.0	59

DATE	NITRO- GEN, AMMONIA DIS- SOLVED (MG/L AS N) (00608)	NITRO- GEN,AM- MONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITRO- GEN,AM- MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO- GEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N) (00631)	NITRO- GEN, NITRITE DIS- SOLVED (MG/L AS N) (00613)	PHOS- PHORUS DIS- SOLVED (MG/L AS P) (00666)	PHOS- PHORUS ORTHO, DIS- SOLVED (MG/L AS P) (00671)	PHOS- PHORUS TOTAL (MG/L AS P) (00665)	CARBON, ORGANIC DIS- SOLVED (MG/L AS C) (00681)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	OXYGEN DEMAND, BIOCHEM CARBON. 20 (MG/L) (80087)	OXYGEN DEMAND, CHEM- ICAL (HIGH LEVEL) (MG/L) (00340)

01480878 UNN TRIB TO VALLEY CR AT HWY 30 AT EXTON, PA (LAT 40 01 35N LONG 075 38 11W)

DATE	00608	00623	00625	00610	00631	00613	00666	00671	00665	00681	00680	80087	00340
JUL 1998													
08...	.037	.53	1.1	.08	.521	--	.052	.068	.169	6.0	--	7.2	--
OCT													
08...	.016	--	--	.21	.644	--	--	.056	--	7.0	--	6.4	--
08...	<.005	--	--	.04	1.34	--	--	.051	--	8.0	--	7.7	--
08...	<.005	--	--	.06	.001	--	--	.066	--	8.0	--	5.2	--
08...	<.005	--	--	.04	.784	--	--	.060	--	7.0	--	3.4	--
08...	<.005	--	--	.05	.573	--	--	.056	--	7.0	--	6.1	--
08...	--	--	--	--	--	--	--	--	--	--	--	--	--

01481000 BRANDYWINE CREEK AT CHADDS FORD, PA (LAT 39 52 11N LONG 075 35 37W)

DATE	00608	00623	00625	00610	00631	00613	00666	00671	00665	00681	00680	80087	00340
MAR 1998													
05...	--	--	--	--	--	--	--	--	--	--	--	--	--
08...	.027	.42	1.9	.03	2.18	--	.112	.055	.344	6.0	5.0	5.1	15
09...	.024	.16	.47	.03	2.83	--	.086	.062	.131	4.0	3.0	<2.4	4
09...	.041	.26	1.3	.05	2.38	--	.089	.061	.243	3.0	4.0	2.8	11
09...	.038	.37	1.7	.05	2.20	--	.089	.045	.302	6.0	4.0	2.8	11
09...	.041	.34	--	--	1.60	.035	.037	.031	--	--	--	--	--
MAY													
02...	<.004	.36	.42	.02	3.01	--	.011	.028	.036	6.0	--	<2.4	--
03...	.017	.32	.49	.04	2.86	--	.054	.050	.064	3.0	--	<2.4	--
03...	.023	.22	.19	.03	2.67	--	.051	.182	.060	3.0	--	<2.4	--
04...	--	--	--	--	--	--	--	--	--	--	--	--	--
JUN													
12...	.043	.80	2.5	.06	1.73	--	.051	.038	.420	5.0	4.0	6.0	<1
12...	.074	.20	3.5	.08	1.76	--	.084	.066	1.15	11	9.0	7.5	<1
12...	.066	.95	3.4	.07	1.56	--	.115	.064	.909	9.0	8.0	5.0	<1
12...	.070	.97	2.1	.06	1.69	--	.091	.074	.370	11	9.0	4.0	<1
JUL													
07...	--	--	--	--	--	--	--	--	--	--	--	--	--
08...	.021	.20	.53	.03	2.09	--	.017	.037	.148	5.0	4.0	4.0	21
08...	.053	.30	.49	.06	2.75	--	.018	.041	.113	5.0	4.0	<3.0	11
08...	.051	.52	1.1	.06	2.46	--	.024	.060	.195	5.0	4.0	3.3	17
08...	.053	.19	.64	.06	1.90	--	.028	.048	.158	5.0	5.0	<3.0	17
09...	.070	.17	.74	.09	1.84	--	.034	.050	.172	6.0	5.0	3.2	47
OCT													
08...	.011	--	--	.04	2.93	--	--	.070	--	8.0	24	8.3	<1
08...	<.005	--	--	.03	2.29	--	--	.058	--	6.0	8.0	4.7	<1
08...	.014	--	--	.02	2.95	--	--	.075	--	5.0	7.0	<3.0	<1
08...	.049	--	--	.06	2.64	--	--	.111	--	7.0	6.0	3.9	1
09...	.036	--	--	.06	1.96	--	--	.074	--	7.0	7.0	3.7	4
09...	.076	--	--	.08	2.10	--	--	.071	--	6.0	8.0	<3.0	<1

Remark Codes Used in This report:
< -- Less than
> -- Greater than

DATE	TIME	AGENCY ANA- LYZING SAMPLE (CODE NUMBER) (00028)	DIS- CHARGE, INST. CUBIC FEET PER SECOND (00061)	OXYGEN, DIS- SOLVED (MG/L) (00300)	PH WATER WHOLE FIELD (STAND- ARD UNITS) (00400)	SPE- CIFIC CON- DUCT- ANCE (US/CM) (00095)	TEMPER- ATURE WATER (DEG C) (00010)	ANC WATER UNFLTRD FET FIELD MG/L AS CACO3 (00410)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL) (00940)	RESIDUE TOTAL AT 105 DEG. C, SUS- PENDED (MG/L) (00530)	NITRO- GEN, AMMONIA DIS- SOLVED (MG/L AS N) (00608)	NITRO- GEN,AM- MONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITRO- GEN,AM- MONIA + ORGANIC TOTAL (MG/L AS N) (00625)
01480300 WEST BRANCH BRANDYWINE CREEK NEAR HONEY BROOK, PA (LAT 40 04 22N LONG 075 51 40W)													
APR 1998													
27...	1005	10003	27	10.6	7.7	165	9.8	52	20.0	8	.355	1.6	2.0
JUL													
23...	0950	10003	13	6.7	7.4	274	25.1	69	24.0	6	.016	.48	.65
SEP													
15...	1005	10003	7.6	7.4	7.8	295	20.8	74	34.0	6	.044	.82	1.2
014806318 DOE RUN ABOVE TRIBUTARY AT SPRINGDELL, PA (LAT 39 54 26N LONG 075 50 01W)													
APR 1998													
27...	1210	10003	16	11.9	7.5	112	12.5	16	14.6	3	.010	.16	.63
JUL													
23...	1150	10003	9.6	8.1	8.1	133	2.3	22	13.0	4	.014	.53	1.3
SEP													
15...	1210	10003	5.4	9.3	7.5	140	19.5	23	11.0	1	.016	.58	.89
01480637 LITTLE BROAD RUN NEAR MARSHALLTON, PA (LAT 39 57 38N LONG 075 42 44W)													
APR 1998													
27...	1140	10003	1.3	11.6	7.0	140	13.0	27	31.2	3	.015	.16	.55
JUL													
23...	1120	10003	.50	7.3	7.3	220	22.5	38	34.0	1	.016	.50	1.1
SEP													
15...	1135	10003	.20	8.4	7.5	217	19.8	39	31.0	4	.069	.81	1.3
01480675 MARSH CREEK NEAR GLENMOORE, PA (LAT 40 05 52N LONG 075 44 31W)													
APR 1998													
27...	1040	10003	23	10.1	7.1	110	9.8	43	19.9	6	.042	1.1	1.6
JUL													
23...	1015	10003	3.6	6.1	7.4	163	25.1	52	23.0	1	.013	.43	.71
SEP													
15...	1035	10003	2.0	8.0	7.7	172	19.4	50	22.0	4	.021	.64	.96
01480878 UNN TRIB TO VALLEY CR AT HWY 30 AT EXTON, PA (LAT 40 01 35N LONG 075 38 11W)													
APR 1998													
27...	1110	10003	2.1	12.4	8.5	222	11.4	64	40.0	1	.011	.21	.23
JUL													
23...	1045	10003	.80	7.3	8.1	350	24.9	87	51.0	1	.016	.49	1.1
SEP													
15...	1110	10003	.30	10.4	8.8	315	21.3	86	56.0	<1	.018	.60	.95
01481000 BRANDYWINE CREEK AT CHADDS FORD, PA (LAT 39 52 11N LONG 075 35 37W)													
APR 1998													
27...	1240	10003	489	12.2	7.4	265	13.0	47	26.6	14	.008	.42	.63
JUL													
23...	1305	--	175	9.2	7.8	255	25.4	60	24.0	4	.031	.54	1.2
SEP													
15...	1219	10003	100	9.5	7.9	306	24.4	67	32.0	13	<.005	.32	.63

DATE	NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	PHOS-PHORUS DIS-SOLVED (MG/L AS P) (00666)	PHOS-PHORUS ORTHO, DIS-SOLVED (MG/L AS P) (00671)	PHOS-PHORUS TOTAL (MG/L AS P) (00665)	CARBON, ORGANIC DIS-SOLVED (MG/L AS C) (00681)	OXYGEN DEMAND, BIOCHEM CARBON. 20 (MG/L) (80087)	PHEO-PHYTIN PHYTO-PLANK-TON, ACID M. (UG/L) (32218)	CHLORO-HPYLL A PHYTO-PLANK-TON ACID M. (UG/L) (32211)
01480300 WEST BRANCH BRANDYWINE CREEK NEAR HONEY BROOK, PA (LAT 40 04 22N LONG 075 51 40W)									
APR 1998									
27...	.36	4.63	.101	.075	.122	6.0	<2.4	2.00	11.0
JUL									
23...	.04	3.72	.032	.051	.136	5.0	<2.4	<2.00	5.00
SEP									
15...	.04	3.44	.103	.147	.163	4.0	<2.4	<2.00	8.00
014806318 DOE RUN ABOVE TRIBUTARY AT SPRINGDELL, PA (LAT 39 54 26N LONG 075 50 01W)									
APR 1998									
27...	.01	5.34	.032	.022	.043	3.0	<2.4	<2.00	3.00
JUL									
23...	.02	4.41	<.005	.024	.022	2.0	2.9	<2.00	3.00
SEP									
15...	.01	4.61	.006	.060	.081	1.0	<2.4	<2.00	3.00
01480637 LITTLE BROAD RUN NEAR MARSHALLTON, PA (LAT 39 57 38N LONG 075 42 44W)									
APR 1998									
27...	.02	4.64	.019	.020	.018	2.0	<2.4	<2.00	3.00
JUL									
23...	.07	3.22	<.005	.024	.128	2.0	<2.4	<2.00	3.00
SEP									
15...	.10	3.03	.005	.031	.069	2.0	<2.4	<2.00	3.00
01480675 MARSH CREEK NEAR GLENMOORE, PA (LAT 40 05 52N LONG 075 44 31W)									
APR 1998									
27...	.04	1.53	.022	.029	.038	7.0	<2.4	<2.00	5.00
JUL									
23...	.09	.655	.057	.064	.061	4.0	<2.4	<2.00	3.00
SEP									
15...	.02	.494	.036	.040	.046	5.0	<2.4	<2.00	3.00
01480878 UNN TRIB TO VALLEY CR AT HWY 30 AT EXTON, PA (LAT 40 01 35N LONG 075 38 11W)									
APR 1998									
27...	.01	1.83	.010	.022	.037	4.0	<2.4	<2.00	8.00
JUL									
23...	.05	1.49	.013	.032	.034	4.0	2.7	<2.00	5.00
SEP									
15...	.02	.867	.008	.020	.047	2.0	<2.4	4.00	<1.00
01481000 BRANDYWINE CREEK AT CHADDS FORD, PA (LAT 39 52 11N LONG 075 35 37W)									
APR 1998									
27...	.01	3.35	.080	.090	.101	4.0	<2.4	2.00	5.00
JUL									
23...	.04	2.59	.060	.080	.103	--	<2.4	<2.00	3.00
SEP									
15...	<.01	3.02	.073	.115	.130	7.0	5.9	<2.00	11.0

Remark Codes Used in This report:
- < -- Less than
- > -- Greater than

APPENDIX 2

SIMULATED AND OBSERVED STREAMFLOW AND WATER QUALITY FOR SELECTED STORMS AT SIX MONITORING SITES IN THE BRANDYWINE CREEK BASIN

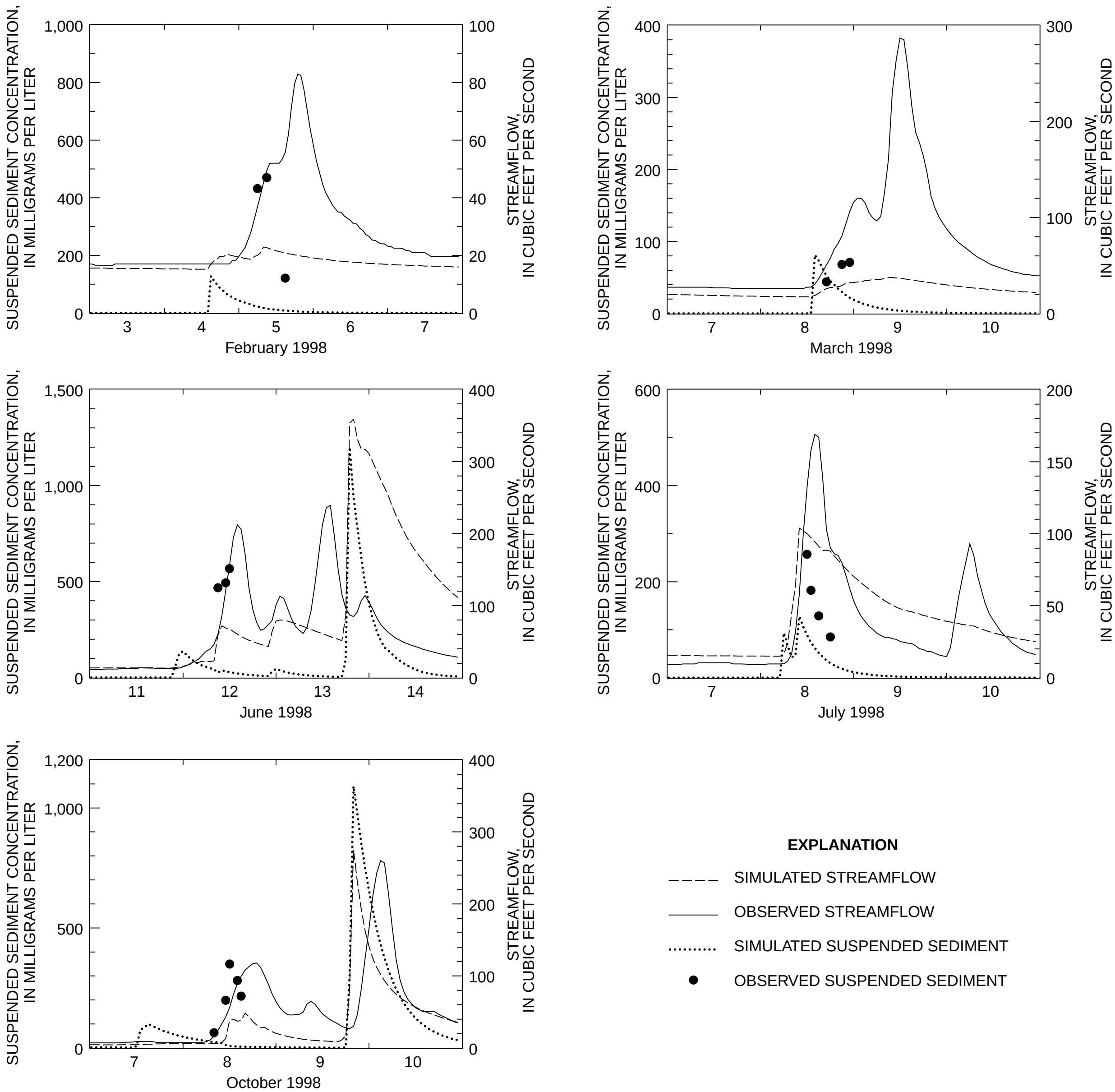

Figure 1. Simulated and observed streamflow and suspended sediment concentrations during five storms in 1998 at streamflow-measurement station 01480300, West Branch Brandywine Creek at Honey Brook, Pa.

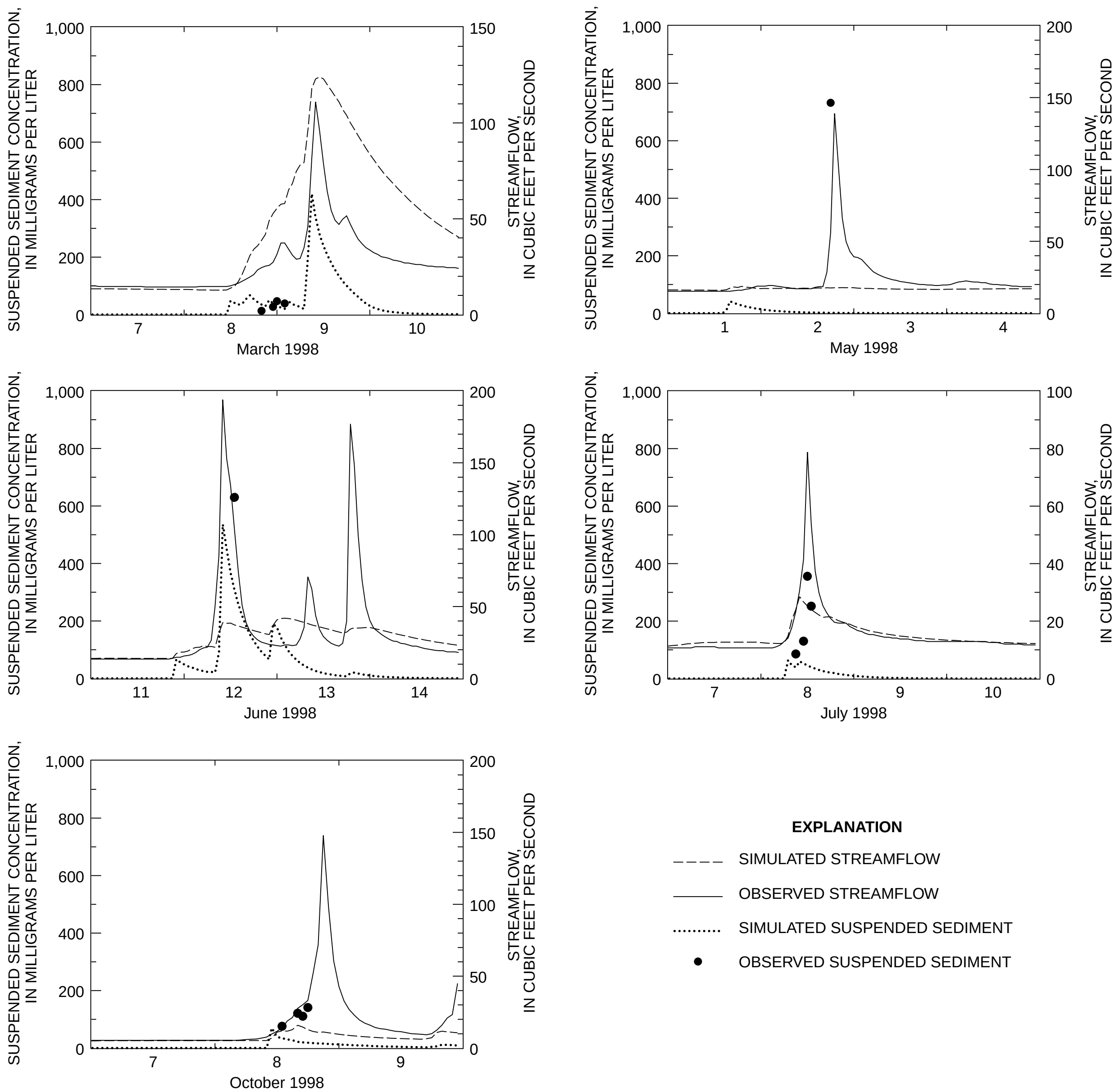

Figure 2. Simulated and observed streamflow and suspended sediment concentrations during five storms in 1998 at streamflow-measurement station 014806318, Doe Run at Springdell, Pa.

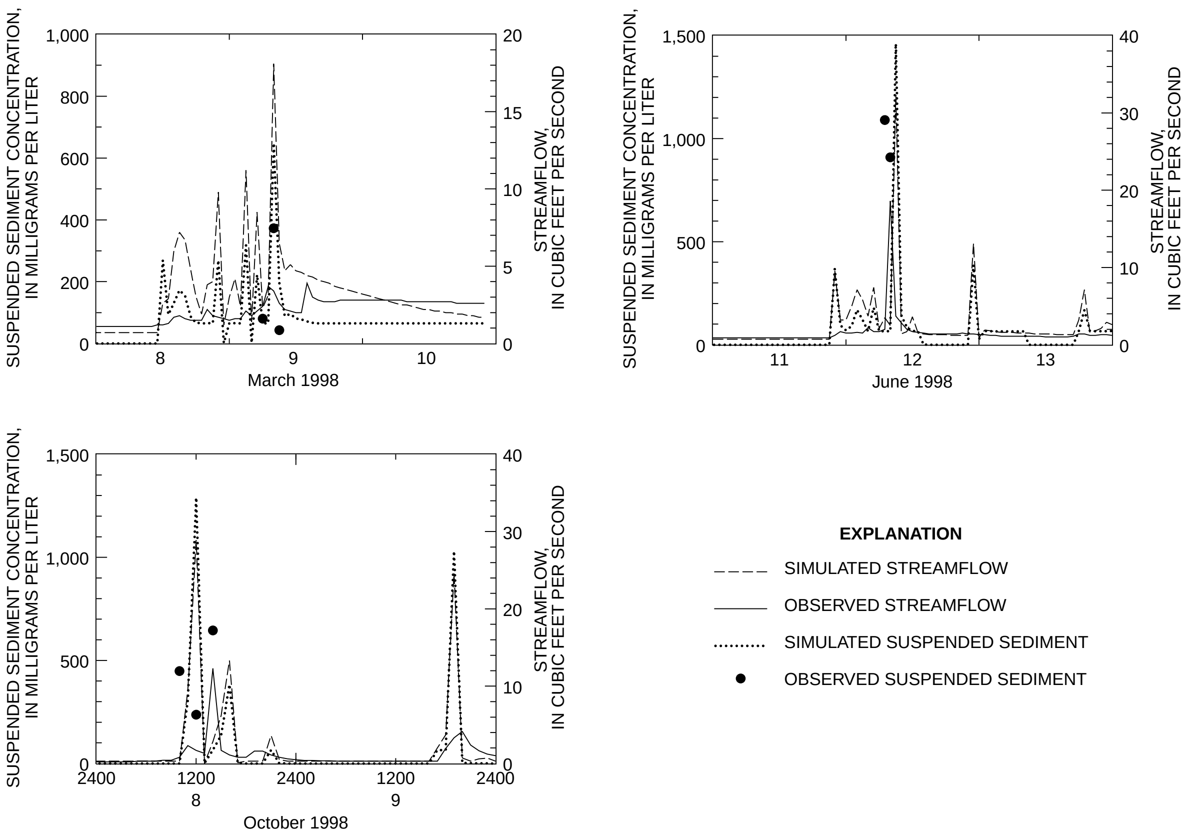

Figure 3. Simulated and observed streamflow and suspended sediment concentrations during three storms in 1998 at streamflow-measurement station 01480637, Little Broad Run near Marshallton, Pa.

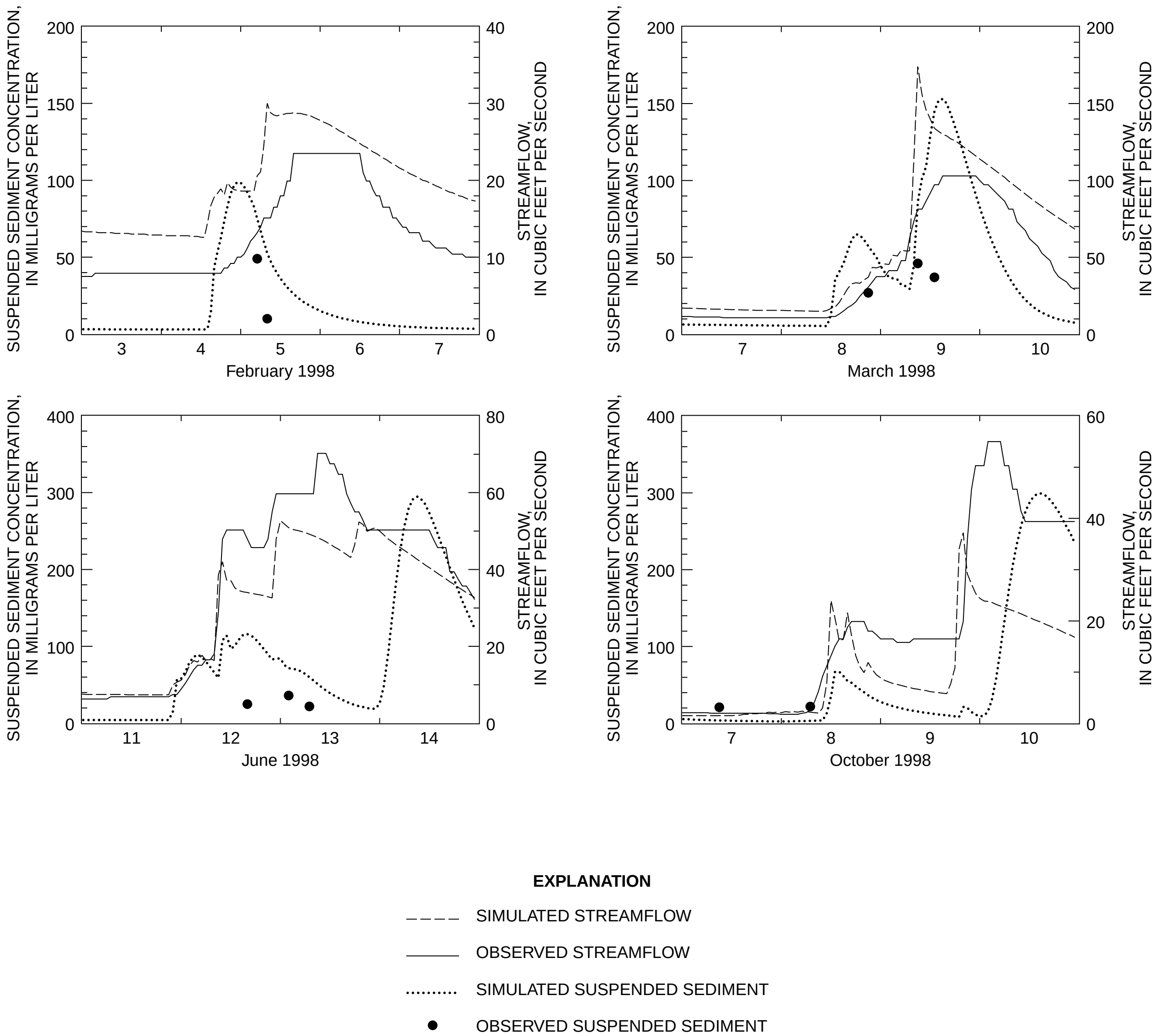

Figure 4. Simulated and observed streamflow and suspended sediment concentrations during four storms in 1998 at streamflow-measurement station 01480675, Marsh Creek near Glenmoore, Pa.

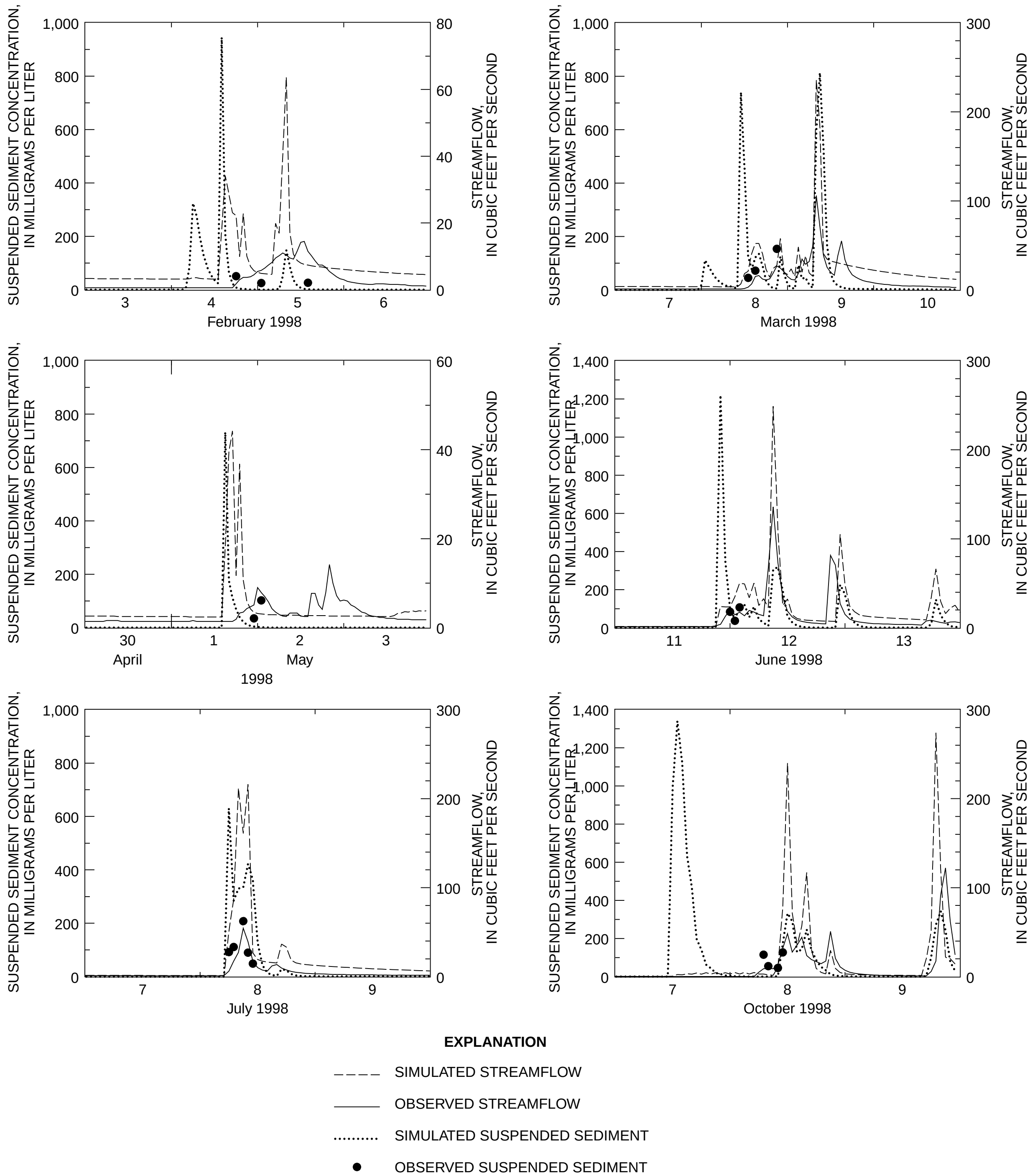

Figure 5. Simulated and observed streamflow and suspended sediment concentrations during six storms in 1998 at streamflow-measurement station 01480878, Unnamed Tributary to Valley Creek near Exton, Pa

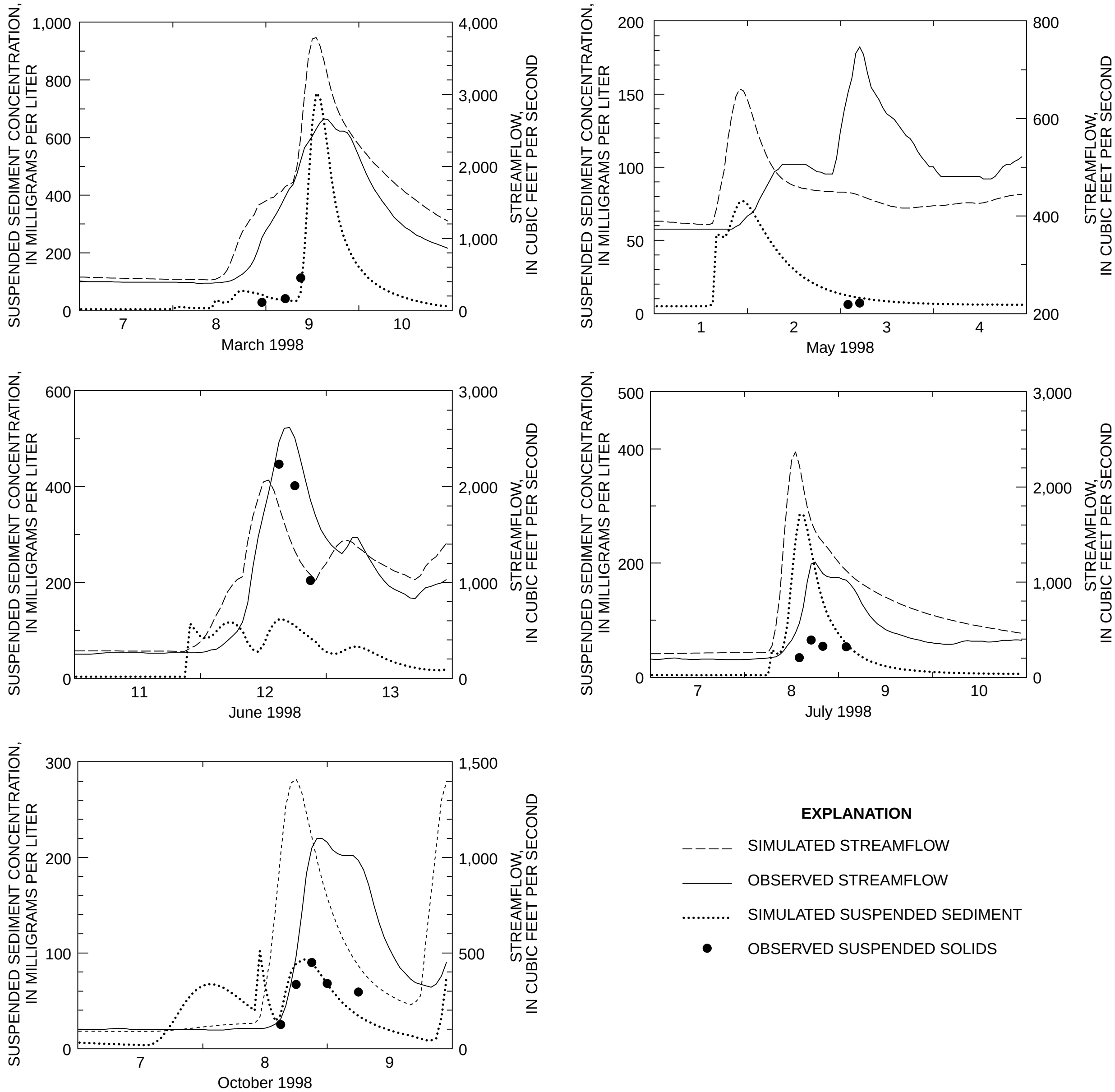

Figure 6. Simulated and observed streamflow and suspended sediment concentrations during five storms in 1998 at streamflow-measurement station 01481000, Brandywine Creek at Chadds Ford, Pa.

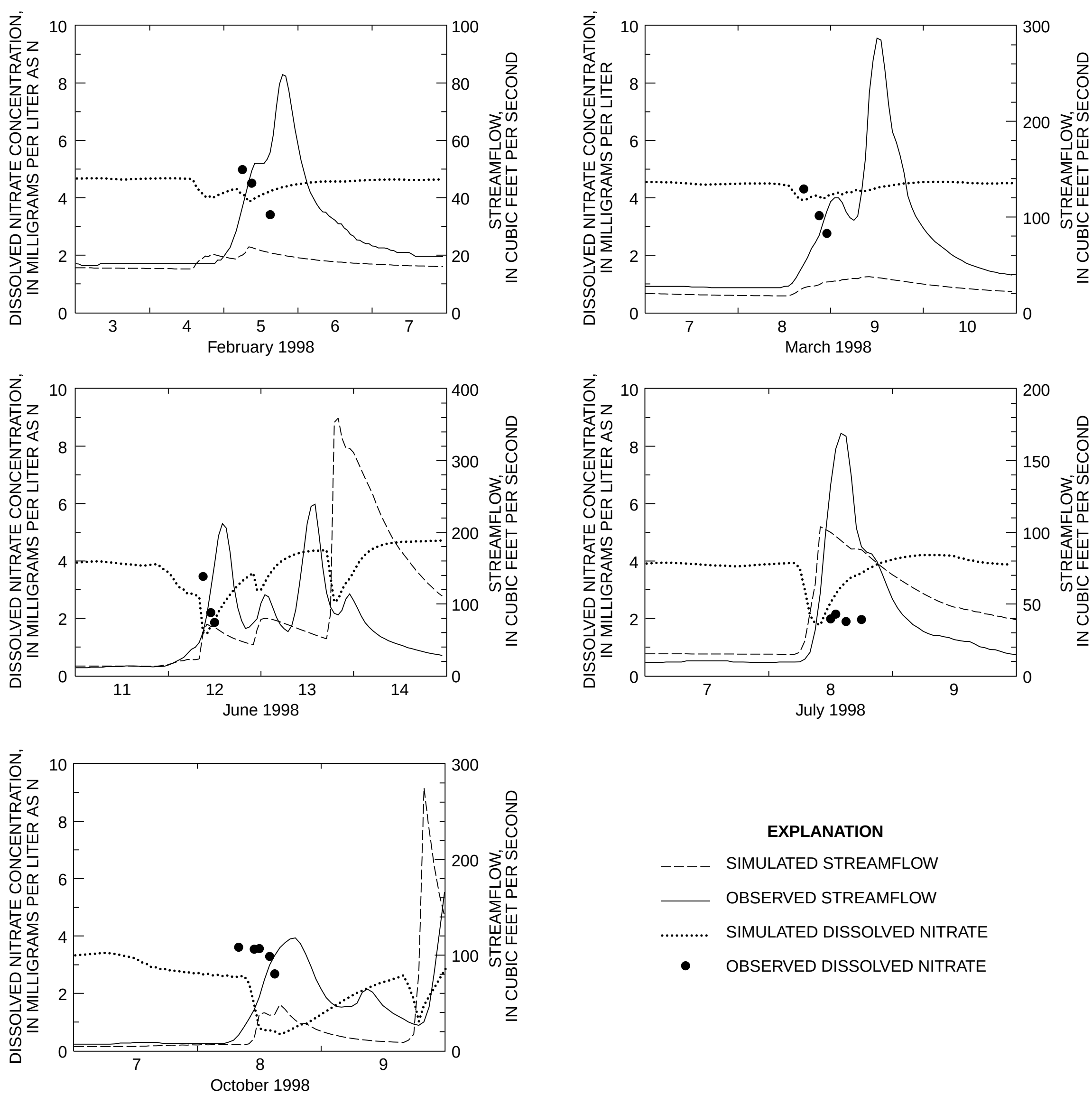

Figure 7. Simulated and observed streamflow and dissolved nitrate concentrations during five storms in 1998 at streamflow-measurement station 01480300, West Branch Brandywine Creek at Honey Brook, Pa

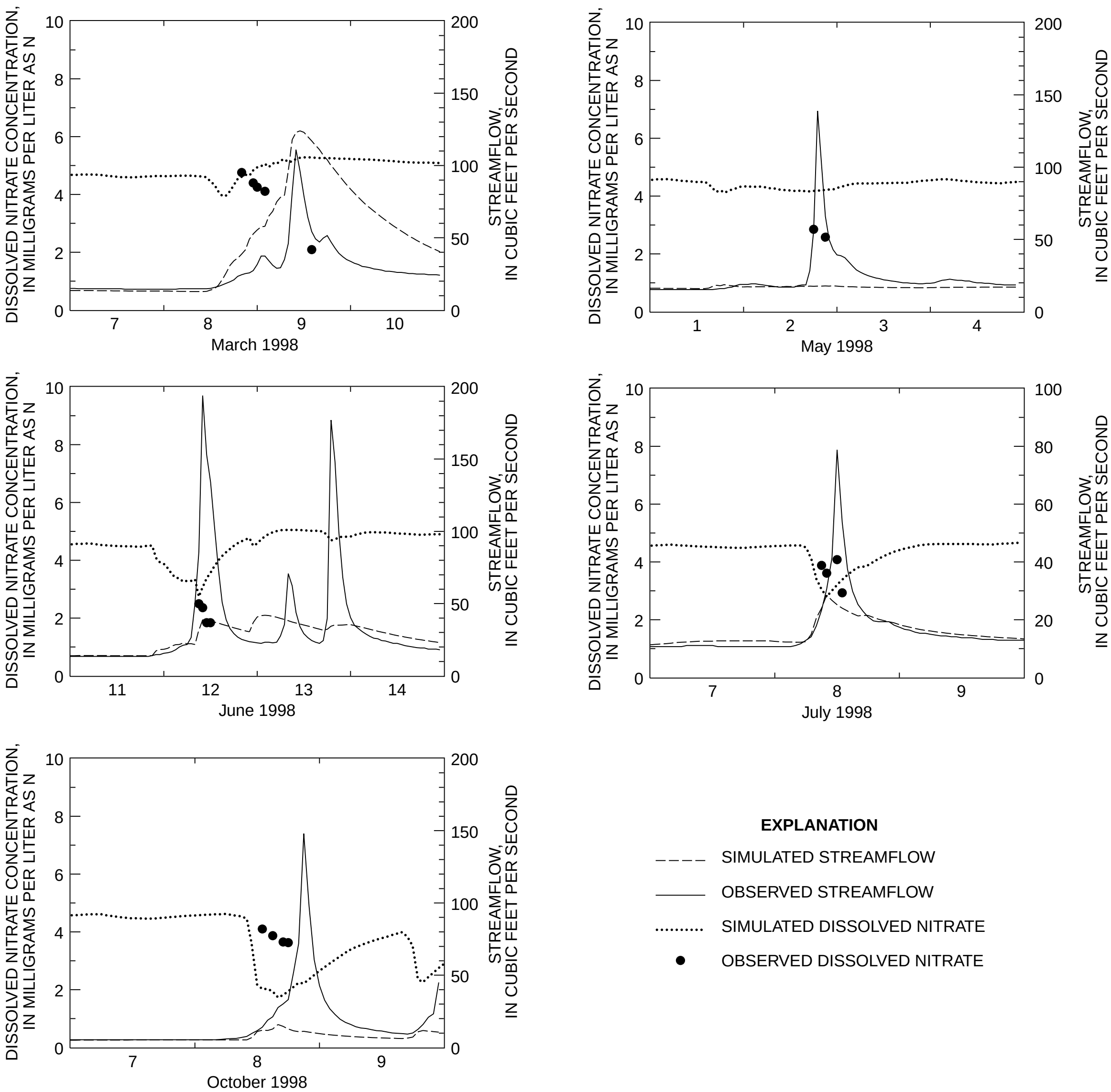

Figure 8. Simulated and observed streamflow and dissolved nitrate concentrations during five storms in 1998 at streamflow-measurement station 014806318, Doe Run at Springdell, Pa.

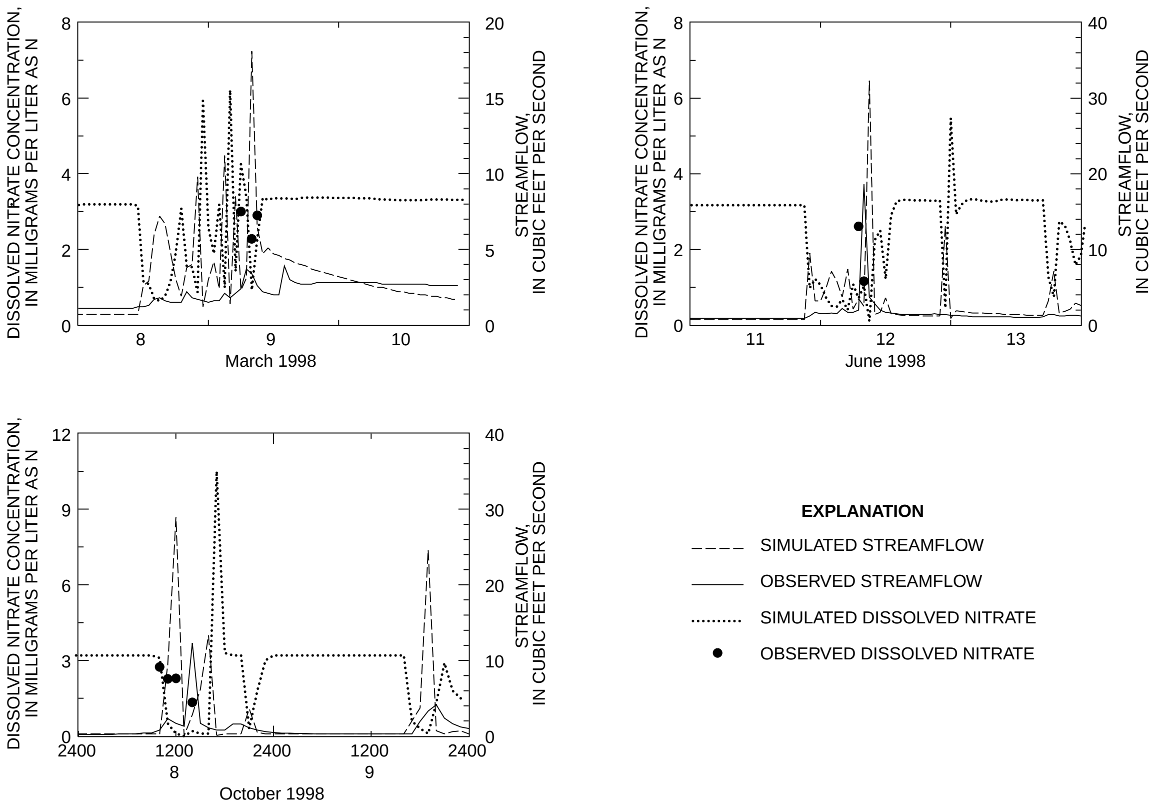

Figure 9. Simulated and observed streamflow and dissolved nitrate concentrations during three storms in 1998 at streamflow-measurement station 01480637, Little Broad Run near Marshallton, Pa.

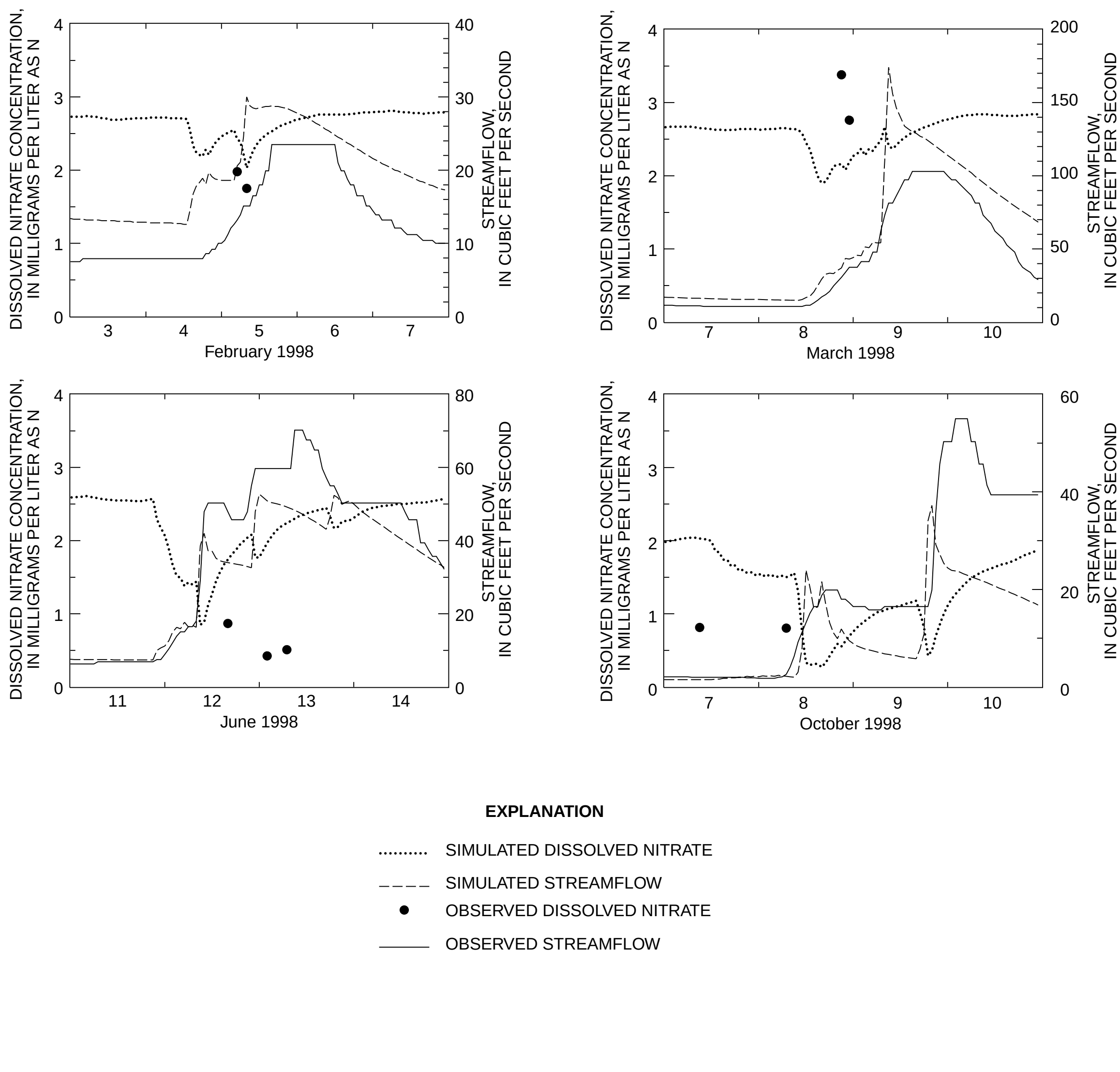

Figure 10. Simulated and observed streamflow and dissolved nitrate concentrations during four storms in 1998 at streamflow-measurement station 01480675, Marsh Creek near Glenmoore, Pa

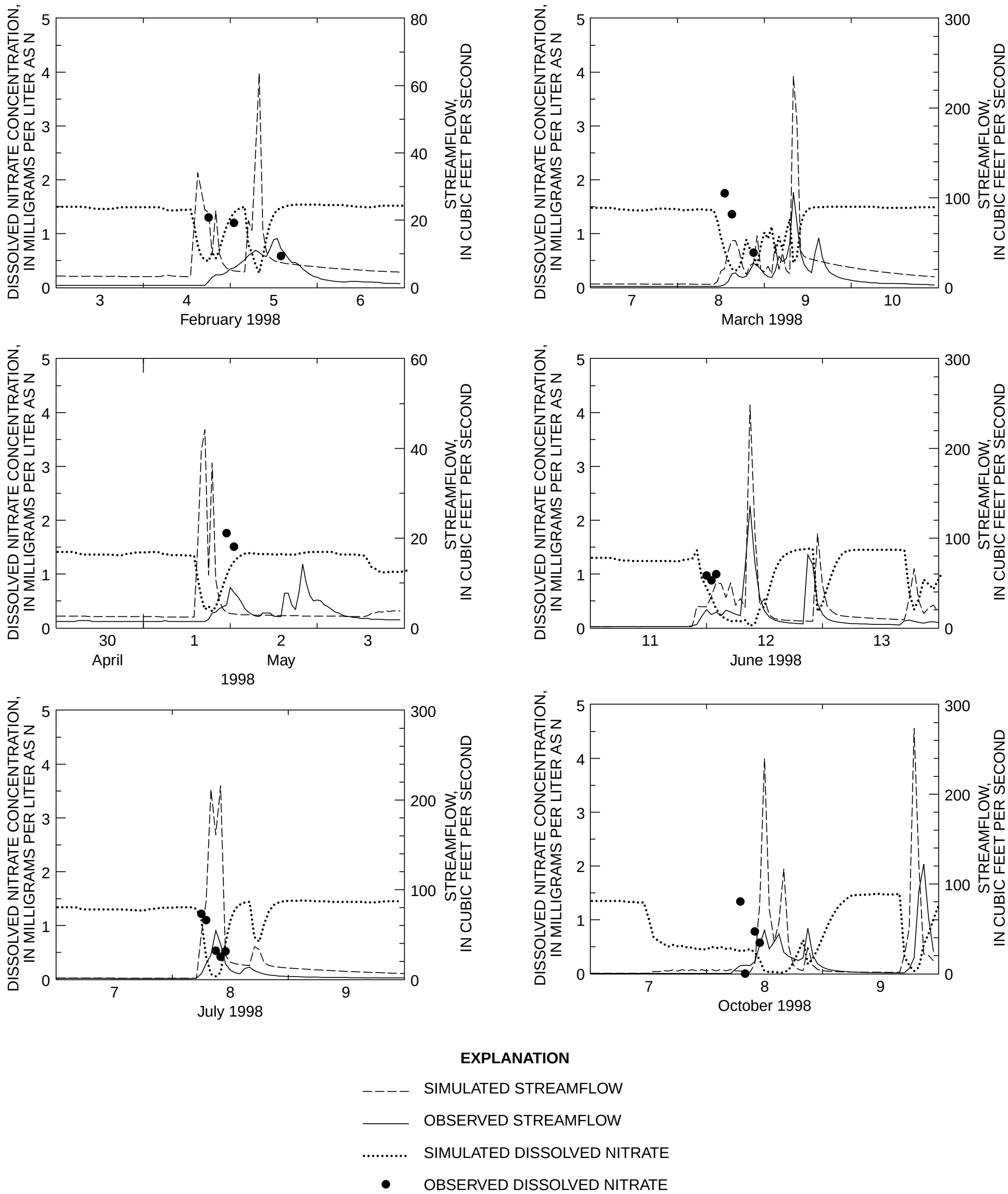

Figure 11. Simulated and observed streamflow and dissolved nitrate concentrations during six storms in 1998 at streamflow-measurement station 01480878, Unnamed Tributary to Valley Creek near Exton, Pa

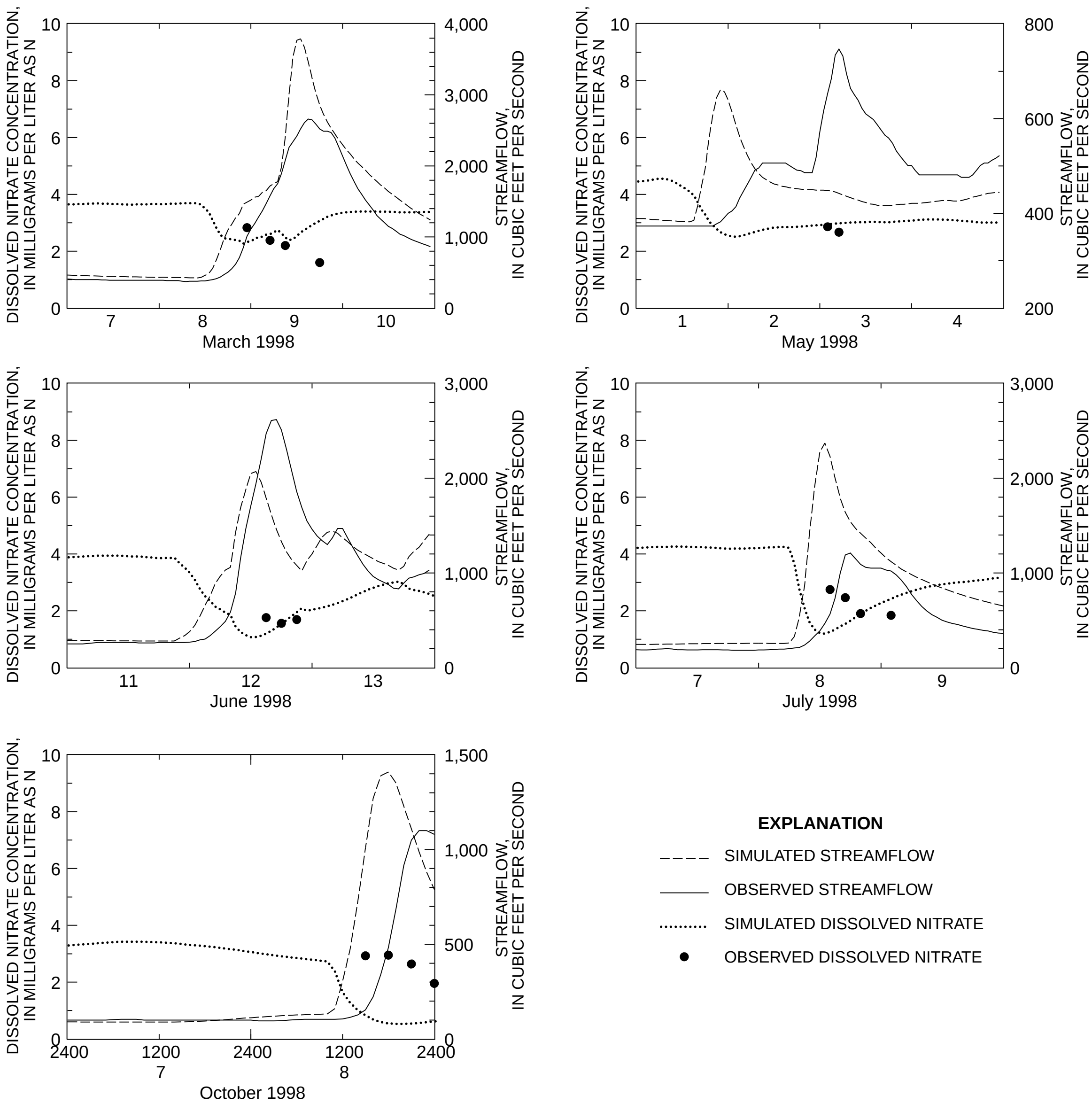

Figure 12. Simulated and observed streamflow and dissolved nitrate concentrations during five storms in 1998 at streamflow-measurement station 01481000, Brandywine Creek at Chadds Ford, Pa.

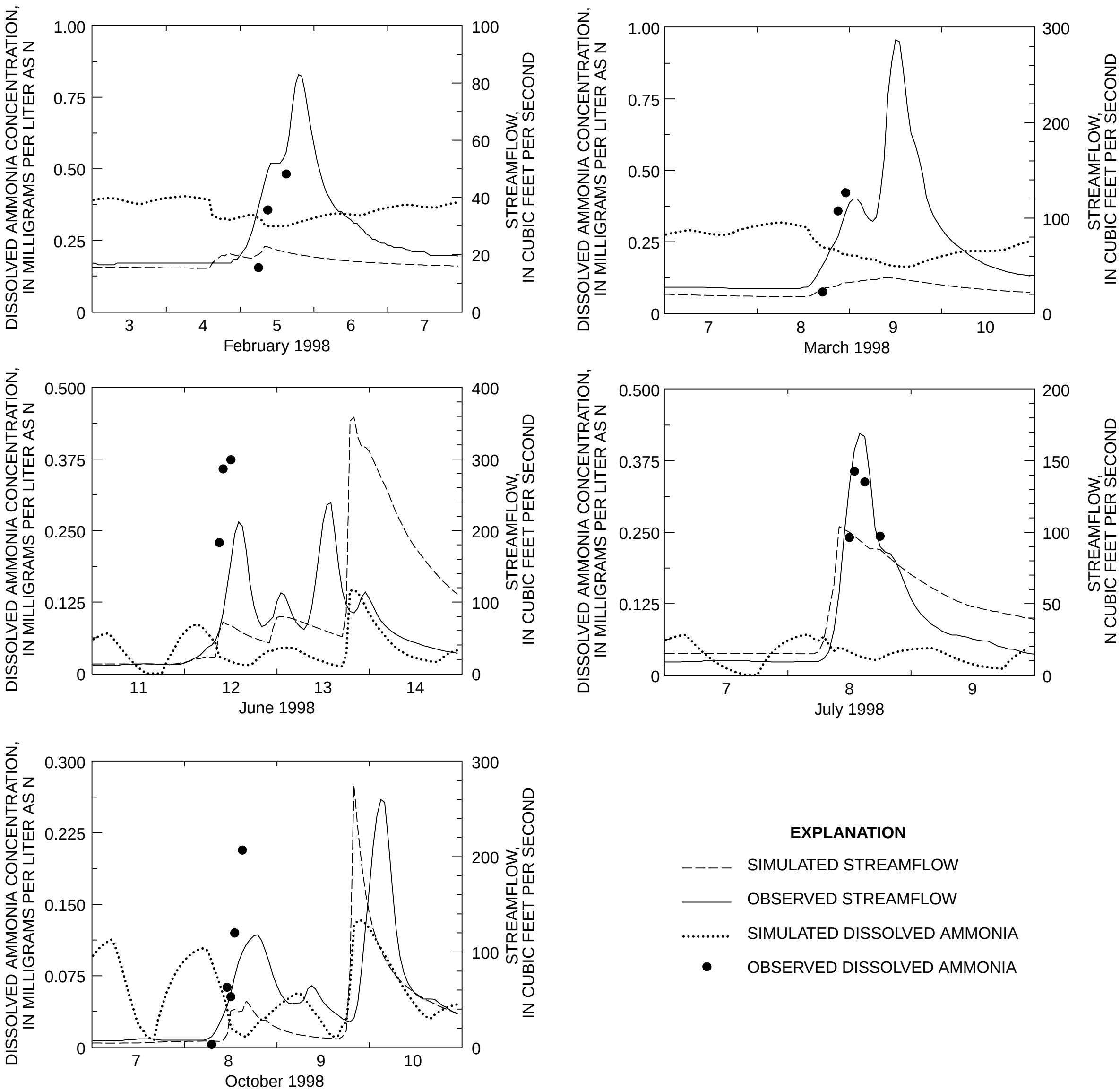

Figure 13. Simulated and observed streamflow and dissolved ammonia concentrations during five storms in 1998 at streamflow-measurement station 01480300, West Branch Brandywine Creek at Honey Brook, Pa.

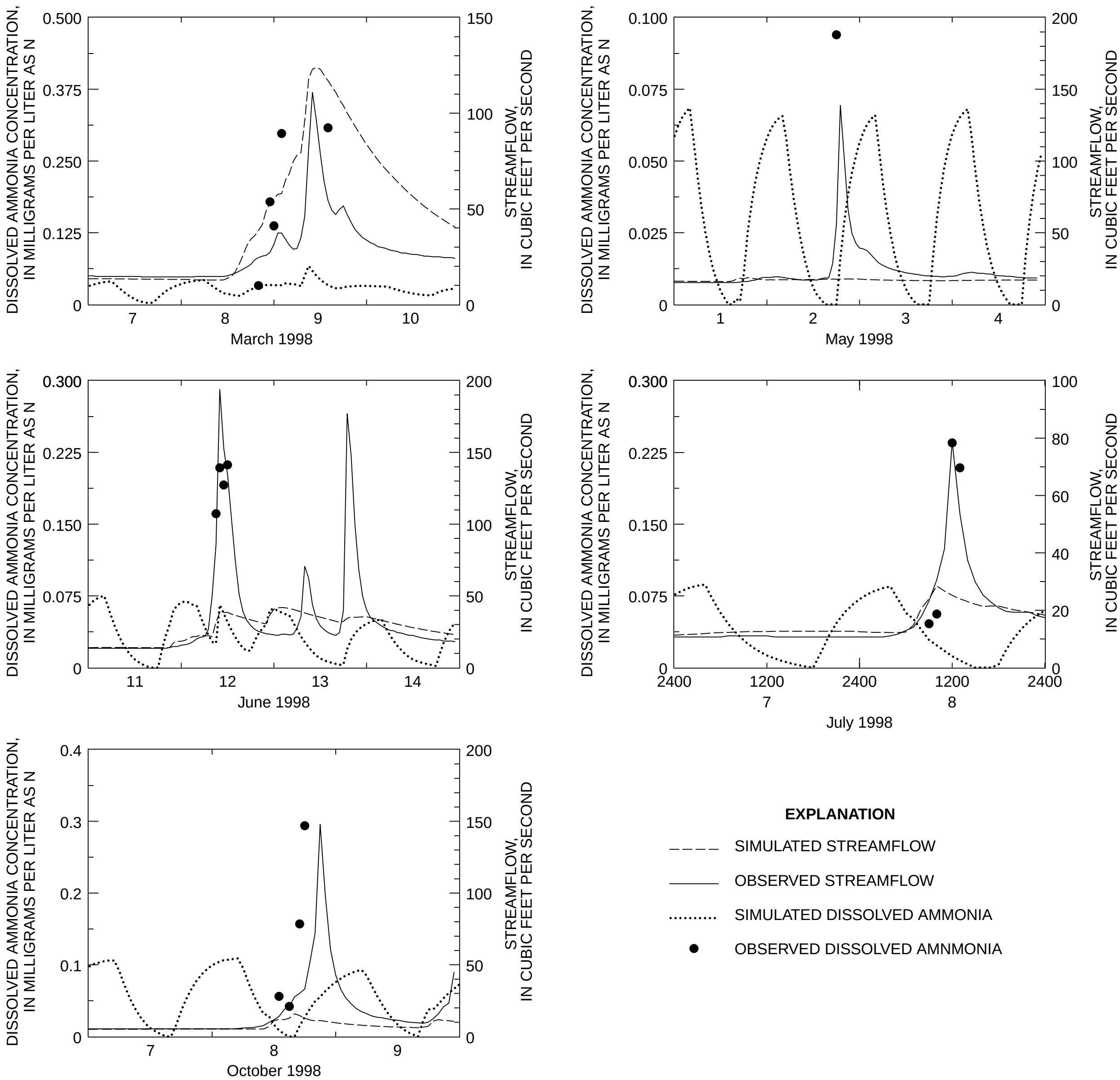

Figure 14. Simulated and observed streamflow and dissolved ammonia concentrations during five storms in 1998 at streamflow-measurement station 014806318, Doe Run at Springdell, Pa.

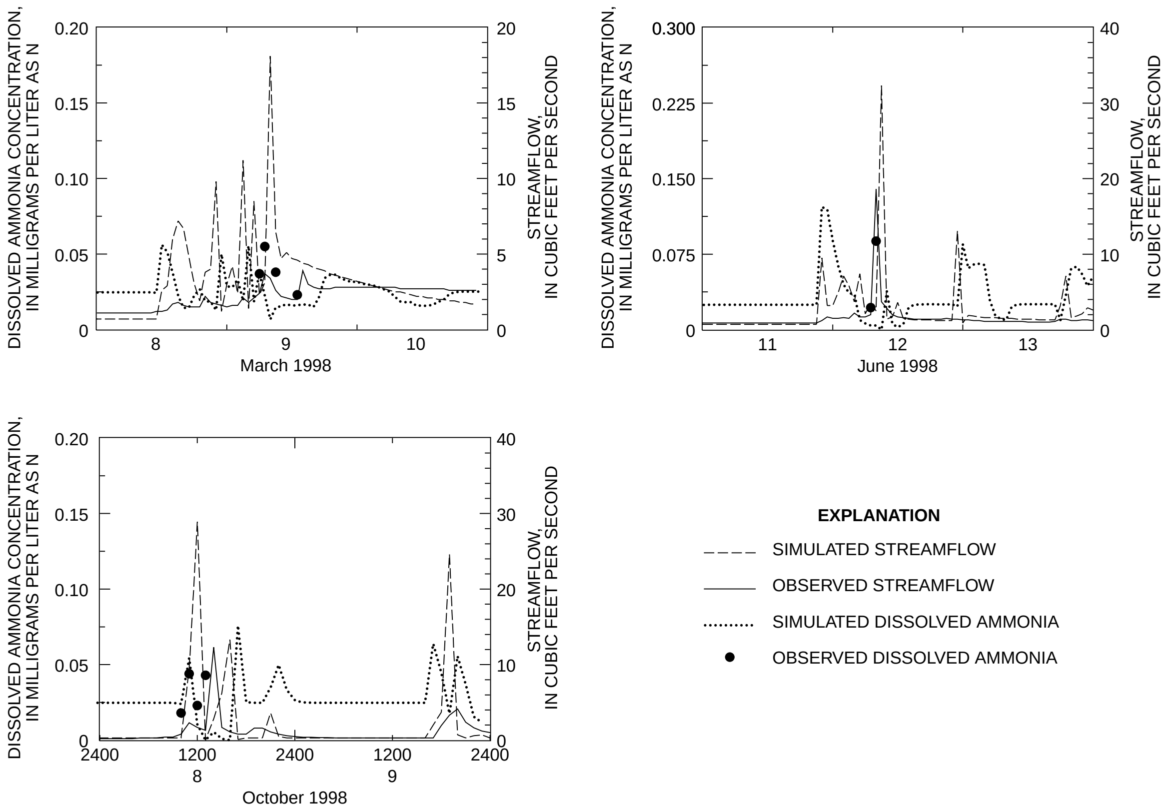

Figure 15. Simulated and observed streamflow and dissolved ammonia concentrations during three storms in 1998 at streamflow-measurement station 01480637, Little Broad Run near Marshallton, Pa.

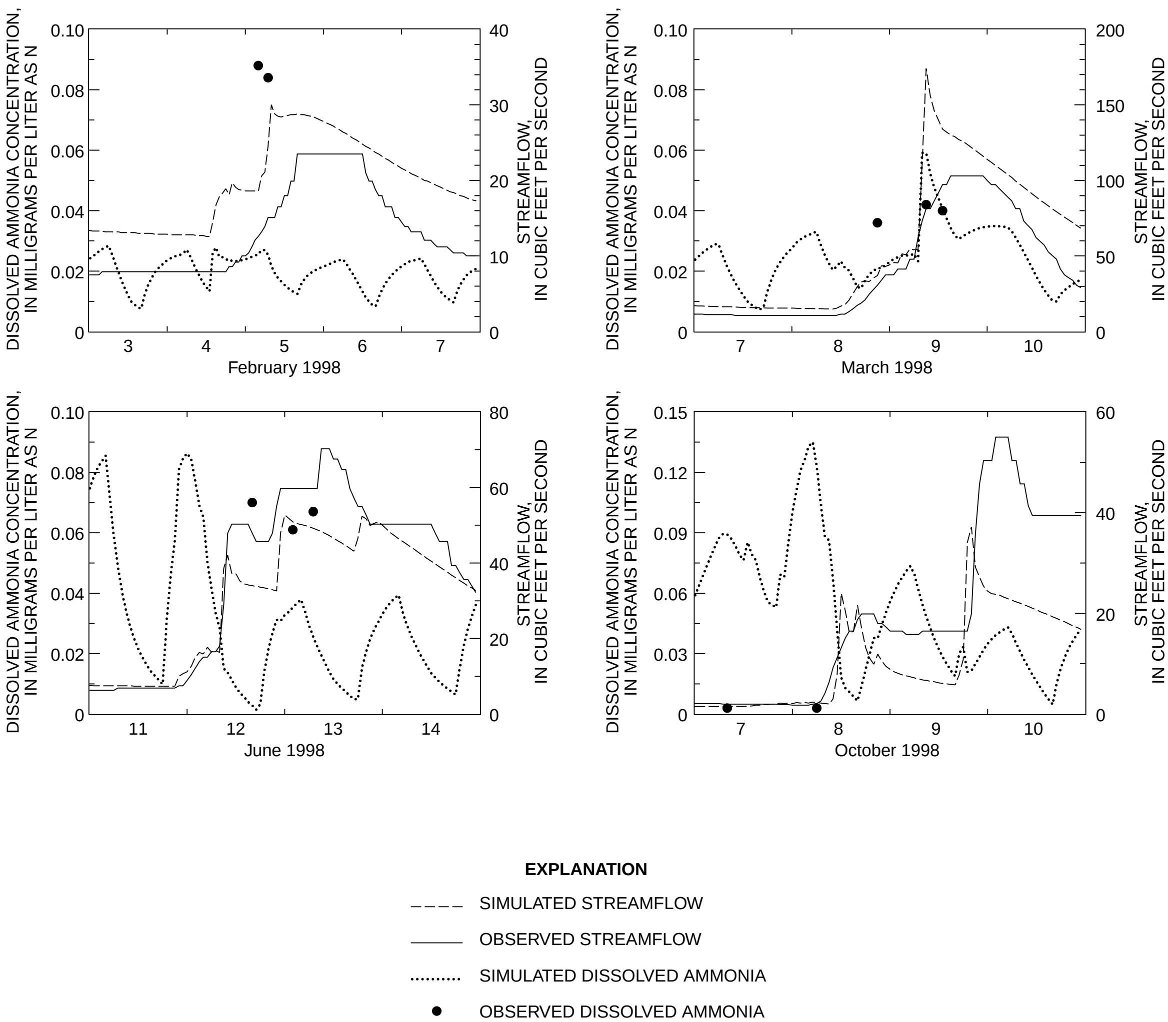

Figure 16. Simulated and observed streamflow and dissolved ammonia concentrations during four storms in 1998 at streamflow-measurement station 01480675, Marsh Creek near Glenmoore, Pa.

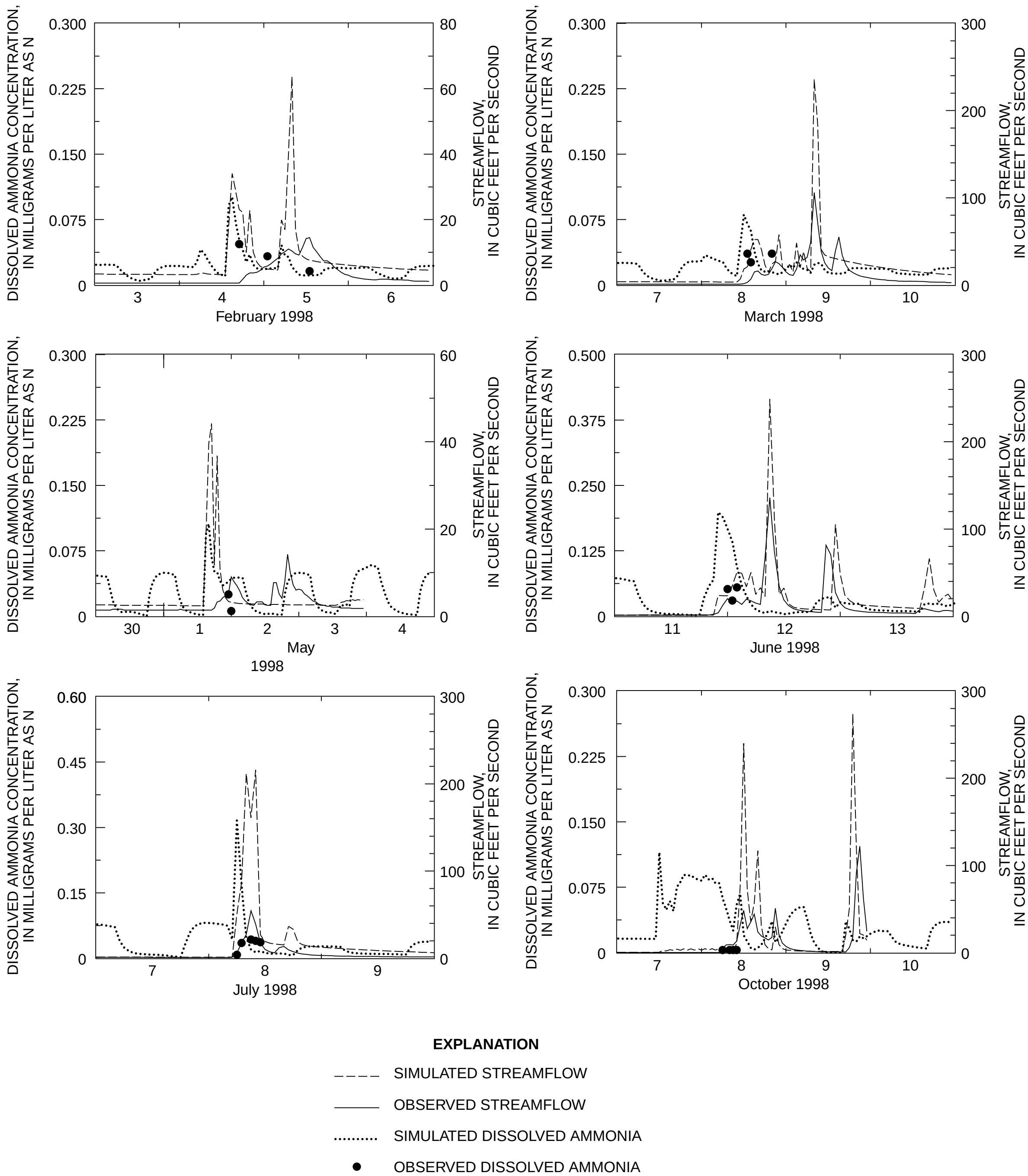

Figure 17. Simulated and observed streamflow and dissolved ammonia concentrations during six storms in 1998 at streamflow-measurement station 01480878, Unnamed Tributary to Valley Creek near Exton, Pa.

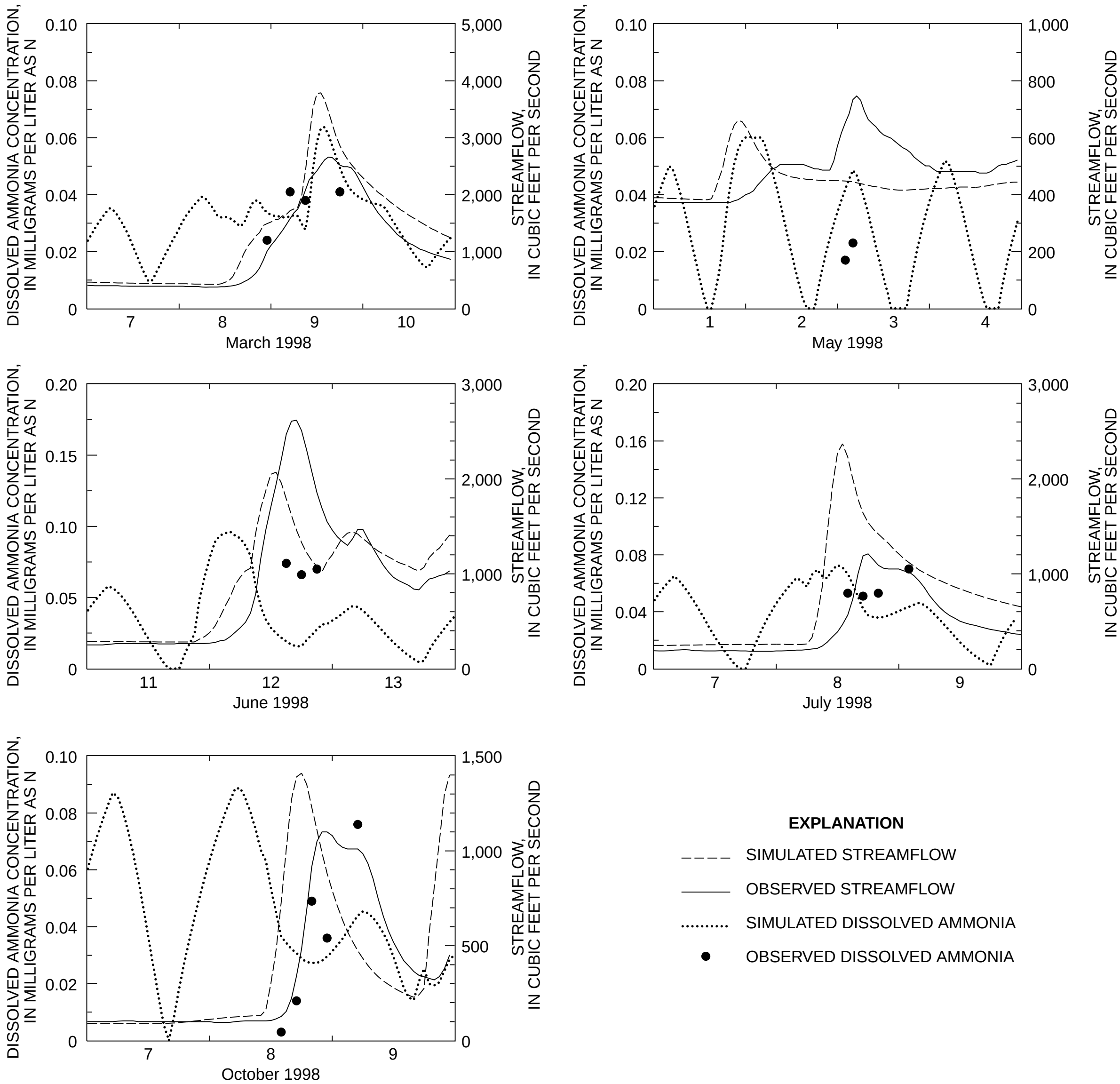

Figure 18. Simulated and observed streamflow and dissolved ammonia concentrations during five storms in 1998 at streamflow-measurement station 01481000, Brandywine Creek at Chadds Ford, Pa.

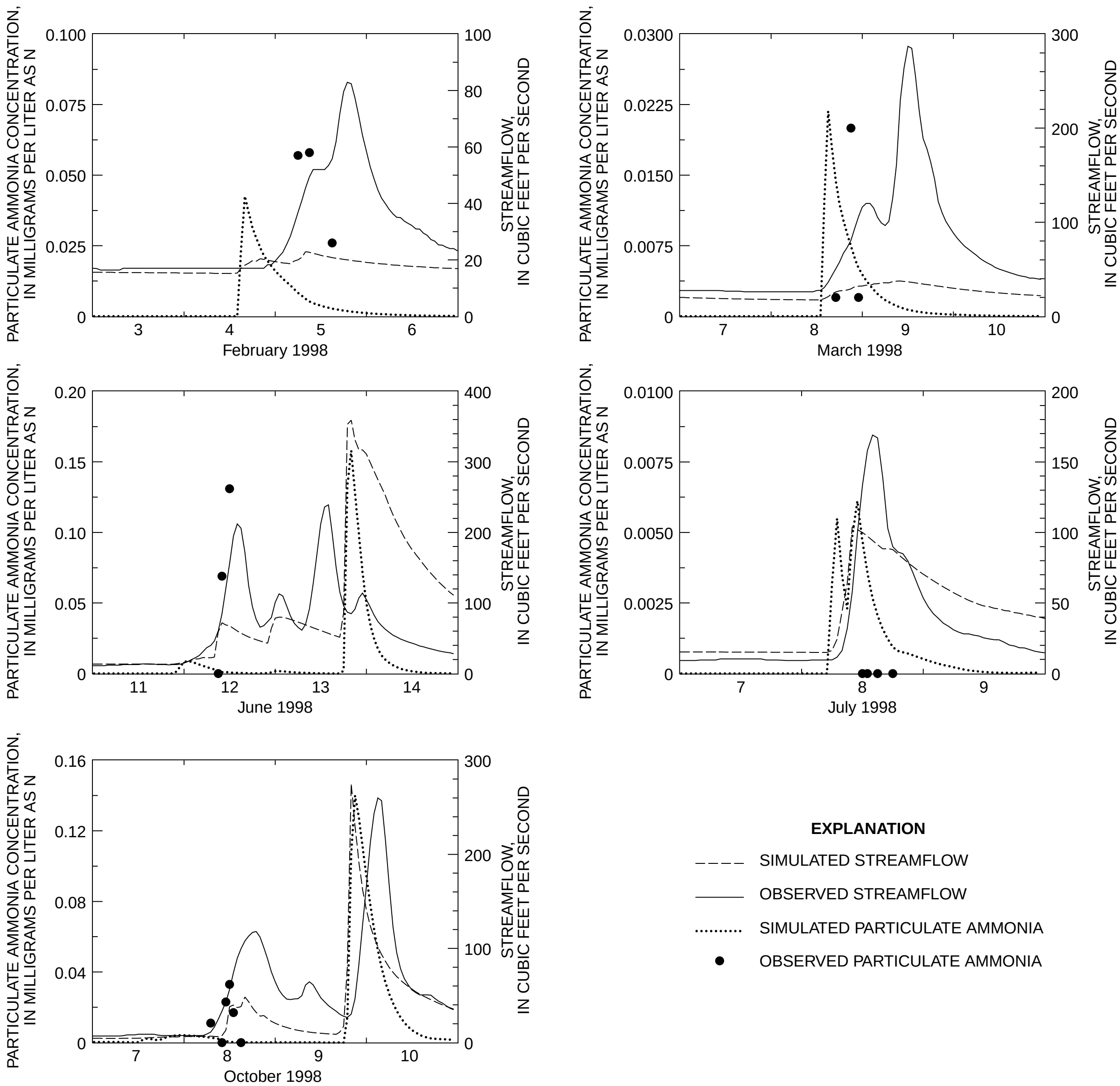

Figure 19. Simulated and observed streamflow and particulate ammonia concentrations during five storms in 1998 at streamflow-measurement station 01480300, West Branch Brandywine Creek at Honey Brook, Pa.

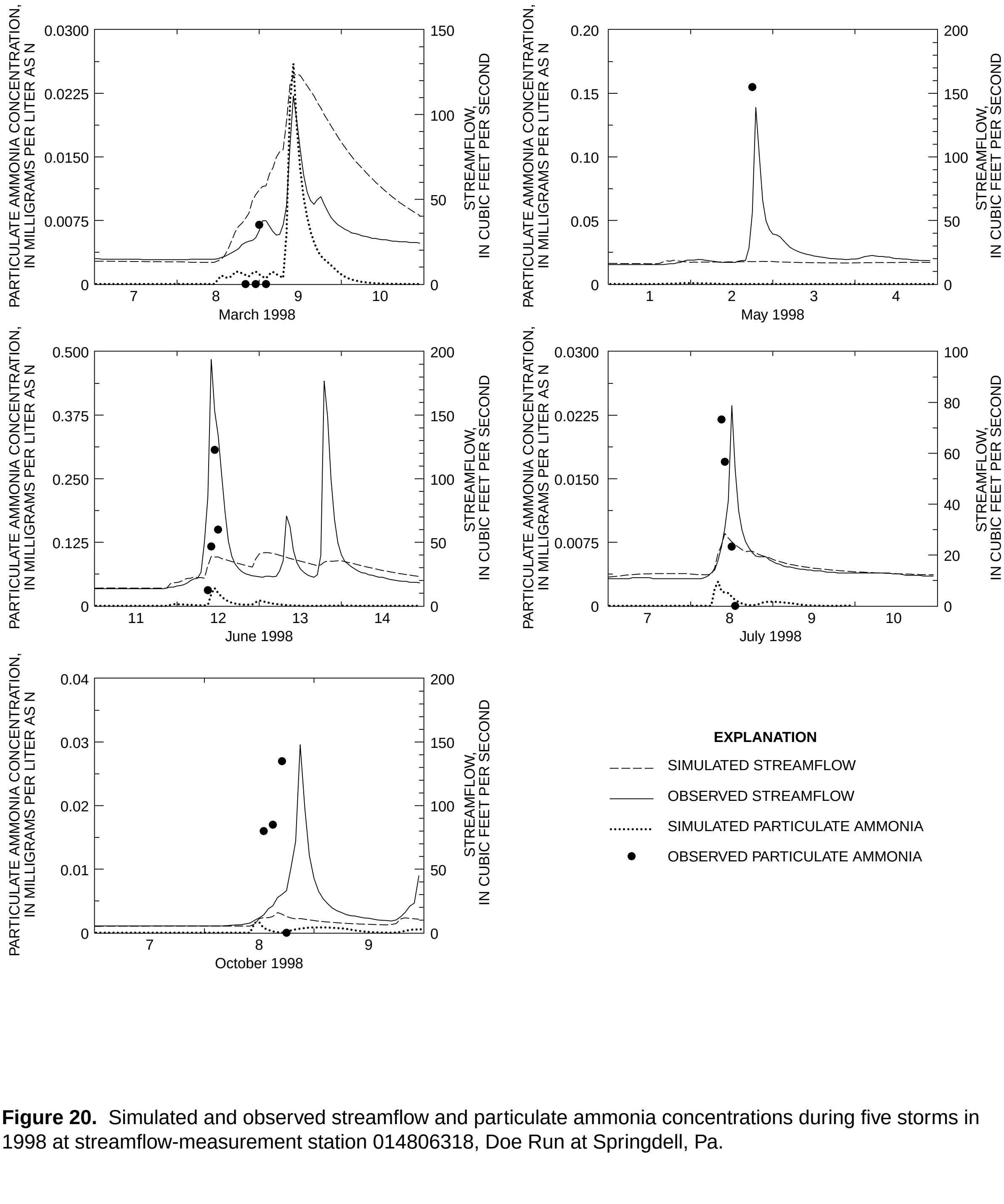

Figure 20. Simulated and observed streamflow and particulate ammonia concentrations during five storms in 1998 at streamflow-measurement station 014806318, Doe Run at Springdell, Pa.

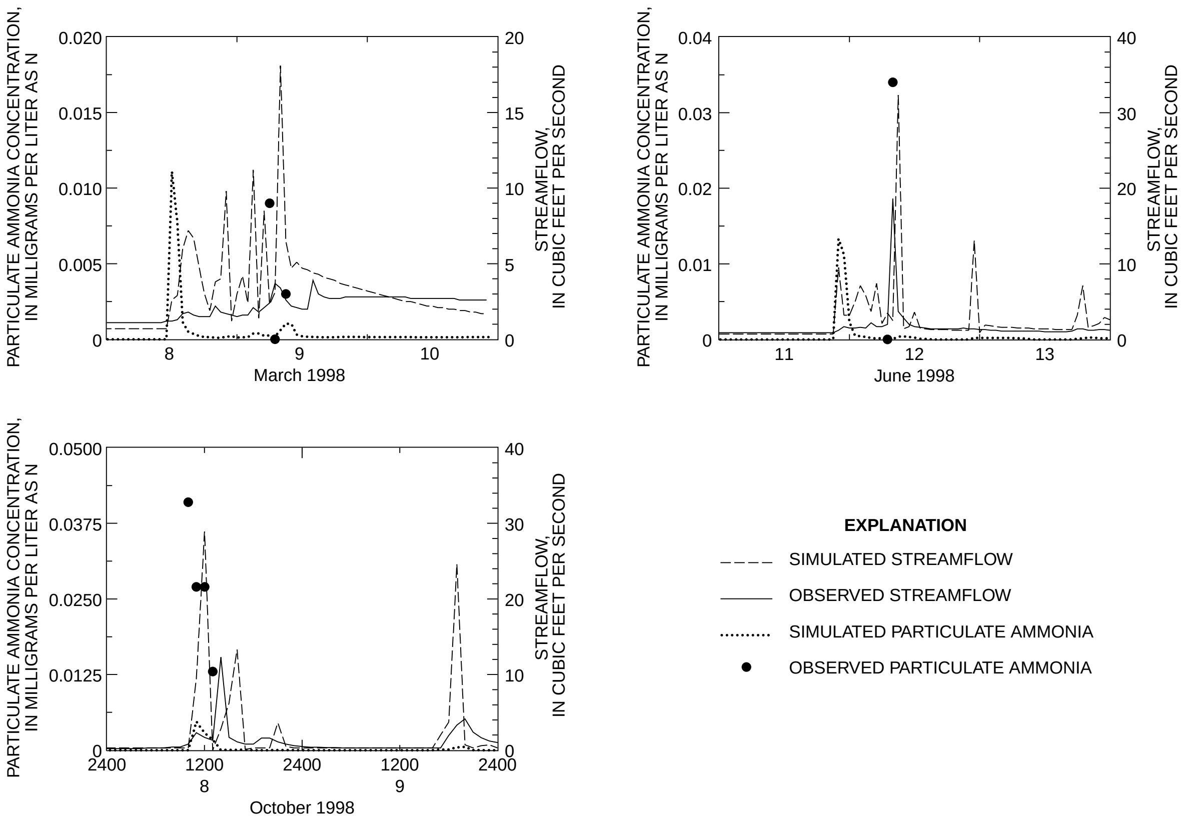

Figure 21. Simulated and observed streamflow and particulate ammonia concentrations during three storms in 1998 at streamflow-measurement station 01480637, Little Broad Run near Marshallton, Pa.

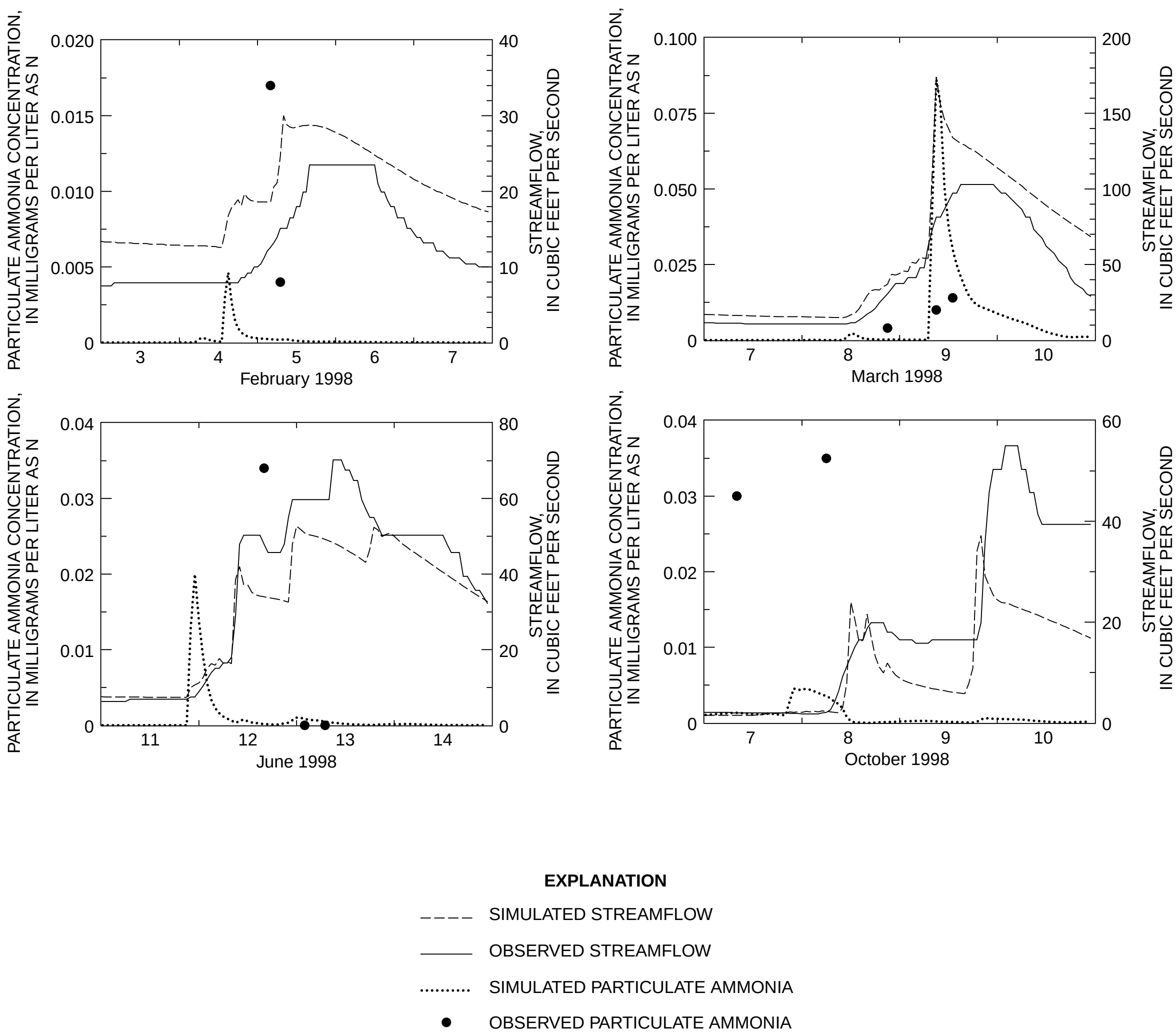

Figure 22. Simulated and observed streamflow and particulate ammonia concentrations during four storms in 1998 at streamflow-measurement station 01480675, Marsh Creek near Glenmoore, Pa.

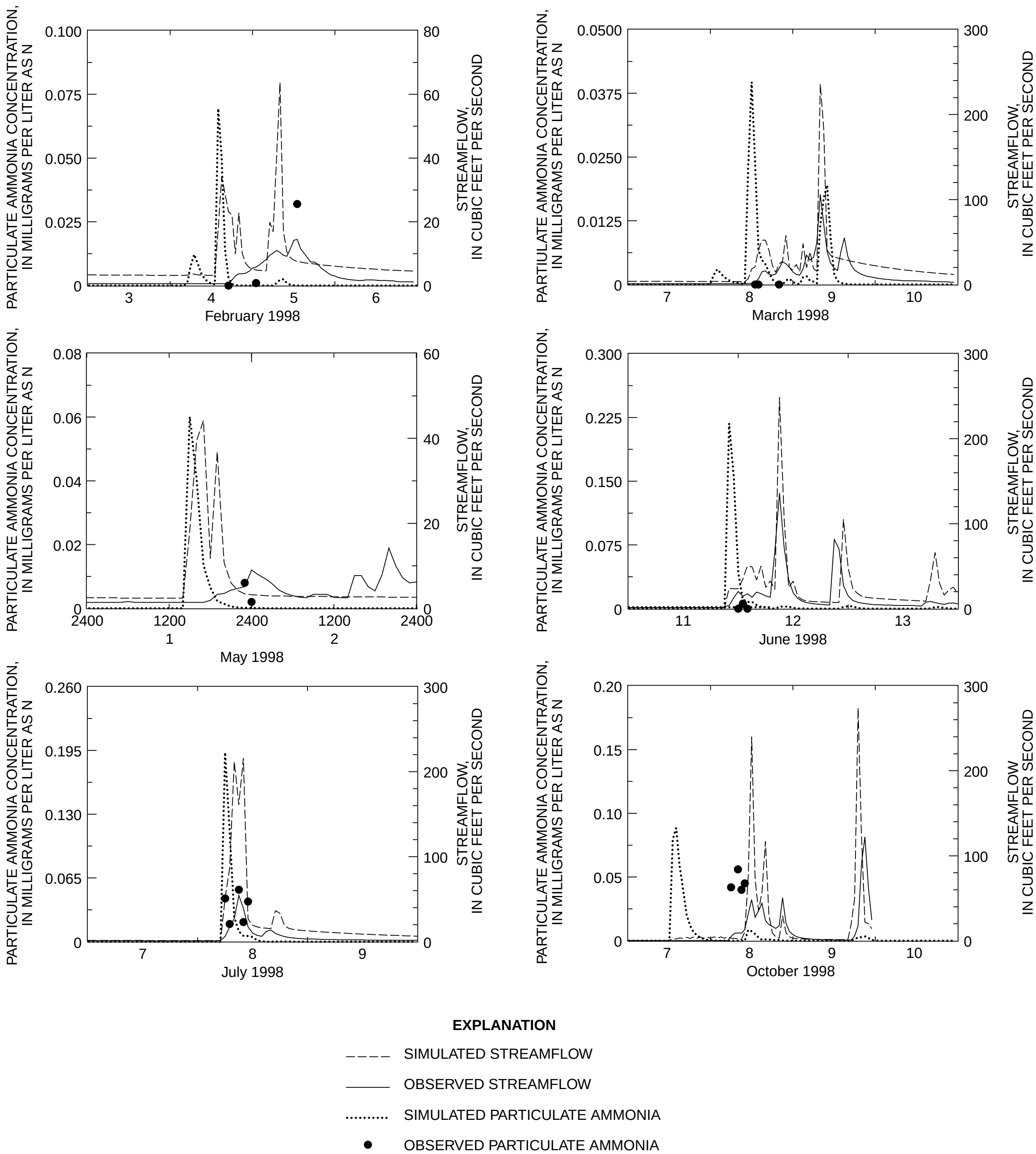

Figure 23. Simulated and observed streamflow and particulate ammonia concentrations during six storms in 1998 at streamflow-measurement station 01480878, Unnamed Tributary to Valley Creek near Exton, Pa.

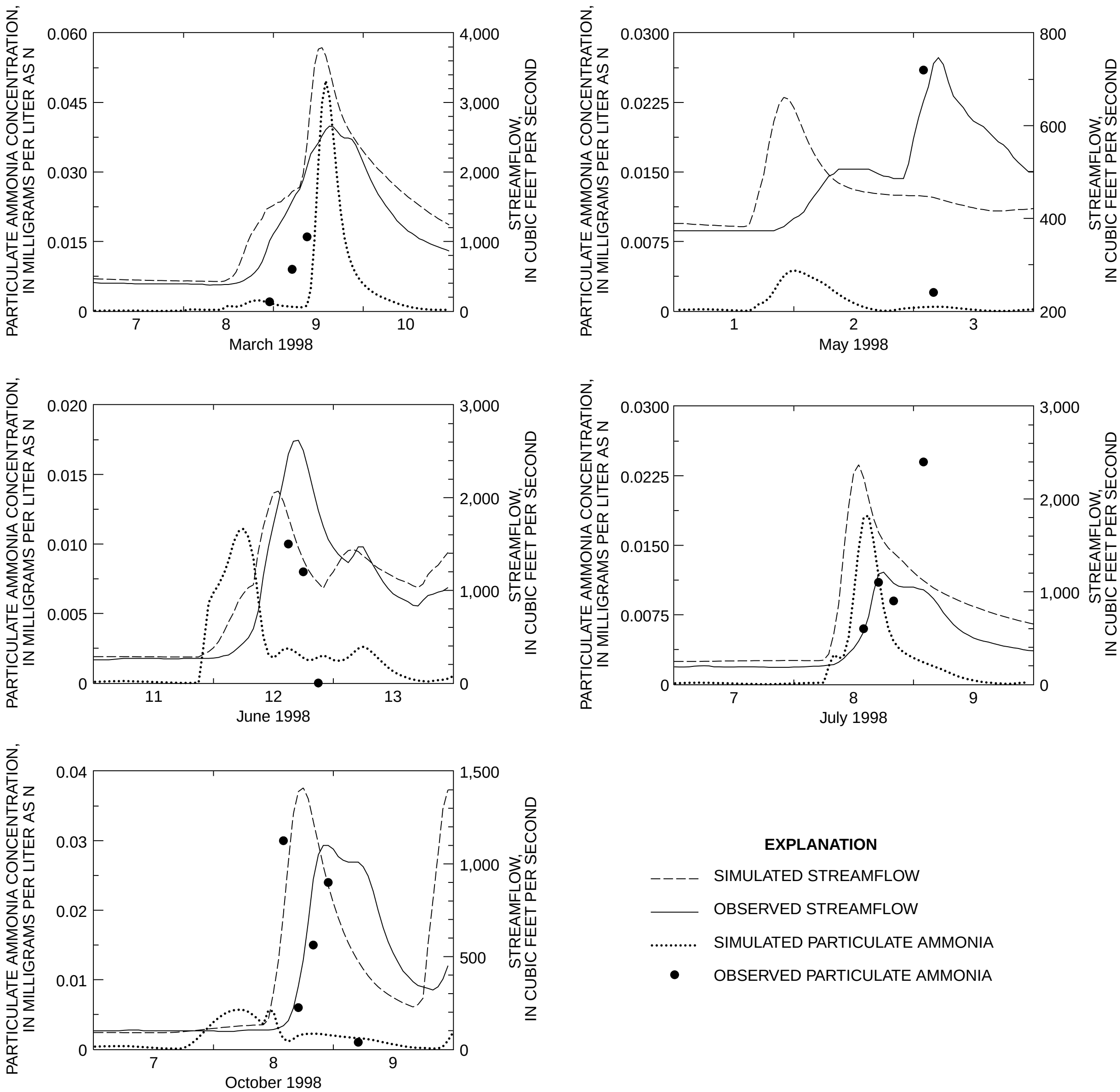

Figure 24. Simulated and observed streamflow and particulate ammonia concentrations during five storms in 1998 at streamflow-measurement station 01481000, Brandywine Creek at Chadds Ford, Pa.

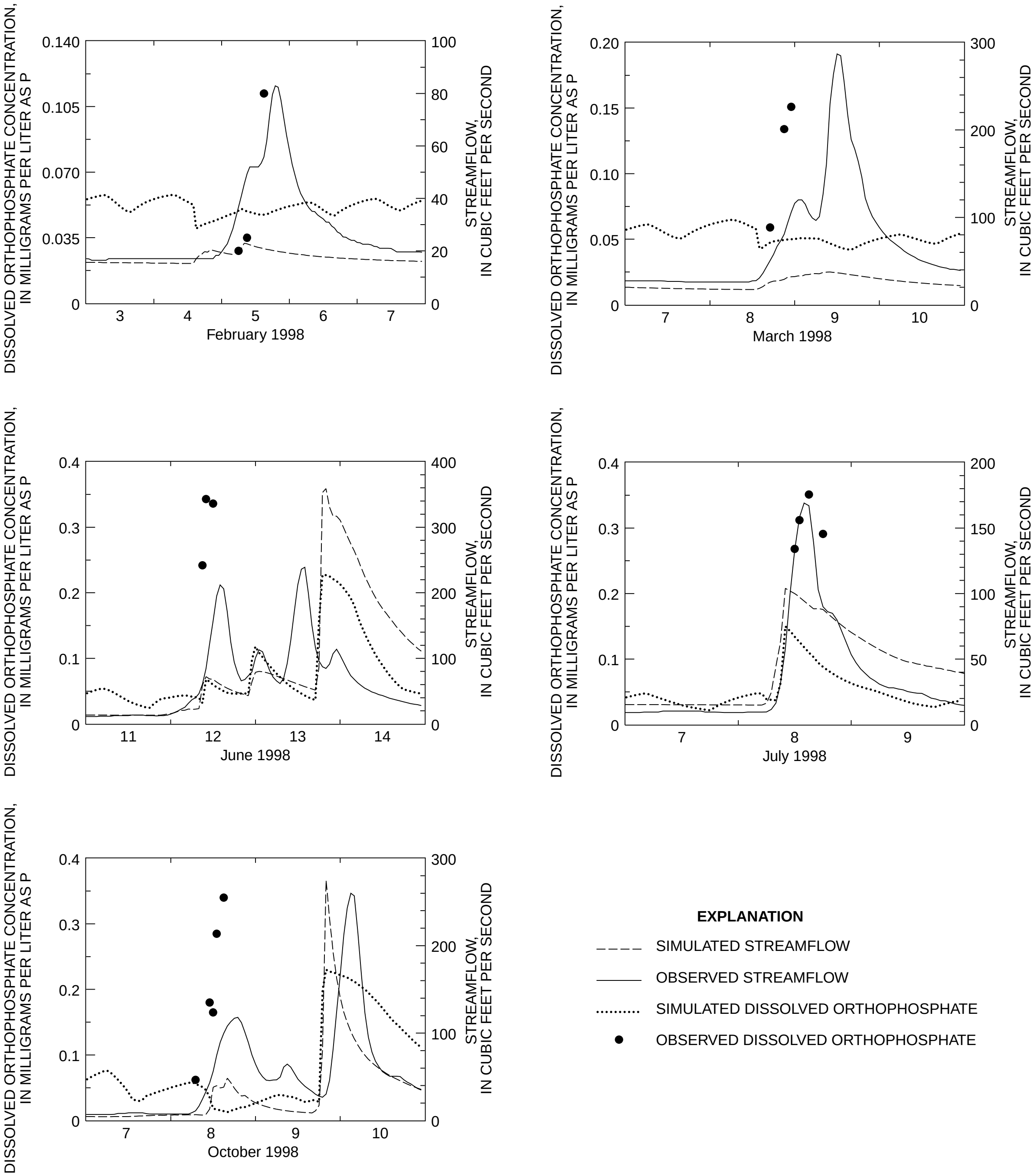

Figure 25. Simulated and observed streamflow and dissolved orthophosphate concentrations during five storms in 1998 at streamflow-measurement station 01480300, West Branch Brandywine Creek at Honey Brook, Pa.

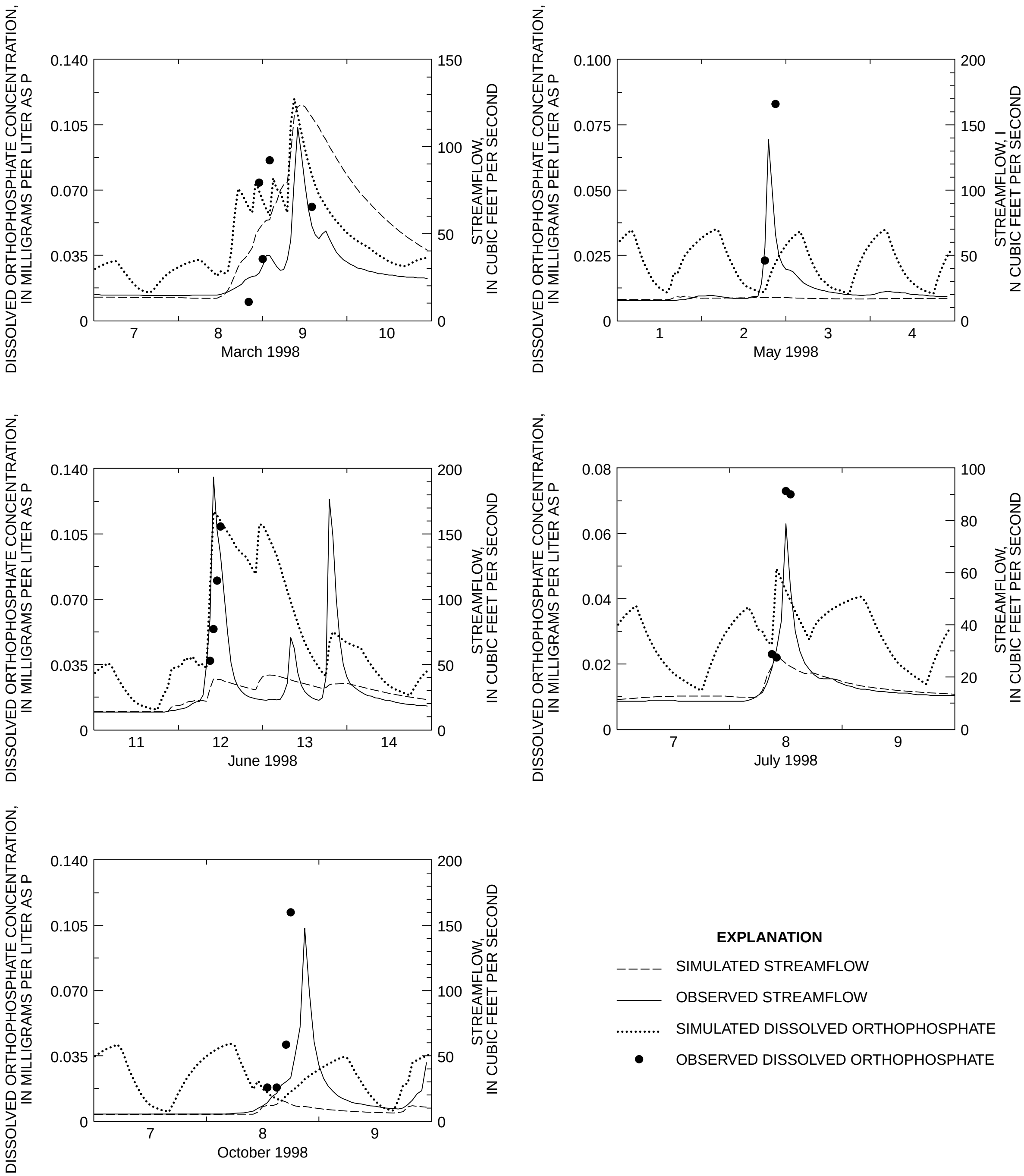

Figure 26. Simulated and observed streamflow and dissolved orthophosphate concentrations during five storms in 1998 at streamflow-measurement station 014806318, Doe Run at Springdell, Pa.

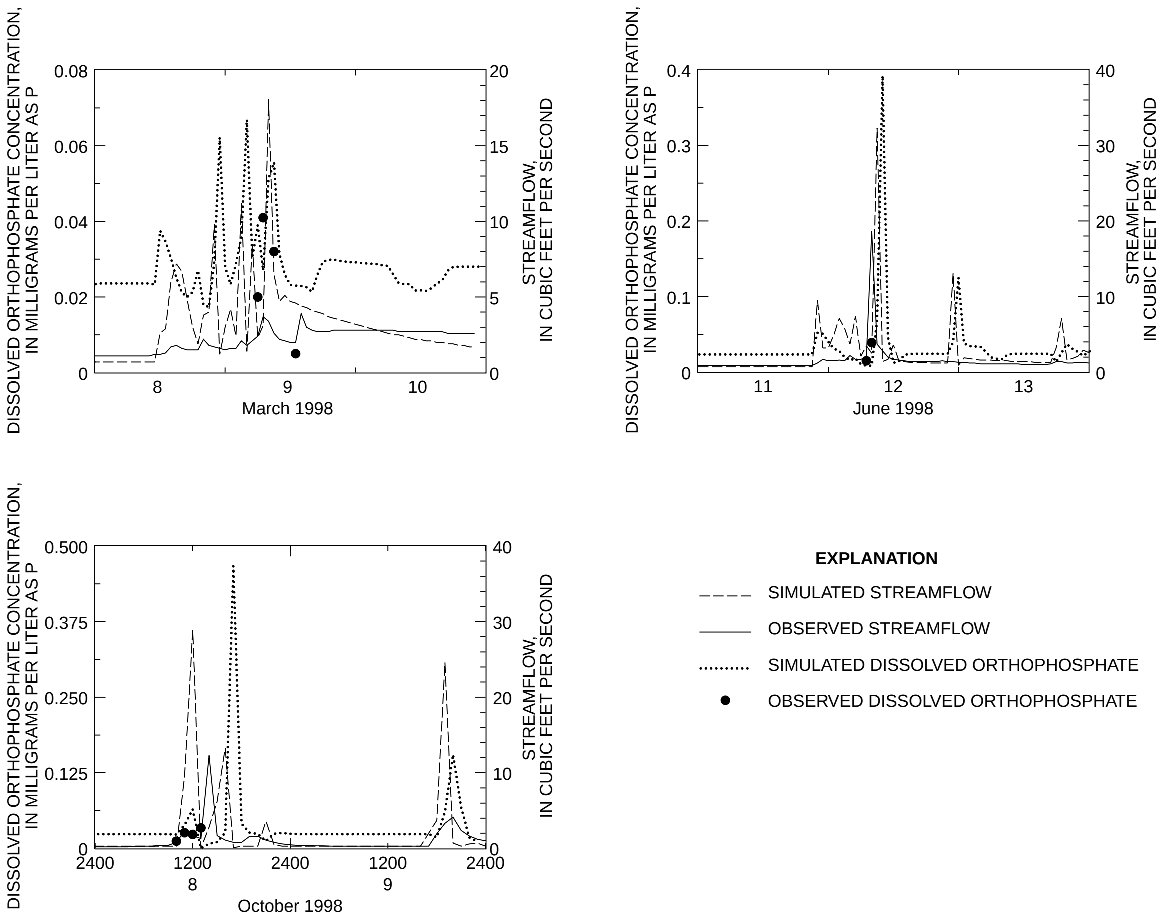

Figure 27. Simulated and observed streamflow and dissolved orthophosphate concentrations during three storms in 1998 at streamflow-measurement station 01480637, Little Broad Run near Marshallton, Pa.

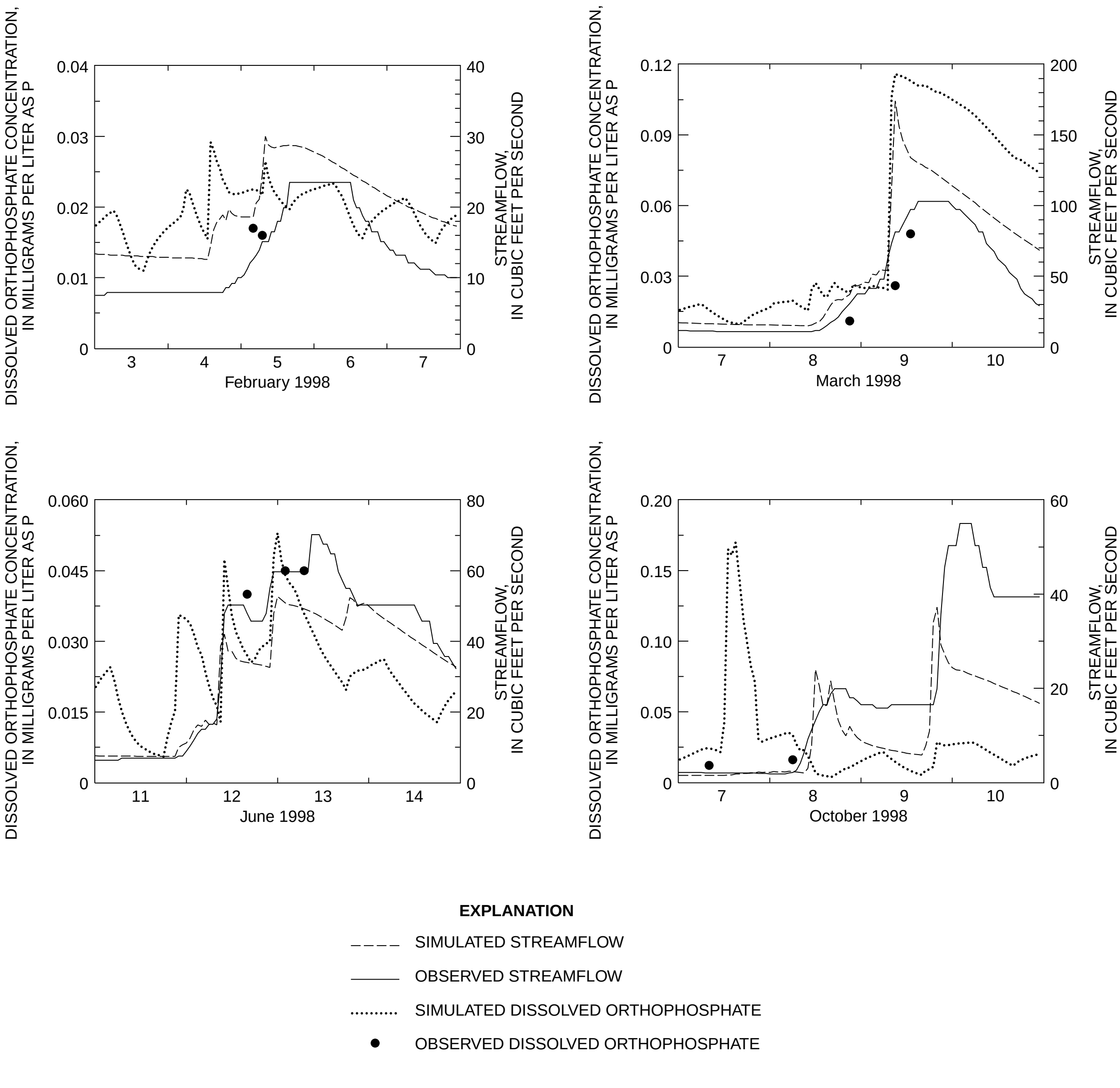

Figure 28. Simulated and observed streamflow and dissolved orthophosphate concentrations during four storms in 1998 at streamflow-measurement station 01480675, Marsh Creek near Glenmoore, Pa.

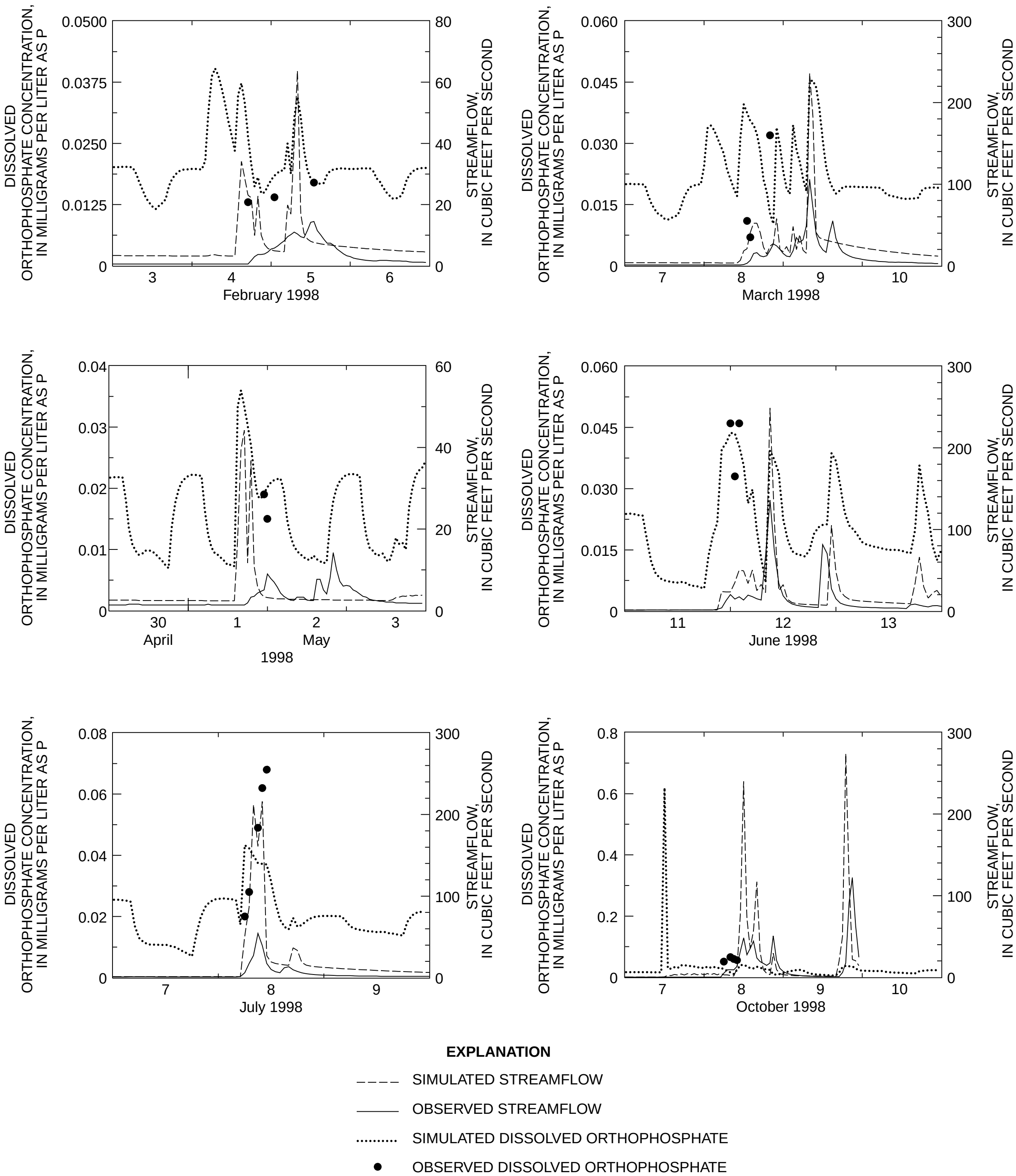

Figure 29. Simulated and observed streamflow and dissolved orthophosphate concentrations during six storms in 1998 at streamflow-measurement station 01480878, Unnamed Tributary to Valley Creek near Exton, Pa.

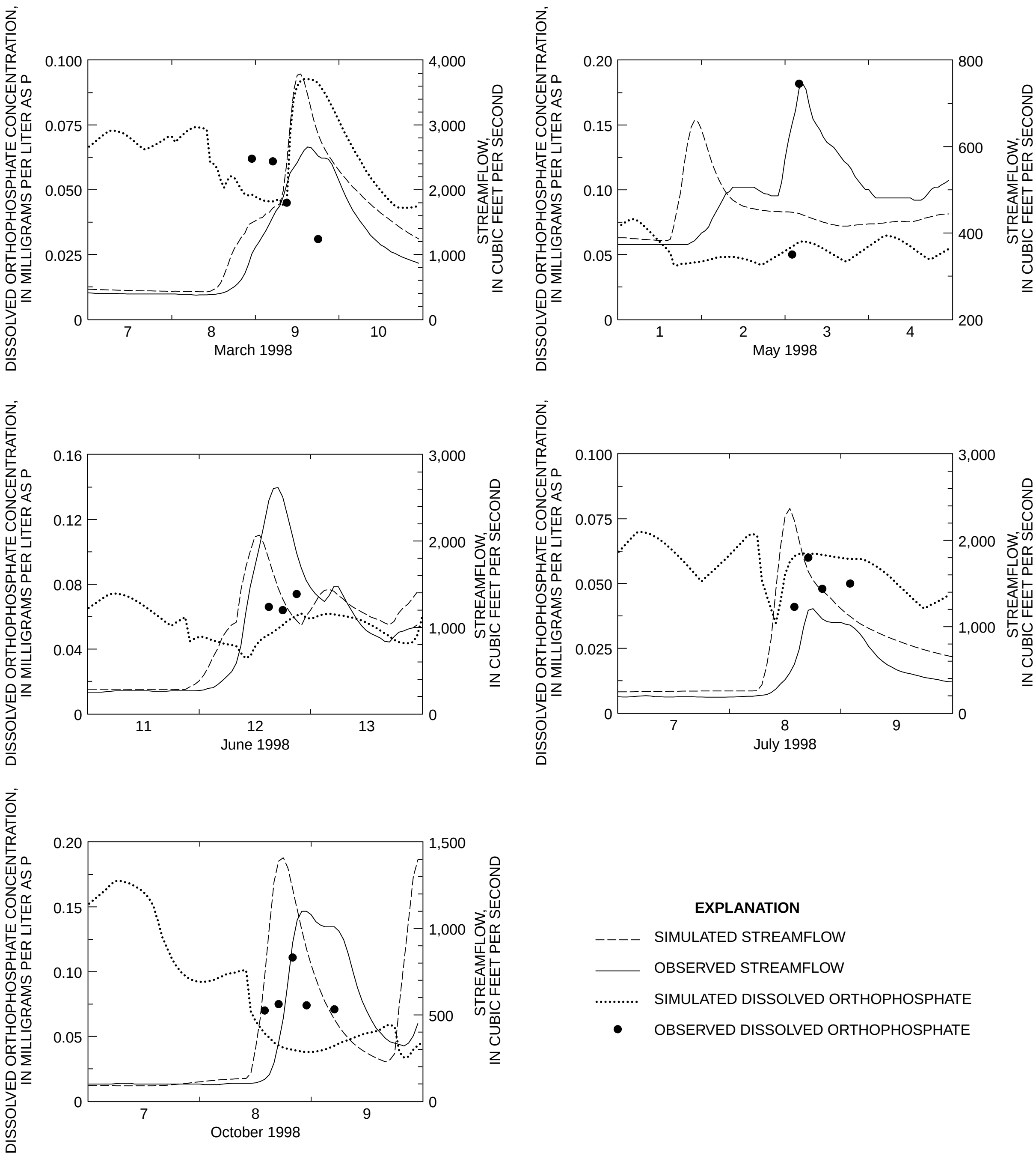

Figure 30. Simulated and observed streamflow and dissolved orthophosphate concentrations during five storms in 1998 at streamflow-measurement station 01481000, Brandywine Creek at Chadds Ford, Pa.

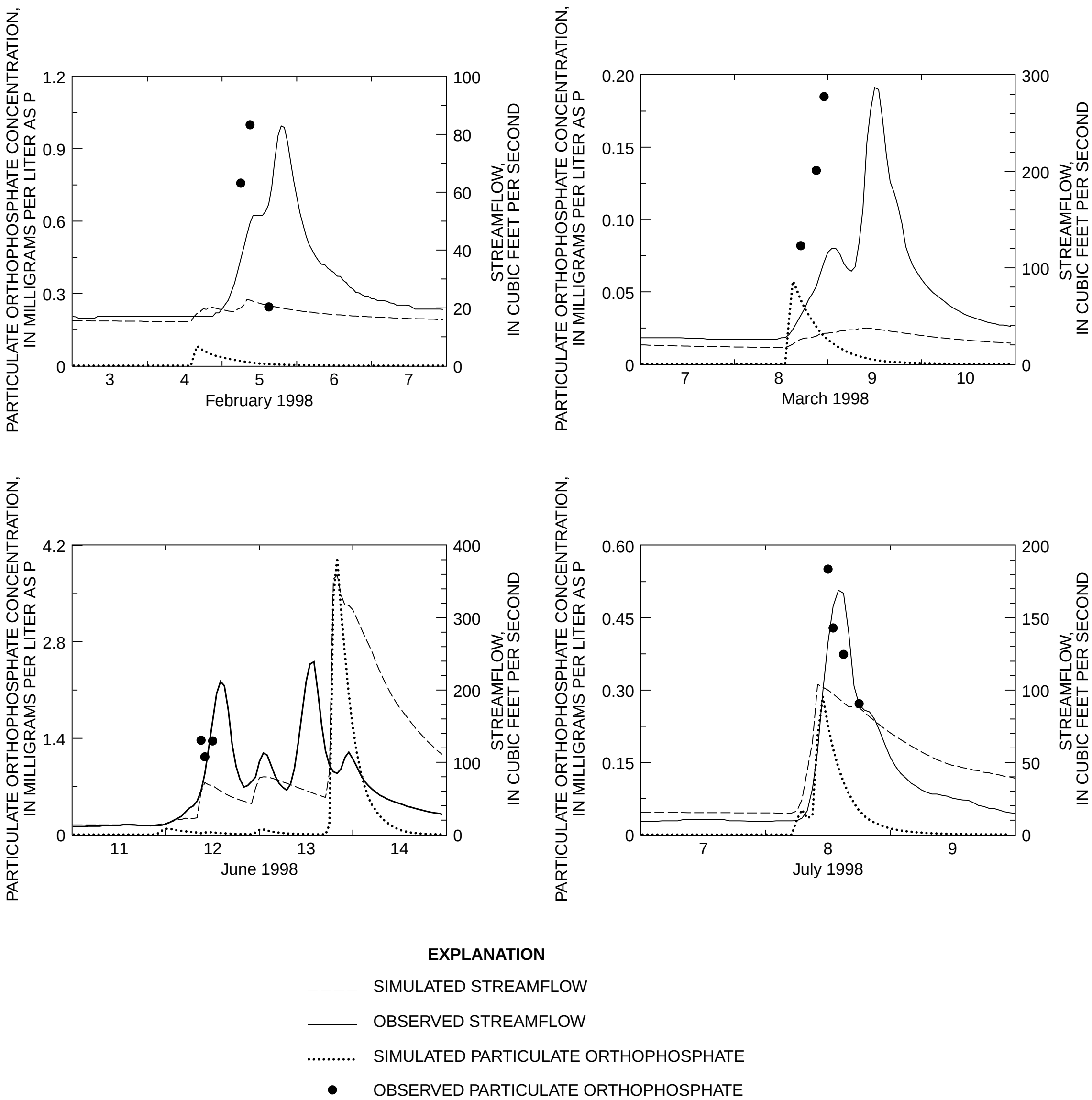

Figure 31. Simulated and observed streamflow and particulate orthophosphate concentrations during four storms in 1998 at streamflow-measurement station 01480300, West Branch Brandywine Creek at Honey Brook, Pa.

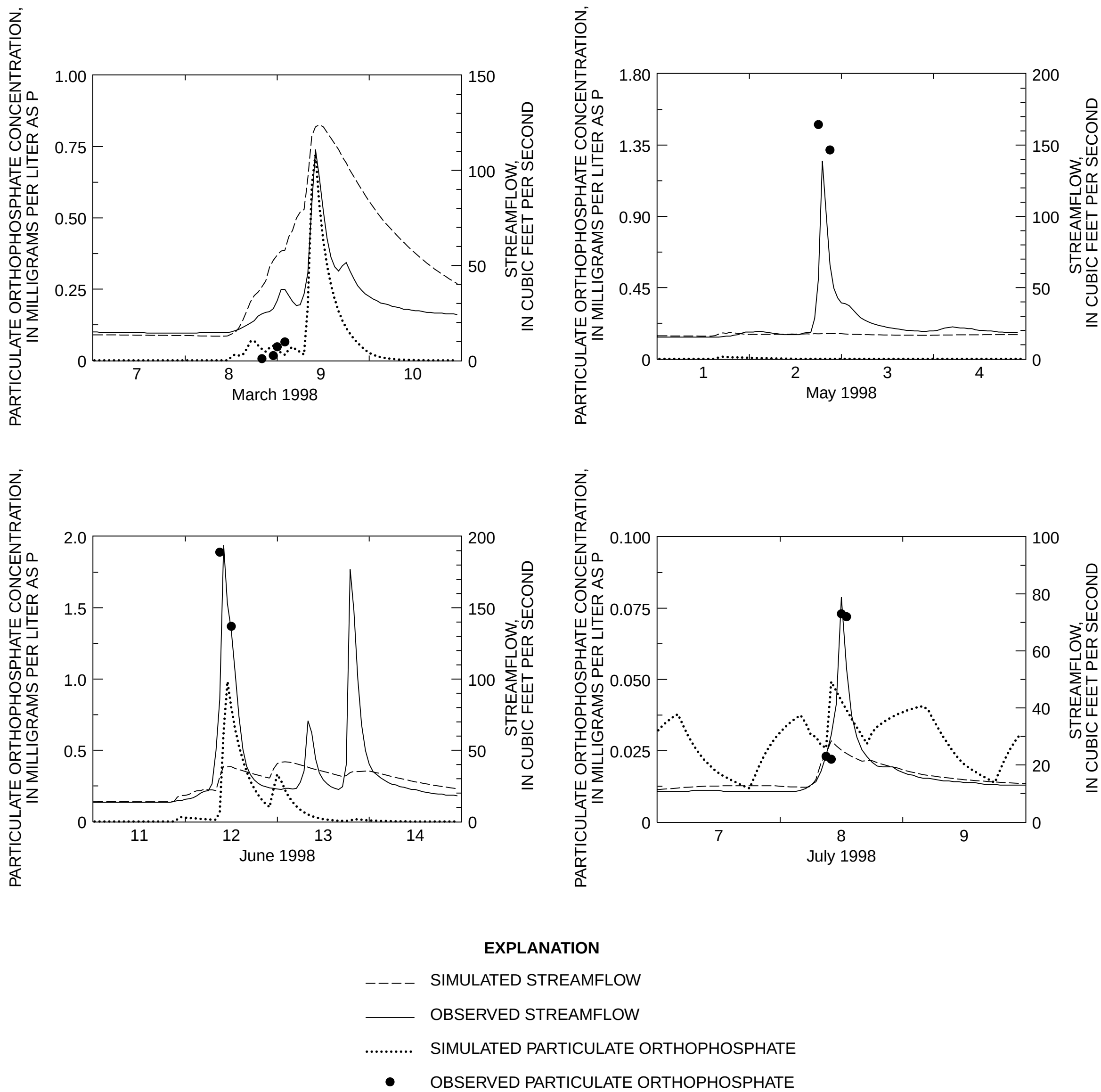

Figure 32. Simulated and observed streamflow and particulate orthophosphate concentrations during four storms in 1998 at streamflow-measurement station 014806318, Doe Run at Springdell, Pa.

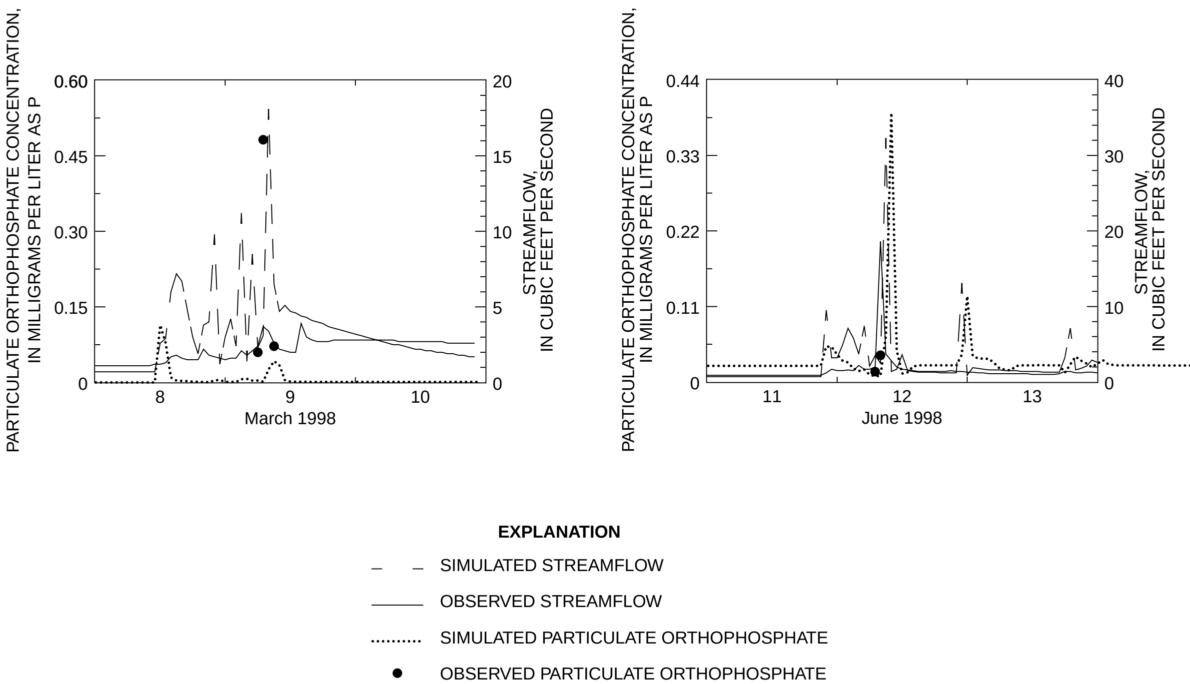

Figure 33. Simulated and observed streamflow and particulate orthophosphate concentrations during two storms in 1998 at streamflow-measurement station 01480637, Little Broad Run near Marshallton, Pa.

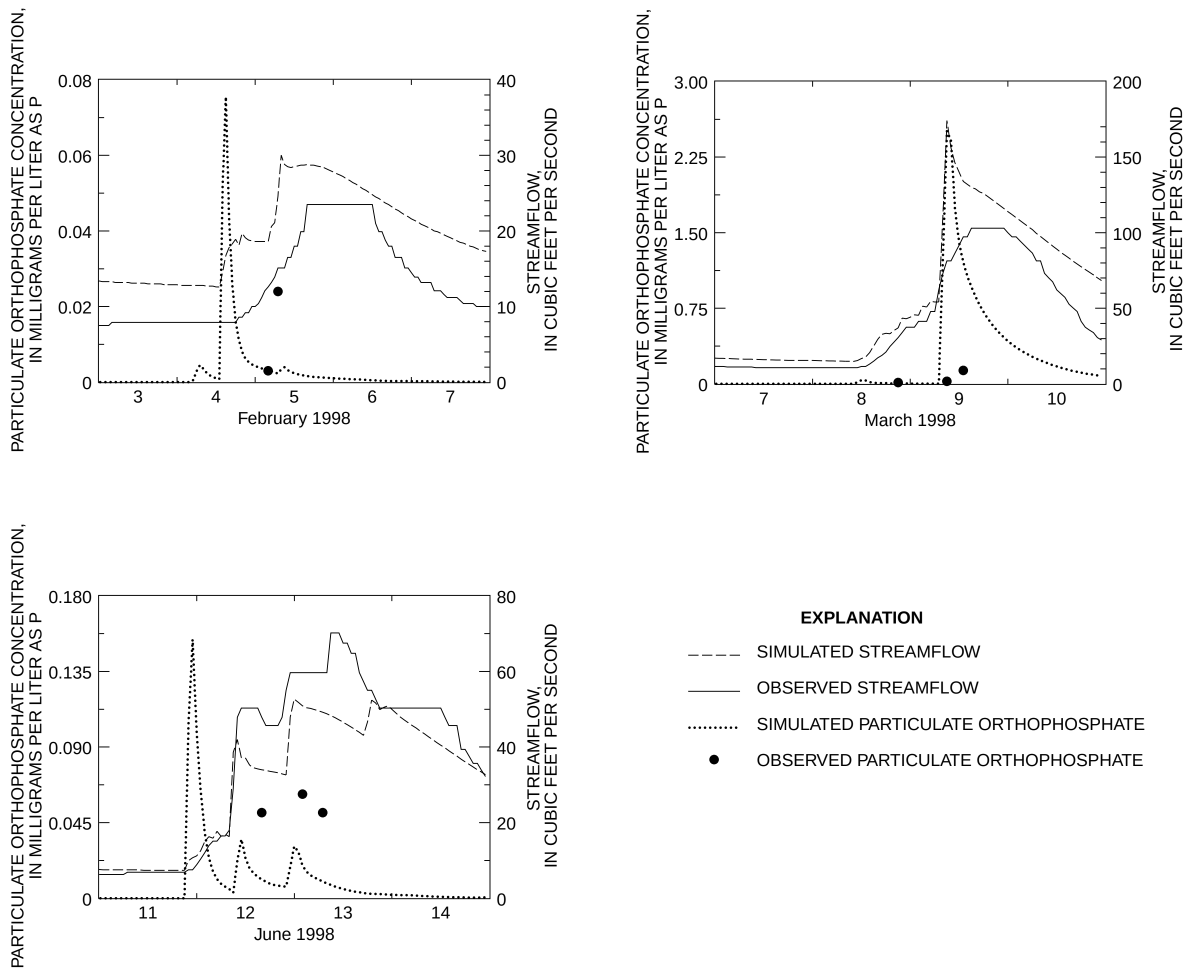

Figure 34. Simulated and observed streamflow and particulate orthophosphate concentrations during three storms in 1998 at streamflow-measurement station 01480675, Marsh Creek near Glenmoore, Pa.

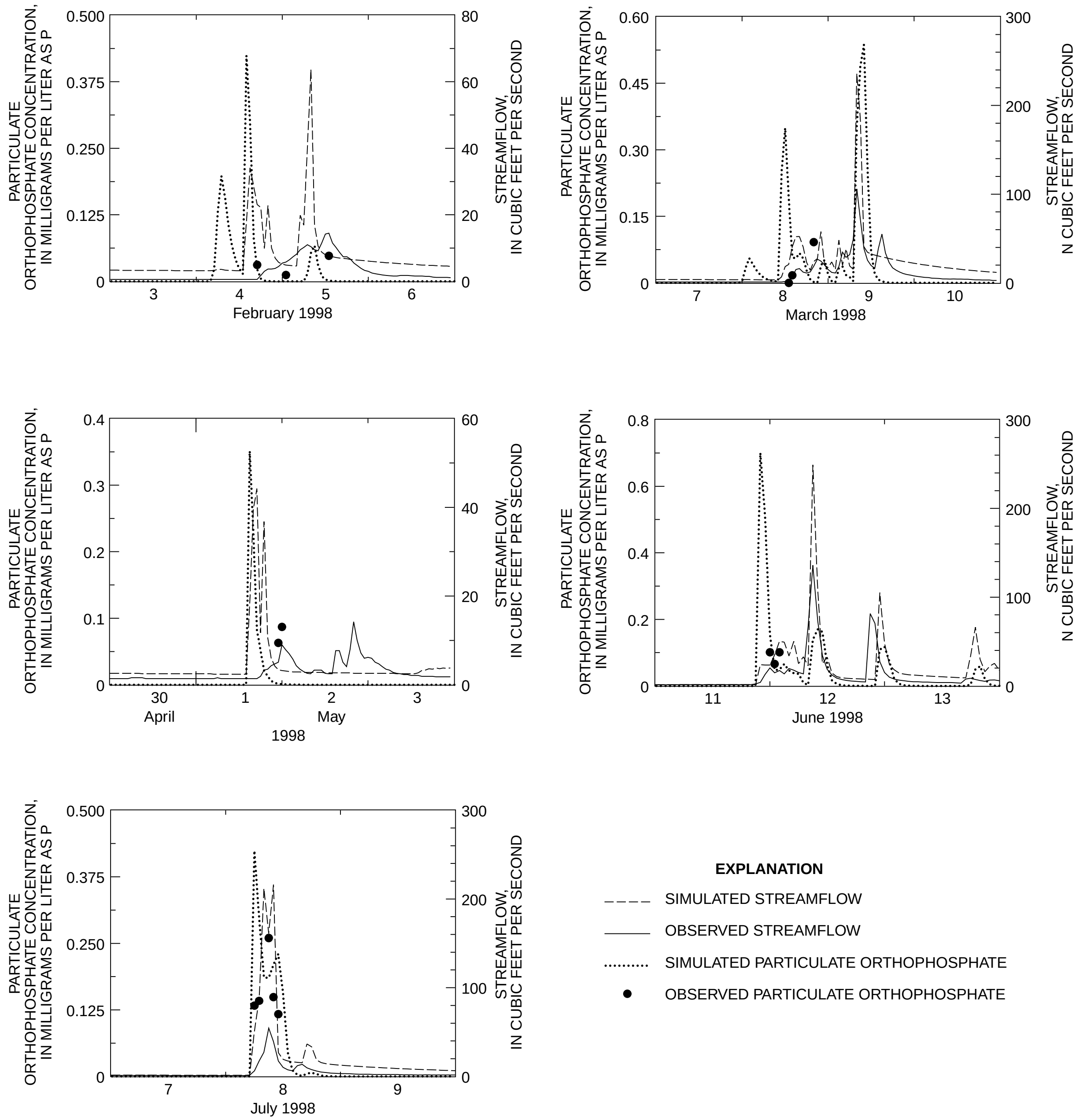

Figure 35. Simulated and observed streamflow and particulate orthophosphate concentrations during five storms in 1998 at streamflow-measurement station 01480878, Unnamed Tributary to Valley Creek near Exton, Pa.

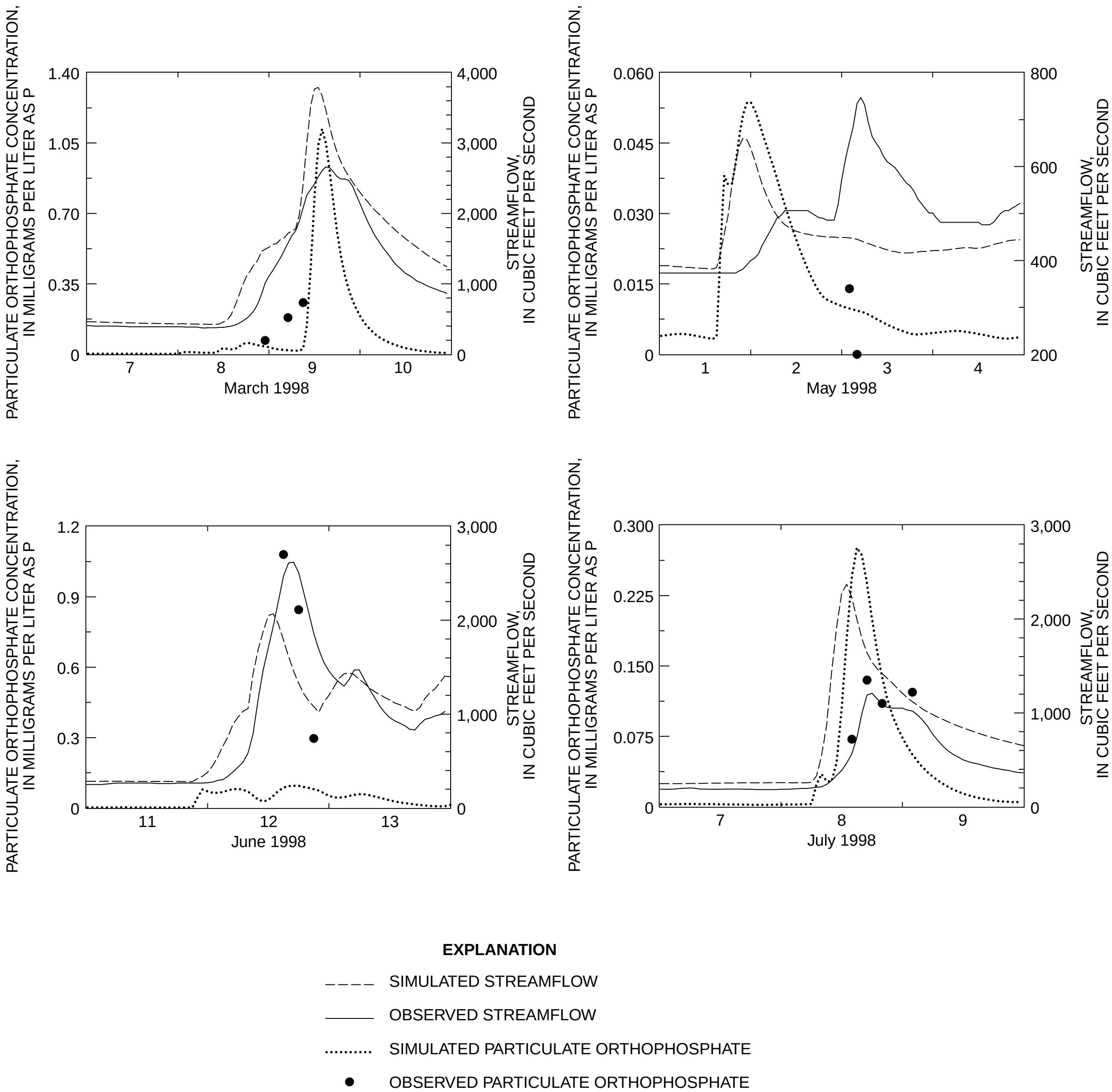

Figure 36. Simulated and observed streamflow and particulate orthophosphate concentrations during four particulate storms in 1998 at streamflow-measurement station 01481000, Brandywine Creek at Chadds Ford, Pa.

APPENDIX 3

USER CONTROL INPUT (UCI) FILE

```
RUN
GLOBAL
BRANDYWINE CREEK HYDROLOGY - BASE SCENARIO - ALL SEGMENTS
  START       1994  1  1  0  0  END    1998 10 29 24  0
  RUN INTERP OUTPUT LEVEL    3    2
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL

FILES
<type>  <fun>***<------------fname--------------------------------------------->
MESSU      25   BRANDYW.ech
WDM        26   brandyw.wdm
           90   BRANDYW.out
END FILES

OPN SEQUENCE
    INGRP              INDELT  1:00
      PERLND     102
      PERLND     103
      PERLND     104
      PERLND     105
      PERLND     106
      PERLND     107
      PERLND     108
      PERLND     109
      PERLND     110
      PERLND     111
      IMPLND     101
      IMPLND     102

      RCHRES       1
      GENER        1
      GENER        2
      COPY        10
      COPY       100
      RCHRES       2
      RCHRES      32
      RCHRES       9

      PERLND     202
      PERLND     203
      PERLND     204
      PERLND     205
      PERLND     206
      PERLND     207
      PERLND     208
      PERLND     209
      PERLND     210
      PERLND     211
      IMPLND     201
      IMPLND     202
      RCHRES       3
      RCHRES      33
      RCHRES       4
      COPY       200
      RCHRES       5
      COPY       300

      RCHRES       6
      RCHRES      20
      RCHRES      21
      GENER        3
      GENER        4
      COPY        11
      COPY       400
      RCHRES      22
      RCHRES      23
      RCHRES       7
      RCHRES      24
      GENER        5
      GENER        6
      COPY        12
      COPY       500
      RCHRES      25
      RCHRES       8

      PERLND     302
      PERLND     303
      PERLND     304
      PERLND     305
      PERLND     306
      PERLND     307
      PERLND     308
      PERLND     309
      PERLND     310
      PERLND     311
      IMPLND     301
      IMPLND     302
      RCHRES      35
      RCHRES      26
      GENER        7
```

```
      GENER        8
      COPY        13
      COPY       600

      RCHRES      27
      COPY       700
      RCHRES      10
      RCHRES      11
      COPY       800
      RCHRES      12
      RCHRES      30
      RCHRES      13
      COPY       900
      RCHRES      28
      GENER        9
      GENER       10
      COPY        14
      COPY       910
      RCHRES      29
      RCHRES      14

      PERLND     402
      PERLND     403
      PERLND     404
      PERLND     405
      PERLND     406
      PERLND     407
      PERLND     408
      PERLND     409
      PERLND     410
      PERLND     411
      IMPLND     401
      IMPLND     402
      RCHRES      15
      RCHRES      31

      RCHRES      16
      GENER       11
      GENER       12
      COPY        15
      COPY       920
      RCHRES      17
      RCHRES      18
      RCHRES      19
      RCHRES      34
      COPY       930
    END INGRP
END OPN SEQUENCE

PERLND
  ACTIVITY
    #    # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC   ***
  102  411    1    1    1    1    1    1    1    0    0    0    0    0
  END ACTIVITY

  PRINT-INFO
    #    # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC *********
  102  411    5    5    5    5    5    5    5    0    0    0    0    0    0   12
  END PRINT-INFO

  GEN-INFO
    #    #      NAME          NBLKS  UCI   IN  OUT ENGL METR  ***
  102     RESIDENTIAL-SEPTIC      1    1    1    1   90    0
  103     RESIDENTIAL-SEWER       1    1    1    1   90    0
  104     COMMERCIAL/INDUSTRY     1    1    1    1   90    0
  105     AGRICULTURAL-COWS       1    1    1    1   90    0
  106     AGRICULTURAL-CROPS      1    1    1    1   90    0
  107     AGRICULTURAL-MUSHROOM   1    1    1    1   90    0
  108     FOREST                  1    1    1    1   90    0
  109     OPEN LAND               1    1    1    1   90    0
  110     WETLANDS, WATER         1    1    1    1   90    0
  111     undesignated use        1    1    1    1   90    0
  202     RESIDENTIAL-SEPTIC      1    1    1    1   90    0
  203     RESIDENTIAL-SEWER       1    1    1    1   90    0
  204     COMMERCIAL/INDUSTRY     1    1    1    1   90    0
  205     AGRICULTURAL-COWS       1    1    1    1   90    0
  206     AGRICULTURAL-CROPS      1    1    1    1   90    0
  207     AGRICULTURAL-MUSHROOM   1    1    1    1   90    0
  208     FOREST                  1    1    1    1   90    0
  209     OPEN LAND               1    1    1    1   90    0
  210     WETLANDS, WATER         1    1    1    1   90    0
  211     undesignated use        1    1    1    1   90    0
  302     RESIDENTIAL-SEPTIC      1    1    1    1   90    0
  303     RESIDENTIAL-SEWER       1    1    1    1   90    0
  304     COMMERCIAL/INDUSTRY     1    1    1    1   90    0
  305     AGRICULTURAL-COWS       1    1    1    1   90    0
  306     AGRICULTURAL-CROPS      1    1    1    1   90    0
  307     AGRICULTURAL-MUSHROOM   1    1    1    1   90    0
  308     FOREST                  1    1    1    1   90    0
  309     OPEN LAND               1    1    1    1   90    0
  310     WETLANDS, WATER         1    1    1    1   90    0
  311     undesignated use        1    1    1    1   90    0
```

```
  402     RESIDENTIAL-SEPTIC      1    1    1    1   90    0
  403     RESIDENTIAL-SEWER       1    1    1    1   90    0
  404     COMMERCIAL/INDUSTRY     1    1    1    1   90    0
  405     AGRICULTURAL-COWS       1    1    1    1   90    0
  406     AGRICULTURAL-CROPS      1    1    1    1   90    0
  407     AGRICULTURAL-MUSHROOM   1    1    1    1   90    0
  408     FOREST                  1    1    1    1   90    0
  409     OPEN LAND               1    1    1    1   90    0
  410     WETLANDS, WATER         1    1    1    1   90    0
  411     undesignated use        1    1    1    1   90    0
  END GEN-INFO

**** AIR TEMPERATURE ****

  ATEMP-DAT
*** <PLS >     ELDAT    AIRTMP
*** #    #      (ft)   (deg F)
  102  111        0.       25.
  202  211        0.       27.
  302  311        0.       25.
  402  411        0.       27.
  END ATEMP-DAT

**** SNOW ****

  ICE-FLAG
*** <PLS > ICEFG
*** #    #
  102  411    1
  END ICE-FLAG

  SNOW-PARM1
*** <PLS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** #    #     (deg)      (ft)                          (in)
  102  111      40.1      700.      0.10       1.0      1.00
  202  211      40.0      450.      0.60       1.0      1.00
  302  311      40.0      500.      0.70       1.0      1.00
  402  411      39.9      250.      0.70       1.0      1.00
  END SNOW-PARM1

  SNOW-PARM2
*** <PLS >     RDSCN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT
*** #    #              (degF)                                (in/day)
  102  111      0.35      30.0      0.05      1.00      0.05     0.020
  202  211      0.23      30.0      0.10      0.28      0.25     0.010
  302  311      0.23      30.0      0.10      0.28      0.25     0.010
  402  411      0.23      30.0      0.10      0.28      0.25     0.010
  END SNOW-PARM2

**** HYDROLOGY ****

  PWAT-PARM1
*** <PLS >                  Flags
*** x -   x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE IFFC
  102         1    1    1    1    0    0    1    0    1    1
  103         1    1    1    1    0    0    1    0    1    1
  104         1    1    1    1    0    0    1    0    1    1
  105         1    1    1    1    1    0    1    0    1    1
  106         1    1    1    1    1    0    1    0    1    1
  107         1    1    1    1    0    0    1    0    1    1
  108         1    1    1    1    0    0    1    0    1    1
  109         1    1    1    1    0    0    1    0    0    1
  110         1    1    1    0    0    0    1    0    0    1
  111         1    1    1    1    0    0    1    0    0    1
  202         0    1    1    1    0    0    1    0    1    1
  203         0    1    1    1    0    0    1    0    1    1
  204         0    1    1    1    0    0    1    0    1    1
  205         0    1    1    1    1    0    1    0    1    1
  206         0    1    1    1    1    0    1    0    1    1
  207         0    1    1    1    0    0    1    0    1    1
  208         0    1    1    1    0    0    1    0    1    1
  209         0    1    1    1    0    0    1    0    0    1
  210         0    1    1    0    0    0    1    0    0    1
  211         0    1    1    1    0    0    1    0    0    1
  302         0    1    1    1    0    0    1    0    0    1
  303         0    1    1    1    0    0    1    0    0    1
  304         0    1    1    1    0    0    1    0    0    1
  305         0    1    1    1    1    0    1    0    1    1
  306         0    1    1    1    1    0    1    0    1    1
  307         0    1    1    1    0    0    1    0    1    1
  308         0    1    1    1    0    0    1    0    1    1
  309         0    1    1    1    0    0    1    0    0    1
  310         0    1    1    0    0    0    1    0    0    1
  311         0    1    1    1    0    0    1    0    0    1
  402         0    1    1    1    0    0    1    0    0    1
  403         0    1    1    1    0    0    1    0    0    1
  404         0    1    1    1    0    0    1    0    0    1
  405         0    1    1    1    1    0    1    0    1    1
  406         0    1    1    1    1    0    1    0    1    1
  407         0    1    1    1    0    0    1    0    1    1
  408         0    1    1    1    0    0    1    0    1    1
  409         0    1    1    1    0    0    1    0    0    1
```

```
  410        0    1    1    0    0    0    1    0    0    1
  411        0    1    1    1    0    0    1    0    0    1
  END PWAT-PARM1

  PWAT-PARM2
***  <PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
***  x - x                (in)   (in/hr)      (ft)              (1/in)   (1/day)
  102           0.00     2.400     0.060    1800.0    0.2107     0.000     0.980
  103           0.00     2.400     0.060    1800.0    0.1459     0.000     0.980
  104           0.00     2.400     0.055    1800.0    0.1781     0.000     0.980
  105           0.00     2.400     0.050    1800.0    0.1871     0.000     0.980
  106           0.00     2.400     0.050    1800.0    0.1871     0.000     0.980
  107           0.00     2.400     0.055    1800.0    0.1871     0.000     0.980
  108           0.00     2.400     0.090    1800.0    0.2456     0.000     0.980
  109           0.00     2.400     0.060    1800.0    0.1673     0.000     0.980
  110           0.00     2.400     0.005    1800.0    0.0980     0.000     0.980
  111           0.00     2.400     0.060    1800.0    0.1423     0.000     0.980
  202           0.00     6.500     0.120    2000.0    0.2419     0.000     0.988
  203           0.00     6.500     0.120    2000.0    0.2661     0.000     0.988
  204           0.00     6.500     0.120    2000.0    0.2382     0.000     0.988
  205           0.00     6.500     0.080    2000.0    0.2456     0.000     0.988
  206           0.00     6.500     0.080    2000.0    0.2456     0.000     0.988
  207           0.00     6.500     0.080    2000.0    0.2456     0.000     0.988
  208           0.00     6.500     0.200    2000.0    0.3779     0.000     0.988
  209           0.00     6.500     0.120    2000.0    0.2144     0.000     0.988
  210           0.00     6.500     0.005    2000.0    0.2235     0.000     0.988
  211           0.00     6.500     0.120    2000.0    0.1566     0.000     0.988
  302           0.00     6.000     0.080    1800.0    0.2754     0.000     0.940
  303           0.00     6.000     0.080    1800.0    0.2438     0.000     0.940
  304           0.00     6.000     0.070    1800.0    0.2034     0.000     0.940
  305           0.00     6.000     0.080    1800.0    0.2346     0.000     0.970
  306           0.00     6.000     0.080    1800.0    0.2346     0.000     0.970
  307           0.00     6.000     0.080    1800.0    0.2346     0.000     0.970
  308           0.00     6.000     0.100    1800.0    0.3561     0.000     0.970
  309           0.00     6.000     0.080    1800.0    0.1853     0.000     0.970
  310           0.00     6.000     0.005    1800.0    0.1122     0.000     0.970
  311           0.00     6.000     0.080    1800.0    0.1548     0.000     0.970
  402           0.00     6.200     0.090    1800.0    0.2717     0.000     0.970
  403           0.00     6.200     0.090    1800.0    0.1370     0.000     0.970
  404           0.00     6.200     0.070    1800.0    0.1530     0.000     0.970
  405           0.00     6.200     0.090    1800.0    0.2642     0.000     0.970
  406           0.00     6.200     0.090    1800.0    0.2642     0.000     0.970
  407           0.00     6.200     0.090    1800.0    0.2642     0.000     0.970
  408           0.00     6.200     0.130    1800.0    0.3620     0.000     0.970
  409           0.00     6.200     0.090    1800.0    0.2272     0.000     0.970
  410           0.00     6.200     0.005    1800.0    0.1799     0.000     0.990
  411           0.00     6.200     0.090    1800.0    0.1281     0.000     0.970
  END PWAT-PARM2

  PWAT-PARM3
***  <PLS>    PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
***  x - x   (deg F)   (deg F)
  102            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  103            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  104            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  105            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  106            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  107            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  108            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  109            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  110            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  111            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  202            0.0       0.0       2.0       2.0     0.000     0.040     0.000
  203            0.0       0.0       2.0       2.0     0.000     0.040     0.000
  204            0.0       0.0       2.0       2.0     0.000     0.040     0.000
  205            0.0       0.0       2.0       2.0     0.000     0.040     0.000
  206            0.0       0.0       2.0       2.0     0.000     0.040     0.000
  207            0.0       0.0       2.0       2.0     0.000     0.040     0.000
  208            0.0       0.0       2.0       2.0     0.000     0.040     0.000
  209            0.0       0.0       2.0       2.0     0.000     0.040     0.000
  210            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  211            0.0       0.0       2.0       2.0     0.000     0.040     0.000
  302            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  303            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  304            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  305            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  306            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  307            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  308            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  309            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  310            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  311            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  403            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  404            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  405            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  406            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  407            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  408            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  409            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  410            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  411            0.0       0.0       2.0       2.0     0.000     0.000     0.000
  END PWAT-PARM3
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  PWAT-PARM4
*** <PLS >      CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)       (in)                         (1/day)
  102          0.050      1.000      0.25       1.5     0.300     0.400
  103          0.050      1.000      0.25       1.5     0.300     0.400
  104          0.050      1.000      0.15       1.5     0.300     0.380
  105          0.000      0.500      0.10       1.5     0.300     0.000
  106          0.000      0.500      0.10       1.5     0.300     0.000
  107          0.000      1.000      0.15       1.5     0.300     0.000
  108          0.000      2.000      0.30       1.5     0.300     0.000
  109          0.000      1.000      0.25       1.5     0.300     0.400
  110          0.050      0.010      0.05       1.5     0.300     0.750
  111          0.000      1.000      0.25       1.5     0.300     0.400
  202          0.050      0.500      0.25         2     0.350     0.550
  203          0.050      0.500      0.25         2     0.350     0.550
  204          0.050      0.500      0.15         2     0.350     0.500
  205          0.050      0.500      0.10         2     0.350     0.000
  206          0.050      0.500      0.10         2     0.350     0.000
  207          0.050      0.500      0.15         2     0.350     0.000
  208          0.050      0.500      0.30         2     0.350     0.000
  209          0.050      0.500      0.25         2     0.350     0.550
  210          0.010      0.010      0.05         2     0.350     0.800
  211          0.050      0.500      0.25         2     0.350     0.550
  302          0.100      0.600      0.35         3     0.400     0.450
  303          0.100      0.600      0.35         3     0.400     0.450
  304          0.100      0.600      0.20         3     0.400     0.400
  305          0.000      0.500      0.15         3     0.400     0.450
  306          0.000      0.500      0.15         3     0.400     0.450
  307          0.000      0.500      0.25         3     0.400     0.450
  308          0.000      0.500      0.25         3     0.400     0.650
  309          0.000      0.500      0.25         3     0.400     0.450
  310          0.050      0.800      0.25         3     0.400     0.800
  311          0.000      0.500      0.25         3     0.400     0.450
  402          0.100      0.800      0.25         1     0.400     0.450
  403          0.100      0.800      0.25         1     0.400     0.450
  404          0.100      0.800      0.25         1     0.400     0.400
  405          0.000      0.500      0.10         1     0.400     0.450
  406          0.000      0.500      0.10         1     0.400     0.450
  407          0.000      0.800      0.20         1     0.400     0.450
  408          0.000      1.200      0.35         1     0.400     0.650
  409          0.000      0.800      0.35         1     0.400     0.450
  410          0.050      0.010      0.05         1     0.400     0.800
  411          0.000      0.800      0.35         1     0.400     0.450
  END PWAT-PARM4

  MON-INTERCEP
*** <PLS >  Interception storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  104 .030 .030 .040 .070 .120 .130 .130 .130 .120 .085 .070 .050
  105  107 .020 .020 .020 .030 .060 .090 .130 .130 .130 .085 .070 .050
  108      .030 .030 .040 .080 .140 .140 .140 .140 .120 .080 .060 .060
  111      .060 .060 .060 .080 .120 .130 .130 .130 .120 .085 .070 .050
  202  204 .060 .060 .060 .080 .120 .130 .130 .130 .120 .085 .070 .050
  205  207 .050 .055 .050 .050 .060 .090 .130 .130 .130 .085 .070 .050
  208      .060 .060 .060 .100 .140 .140 .140 .140 .120 .080 .060 .060
  211      .060 .060 .060 .080 .120 .130 .130 .130 .120 .085 .070 .050
  302  304 .060 .060 .060 .080 .120 .130 .130 .130 .120 .085 .070 .050
  305  307 .050 .050 .050 .050 .055 .080 .130 .140 .130 .105 .070 .050
  308      .060 .060 .060 .100 .140 .140 .140 .140 .120 .080 .060 .060
  311      .060 .060 .060 .080 .120 .130 .130 .130 .120 .085 .070 .050
  402  404 .040 .040 .050 .060 .120 .130 .130 .130 .120 .085 .070 .050
  405  407 .040 .040 .050 .050 .055 .080 .130 .140 .130 .105 .070 .050
  408      .050 .050 .060 .080 .140 .140 .140 .140 .120 .080 .060 .060
  411      .040 .040 .050 .060 .120 .130 .130 .130 .120 .085 .070 .050
  END MON-INTERCEP

  MON-UZSN
*** <PLS >  Upper zone storage at start of each month  (inches)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  105  106  0.1  0.1 0.25 0.40 0.65 0.70 0.75 0.70 0.70 0.55 0.50  0.4
  205  206  0.3  0.2 0.25 0.50 0.55 0.55 0.55 0.55 0.50 0.50 0.45  0.4
  305  306  0.4  0.3 0.20 0.20 0.20 0.40 0.40 0.40 0.50 0.60 0.55  0.5
  405  406  0.2  0.3 0.20 0.20 0.20 0.55 0.60 0.60 0.60 0.65 0.65  0.5
  END MON-UZSN

  MON-INTERFLW
***
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  111  2.0  1.0  1.5  2.0  2.5  3.5  3.5  3.0  2.5  2.0  2.5  2.5
  202  211  3.0  5.0  5.0  5.0  3.0  3.0  3.0  3.0  2.0  2.0  2.5  2.5
  302  311  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
  402  411  3.0  3.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  3.0  3.0  3.0
  END MON-INTERFLW

  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  104  0.0  0.0  0.0  0.2  0.4  .65  0.8  0.8  0.7  0.5  0.5  0.5
  105  107  0.0  0.0  0.0  0.2  0.3  .60  0.7  0.7  0.6  0.5  0.5  0.5
  108       0.1  0.1  0.1  0.3  .55  .70  .80  .80  .65  0.6  0.6  0.5
  202  204  0.3  0.3  0.3  0.4  0.5  .65  0.7  0.6  0.6  0.5  0.5  0.5
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  205  207  0.1  0.2  0.3  0.4  0.5  .55  .60  .55  0.5  0.4  0.3  0.3
  208       0.3  0.3  0.3  0.4  0.6  .70  .80  .80  0.7  0.6  0.4  0.4
  305  307  0.1  0.1  0.2  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
  308       0.2  0.4  0.4  0.4  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
  405  407  0.1  0.1  0.2  0.4  0.5  0.6  0.6  0.6  0.5  0.5  0.5  0.5
  408       0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.8  0.7  0.7  0.6  0.6
  END MON-LZETPARM

  PWAT-STATE1
***  <PLS>  PWATER state variables (in)
***  x - x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  102            0.0      0.05       1.0       0.0       3.0       3.0       0.0
  103            0.0      0.05       1.0       0.0       3.0       3.0       0.0
  104            0.0      0.05       1.0       0.0       3.0       3.0       0.0
  105            0.0      0.05       1.0       0.0       3.0       3.0       0.0
  106            0.0      0.05       1.0       0.0       3.0       3.0       0.0
  107            0.0      0.05       1.0       0.0       3.0       3.0       0.0
  108            0.0      0.10       1.0       0.0       3.0       3.0       0.0
  109            0.0      0.05       1.0       0.0       3.0       3.0       0.0
  110            0.0         0      .001       0.0      .001       3.0       0.0
  111            0.0      0.05       1.0       0.0       3.0       3.0       0.0
  202            0.0      0.05       0.5       0.0       3.0       4.5       0.0
  203            0.0      0.05       0.5       0.0       3.0       4.5       0.0
  204            0.0      0.05       0.5       0.0       3.0       4.5       0.0
  205            0.0      0.05       0.5       0.0       3.0       4.5       0.0
  206            0.0      0.05       0.5       0.0       3.0       4.5       0.0
  207            0.0      0.05       0.5       0.0       3.0       4.5       0.0
  208            0.0      0.10       0.5       0.0       3.0       4.5       0.0
  209            0.0      0.05       0.5       0.0       3.0       4.5       0.0
  210            0.0         0      .001       0.0      .001       4.5       0.0
  211            0.0      0.05       0.5       0.0       3.0       4.5       0.0
  302            0.0      0.05       0.5       0.0         4       1.5       0.0
  303            0.0      0.05       0.5       0.0         4       1.5       0.0
  304            0.0      0.05       0.5       0.0         4       1.5       0.0
  305            0.0      0.05       0.5       0.0         4       1.5       0.0
  306            0.0      0.05       0.5       0.0         4       1.5       0.0
  307            0.0      0.05       0.5       0.0         4       1.5       0.0
  308            0.0      0.10       0.5       0.0         4       1.5       0.0
  309            0.0      0.05       0.5       0.0         4       1.5       0.0
  310            0.0         0      .001       0.0      .001       1.5       0.0
  311            0.0      0.05       0.5       0.0         4       1.5       0.0
  402            0.0      0.05       1.0       0.0       4.5       3.0       0.0
  403            0.0      0.05       1.0       0.0       4.5       3.0       0.0
  404            0.0      0.05       1.0       0.0       4.5       3.0       0.0
  405            0.0      0.05       1.0       0.0       4.5       3.0       0.0
  406            0.0      0.05       1.0       0.0       4.5       3.0       0.0
  407            0.0      0.05       1.0       0.0       4.5       3.0       0.0
  408            0.0      0.10       1.0       0.0       4.5       3.0       0.0
  409            0.0      0.05       1.0       0.0       4.5       3.0       0.0
  410            0.0         0      .001       0.0      .001       3.0       0.0
  411            0.0      0.05       1.0       0.0       4.5       3.0       0.0
  END PWAT-STATE1

  SED-PARM1
*** <PLS >  Sediment parameters 1
*** x -  x  CRV VSIV SDOP
  102  411    1    0    1
  END SED-PARM1

  SED-PARM2
*** <PLS >      SMPF      KRER      JRER     AFFIX     COVER      NVSI
*** x -  x                                  (/day)           lb/ac-day
  102  103     1.000     0.350     2.000     0.010     0.000     1.000
  104          1.000     0.350     2.000     0.010     0.000     1.000
  105  107     1.000     0.450     2.000     0.010     0.000     1.000
  108          1.000     0.300     2.000     0.002     0.000     2.000
  109          1.000     0.350     2.000     0.010     0.000     2.000
  110          1.000     0.150     2.000     0.002     0.000     2.000
  111          1.000     0.350     2.000     0.010     0.000     2.000
  202  203     1.000     0.450     2.000     0.010     0.000     1.000
  204          1.000     0.500     2.000     0.010     0.000     1.000
  205  207     1.000     0.650     2.000     0.010     0.000     1.000
  208          1.000     0.400     2.000     0.002     0.000     2.000
  209          1.000     0.450     2.000     0.010     0.000     2.000
  210          1.000     0.200     2.000     0.002     0.000     2.000
  211          1.000     0.450     2.000     0.010     0.000     2.000
  302  303     1.000     0.400     2.000     0.010     0.000     1.000
  304          1.000     0.420     2.000     0.010     0.000     1.000
  305  307     1.000     0.400     2.000     0.010     0.000     1.000
  308          1.000     0.400     2.000     0.002     0.000     2.000
  309          1.000     0.400     2.000     0.010     0.000     2.000
  310          1.000     0.150     2.000     0.002     0.000     2.000
  311          1.000     0.400     2.000     0.010     0.000     2.000
  402  403     1.000     0.440     2.000     0.010     0.000     1.000
  404          1.000     0.440     2.000     0.010     0.000     1.000
  405  407     1.000     0.440     2.000     0.010     0.000     1.000
  408          1.000     0.400     2.000     0.002     0.000     2.000
  409          1.000     0.440     2.000     0.010     0.000     2.000
  410          1.000     0.150     2.000     0.002     0.000     2.000
  411          1.000     0.440     2.000     0.010     0.000     2.000
  END SED-PARM2
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  SED-PARM3
*** <PLS >  Sediment parameter 3
*** x -  x      KSER      JSER      KGER      JGER
  102          0.060     1.700     0.007     2.000
  103          0.080     1.700     0.020     2.000
  104          0.130     1.700     0.030     2.000
  105  107     0.600     1.500     0.050     2.000
  108          0.050     1.500     0.002     2.000
  109          0.120     1.500     0.005     2.000
  110          0.004     1.500     0.000     2.000
  111          0.120     1.500     0.005     2.000
  202          2.600     1.700     0.200     2.000
  203          2.800     1.700     0.300     2.000
  204          3.000     1.700     0.500     2.000
  205  207     6.000     1.500     0.600     2.000
  208          2.000     1.500     0.030     2.000
  209          3.200     1.500     0.050     2.000
  210          0.008     1.500     0.000     2.000
  211          3.200     1.500     0.050     2.000
  302          0.700     1.800     0.100     2.000
  303          0.900     1.800     0.250     2.000
  304          1.200     1.800     0.350     2.000
  305  307     2.800     1.600     0.400     2.000
  308          0.400     1.600     0.010     2.000
  309          0.900     1.600     0.020     2.000
  310          0.008     1.600     0.000     2.000
  311          0.900     1.600     0.020     2.000
  402          0.800     1.800     0.100     2.000
  403          1.250     1.800     0.300     2.000
  404          1.300     1.800     0.500     2.000
  405  406     3.700     1.600     0.600     2.000
  407          3.700     1.600     0.600     2.000
  408          0.600     1.600     0.010     2.000
  409          1.050     1.600     0.020     2.000
  410          0.006     1.600     0.000     2.000
  411          1.050     1.600     0.020     2.000
  END SED-PARM3

  MON-COVER
*** <PLS >  Monthly values for erosion related cover
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  104 0.90 0.90 0.90 0.91 0.93 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  105  107 0.50 0.45 0.20 0.10 0.15 0.45 0.65 0.65 0.65 0.60 0.60 0.55
  108      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  109      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  110      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  111      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  202  204 0.90 0.90 0.90 0.91 0.93 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  205  207 0.50 0.45 0.20 0.10 0.15 0.45 0.65 0.65 0.65 0.60 0.60 0.55
  208      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  209      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  210      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  211      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  302  304 0.90 0.90 0.90 0.91 0.93 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  305  307 0.50 0.45 0.20 0.10 0.15 0.50 0.75 0.75 0.75 0.70 0.65 0.55
  308      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  309      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  310      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  311      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  402  404 0.90 0.90 0.90 0.91 0.93 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  405  407 0.50 0.45 0.20 0.10 0.15 0.50 0.75 0.75 0.75 0.70 0.65 0.55
  408      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  409      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  410      0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97 0.97
  411      0.90 0.90 0.90 0.90 0.92 0.93 0.93 0.93 0.93 0.91 0.90 0.90
  END MON-COVER

  SED-STOR
*** <PLS >  Detached sediment storage (tons/acre)
*** x -  x      DETS
  102  411    0.3000
  END SED-STOR

  PSTEMP-PARM1
*** <PLS >  Flags for section PSTEMP
*** x -  x SLTV ULTV LGTV TSOP
  102  411    1    1    1    1
  END PSTEMP-PARM1

  PSTEMP-PARM2
PERLND ***      ASLT      BSLT     ULTP1     ULTP2     LGTP1     LGTP2
  102  411      32.0      0.50      32.0      0.90      75.0       0.0
  END PSTEMP-PARM2

  MON-ASLT
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  411 32.0 32.0 38.5 47.0 55.5 64.5 69.0 70.0 61.5 53.0 44.5 36.0
  END MON-ASLT

  MON-BSLT
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  411 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
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  END MON-BSLT

  MON-ULTP1
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  411 43.0 43.0 44.0 45.0 52.0 52.5 56.0 58.0 55.0 51.8 46.0 44.0
  END MON-ULTP1

  MON-ULTP2
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  411 0.06 0.06 0.06 0.06 0.06 0.07 0.07 0.07 0.06 0.06 0.09 0.09
  END MON-ULTP2

  MON-LGTP1
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  411 52.0 53.0 57.0 60.0 62.5 64.5 68.0 68.5 66.5 62.0 59.0 53.0
  END MON-LGTP1

  PSTEMP-TEMPS
PERLND ***     AIRTC     SLTMP     ULTMP     LGTMP
  102  411      16.0      25.0      34.0      49.0
  END PSTEMP-TEMPS

  PWT-PARM2
PERLND ***      ELEV     IDOXP     ICO2P     ADOXP     ACO2P
  102  411      400.      8.80         0      8.80         0
  END PWT-PARM2

  MON-IFWDOX
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  411 11.0 10.0 10.0 10.0 9.00 7.00 6.00 6.00 7.00 9.00 10.0 11.0
  END MON-IFWDOX

  MON-GRNDDOX
PERLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  102  411 11.0 10.0 10.0 10.0 9.00 7.00 6.00 6.00 7.00 9.00 10.0 11.0
  END MON-GRNDDOX

  PWT-TEMPS
PERLND ***     SOTMP     IOTMP     AOTMP
  102  411       32.       36.       56.
  END PWT-TEMPS

  PWT-GASES
PERLND ***     SODOX     SOCO2     IODOX     IOCO2     AODOX     AOCO2
  102  411       8.8         0       8.8         0       8.8         0
  END PWT-GASES

*** Water Quality Constituents N and P ***
  NQUALS
    #    # NQAL  ***
  102  411    5
  END NQUALS

  QUAL-PROPS
    #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
  102  411         NO3     LBS    1    2    0    0    0    1    4    1    4
  END QUAL-PROPS

  QUAL-INPUT
    #    #      SQO   POTFW   POTFS   ACQOP  SQOLIM   WSQOP    IOQC    AOQC  ***
  102        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  103        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  104        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  105        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
  106        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
  107        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
  108        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
  109        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  110        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
  111        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  202        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  203        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  204        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  205        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
  206        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
  207        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
  208        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
  209        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  210        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
  211        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  302        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  303        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  304        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  305        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
  306        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
  307        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
  308        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
  309        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  310        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
  311        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  402        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
  403        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
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404        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
405        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
406        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
407        0.100      1.      1.  0.0411  0.7500   0.500      1.      1. ***
408        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
409        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
410        0.100      1.      1.  0.0137  0.2500   0.500      1.      1. ***
411        0.100      1.      1.  0.0274  0.5000   0.500      1.      1. ***
END QUAL-INPUT

MON-POTFW
          Potency factors for NO3 (lb NO3-N/ton sediment)                ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC    ***
102       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
202       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
302       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
402       1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5  1.5
103       1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4
203       1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4
303       1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4
403       1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4  1.4
104       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
204       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
304       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
404       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
105       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
205       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
305       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
405       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
106       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
206       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
306       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
406       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
107       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
207       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
307       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
407       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
108        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
208        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
308        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
408        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
109        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
209        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
309        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
409        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
110        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
210        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
310        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
410        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
111        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
211        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
311        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
411        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
END MON-POTFW

MON-IFLW-CONC
          Interflow concentration of NO3-N (mg/l)                        ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC    ***
102       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
202       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
302       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
402       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
103       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
203       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
303       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
403       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
104       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
204       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
304       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
404       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
105       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
205       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
305       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
405       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
106       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
206       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
306       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
406       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
107       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
207       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
307       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
407       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
108      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
208      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
308      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
408      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
109       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
209       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
309       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
409       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
110      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
210      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
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310      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
410      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
111       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
211       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
311       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
411       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
END MON-IFLW-CONC

MON-GRND-CONC
          Active groundwater concentration of NO3-N (mg/l)            ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
102       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
202       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
302       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
402       3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5  3.5
103       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
203       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
303       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
403       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
104       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
204       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
304       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
404       1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8  1.8
105       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
205       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
305       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
405       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
106       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
206       6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
306       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
406       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
107       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
207       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
307       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
407       8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
108      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
208      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
308      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
408      .400 .400 .400 .350 .350 .300 .300 .250 .300 .300 .350 .400
109       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
209       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
309       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
409       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
110      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
210      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
310      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
410      .700 .680 .600 .570 .530 .470 .430 .360 .430 .500 .570 .640
111       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
211       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
311       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
411       1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2  1.2
END MON-GRND-CONC

QUAL-PROPS
  #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
102  411         NH4     LBS    1    2    0    0    0    1    4    1    4
END QUAL-PROPS

MON-POTFW
          Potency factors for NH4 (lb NH4-N/ton sediment)             ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
102       .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24
202       .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24
302       .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24
402       .18  .18  .18  .18  .18  .18  .18  .18  .18  .18  .18  .18
103       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
203       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
303       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
403       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
104       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
204       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
304       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
404       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
105       .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40
205       .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40  .40
305       .30  .30  .30  .30  .30  .30  .30  .30  .30  .30  .30  .30
405       .07  .07  .07  .07  .07  .07  .07  .07  .07  .07  .07  .07
106       .35  .35  .35  .35  .35  .35  .35  .35  .35  .35  .35  .35
206       .30  .30  .30  .30  .30  .30  .30  .30  .30  .30  .30  .30
306       .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15
406       .06  .06  .06  .06  .06  .06  .06  .06  .06  .06  .06  .06
107       .20  .20  .20  .20  .20  .20  .20  .20  .20  .20  .20  .20
207       .20  .20  .20  .20  .20  .20  .20  .20  .20  .20  .20  .20
307       .20  .20  .20  .20  .20  .20  .20  .20  .20  .20  .20  .20
407       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
108      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
208      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
308      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
408      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
109       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
209       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
309       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
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409       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
110      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
210      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
310      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
410      .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002 .002
111       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
211       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
311       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
411       .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10  .10
END MON-POTFW

MON-IFLW-CONC
          Interflow concentration of NH4-N (mg/l)                       ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC    ***
102      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
202      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
302      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
402      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
103      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
203      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
303      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
403      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
104      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
204      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
304      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
404      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
105      .030 .030 .030 .030 .030 .030 .030 .030 .030 .030 .030 .030
205      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
305      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
405      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
106      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
206      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
306      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
406      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
107      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
207      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
307      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
407      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
108      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
208      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
308      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
408      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
109      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
209      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
309      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
409      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
110      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
210      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
310      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
410      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
111      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
211      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
311      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
411      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
END MON-IFLW-CONC

MON-GRND-CONC
          Active groundwater concentration of NH4-N (mg/l)              ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC    ***
102      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
202      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
302      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
402      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
103      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
203      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
303      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
403      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
104      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
204      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
304      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
404      .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015 .015
105      .030 .030 .030 .030 .030 .030 .030 .030 .030 .030 .030 .030
205      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
305      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
405      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
106      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
206      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
306      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
406      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
107      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
207      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
307      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
407      .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028 .028
108      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
208      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
308      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
408      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
109      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
209      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
309      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
409      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
110      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
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210      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
310      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
410      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
111      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
211      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
311      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
411      .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027 .027
END MON-GRND-CONC

QUAL-PROPS
  #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
102  411         PO4     LBS    1    2    0    0    0    1    4    1    4
END QUAL-PROPS

MON-POTFW
          Potency factors for PO4 (lb PO4-P/ton sediment)             ***
  #     #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
102        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
202        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
302        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
402        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
103        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
203        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
303        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
403        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
104        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
204        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
304        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
404        0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6  0.6
105        8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0  8.0
205        4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
305        4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
405        4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
106        6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0  6.0
206        4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
306        4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
406        4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
107        10.  10.  10.  10.  10.  10.  10.  10.  10.  10.  10.  10.
207        10.  10.  10.  10.  10.  10.  10.  10.  10.  10.  10.  10.
307        10.  10.  10.  10.  10.  10.  10.  10.  10.  10.  10.  10.
407        10.  10.  10.  10.  10.  10.  10.  10.  10.  10.  10.  10.
108       .020 .020 .020 .020 .020 .035 .035 .035 .035 .020 .020 .020
208       .020 .020 .020 .020 .020 .035 .035 .035 .035 .020 .020 .020
308       .010 .010 .010 .010 .010 .025 .025 .025 .025 .010 .010 .010
408       .010 .010 .010 .010 .010 .025 .025 .025 .025 .010 .010 .010
109        1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
209        1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
309        0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8
409        0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8
110       .020 .020 .020 .020 .020 .035 .035 .035 .035 .020 .020 .020
210       .020 .020 .020 .020 .020 .035 .035 .035 .035 .020 .020 .020
310       .020 .020 .020 .020 .020 .035 .035 .035 .035 .020 .020 .020
410       .020 .020 .020 .020 .020 .035 .035 .035 .035 .020 .020 .020
111        1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
211        1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0  1.0
311        0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8
411        0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8  0.8
END MON-POTFW

MON-IFLW-CONC
          Interflow concentration of PO4-P (mg/l)                     ***
  #     #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
102       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
202       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
302       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
402       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
103       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
203       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
303       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
403       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
104       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
204       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
304       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
404       .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
105       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
205       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
305       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
405       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
106       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
206       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
306       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
406       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
107       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
207       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
307       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
407       .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
108       .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
208       .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
308       .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
408       .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
109       .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
209       .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
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309      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
409      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
110      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
210      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
310      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
410      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
111      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
211      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
311      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
411      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
END MON-IFLW-CONC

MON-GRND-CONC
          Active groundwater concentration of PO4-P (mg/l)          ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
102      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
202      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
302      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
402      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
103      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
203      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
303      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
403      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
104      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
204      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
304      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
404      .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025 .025
105      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
205      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
305      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
405      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
106      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
206      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
306      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
406      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
107      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
207      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
307      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
407      .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040 .040
108      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
208      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
308      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
408      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
109      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
209      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
309      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
409      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
110      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
210      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
310      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
410      .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005 .005
111      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
211      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
311      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
411      .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010 .010
END MON-GRND-CONC

QUAL-PROPS
  #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
102  411         BOD     LBS    1    2    0    0    0    1    4    1    4
END QUAL-PROPS

MON-POTFW
          Potency factors for BOD (lb BOD/ton sediment)                 ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
102       25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.
202       25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.
302       25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.
402       25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.  25.
103       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
203       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
303       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
403       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
104       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
204       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
304       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
404       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
105       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
205       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
305       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
405       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
106       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
206       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
306       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
406       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
107       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
207       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
307       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
407       35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.  35.
108       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
208       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
308       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
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408       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
109       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
209       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
309       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
409       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
110       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
210       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
310       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
410       8.5  8.5  8.5  8.5  8.5  5.5  5.5  5.5  5.5  8.5  8.5  8.5
111       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
211       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
311       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
411       20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
END MON-POTFW

MON-IFLW-CONC
          Interflow concentration of BOD (mg/l)                         ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC    ***
102       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
202       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
302       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
402       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
103        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
203        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
303        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
403        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
104        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
204        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
304        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
404        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
105        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
205        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
305        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
405        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
106        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
206        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
306        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
406        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
107        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
207        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
307        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
407        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
108        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
208        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
308        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
408        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
109        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
209        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
309        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
409        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
110        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
210        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
310        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
410        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
111        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
211        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
311        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
411        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
END MON-IFLW-CONC

MON-GRND-CONC
          Active groundwater concentration of BOD (mg/l)                ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC    ***
102       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
202       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
302       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
402       .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65  .65
103        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
203        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
303        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
403        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
104        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
204        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
304        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
404        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
105        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
205        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
305        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
405        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
106        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
206        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
306        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
406        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
107        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
207        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
307        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
407        2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.
108        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
208        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
308        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
408        .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
109        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
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209        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
309        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
409        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
110        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
210        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
310        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
410        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
111        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
211        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
311        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
411        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
END MON-GRND-CONC

QUAL-PROPS
  #    #<--QUALID-->    QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC  ***
102  411        ORGN     LBS    1    1    0    0    0    1    4    1    4
END QUAL-PROPS

MON-POTFW
          Potency factors for ORGN (lb ORGN/ton sediment)              ***
102       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
202       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
302       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
402       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
103       1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3
203       1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3
303       1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3  1.3
403        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
104        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
204        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
304        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
404        1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
105       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
205       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
305       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
405       4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0  4.0
106       3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0
206       3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0
306       3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0
406       3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0  3.0
107       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
207       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
307       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
407       5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0  5.0
108       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
208       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
308       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
408       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
109       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
209       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
309       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
409       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
110       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
210       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
310       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
410       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
111       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
211       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
311       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
411       2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0  2.0
END MON-POTFW

MON-IFLW-CONC
          Interflow concentration of ORGN (mg/l)                       ***
  #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
102       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
202       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
302       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
402       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
103        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
203        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
303        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
403        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
104        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
204        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
304        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
404        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
105        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
205        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
305        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
405        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
106        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
206        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
306        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
406        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
107        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
207        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
307        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
407        .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6   .6
108        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
208        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
308        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
```

```
  408        .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2   .2
  109       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
  209       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
  309       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
  409       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
  110        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
  210        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
  310        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
  410        .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1   .1
  111       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
  211       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
  311       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
  411       .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25  .25
  END MON-IFLW-CONC

  MON-GRND-CONC
          Active groundwater concentration of ORGN (mg/l)              ***
    #    #  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC  ***
  102  411  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15
  END MON-GRND-CONC

END PERLND

*** Impervious ***

IMPLND
  ACTIVITY
    #    # ATMP SNOW IWAT  SLD  IWG IQAL  ***
  101  402    1    1    1    1    1    1
  END ACTIVITY

  PRINT-INFO
    #    # ATMP SNOW IWAT  SLD  IWG IQAL PIVL  PYR  ***
  101  402    5    5    5    5    5    5    0   12
  END PRINT-INFO

  GEN-INFO
    #    #      NAME            UCI   IN  OUT ENGL METR  ***
  101     ROADS,BUILDING-resid    1    1    1   90    0
  102     ROADS,BUILDING-urban    1    1    1   90    0
  201     ROADS,BUILDING-resid    1    1    1   90    0
  202     ROADS,BUILDING-urban    1    1    1   90    0
  301     ROADS,BUILDING-resid    1    1    1   90    0
  302     ROADS,BUILDING-urban    1    1    1   90    0
  401     ROADS,BUILDING-resid    1    1    1   90    0
  402     ROADS,BUILDING-urban    1    1    1   90    0
  END GEN-INFO

**** AIR TEMPERATURE ****

  ATEMP-DAT
              ELDAT    AIRTMP ***
    #    #     (ft)   (deg F) ***
  101  102      0.0       25.
  201  202      0.0       27.
  301  302      0.0       25.
  401  402      0.0       27.
  END ATEMP-DAT

**** SNOW ****

  ICE-FLAG
*** <ILS > ICEFG
*** #    #
  101  402    1
  END ICE-FLAG

  SNOW-PARM1
*** <ILS >       LAT     MELEV     SHADE    SNOWCF    COVIND
*** #    #     (deg)      (ft)                          (in)
  101  102      40.1      700.      0.10       1.0      1.00
  201  202      40.0      450.      0.65       1.0      1.00
  301  302      40.0      500.      0.70       1.0      1.00
  401  402      39.9      250.      0.70       1.0      1.00
  END SNOW-PARM1

  SNOW-PARM2
*** <ILS >     RDSCN     TSNOW    SNOEVP    CCFACT    MWATER    MGMELT
*** #    #              (degF)                                (in/day)
  101  102      0.35      30.0      0.05      1.00      0.25      0.02
  201  202      0.23      30.0      0.10      0.28      0.25      0.01
  301  302      0.23      30.0      0.10      0.28      0.25      0.01
  401  402      0.23      30.0      0.10      0.28      0.25      0.01
  END SNOW-PARM2

**** HYDROLOGY ****

  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  101  402    1    1    1    0    0
  END IWAT-PARM1
```

```
  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (in)
  101          200.0     0.036      0.07       0.0
  102          200.0     0.031      0.05       0.0
  201          200.0     0.036      0.07       0.0
  202          200.0     0.031      0.05       0.0
  301          200.0     0.036      0.07       0.0
  302          200.0     0.031      0.05       0.0
  401          200.0     0.036      0.07       0.0
  402          200.0     0.031      0.05       0.0
  END IWAT-PARM2

  IWAT-PARM3
*** <ILS >    PETMAX    PETMIN
*** x -  x   (deg F)   (deg F)
  101  402      40.0      35.0
  END IWAT-PARM3

  MON-RETN
*** <ILS >  Retention storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101  4020.0370.0370.0490.0490.0490.0650.0650.0650.0490.0490.0490.037
  END MON-RETN

  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
  101  402       0.0       0.0
  END IWAT-STATE1

  SLD-PARM1
*** <ILS >     Flags
*** x -  x VASD VRSD SDOP
  101         0    0    1
  102         0    0    1
  201         0    0    1
  202         0    0    1
  301         0    0    1
  302         0    0    1
  401         0    0    1
  402         0    0    1
  END SLD-PARM1

  SLD-PARM2
IMPLND ***      KEIM      JEIM    ACCSDP    REMSDP
  101            1.0       1.2    0.0006      0.08
  102            1.0       1.2    0.0060      0.08
  201            1.0       1.2    0.0006      0.08
  202            1.0       1.2    0.0060      0.08
  301            1.0       1.2    0.0006      0.08
  302            1.0       1.2    0.0060      0.08
  401            1.0       1.2    0.0006      0.08
  402            1.0       1.2    0.0060      0.08
  END SLD-PARM2

  SLD-STOR
IMPLND ***      SLDS
  101  402      0.05
  END SLD-STOR

  IWT-PARM1
*** <ILS >  Flags for section IWTGAS
*** x -  x WTFV CSNO
  101  102    1    1
  201  202    1    1
  301  302    1    1
  401  402    1    1
  END IWT-PARM1

  IWT-PARM2
IMPLND ***      ELEV      AWTF      BWTF
  101  102      600.      34.0      0.3
  201  202      600.      34.0      0.3
  301  302      600.      34.0      0.3
  401  402      600.      34.0      0.3
  END IWT-PARM2

  MON-AWTF
IMPLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101  402 32.0 32.0 38.5 47.0 55.5 63.5 68.0 69.0 61.5 53.0 44.5 36.0
  END MON-AWTF

  MON-BWTF
IMPLND ***  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  101  402 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
  END MON-BWTF

  IWT-INIT
*** <ILS >     SOTMP     SODOX     SOCO2
*** x -  x   (deg F)    (mg/l)  (mg C/l)
```

```
  101  102  33.
  201  202  33.
  301  302  33.
  401  402  33.
  END IWT-INIT

*** WATER QUALITY CONSTITUENTS ***

  NQUALS
    #    # NQAL  ***
  101  102    4
  201  202    4
  301  302    4
  401  402    4
  END NQUALS

  QUAL-PROPS
    #    #<--QUALID-->    QTID  QSD VPFW  QSO  VQO  ***
  101  102         NO3     LBS    0    0    1    0
  201  202         NO3     LBS    0    0    1    0
  301  302         NO3     LBS    0    0    1    0
  401  402         NO3     LBS    0    0    1    0
  END QUAL-PROPS

  QUAL-INPUT
    #    #     SQO   POTFW   ACQOP  SQOLIM   WSQOP  ***
  101  102   0.050          0.0060  0.4000   0.500
  201  202   0.050          0.0060  0.4000   0.500
  301  302   0.050          0.0060  0.4000   0.500
  401  402   0.050          0.0060  0.4000   0.500
  END QUAL-INPUT

  QUAL-PROPS
    #    #<--QUALID-->    QTID  QSD VPFW  QSO  VQO  ***
  101  102         NH4     LBS    1    0    1    0
  201  202         NH4     LBS    1    0    1    0
  301  302         NH4     LBS    1    0    1    0
  401  402         NH4     LBS    1    0    1    0
  END QUAL-PROPS

  QUAL-INPUT
    #    #     SQO   POTFW   ACQOP  SQOLIM   WSQOP  ***
  101  102   0.020     0.1  0.0010  0.1200   0.500
  201  202   0.020     0.1  0.0010  0.1200   0.500
  301  302   0.020     0.1  0.0010  0.1200   0.500
  401  402   0.020     0.1  0.0010  0.1200   0.500
  END QUAL-INPUT

  QUAL-PROPS
    #    #<--QUALID-->    QTID  QSD VPFW  QSO  VQO  ***
  101  102         PO4     LBS    1    0    1    0
  201  202         PO4     LBS    1    0    1    0
  301  302         PO4     LBS    1    0    1    0
  401  402         PO4     LBS    1    0    1    0
  END QUAL-PROPS

  QUAL-INPUT
    #    #     SQO   POTFW   ACQOP  SQOLIM   WSQOP  ***
  101        0.010     1.2  0.0006  0.0090   0.500
  102        0.010     1.0  0.0004  0.0090   0.500
  201        0.010     1.2  0.0006  0.0090   0.500
  202        0.010     1.0  0.0004  0.0090   0.500
  301        0.010     1.2  0.0006  0.0090   0.500
  302        0.010     1.0  0.0004  0.0090   0.500
  401        0.010     1.2  0.0006  0.0090   0.500
  402        0.010     1.0  0.0004  0.0090   0.500
  END QUAL-INPUT

  QUAL-PROPS
    #    #<--QUALID-->    QTID  QSD VPFW  QSO  VQO  ***
  101  102         BOD     LBS    0    0    1    0
  201  202         BOD     LBS    0    0    1    0
  301  302         BOD     LBS    0    0    1    0
  401  402         BOD     LBS    0    0    1    0
  END QUAL-PROPS

  QUAL-INPUT
    #    #     SQO   POTFW   ACQOP  SQOLIM   WSQOP  ***
  101  102   1.900          0.3600  9.0000   0.500
  201  202   1.900          0.3600  9.0000   0.500
  301  302   1.900          0.3600  9.0000   0.500
  401  402   1.900          0.3600  9.0000   0.500
  END QUAL-INPUT
END IMPLND

RCHRES
  ACTIVITY
    RCHRES  Active Sections (1=Active; 0=Inactive)           ***
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
    1   35    1    1    0    1    1    0    1    1    1    0
  END ACTIVITY
```

```
  PRINT-INFO
    RCHRES  Print-flags                                                  ***
    # -   # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR ***
    1   35    5    5         5    5    5    5    5    5             12
  END PRINT-INFO

  GEN-INFO
    RCHRES<-------Name------->Nexit   Unit Systems   Printer      ***
    # -  #                              t-series  Engl Metr LKFG ***
                                          in  out                ***
    1     WBR-HONEYBROOK         1         1    1   90    0    0
    2     WBR-HIBERNIA           1         1    1   90    0    0
    3     WBR-ROCK RUN           2         1    1   90    0    0
    4     WBR-COATESVILLE        1         1    1   90    0    0
    5     WBR-MODENA             2         1    1   90    0    0
    6     WBR-BUCK&DOE           2         1    1   90    0    0
    7     WBR-BROAD RUN          2         1    1   90    0    0
    8     WBR-WAWASET            1         1    1   90    0    0
    9     EBR-STRUBLE LAKE       1         1    1   90    0    0
   10     EBR-INDIAN RUN         1         1    1   90    0    0
   11     EBR-NEAR DOWNINGTOWN   1         1    1   90    0    0
   12     EBR-DOWNINGTOWN        2         1    1   90    0    0
   13     EBR-BELOW DOWNGTOWN    3         1    1   90    0    0
   14     EBR-WAWASET            2         1    1   90    0    0
   15     MS-LENAPE              1         1    1   90    0    0
   16     MS-CHADDS FORD         2         1    1   90    0    0
   17     MS-SMITHS BRIDGE       1         1    1   90    0    0
   18     MS-ROCKLAND            2         1    1   90    0    0
   19     MS-WILMINGTON          3         1    1   90    0    0
   20     BUCK RUN               1         1    1   90    0    0
   21     DOE RUN-UPPER          1         1    1   90    0    0
   22     DOE RUN-LOWER          1         1    1   90    0    0
   23     BUCK&DOE               1         1    1   90    0    0
   24     LITTLE BROAD           1         1    1   90    0    0
   25     BROAD RUN              1         1    1   90    0    0
   26     MARSH CK ABOVE RES     1         1    1   90    0    0
   27     MARSH CK RESERVOIR     1         1    1   90    0    1
   28     TRIB-VALLEY CK,EXTON   1         1    1   90    0    0
   29     W.VALLEY CK            3         1    1   90    0    0
   30     BEAVER CREEK           1         1    1   90    0    0
   31     POCOPSON CREEK         1         1    1   90    0    0
   32     BIRCH RUN (HIBERNIA)   1         1    1   90    0    0
   33     ROCK RUN               2         1    1   90    0    0
   34     MS-BELOW WILMINGTON    2         1    1   90    0    0
   35     MARSH CK-LYONS RUN     1         1    1   90    0    0
  END GEN-INFO

**** HYDRAULICS

  HYDR-PARM1
    RCHRES  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
    # -  #  FG FG FG FG  possible    exit *** possible   exit     possible   exit
    1    2   0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1
    3        0  1  1  1    4  0  0  0  0        0  2  0  0  0        2  2  2  1  1
    4        0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1
    5    7   0  1  1  1    4  0  0  0  0        0  2  0  0  0        2  2  2  1  1
    8   11   0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1
   12        0  1  1  1    4  0  0  0  0        0  2  0  0  0        2  2  2  1  1
   13        0  1  1  1    4  0  0  0  0        0  2  3  0  0        2  2  2  1  1
   14        0  1  1  1    4  0  0  0  0        0  2  0  0  0        2  2  2  1  1
   15        0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1
   16        0  1  1  1    4  0  0  0  0        0  2  0  0  0        2  2  2  1  1
   17        0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1
   18        0  1  1  1    4  0  0  0  0        0  2  0  0  0        2  2  2  1  1
   19        0  1  1  1    4  0  0  0  0        0  2  3  0  0        2  2  2  1  1
   20   26   0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1
   27        0  1  1  1    0  0  0  0  0        1  0  0  0  0        2  2  2  1  1
   28        0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1
   29        0  1  1  1    4  0  0  0  0        0  2  3  0  0        2  2  2  1  1
   30        0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1
   31        0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1
   32        0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1
   33        0  1  1  1    4  0  0  0  0        0  2  0  0  0        2  2  2  1  1
   34        0  1  1  1    4  0  0  0  0        0  2  0  0  0        2  2  2  1  1
   35        0  1  1  1    4  0  0  0  0        0  0  0  0  0        2  2  2  1  1

  END HYDR-PARM1

  HYDR-PARM2
    RCHRES FTBW FTID        LEN     DELTH     STCOR        KS      DB50  ***
    # -  #               (miles)     (ft)      (ft)                (in)  ***
    1       0.0    1       6.60     101.0       0.0       0.5      0.01
    2       0.0    2       7.60     104.0       0.0       0.5      0.01
    3       0.0    3       2.94     140.0       0.0       0.5      0.01
    4       0.0    4       1.85      50.0       0.0       0.5      0.01
    5       0.0    5       2.91      40.0       0.0       0.5      0.01
    6       0.0    6       2.93      35.0       0.0       0.5      0.01
    7       0.0    7       7.80      42.0       0.0       0.5      0.01
    8       0.0    8       2.19      13.0       0.0       0.5      0.01
    9       0.0    9       7.10     130.0       0.0       0.5      0.01
   10       0.0   10      12.10     180.0       0.0       0.5      0.01
   11       0.0   11       1.79      30.0       0.0       0.5      0.01
```

```
    12        0.0   12      2.02      45.0       0.0       0.5      0.01
    13        0.0   13      3.86      21.0       0.0       0.5      0.01
    14        0.0   14      4.86      24.0       0.0       0.5      0.01
    15        0.0   15      2.49      10.0       0.0       0.5      0.01
    16        0.0   16      2.88      15.0       0.0       0.5      0.01
    17        0.0   17      4.15      15.0       0.0       0.5      0.01
    18        0.0   18      3.39      10.0       0.0       0.5      0.01
    19        0.0   19      2.71      67.0       0.0       0.5      0.01
    20        0.0   20      8.66     188.0       0.0       0.5      0.01
    21        0.0   21      6.73     165.0       0.0       0.5      0.01
    22        0.0   22      3.18      73.0       0.0       0.5      0.01
    23        0.0   23      0.87     160.0       0.0       0.5      0.01
    24        0.0   24      3.14     122.0       0.0       0.5      0.01
    25        0.0   25      3.14     122.0       0.0       0.5      0.01
    26        0.0   26      1.60      60.0       0.0       0.5      0.01
    27        0.0   27      4.80       0.0     289.5       0.5      0.01
    28        0.0   28      2.00     165.0       0.0       0.5      0.01
    29        0.0   29      7.20     131.0       0.0       0.5      0.01
    30        0.0   30      4.09     300.0       0.0       0.5      0.01
    31        0.0   31      4.09     120.0       0.0       0.5      0.01
    32        0.0   32      2.00     115.0     547.0       0.5      0.01
    33        0.0   33      2.75     155.0       0.0       0.5      0.01
    34        0.0   34      4.46      57.0       0.0       0.5      0.01
    35        0.0   35      4.00      10.0       0.0       0.5      0.01
  END HYDR-PARM2

  HYDR-INIT
    RCHRES       VOL ***   Initial value of COLIND      Initial value  of OUTDGT
    # -  #     ac-ft ***   for each exit                for each exit (ft3)
     1          7.00       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
     2         19.78       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
     3          5.45       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
     4          4.98       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
     5         10.00       4.0  0.0  0.0  0.0  0.0       0.0  2.1  0.0  0.0  0.0
     6         13.25       4.0  0.0  0.0  0.0  0.0       0.0  0.1  0.0  0.0  0.0
     7         72.15       4.0  0.0  0.0  0.0  0.0       0.0  0.2  0.0  0.0  0.0
     8         23.00       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
     9          6.00       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    10         17.60       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    11          5.80       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    12          6.48       4.0  0.0  0.0  0.0  0.0       0.0  2.0  0.0  0.0  0.0
    13         17.90       4.0  0.0  0.0  0.0  0.0       0.0  1.8  0.3  0.0  0.0
    14         35.80       4.0  0.0  0.0  0.0  0.0       0.0  5.8  0.0  0.0  0.0
    15         30.00       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    16         40.60       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    17         84.40       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    18         89.70       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    19         42.30       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    20         31.69       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    21          3.20       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    22         11.64       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    23          8.71       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    24          0.53       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    25          3.83       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    26          1.40       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    27      14130.00       4.0  0.0  0.0  0.0  0.0      11.0  0.0  0.0  0.0  0.0
    28          0.30       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    29          5.80       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    30         46.64       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    31          7.70       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    32          2.00       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    33        773.00       4.0  0.0  0.0  0.0  0.0       0.0  4.7  0.0  0.0  0.0
    34         46.00       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
    35          8.00       4.0  0.0  0.0  0.0  0.0       0.0  0.0  0.0  0.0  0.0
  END HYDR-INIT

  HT-BED-FLAGS
RCHRES *** BDFG TGFG TSTP
    1   35    1    3
  END HT-BED-FLAGS

  HEAT-PARM
RCHRES ***       ELEV     ELDAT    CFSAEX    KATRAD     KCOND     KEVAP
    1    5       350.        0.       0.5      10.5       7.0       2.0
    6   35       350.        0.       1.3      11.0       5.5       2.0
  END HEAT-PARM

  HT-BED-PARM
RCHRES ***     MUDDEP     TGRND      KMUD     KGRND
    1   35       0.25       61.       90.       1.4
  END HT-BED-PARM

  MON-HT-TGRND
RCHRES ***   JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
    1    26 36.0 38.0 40.0 48.0 56.5 62.0 68.0 69.5 67.0 59.0 50.5 43.5
   27       41.0 40.0 42.0 49.0 54.5 60.5 68.5 68.5 68.0 60.0 52.5 46.0
   28    35 36.0 38.0 40.0 48.0 56.5 62.0 68.0 69.5 67.0 59.0 50.5 43.5
  END MON-HT-TGRND

  HEAT-INIT
RCHRES ***         TW    AIRTMP
    1   35        32.       16.
```

```
  END HEAT-INIT

  SANDFG
*** RCHRES

*** x -  x SNDFG
    1   35    3

  END SANDFG

  SED-GENPARM
RCHRES ***    BEDWID    BEDWRN       POR
    1   35       25.        6.       0.7
  END SED-GENPARM

  SAND-PM
RCHRES ***         D         W       RHO     KSAND    EXPSND
    1   23      .005       0.1       2.6      0.10      3.92
   24           .005       0.1       2.6      0.05      3.45
   25   35      .005       0.1       2.6      0.10      3.92
  END SAND-PM

  SILT-CLAY-PM
RCHRES ***         D         W       RHO     TAUCD     TAUCS         M
    1        0.00040    0.0003       2.2      0.03      0.45      0.90
    2        0.00040    0.0003       2.2      0.12      0.45      0.90
    3        0.00040    0.0003       2.2      0.20      0.90      0.90
    4        0.00040    0.0003       2.2      0.20      0.75      0.90
    5        0.00040    0.0003       2.2      0.12      0.45      0.90
    6        0.00040    0.0003       2.2      0.10      0.33      0.90
    7   10   0.00040    0.0003       2.2      0.12      0.45      0.90
   11   12   0.00040    0.0003       2.2      0.10      0.50      0.90
   13   18   0.00040    0.0003       2.2      0.12      0.45      0.90
   19        0.00040    0.0003       2.2      0.95      1.35      0.90
   20   22   0.00040    0.0003       2.2      0.03      0.40      0.90
   23        0.00040    0.0003       2.2      1.75      3.35      0.90
   24        0.00040    0.0003       2.2      0.12      0.45      0.90
   25        0.00040    0.0003       2.2      0.12      0.45      0.90
   26        0.00040    0.0003       2.2      0.38      0.65      0.90
   27        0.00040    0.0003       2.2      0.12      0.45      0.90
   28        0.00040    0.0003       2.2      0.35      0.95      0.90
   29        0.00040    0.0003       2.2      0.12      0.45      0.90
   30        0.00040    0.0003       2.2      0.25      0.85      0.90
   31        0.00040    0.0003       2.2      0.12      0.45      0.90
   32   33   0.00040    0.0003       2.2      9.00      9.50      0.90
   34        0.00040    0.0003       2.2      0.23      0.75      0.90
   35        0.00040    0.0003       2.2      0.60      0.95      0.90
  END SILT-CLAY-PM

  SILT-CLAY-PM
RCHRES ***         D         W       RHO     TAUCD     TAUCS         M
    1        0.00010   0.00001       2.1      0.01      0.40      0.90
    2        0.00010   0.00001       2.1      0.10      0.40      0.90
    3        0.00010   0.00001       2.1      0.17      0.85      0.90
    4        0.00010   0.00001       2.1      0.17      0.70      0.90
    5        0.00010   0.00001       2.1      0.10      0.40      0.90
    6        0.00010   0.00001       2.1      0.07      0.30      0.90
    7   10   0.00010   0.00001       2.1      0.10      0.40      0.90
   11   12   0.00010   0.00001       2.1      0.10      0.45      0.90
   13   18   0.00010   0.00001       2.1      0.11      0.42      0.90
   19        0.00010   0.00001       2.1      0.85      1.25      0.90
   20   22   0.00010   0.00001       2.1      0.01      0.35      0.90
   23        0.00010   0.00001       2.1      1.70      3.25      0.90
   24        0.00010   0.00001       2.1      0.10      0.40      0.90
   25        0.00010   0.00001       2.1      0.10      0.40      0.90
   26        0.00010   0.00001       2.1      0.30      0.80      0.90
   27        0.00010   0.00001       2.1      0.10      0.40      0.90
   28        0.00010   0.00001       2.1      0.33      0.85      0.90
   29        0.00010   0.00001       2.1      0.10      0.40      0.90
   30        0.00010   0.00001       2.1      0.20      0.75      0.90
   29        0.00010   0.00001       2.1      0.10      0.40      0.90
   32   33   0.00010   0.00001       2.1      8.00      9.00      0.90
   34        0.00010   0.00001       2.1      0.20      0.70      0.90
   35        0.00010   0.00001       2.1      0.35      0.65      0.90
  END SILT-CLAY-PM

  SSED-INIT
RCHRES ***     SSED1     SSED2     SSED3
    1   35        1.       25.       25.
  END SSED-INIT

  BED-INIT
RCHRES ***    BEDDEP    SANDFR    SILTFR    CLAYFR
    1   35        4.       .70       .20       .10
  END BED-INIT

  BENTH-FLAG
*** RCHRES  Benthic release flag
*** x -  x BENF
    1   35    1

   END BENTH-FLAG
```

```
  SCOUR-PARMS
RCHRES ***    SCRVEL    SCRMUL
    1   35        3.         2
  END SCOUR-PARMS

  OX-FLAGS
*** RCHRES Oxygen flags
*** x -  x REAM
    1   35    3

  END OX-FLAGS

  OX-GENPARM
RCHRES ***    KBOD20     TCBOD    KODSET    SUPSAT
    1   35      .025     1.050      .200      1.25
  END OX-GENPARM

  OX-BENPARM
RCHRES ***     BENOD     TCBEN     EXPOD    BRBOD1    BRBOD2    EXPREL
    1   35       10.       1.1       1.2       10.       15.       2.5
  END OX-BENPARM

  OX-REAPARM
RCHRES ***    TCGINV      REAK    EXPRED    EXPREV
    1   35     1.024      .726    -1.673      .969
  END OX-REAPARM

  OX-INIT
RCHRES ***       DOX       BOD     SATDO
    1   35      11.3      2.92      12.0
  END OX-INIT

*** ORG-N ADVECTION ***
  GQ-QALDATA***
   *** RCHRES      GQID      DQAL  PO4  AMV  DEN ADNH ADPO PHFG ***



**** NUTRIENTS ****

  NUT-FLAGS
    RCHRES  TAM  NO2  PO4  AMV  DEN ADNH ADPO PHFG ***
    # -  #                                        ***
    1   35    1    0    1    0    1    1    1    2
  END NUT-FLAGS

  NUT-NITDENIT
    RCHRES    KTAM20    KNO220     TCNIT    KNO320     TCDEN    DENOXT ***
    # -  #       /hr       /hr                 /hr                mg/l ***
    1   25       .05      .050     1.045      .005      1.04        1.
   26            .05      .050     1.045      .005      1.04        1.
   27   34       .05      .050     1.045      .005      1.04        1.
   35            .05      .050     1.045      .005      1.04        1.
  END NUT-NITDENIT

  NUT-BEDCONC
    RCHRES       Bed concentrations of NH4 & PO4 (mg/kg)              ***
    # -  #  NH4-sand  NH4-silt  NH4-clay  PO4-sand  PO4-silt  PO4-clay ***
    1   35       1.0       30.       50.       90.      700.      900.
  END NUT-BEDCONC

  NUT-ADSPARM
    RCHRES       Partition coefficients for NH4 AND PO4  (ml/g)        ***
    # -  #  NH4-sand  NH4-silt  NH4-clay  PO4-sand  PO4-silt  PO4-clay ***
    1   35       90.      900.     1200.      600.    15000.    18000.
  END NUT-ADSPARM

  NUT-DINIT
    RCHRES       NO3       TAM       NO2       PO4        PH ***
    # -  #      mg/l      mg/l      mg/l      mg/l           ***
    1   35       2.0      .055                .033        7.
  END NUT-DINIT

  NUT-ADSINIT
    RCHRES        Initial suspended NH4 and PO4 concentrations (mg/kg) ***
    # -  #  NH4-sand  NH4-silt  NH4-clay  PO4-sand  PO4-silt  PO4-clay ***
    1   35        0.       0.1       0.3        0.       0.1       0.3
  END NUT-ADSINIT
**** PLANKTON ****

  PLNK-FLAGS
    RCHRES PHYF ZOOF BALF SDLT AMRF DECF NSFG ZFOO ***
    # -  #                                        ***
    1   35    1    0    1    0    0    1    1    2
  END PLNK-FLAGS

  PLNK-PARM1
    RCHRES    RATCLP    NONREF    LITSED     ALNPR      EXTB     MALGR ***
    # -  #                                                 /ft       /hr ***
    1    5       .60        .5        0.       0.8       .20      .200
```

```
    6    8       .60        .5        0.       0.7       .20      .200
    9   12       .60        .5        0.       0.8       .20      .200
   13   19       .60        .5        0.       0.7       .20      .200
   20   35       .60        .5        0.       0.8       .20      .200
  END PLNK-PARM1

  PLNK-PARM2
    RCHRES *** CMMLT      CMMN     CMMNP      CMMP    TALGRH    TALGRL    TALGRM
    # -  # ***ly/min      mg/l      mg/l      mg/l     deg F     deg F     deg F
    1   35       .03      .045      .029      .015       95.       32.       55.
  END PLNK-PARM2

  PLNK-PARM3
    RCHRES     ALR20      ALDH      ALDL     OXALD     NALDH     PALDH ***
    # -  #       /hr       /hr       /hr       /hr      mg/l      mg/l ***
    1   35      .045      .010      .001       .03      .015      .001
  END PLNK-PARM3

  PHYTO-PARM
    RCHRES      SEED    MXSTAY      OREF    CLALDH    PHYSET    REFSET ***
    # -  #      mg/l      mg/l                ug/l                     ***
    1   35        .4        .8       20.       50.      .012      .010
  END PHYTO-PARM

  PLNK-INIT
    RCHRES     PHYTO       ZOO     BENAL       ORN       ORP       ORC ***
    # -  #      mg/l     org/l     mg/m2      mg/l      mg/l      mg/l ***
    1   35      .700       .03    1.0E-8        1.        .2        8.
  END PLNK-INIT

END RCHRES

FTABLES
  FTABLE      1
 ROWS COLS ***  WBr Brandywine, Honeybrook
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.33      15.7       5.0       3.3     1089.
      0.67      16.9      10.4      10.7      706.
      1.00      18.2      16.3      21.4      552.
      1.33      19.5      22.6      35.2      466.
      1.67      20.7      29.3      51.9      410.
      2.00      22.0      36.4      71.6      369.
      2.67      24.5      51.9     119.8      315.
      3.33      27.1      69.1     180.2      278.
      4.00      29.6      88.0     253.4      252.
      5.33     100.7     174.9     497.8      255.
      6.67     171.8     356.6     913.9      283.
      8.00     242.9     633.1     1572.      292.
      9.33     314.0    1004.4     2530.      288.
     10.67     385.2    1470.5     3841.      278.
  END FTABLE  1

  FTABLE      2
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.38      24.6       8.9       6.2     1044.
      0.75      26.1      18.4      19.9      672.
      1.13      27.6      28.5      39.5      524.
      1.50      29.2      39.2      64.5      441.
      1.88      30.7      50.4      94.7      386.
      2.25      32.2      62.2     129.9      348.
      3.00      35.3      87.5     215.2      295.
      3.75      38.4     115.2     320.6      261.
      4.50      41.5     145.1     446.5      236.
      6.00      80.9     236.9     829.3      207.
      7.50     120.4     387.9     1381.      204.
      9.00     159.9     598.1     2148.      202.
     10.50     199.4     867.6     3169.      199.
     12.00     238.9    1196.3     4482.      194.
  END FTABLE  2

  FTABLE      3
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.42      10.6       4.3      15.4      202.
      0.83      11.2       8.8      49.4      130.
      1.25      11.8      13.6      98.1      101.
      1.67      12.5      18.7     160.0       85.
      2.08      13.1      24.0     234.5       74.
      2.50      13.7      29.6     321.3       67.
      3.33      15.0      41.6     531.2       57.
      4.17      16.2      54.6     789.7       50.
      5.00      17.5      68.6     1097.       45.
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     6.67      34.4     111.8     2028.       40.
     8.33      51.4     183.4     3371.       39.
    10.00      68.4     283.2     5242.       39.
    11.67      85.3     411.3     7738.       39.
    13.33     102.3     567.7    10948.       38.
  END FTABLE  3
  FTABLE      4
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.46       9.8       4.4      30.6      104.
      0.92      10.1       9.0      97.4       67.
      1.38      10.5      13.7     192.2       52.
      1.83      10.8      18.6     311.8       43.
      2.29      11.2      23.6     454.4       38.
      2.75      11.5      28.8     618.9       34.
      3.67      12.3      39.7     1011.       29.
      4.58      13.0      51.3     1484.       25.
      5.50      13.7      63.5     2037.       23.
      7.33      30.1     103.7     3644.       21.
      9.17      46.6     174.0     5987.       21.
     11.00      63.0     274.4     9300.       21.
     12.83      79.5     405.0    13777.       21.
     14.67      95.9     565.8    19592.       21.
  END FTABLE  4

  FTABLE      5
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.46      18.3       8.3      39.7      151.
      0.92      18.8      16.8     126.4       96.
      1.38      19.3      25.5     249.2       74.
      1.83      19.8      34.5     403.7       62.
      2.29      20.4      43.7     587.5       54.
      2.75      20.9      53.2     798.9       48.
      3.67      21.9      72.8     1300.       41.
      4.58      22.9      93.3     1902.       36.
      5.50      23.9     114.8     2601.       32.
      7.33      53.6     185.9     4552.       30.
      9.17      83.3     311.4     7276.       31.
     11.00     112.9     491.3    10981.       32.
     12.83     142.6     725.5    15844.       33.
     14.67     172.3    1014.2    22023.       33.
  END FTABLE  5

  FTABLE      6
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.46      21.9       9.9      29.0      248.
      0.92      22.4      20.0      92.3      158.
      1.38      23.0      30.5     181.9      122.
      1.83      23.6      41.1     294.6      101.
      2.29      24.1      52.1     428.6       88.
      2.75      24.7      63.2     582.7       79.
      3.67      25.8      86.4     947.6       66.
      4.58      26.9     110.6     1385.       58.
      5.50      28.1     135.8     1892.       52.
      7.33      71.5     227.0     3339.       49.
      9.17     114.9     397.8     5523.       52.
     11.00     158.3     648.2     8711.       54.
     12.83     201.7     978.1    13120.       54.
     14.67     245.1    1387.7    18950.       53.
  END FTABLE  6

  FTABLE      7
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.46      72.4      32.8      24.3      980.
      0.92      73.9      66.4      77.4      623.
      1.38      75.4     100.6     152.4      479.
      1.83      76.9     135.5     246.7      399.
      2.29      78.4     171.1     358.7      346.
      2.75      79.9     207.4     487.2      309.
      3.67      82.9     282.0     790.9      259.
      4.58      85.9     359.3     1154.      226.
      5.50      88.9     439.4     1573.      203.
      7.33     262.2     761.2     2768.      200.
      9.17     435.5    1400.8     4650.      219.
     11.00     608.9    2358.2     7489.      229.
     12.83     782.2    3633.4    11510.      229.
     14.67     955.5    5226.3    16916.      224.
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  END FTABLE  7

  FTABLE      8
 ROWS COLS ***
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.46      22.3      10.1      26.9      273.
      0.92      22.7      20.4      85.5      173.
      1.38      23.1      30.9     168.4      133.
      1.83      23.5      41.6     272.5      111.
      2.29      24.0      52.5     396.1       96.
      2.75      24.4      63.6     537.8       86.
      3.67      25.3      86.3     872.8       72.
      4.58      26.1     109.9     1272.       63.
      5.50      27.0     134.3     1734.       56.
      7.33      77.0     229.6     3037.       55.
      9.17     127.0     416.6     5063.       60.
     11.00     177.0     695.3     8092.       62.
     12.83     227.0    1065.6    12356.       63.
     14.67     277.0    1527.6    18064.       61.
  END FTABLE  8

  FTABLE      9
 ROWS COLS ***  E.Br. Brandywine,Struble Lake
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.33      17.8       5.8      11.1      378.
      0.67      18.5      11.8      35.5      242.
      1.00      19.2      18.1      70.0      188.
      1.33      20.0      24.7     113.7      157.
      1.67      20.7      31.4     165.9      138.
      2.00      21.4      38.4     226.2      123.
      2.67      22.9      53.2     370.3      104.
      3.33      24.4      69.0     545.0       92.
      4.00      25.8      85.7     749.9       83.
      5.33      59.5     142.6     1352.       77.
      6.67      93.1     244.3     2226.       80.
      8.00     126.7     390.8     3455.       82.
      9.33     160.3     582.1     5108.       83.
     10.67     193.9     818.3     7248.       82.
  END FTABLE  9

  FTABLE     10
 ROWS COLS ***  E.Br. Brandywine,Indian Run
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.38      57.2      21.2      14.6     1049.
      0.75      58.7      42.9      46.5      669.
      1.13      60.1      65.2      91.6      517.
      1.50      61.6      88.0     148.2      431.
      1.88      63.1     111.4     215.3      376.
      2.25      64.5     135.3     292.3      336.
      3.00      67.5     184.8     474.2      283.
      3.75      70.4     236.5     691.6      248.
      4.50      73.3     290.4     943.0      224.
      6.00     183.3     482.9     1657.      212.
      7.50     293.3     840.4     2706.      226.
      9.00     403.3    1362.9     4202.      235.
     10.50     513.3    2050.4     6238.      239.
     12.00     623.3    2902.9     8899.      237.
  END FTABLE 10

  FTABLE     11
 ROWS COLS ***  E.Br. Brandywine nr Downingtown
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.42       9.9       4.1      21.9      136.
      0.83      10.0       8.2      69.1       87.
      1.25      10.1      12.4     135.4       67.
      1.67      10.3      16.7     218.0       56.
      2.08      10.4      21.0     315.2       48.
      2.50      10.5      25.4     425.9       43.
      3.33      10.8      34.2     684.3       36.
      4.17      11.0      43.3     988.0       32.
      5.00      11.3      52.6     1334.       29.
      6.67      29.4      86.5     2284.       27.
      8.33      47.4     150.5     3687.       30.
     10.00      65.5     244.6     5701.       31.
     11.67      83.6     368.9     8459.       32.
     13.33     101.7     523.3    12080.       31.
  END FTABLE 11

  FTABLE     12
 ROWS COLS ***  E.Br. Brandywine, Downingtown
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  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.29      13.1       3.8      16.4      168.
     0.58      13.3       7.7      52.1      107.
     0.88      13.4      11.5     102.3       82.
     1.17      13.5      15.5     165.2       68.
     1.46      13.7      19.4     239.4       59.
     1.75      13.8      23.5     324.2       53.
     2.33      14.1      31.6     523.2       44.
     2.92      14.4      39.9     758.3       38.
     3.50      14.7      48.4     1027.       34.
     4.67      29.0      73.9     1731.       31.
     5.83      43.3     116.0     2690.       31.
     7.00      57.5     174.8     3970.       32.
     8.17      71.8     250.3     5628.       32.
     9.33      86.1     342.4     7714.       32.
 END FTABLE 12

 FTABLE     13
ROWS COLS ***  E.Br below Downingtown
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.67      23.9      15.8      30.3      378.
     1.33      24.4      31.9      95.7      242.
     2.00      24.9      48.3     187.6      187.
     2.67      25.4      65.1     302.1      156.
     3.33      25.9      82.2     437.0      137.
     4.00      26.4      99.7     590.9      122.
     5.33      27.4     135.6     951.3      103.
     6.67      28.5     172.9     1377.       91.
     8.00      29.5     211.5     1864.       82.
    10.67     112.7     401.0     3354.       87.
    13.33     195.8     812.3     5955.       99.
    16.00     279.0    1445.4    10172.      103.
    18.67     362.2    2300.4    16424.      102.
    21.33     445.4    3377.1    25084.       98.
 END FTABLE 13

 FTABLE     14
ROWS COLS ***  E.Br. Brandywine,Wawaset
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.71      30.1      21.1      31.9      480.
     1.42      30.8      42.7     100.9      307.
     2.13      31.5      64.8     197.7      238.
     2.83      32.2      87.3     318.3      199.
     3.54      32.9     110.4     460.6      174.
     4.25      33.6     133.9     622.9      156.
     5.67      35.0     182.5     1003.      132.
     7.08      36.3     233.0     1453.      116.
     8.50      37.7     285.4     1968.      105.
    11.33     204.6     628.7     3673.      124.
    14.17     371.5    1444.9     7089.      148.
    17.00     538.4    2734.0    13075.      152.
    19.83     705.3    4496.0    22342.      146.
    22.67     872.2    6730.9    35526.      138.
 END FTABLE 14

 FTABLE     15
ROWS COLS *** Main Stem Brandywine, Lenape
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.81      18.7      14.4      40.8      255.
     1.63      20.9      30.4     132.8      166.
     2.44      23.0      48.3     268.1      131.
     3.25      25.2      67.8     445.0      111.
     4.06      27.3      89.2     663.9       97.
     4.88      29.4     112.2     925.4       88.
     6.50      33.7     163.5     1582.       75.
     8.13      38.0     221.7     2425.       66.
     9.75      42.3     286.9     3468.       60.
    13.00     140.3     583.6     7084.       60.
    16.25     238.4    1199.2    13344.       65.
    19.50     336.5    2133.5    23323.       66.
    22.75     434.6    3386.6    37915.       65.
    26.00     532.7    4958.5    57924.       62.
 END FTABLE 15

 FTABLE     16
ROWS COLS ***  Main Stem Brandywine, Chadds Ford
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
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     0.83      23.2      18.1      51.3      256.
     1.67      26.2      38.7     167.8      167.
     2.50      29.1      61.7     340.1      132.
     3.33      32.1      87.3     567.1      112.
     4.17      35.1     115.3     849.6       99.
     5.00      38.1     145.7     1189.       89.
     6.67      44.0     214.1     2048.       76.
     8.33      49.9     292.4     3162.       67.
    10.00      55.9     380.5     4549.       61.
    13.33     172.2     760.6     9358.       59.
    16.67     288.6    1528.6    17504.       63.
    20.00     404.9    2684.5    30285.       64.
    23.33     521.3    4228.3    48784.       63.
    26.67     637.7    6159.9    73973.       60.
  END FTABLE 16

  FTABLE     17
 ROWS COLS ***  Main Stem Brandywine, Smiths Bridge
   15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.85      38.5      31.0      52.0      433.
     1.71      42.8      65.7     169.2      282.
     2.56      47.0     104.1     341.3      221.
     3.42      51.3     146.1     566.3      187.
     4.27      55.6     191.7     844.1      165.
     5.13      59.9     241.0     1176.      149.
     6.83      68.4     350.6     2007.      127.
     8.54      77.0     474.8     3073.      112.
    10.25      85.5     613.6     4390.      101.
    13.67     257.4    1199.4     8868.       98.
    17.08     429.3    2372.4    16343.      105.
    20.50     601.1    4132.6    27969.      107.
    23.92     773.0    6480.0    44709.      105.
    27.33     944.9    9414.7    67427.      101.
  END FTABLE 17

  FTABLE     18
 ROWS COLS ***  Main Stem Brandywine, Rockland
   15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.88      34.6      28.6      50.2      414.
     1.75      38.4      60.5     163.2      269.
     2.63      42.1      95.7     328.9      211.
     3.50      45.9     134.2     545.3      179.
     4.38      49.7     176.0     812.4      157.
     5.25      53.4     221.1     1131.      142.
     7.00      61.0     321.2     1928.      121.
     8.75      68.5     434.5     2950.      107.
    10.50      76.0     560.9     4210.       97.
    14.00     117.1     898.9     8169.       80.
    17.50     158.2    1380.7    13613.       74.
    21.00     199.3    2006.3    20799.       70.
    24.50     240.4    2775.7    29950.       67.
    28.00     281.5    3688.9    41269.       65.
  END FTABLE 18

  FTABLE     19
 ROWS COLS ***  Main Stem Brandywine, Wilmington
   15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.92      30.8      26.7     175.7      111.
     1.83      33.9      56.4     570.1       72.
     2.75      37.1      89.0     1147.       56.
     3.67      40.3     124.5     1899.       48.
     4.58      43.5     162.9     2825.       42.
     5.50      46.6     204.2     3926.       38.
     7.33      53.0     295.5     6673.       32.
     9.17      59.3     398.5    10179.       28.
    11.00      65.7     513.1    14489.       26.
    14.67      81.8     783.4    27638.       21.
    18.33      97.8    1112.6    44414.       18.
    22.00     113.9    1500.7    64842.       17.
    25.67     129.9    1947.7    88968.       16.
    29.33     146.0    2453.6   116862.       15.
  END FTABLE 19

  FTABLE     20
 ROWS COLS ***
   15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.42      31.9      13.0      16.2      584.
     0.83      33.4      26.6      51.5      375.
     1.25      34.9      40.8     101.8      291.
     1.67      36.4      55.7     165.4      244.
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     2.08      37.9      71.2     241.6      214.
     2.50      39.4      87.3     329.7      192.
     3.33      42.3     121.3     540.8      163.
     4.17      45.3     157.8     797.7      144.
     5.00      48.3     196.8     1100.      130.
     6.67     188.2     393.9     2083.      137.
     8.33     328.2     824.3     3832.      156.
    10.00     468.2    1487.9     6693.      161.
    11.67     608.1    2384.9    10950.      158.
    13.33     748.1    3515.0    16859.      151.
  END FTABLE 20

  FTABLE     21
 ROWS COLS ***  Doe Run to Springdell
   15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.42      21.1       8.6      11.8      533.
     0.83      21.8      17.6      37.3      342.
     1.25      22.4      26.8      73.1      266.
     1.67      23.1      36.3     118.1      223.
     2.08      23.8      46.0     171.2      195.
     2.50      24.5      56.1     232.2      175.
     3.33      25.8      77.0     376.0      149.
     4.17      27.2      99.1     547.6      131.
     5.00      28.6     122.4     746.2      119.
     6.67     300.5     396.5     1540.      187.
     8.33     572.4    1123.9     3533.      231.
    10.00     844.3    2304.5     7385.      227.
    11.67    1116.2    3938.3    13639.      210.
    13.33    1388.1    6025.3    22781.      192.
  END FTABLE 21

  FTABLE     22
 ROWS COLS ***
   15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.42      11.7       4.8      16.6      209.
     0.83      12.3       9.8      53.0      134.
     1.25      12.8      15.0     104.7      104.
     1.67      13.4      20.5     170.1       87.
     2.08      13.9      26.1     248.4       76.
     2.50      14.5      32.0     339.0       69.
     3.33      15.5      44.5     556.2       58.
     4.17      16.6      58.0     820.3       51.
     5.00      17.7      72.3     1131.       46.
     6.67     146.2     208.9     2349.       65.
     8.33     274.7     559.7     5256.       77.
    10.00     403.2    1124.6    10762.       76.
    11.67     531.7    1903.6    19616.       70.
    13.33     660.2    2896.8    32487.       65.
  END FTABLE 22

  FTABLE     23
 ROWS COLS ***
   15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.42      10.5       4.3      12.7      245.
     0.83      10.9       8.8      40.5      157.
     1.25      11.3      13.4      80.0      122.
     1.67      11.7      18.2     129.8      102.
     2.08      12.1      23.2     189.2       89.
     2.50      12.5      28.3     257.8       80.
     3.33      13.4      39.1     421.4       67.
     4.17      14.2      50.6     619.3       59.
     5.00      15.0      62.7     851.0       54.
     6.67      63.1     127.8     1598.       58.
     8.33     111.2     273.0     2956.       67.
    10.00     159.2     498.4     5208.       69.
    11.67     207.3     803.8     8586.       68.
    13.33     255.4    1189.4    13300.       65.
  END FTABLE 23

  FTABLE     24
 ROWS COLS ***
   15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.25       0.7       0.2       4.2       27.
     0.50       0.9       0.4      14.4       18.
     0.75       1.1       0.6      30.5       14.
     1.00       1.3       0.9      52.9       12.
     1.25       1.4       1.2      82.2       11.
     1.50       1.6       1.6     119.0       10.
     2.00       2.0       2.5     217.1        8.
     2.50       2.3       3.6     351.7        7.
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    3.00      2.7      4.8     526.9        7.
    4.00      3.6      8.0     1108.        5.
    5.00      4.5     12.0     1881.        5.
    6.00      5.4     17.0     2849.        4.
    7.00      6.3     22.8     4020.        4.
    8.00      7.2     29.5     5401.        4.
 END FTABLE 24

 FTABLE     25
ROWS COLS ***
  15    4
   DEPTH     AREA   VOLUME     DISCH  FLO-THRU ***
    (FT)  (ACRES)  (AC-FT)     (CFS)     (MIN) ***
    0.00      0.0      0.0       0.0        0.
    0.42      5.3      2.1       8.8      172.
    0.83      5.9      4.4      28.5      113.
    1.25      6.4      7.0      56.9       89.
    1.67      7.0      9.8      93.8       76.
    2.08      7.5     12.8     139.0       67.
    2.50      8.1     16.1     192.6       61.
    3.33      9.2     23.3     325.7       52.
    4.17     10.3     31.4     495.1       46.
    5.00     11.5     40.5     702.8       42.
    6.67     55.4     96.2     1467.       48.
    8.33     99.3    225.1     2943.       56.
   10.00    143.2    427.1     5462.       57.
   11.67    187.1    702.3     9298.       55.
   13.33    231.0   1050.7    14694.       52.
 END FTABLE 25

 FTABLE     26
ROWS COLS ***  Marsh Crk above Reservoir, Glenmoore gage
  15    4
   DEPTH     AREA   VOLUME     DISCH  FLO-THRU ***
    (FT)  (ACRES)  (AC-FT)     (CFS)     (MIN) ***
    0.00      0.0      0.0       0.0        0.
    0.17      5.5      0.9       1.9      333.
    0.33      5.8      1.8       6.2      214.
    0.50      6.1      2.8      12.3      166.
    0.67      6.5      3.9      20.1      140.
    0.83      6.8      5.0      29.6      122.
    1.00      7.1      6.1      40.6      110.
    1.33      7.8      8.6      67.3       93.
    1.67      8.4     11.3     100.3       82.
    2.00      9.1     14.2     139.7       74.
    2.67     49.5     33.8     273.7       90.
    3.33     89.9     80.2     526.2      111.
    4.00    130.3    153.6     952.3      117.
    4.67    170.7    254.0     1598.      115.
    5.33    211.1    381.2     2504.      111.
 END FTABLE 26

 FTABLE     27
ROWS COLS ***  Marsh Creek Reservoir
  18    4
   DEPTH     AREA   VOLUME     DISCH  FLO-THRU ***
    (FT)  (ACRES)  (AC-FT)     (CFS)     (MIN) ***
    0.00      0.0      0.0       0.0        0.
   10.50     30.0    180.0       0.0        0.
   20.50     81.0    760.0       0.0        0.
   30.50    139.0   1720.0       0.0        0.
   40.50    221.0   3440.0       0.0        0.
   50.50    298.0   6000.0       0.0        0.
   60.50    400.0   9400.0       0.0        0.
   65.50    465.0  11910.0       0.0        0.
   66.50    478.0  12410.0       0.0        0.
   67.50    492.0  12910.0       0.0        0.
   68.50    510.0  13410.0       0.0        0.
   69.50    525.0  13910.0       0.0        0.
   70.00    535.0  14180.0       0.0        0.
   70.50    540.0  14460.0       0.0        0.
   71.50    558.0  15010.0       0.0        0.
   72.50    576.0  15560.0       0.0        0.
   75.50    625.0  17240.0       0.0        0.
   85.50   1625.0  57240.0       0.0        0.
 END FTABLE 27

 FTABLE     28
ROWS COLS ***  Uwchlan Run,Exton
  15    4
   DEPTH     AREA   VOLUME     DISCH  FLO-THRU ***
    (FT)  (ACRES)  (AC-FT)     (CFS)     (MIN) ***
    0.00      0.0      0.0       0.0        0.
    0.33      2.1      0.7       3.4      144.
    0.67      2.3      1.4      10.7       95.
    1.00      2.4      2.2      21.2       75.
    1.33      2.6      3.0      34.4       64.
    1.67      2.7      3.9      50.2       56.
    2.00      2.9      4.8      68.6       51.
    2.67      3.2      6.9     113.3       44.
    3.33      3.6      9.2     168.4       39.
    4.00      3.9     11.6     234.4       36.
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     5.33      20.0      27.6     485.3       41.
     6.67      36.2      65.1     1011.       47.
     8.00      52.4     124.1     1948.       46.
     9.33      68.5     204.7     3409.       44.
    10.67      84.7     306.9     5496.       41.
 END FTABLE 28

 FTABLE     29
ROWS COLS ***  West Valley Creek
  16    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.50      27.3      13.4      20.7      470.
     1.00      28.4      27.3      65.6      302.
     1.50      29.5      41.7     129.2      234.
     2.00      30.5      56.7     209.2      197.
     2.50      31.6      72.3     304.4      172.
     3.00      32.7      88.4     414.1      155.
     4.00      34.9     122.2     674.8      131.
     5.00      37.1     158.2     989.1      116.
     6.00      39.3     196.4     1356.      105.
     8.00     213.8     449.5     2595.      126.
    10.00     388.4    1051.6     5001.      153.
    12.00     562.9    2002.9     9142.      159.
    14.00     737.5    3303.3    15487.      155.
    16.00     912.0    4952.7    24456.      147.
    20.00    1300.0    8152.0    43000.      130.
 END FTABLE 29


 FTABLE     30
ROWS COLS ***  Beaver Creek
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.46      20.1       9.0      31.8      205.
     0.92      21.1      18.4     101.6      131.
     1.38      22.1      28.3     200.8      102.
     1.83      23.1      38.6     326.6       86.
     2.29      24.1      49.4     477.3       75.
     2.75      25.1      60.7     652.0       68.
     3.67      27.1      84.6     1072.       57.
     4.58      29.1     110.4     1584.       51.
     5.50      31.1     138.0     2188.       46.
     7.33     108.8     266.2     4130.       47.
     9.17     186.4     536.7     7464.       52.
    11.00     264.0     949.6    12784.       54.
    12.83     341.6    1504.8    20585.       53.
    14.67     419.3    2202.3    31310.       51.
 END FTABLE 30

 FTABLE     31
ROWS COLS ***  Pocopson Creek
  15    4
    DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
     (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
     0.00       0.0       0.0       0.0        0.
     0.42      14.1       5.7      17.5      238.
     0.83      14.8      11.7      55.8      153.
     1.25      15.5      18.0     110.3      119.
     1.67      16.2      24.7     179.4      100.
     2.08      16.9      31.5     262.1       87.
     2.50      17.6      38.7     358.0       79.
     3.33      19.0      54.0     588.2       67.
     4.17      20.4      70.4     869.0       59.
     5.00      21.8      88.0     1201.       53.
     6.67      49.4     147.3     2194.       49.
     8.33      76.9     252.5     3638.       50.
    10.00     104.4     403.6     5668.       52.
    11.67     132.0     600.6     8397.       52.
    13.33     159.5     843.6    11928.       51.
 END FTABLE 31

 FTABLE     32
ROWS COLS ***  Hibernia Reservoir (Chambers Lake)
  22    4
    DEPTH      AREA    VOLUME  URGDISCH  ***
     (FT)   (ACRES)   (AC-FT)     (CFS)  ***
     0.00       3.0       0.0       0.0
     7.00      14.0      50.0       0.0
    10.00      20.0     110.0       1.0
    15.00      30.5     240.0       1.0
    20.00      42.0     410.0       1.0
    25.00      54.2     640.0       1.0
    28.00      63.0     820.0       1.0
    29.00      66.5     890.0       1.0
    29.50      68.5     925.0       1.0
    30.00      70.0     960.0       1.0
    30.50      72.0    1000.0       1.0
    31.00      74.0    1040.0       1.0
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     31.50      76.0    1075.0       1.0
     32.00      78.0    1110.0       1.0
     32.50      80.0    1142.0       1.0
     33.00      82.5    1175.0       1.0
     33.50      85.0    1225.0      12.0
     34.00      87.0    1275.0      32.0
     35.00      92.0    1375.0      65.0
     40.00     117.0    1900.0     121.0
     40.50     119.5    1960.0     125.0
     45.00     146.0    2575.0     500.0

  END FTABLE 32

  FTABLE     33
 ROWS COLS ***  Rock Run Reservoir
   14    4
     DEPTH      AREA    VOLUME     DISCH ***
      (FT)   (ACRES)   (AC-FT)     (CFS) ***
      0.00       0.0       0.0       0.0
      6.00      18.2     239.0       0.9
     12.00      31.8     420.0       0.9
     16.00      42.7     565.0       0.9
     18.00      49.7     657.0       0.9
     20.00      56.0     740.0       0.9
     21.00      58.5     773.0       0.9
     22.00      61.4     811.0     150.0
     23.00      64.1     847.0     350.0
     24.00      66.8     883.0     540.0
     25.00      69.5     919.0     725.0
     26.00      72.3     955.0     900.0
     27.00      75.2     992.0    1575.0
     37.00     175.2    5992.0    9575.0
*** Discharges above 21.0 ft are guesstimates
  END FTABLE 33

  FTABLE     34
 ROWS COLS ***  Main Stem Brandywine below Wilmington
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.75      55.9      39.2      97.5      292.
      1.50      63.1      83.8     319.1      191.
      2.25      70.3     133.8     647.4      150.
      3.00      77.5     189.2     1081.      127.
      3.75      84.7     250.0     1620.      112.
      4.50      91.9     316.3     2270.      101.
      6.00     106.3     464.9     3914.       86.
      7.50     120.7     635.2     6048.       76.
      9.00     135.2     827.1     8709.       69.
     12.00     200.0    1329.9    17150.       56.
     15.00     264.9    2027.3    28576.       52.
     18.00     329.8    2919.3    43378.       49.
     21.00     394.6    4005.9    61897.       47.
     24.00     459.5    5287.1    84457.       45.
  END FTABLE 34

  FTABLE     35
 ROWS COLS ***  Marsh Creek to Lyons Run
   15    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      0.00       0.0       0.0       0.0        0.
      0.21       8.5       1.4       0.3     3632.
      0.42      12.1       3.5       1.0     2471.
      0.63      15.8       6.4       2.4     1974.
      0.83      19.4      10.1       4.4     1679.
      1.04      23.0      14.5       7.1     1478.
      1.25      26.7      19.7      10.8     1330.
      1.67      33.9      32.3      20.9     1123.
      2.08      41.2      48.0      35.5      982.
      2.50      48.5      66.7      55.1      879.
      3.33     210.1     174.4     146.5      865.
      4.17     371.7     416.8     366.4      826.
      5.00     533.3     793.9     780.1      739.
      5.83     694.9    1305.7     1442.      658.
      6.67     856.6    1952.2     2399.      591.
  END FTABLE 35
END FTABLES

COPY
  TIMESERIES
    # -  #  NPT  NMN ***
    1   20         5
  100  930        16
  END TIMESERIES
END COPY

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
*** Meteorological data
```

```
WDM1    79 PREC    0 ENGL          1.16     PERLND 102 111 EXTNL  PREC    1 1
WDM1    77 PREC    0 ENGL          0.90     PERLND 202 211 EXTNL  PREC    1 1
WDM1    78 PREC    0 ENGL          1.03     PERLND 302 311 EXTNL  PREC    1 1
WDM1    76 PREC    0 ENGL          1.05     PERLND 402 411 EXTNL  PREC    1 1
WDM1   260 NO3X    0 METR           1.0     PERLND 102 411 EXTNL  NIADCN 1 1
WDM1   261 NH3X    0 METR           1.0     PERLND 102 411 EXTNL  NIADCN 2 1
WDM1    79 PREC    0 ENGL        11767.     COPY   100     INPUT  MEAN    4 1
WDM1    77 PREC    0 ENGL        29444.     COPY   200     INPUT  MEAN    4 1
WDM1    77 PREC    0 ENGL        35098.     COPY   300     INPUT  MEAN    4 1
WDM1    77 PREC    0 ENGL         7075.     COPY   400     INPUT  MEAN    4 1
WDM1    77 PREC    0 ENGL          384.     COPY   500     INPUT  MEAN    4 1
WDM1    78 PREC    0 ENGL         5387.     COPY   600     INPUT  MEAN    4 1
WDM1    78 PREC    0 ENGL        12774.     COPY   700     INPUT  MEAN    4 1
WDM1    78 PREC    0 ENGL        37933.     COPY   800     INPUT  MEAN    4 1
WDM1    78 PREC    0 ENGL        56954.     COPY   900     INPUT  MEAN    4 1
WDM1    78 PREC    0 ENGL         1538.     COPY   910     INPUT  MEAN    4 1
WDM1    76 PREC    0 ENGL       186908.     COPY   920     INPUT  MEAN    4 1
WDM1    76 PREC    0 ENGL ***   206812.     COPY   930     INPUT  MEAN    4 1
WDM1    20 PETX    0 ENGL           1.0     PERLND 102 411 EXTNL  PETINP 1 1
WDM1    52 ATMP    0 ENGL           1.0     PERLND 102 311 EXTNL  GATMP  1 1
WDM1    50 ATMP    0 ENGL           1.0     PERLND 402 411 EXTNL  GATMP  1 1
WDM1    30 WIND    0 ENGL           1.0     PERLND 102 411 EXTNL  WINMOV 1 1
WDM1    45 DWPT    0 ENGL           1.0     PERLND 102 411 EXTNL  DTMPG  1 1
WDM1    10 SOLR    0 ENGL           1.0     PERLND 102 411 EXTNL  SOLRAD 1 1
WDM1    79 PREC    0 ENGL          1.16     IMPLND 101 102 EXTNL  PREC    1 1
WDM1    77 PREC    0 ENGL          0.90     IMPLND 201 202 EXTNL  PREC    1 1
WDM1    78 PREC    0 ENGL          1.03     IMPLND 301 302 EXTNL  PREC    1 1
WDM1    76 PREC    0 ENGL          1.05     IMPLND 401 402 EXTNL  PREC    1 1
WDM1    20 PETX    0 ENGL           1.0     IMPLND 101 402 EXTNL  PETINP 1 1
WDM1    52 ATMP    0 ENGL           1.0     IMPLND 101 302 EXTNL  GATMP  1 1
WDM1    50 ATMP    0 ENGL           1.0     IMPLND 401 402 EXTNL  GATMP  1 1
WDM1    30 WIND    0 ENGL           1.0     IMPLND 101 402 EXTNL  WINMOV 1 1
WDM1    45 DWPT    0 ENGL           1.0     IMPLND 101 402 EXTNL  DTMPG  1 1
WDM1    10 SOLR    0 ENGL           1.0     IMPLND 101 402 EXTNL  SOLRAD 1 1
WDM1   260 NO3X    0 METR           1.0     IMPLND 102 402 EXTNL  IQADCN 1 1
WDM1   261 NH3X    0 METR           1.0     IMPLND 102 402 EXTNL  IQADCN 2 1
WDM1    79 PREC    0 ENGL          1.16     RCHRES   1   2 EXTNL  PREC    1 1
WDM1    79 PREC    0 ENGL          1.16     RCHRES   9     EXTNL  PREC    1 1
WDM1    79 PREC    0 ENGL          1.16     RCHRES  32     EXTNL  PREC    1 1
WDM1    77 PREC    0 ENGL          0.90     RCHRES   3   8 EXTNL  PREC    1 1
WDM1    78 PREC    0 ENGL          1.03     RCHRES  10  14 EXTNL  PREC    1 1
WDM1    76 PREC    0 ENGL          1.05     RCHRES  15  19 EXTNL  PREC    1 1
WDM1    77 PREC    0 ENGL          0.90     RCHRES  20  25 EXTNL  PREC    1 1
WDM1    78 PREC    0 ENGL          1.03     RCHRES  26  30 EXTNL  PREC    1 1
WDM1    78 PREC    0 ENGL          1.03     RCHRES  35     EXTNL  PREC    1 1
WDM1    76 PREC    0 ENGL          1.05     RCHRES  34     EXTNL  PREC    1 1
WDM1   260 NO3X    0 METR           1.0     RCHRES   1  35 EXTNL  NUADCN 1 1
WDM1   261 NH3X    0 METR           1.0     RCHRES   1  35 EXTNL  NUADCN 2 1
WDM1    20 PETX    0 ENGL           1.0     RCHRES   1  35 EXTNL  POTEV  1 1
WDM1    52 ATMP    0 ENGL           1.0     RCHRES   1  14 EXTNL  GATMP  1 1
WDM1    50 ATMP    0 ENGL           1.0     RCHRES  15  19 EXTNL  GATMP  1 1
WDM1    52 ATMP    0 ENGL           1.0     RCHRES  20  30 EXTNL  GATMP  1 1
WDM1    50 ATMP    0 ENGL           1.0     RCHRES  31     EXTNL  GATMP  1 1
WDM1    52 ATMP    0 ENGL           1.0     RCHRES  32  33 EXTNL  GATMP  1 1
WDM1    50 ATMP    0 ENGL           1.0     RCHRES  34     EXTNL  GATMP  1 1
WDM1    52 ATMP    0 ENGL           1.0     RCHRES  35     EXTNL  GATMP  1 1
WDM1    40 COVR    0 ENGL           1.0     RCHRES   1  35 EXTNL  CLOUD  1 1
WDM1    30 WIND    0 ENGL           1.0     RCHRES   1  35 EXTNL  WIND   1 1
WDM1    45 DWPT    0 ENGL           1.0     RCHRES   1  35 EXTNL  DEWTMP 1 1
WDM1    10 SOLR    0 ENGL           1.0     RCHRES   1  35 EXTNL  SOLRAD 1 1
***
*** Point source Discharges to W.Br.Brandywine ***
*** City of Coatesville Authority STP
WDM1   301 PTSQ    0 ENGL           1.0     RCHRES   5     EXTNL  IVOL    1 1
WDM1   302 TSSX    0 ENGL           1.0     RCHRES   5     INFLOW ISED    3 1
WDM1   303 BODX    0 ENGL           1.0     RCHRES   5     INFLOW OXIF    2 1
WDM1   304 NH3X    0 ENGL           1.0     RCHRES   5     INFLOW NUIF1   2 1
WDM1   305 PO4X    0 ENGL           1.0     RCHRES   5     INFLOW NUIF1   4 1
WDM1   306 HEAT    0 ENGL           1.0     RCHRES   5     INFLOW IHEAT   1 1
WDM1   307 NO3X    0 ENGL ***       1.0     RCHRES   5     INFLOW NUIF1   1 1
WDM1   308 NO3X    0 ENGL           0.6     RCHRES   5     INFLOW NUIF1   1 1
*** City of Coatesville Authority Water Treatment plant
WDM1   310 PTSQ    0 ENGL           1.0     RCHRES  33     EXTNL  IVOL    1 1
WDM1   311 TSSX    0 ENGL           1.0     RCHRES  33     INFLOW ISED    3 1
WDM1   312 BODX    0 ENGL           1.0     RCHRES  33     INFLOW OXIF    2 1
WDM1   316 HEAT    0 ENGL           1.0     RCHRES  33     INFLOW IHEAT   1 1
*** Embreeville Center STP
WDM1   320 PTSQ    0 ENGL           1.0     RCHRES   7     EXTNL  IVOL    1 1
WDM1   321 TSSX    0 ENGL           1.0     RCHRES   7     INFLOW ISED    3 1
WDM1   322 BODX    0 ENGL           1.0     RCHRES   7     INFLOW OXIF    2 1
WDM1   323 NH3X    0 ENGL           1.0     RCHRES   7     INFLOW NUIF1   2 1
WDM1   324 PO4X    0 ENGL           1.0     RCHRES   7     INFLOW NUIF1   4 1
WDM1   326 HEAT    0 ENGL           1.0     RCHRES   7     INFLOW IHEAT   1 1
WDM1   327 NO3X    0 ENGL           1.0     RCHRES   7     INFLOW NUIF1   1 1
*** Lincoln Crest Mobile Homes, Inc. STP
WDM1   330 PTSQ    0 ENGL           1.0     RCHRES  20     EXTNL  IVOL    1 1
WDM1   331 TSSX    0 ENGL           1.0     RCHRES  20     INFLOW ISED    3 1
WDM1   332 BODX    0 ENGL           1.0     RCHRES  20     INFLOW OXIF    2 1
WDM1   333 NH3X    0 ENGL           1.0     RCHRES  20     INFLOW NUIF1   2 1
WDM1   336 HEAT    0 ENGL           1.0     RCHRES  20     INFLOW IHEAT   1 1
WDM1   337 NO3X    0 ENGL           1.0     RCHRES  20     INFLOW NUIF1   1 1
*** Lukens Inc. Industrial discharge
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WDM1   340 PTSQ   0 ENGL           1.0     RCHRES   5     EXTNL  IVOL    1 1
WDM1   346 HEAT   0 ENGL           1.0     RCHRES   5     INFLOW IHEAT   1 1
*** Lukens Inc. Industrial discharge
WDM1   350 PTSQ   0 ENGL           1.0     RCHRES   5     EXTNL  IVOL    1 1
WDM1   356 HEAT   0 ENGL           1.0     RCHRES   5     INFLOW IHEAT   1 1
*** Northwestern Chester Cty Municipal Auth. STP
WDM1   360 PTSQ   0 ENGL           1.0     RCHRES   1     EXTNL  IVOL    1 1
WDM1   361 TSSX   0 ENGL           1.0     RCHRES   1     INFLOW ISED    3 1
WDM1   362 BODX   0 ENGL           1.0     RCHRES   1     INFLOW OXIF    2 1
WDM1   363 NH3X   0 ENGL           1.0     RCHRES   1     INFLOW NUIF1   2 1
WDM1   364 PO4X   0 ENGL           1.0     RCHRES   1     INFLOW NUIF1   4 1
WDM1   366 HEAT   0 ENGL           1.0     RCHRES   1     INFLOW IHEAT   1 1
WDM1   367 NO3X   0 ENGL           1.0     RCHRES   1     INFLOW NUIF1   1 1
*** Parkesburg Borough STP
WDM1   370 PTSQ   0 ENGL           1.0     RCHRES  20     EXTNL  IVOL    1 1
WDM1   371 TSSX   0 ENGL           1.0     RCHRES  20     INFLOW ISED    3 1
WDM1   372 BODX   0 ENGL           1.0     RCHRES  20     INFLOW OXIF    2 1
WDM1   373 NH3X   0 ENGL           1.0     RCHRES  20     INFLOW NUIF1   2 1
WDM1   374 PO4X   0 ENGL           1.0     RCHRES  20     INFLOW NUIF1   4 1
WDM1   376 HEAT   0 ENGL           1.0     RCHRES  20     INFLOW IHEAT   1 1
WDM1   377 NO3X   0 ENGL           1.0     RCHRES  20     INFLOW NUIF1   1 1
*** South Coatesville Borough STP
WDM1   380 PTSQ   0 ENGL           1.0     RCHRES   5     EXTNL  IVOL    1 1
WDM1   381 TSSX   0 ENGL           1.0     RCHRES   5     INFLOW ISED    3 1
WDM1   382 BODX   0 ENGL           1.0     RCHRES   5     INFLOW OXIF    2 1
WDM1   383 NH3X   0 ENGL           1.0     RCHRES   5     INFLOW NUIF1   2 1
WDM1   384 PO4X   0 ENGL           1.0     RCHRES   5     INFLOW NUIF1   4 1
WDM1   386 HEAT   0 ENGL           1.0     RCHRES   5     INFLOW IHEAT   1 1
WDM1   387 NO3X   0 ENGL ***       1.0     RCHRES   5     INFLOW NUIF1   1 1
WDM1   388 NO3X   0 ENGL           0.6     RCHRES   5     INFLOW NUIF1   1 1
*** Tel Hai Retirement Community STP
WDM1   390 PTSQ   0 ENGL           1.0     RCHRES   1     EXTNL  IVOL    1 1
WDM1   391 TSSX   0 ENGL           1.0     RCHRES   1     INFLOW ISED    3 1
WDM1   393 NH3X   0 ENGL           1.0     RCHRES   1     INFLOW NUIF1   2 1
WDM1   394 PO4X   0 ENGL           1.0     RCHRES   1     INFLOW NUIF1   4 1
WDM1   396 HEAT   0 ENGL           1.0     RCHRES   1     INFLOW IHEAT   1 1
WDM1   397 NO3X   0 ENGL           1.0     RCHRES   1     INFLOW NUIF1   1 1
***
*** Point Source Discharges to E. Br. Brandywine ***
*** Marsh Creek Reservoir discharge
WDM1   192 FLOW   0 ENGL           1.0     RCHRES  11     EXTNL  IVOL    1 1
WDM1   193 NO3X   0 ENGL           1.0     RCHRES  11     INFLOW NUIF1   1 1
WDM1   194 NH3X   0 ENGL           1.0     RCHRES  11     INFLOW NUIF1   2 1
WDM1   195 PO4X   0 ENGL           1.0     RCHRES  11     INFLOW NUIF1   4 1
*** Broad Run Sewer Co. STP
WDM1   500 PTSQ   0 ENGL           1.0     RCHRES  13     EXTNL  IVOL    1 1
WDM1   501 TSSX   0 ENGL           1.0     RCHRES  13     INFLOW ISED    3 1
WDM1   502 BODX   0 ENGL           1.0     RCHRES  13     INFLOW OXIF    2 1
WDM1   503 NH3X   0 ENGL           1.0     RCHRES  13     INFLOW NUIF1   2 1
WDM1   504 PO4X   0 ENGL           1.0     RCHRES  13     INFLOW NUIF1   4 1
WDM1   506 HEAT   0 ENGL           1.0     RCHRES  13     INFLOW IHEAT   1 1
WDM1   507 NO3X   0 ENGL  ***      1.0     RCHRES  13     INFLOW NUIF1   1 1
WDM1   508 NO3X   0 ENGL           0.6     RCHRES  13     INFLOW NUIF1   1 1
*** Downingtown Area Regional Authority STP
WDM1   510 PTSQ   0 ENGL           1.0     RCHRES  13     EXTNL  IVOL    1 1
WDM1   511 TSSX   0 ENGL           1.0     RCHRES  13     INFLOW ISED    3 1
WDM1   512 BODX   0 ENGL           1.0     RCHRES  13     INFLOW OXIF    2 1
WDM1   513 NH3X   0 ENGL           1.0     RCHRES  13     INFLOW NUIF1   2 1
WDM1   514 PO4X   0 ENGL           1.0     RCHRES  13     INFLOW NUIF1   4 1
WDM1   516 HEAT   0 ENGL           1.0     RCHRES  13     INFLOW IHEAT   1 1
WDM1   517 NO3X   0 ENGL ***       1.0     RCHRES  13     INFLOW NUIF1   1 1
WDM1   518 NO3X   0 ENGL           0.6     RCHRES  13     INFLOW NUIF1   1 1
*** Indian Run Village MHP
WDM1   520 PTSQ   0 ENGL           1.0     RCHRES  10     EXTNL  IVOL    1 1
WDM1   521 TSSX   0 ENGL           1.0     RCHRES  10     INFLOW ISED    3 1
WDM1   522 BODX   0 ENGL           1.0     RCHRES  10     INFLOW OXIF    2 1
WDM1   523 NH3X   0 ENGL           1.0     RCHRES  10     INFLOW NUIF1   2 1
WDM1   524 PO4X   0 ENGL           1.0     RCHRES  10     INFLOW NUIF1   4 1
WDM1   526 HEAT   0 ENGL           1.0     RCHRES  10     INFLOW IHEAT   1 1
WDM1   527 NO3X   0 ENGL           1.0     RCHRES  10     INFLOW NUIF1   1 1
*** Little Washington Drainage Co. STP
WDM1   530 PTSQ   0 ENGL           1.0     RCHRES  10     EXTNL  IVOL    1 1
WDM1   531 TSSX   0 ENGL           1.0     RCHRES  10     INFLOW ISED    3 1
WDM1   532 BODX   0 ENGL           1.0     RCHRES  10     INFLOW OXIF    2 1
WDM1   533 NH3X   0 ENGL           1.0     RCHRES  10     INFLOW NUIF1   2 1
WDM1   534 PO4X   0 ENGL           1.0     RCHRES  10     INFLOW NUIF1   4 1
WDM1   536 HEAT   0 ENGL           1.0     RCHRES  10     INFLOW IHEAT   1 1
WDM1   537 NO3X   0 ENGL           1.0     RCHRES  10     INFLOW NUIF1   1 1
*** Pepperidge Farms Industrial Discharge
WDM1   540 PTSQ   0 ENGL           1.0     RCHRES  13     EXTNL  IVOL    1 1
WDM1   546 HEAT   0 ENGL           1.0     RCHRES  13     INFLOW IHEAT   1 1
*** Sonoco Products Co. Industrial Discharge
WDM1   550 PTSQ   0 ENGL           1.0     RCHRES  13     EXTNL  IVOL    1 1
WDM1   551 TSSX   0 ENGL           1.0     RCHRES  13     INFLOW ISED    3 1
WDM1   552 BODX   0 ENGL           1.0     RCHRES  13     INFLOW OXIF    2 1
WDM1   553 NH3X   0 ENGL           1.0     RCHRES  13     INFLOW NUIF1   2 1
WDM1   554 PO4X   0 ENGL           1.0     RCHRES  13     INFLOW NUIF1   4 1
WDM1   556 HEAT   0 ENGL           1.0     RCHRES  13     INFLOW IHEAT   1 1
WDM1   557 NO3X   0 ENGL           1.0     RCHRES  13     INFLOW NUIF1   1 1
*** Uwchlan Twp. Municipal Authority STP
WDM1   560 PTSQ   0 ENGL           1.0     RCHRES  11     EXTNL  IVOL    1 1
WDM1   561 TSSX   0 ENGL           1.0     RCHRES  11     INFLOW ISED    3 1
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WDM1   562 BODX   0 ENGL          1.0     RCHRES  11     INFLOW OXIF   2 1
WDM1   563 NH3X   0 ENGL          1.0     RCHRES  11     INFLOW NUIF1  2 1
WDM1   564 PO4X   0 ENGL          1.0     RCHRES  11     INFLOW NUIF1  4 1
WDM1   566 HEAT   0 ENGL          1.0     RCHRES  11     INFLOW IHEAT  1 1
WDM1   567 NO3X   0 ENGL          1.0     RCHRES  11     INFLOW NUIF1  1 1
*** West Chester Municipal Authority STP - Taylor Run
WDM1   570 PTSQ   0 ENGL          1.0     RCHRES  14     EXTNL  IVOL   1 1
WDM1   571 TSSX   0 ENGL          1.0     RCHRES  14     INFLOW ISED   3 1
WDM1   572 BODX   0 ENGL          1.0     RCHRES  14     INFLOW OXIF   2 1
WDM1   573 NH3X   0 ENGL          1.0     RCHRES  14     INFLOW NUIF1  2 1
WDM1   574 PO4X   0 ENGL          1.0     RCHRES  14     INFLOW NUIF1  4 1
WDM1   576 HEAT   0 ENGL          1.0     RCHRES  14     INFLOW IHEAT  1 1
WDM1   577 NO3X   0 ENGL          1.0     RCHRES  14     INFLOW NUIF1  1 1
*** Eaglepoint Devel. Assoc. STP
WDM1   580 PTSQ   0 ENGL          1.0     RCHRES  27     EXTNL  IVOL   1 1
WDM1   581 TSSX   0 ENGL    ***      1.0     RCHRES  27     INFLOW ISED   3 1
WDM1   582 BODX   0 ENGL          1.0     RCHRES  27     INFLOW OXIF   2 1
WDM1   583 NH3X   0 ENGL          1.0     RCHRES  27     INFLOW NUIF1  2 1
WDM1   584 PO4X   0 ENGL          1.0     RCHRES  27     INFLOW NUIF1  4 1
WDM1   586 HEAT   0 ENGL          1.0     RCHRES  27     INFLOW IHEAT  1 1
WDM1   587 NO3X   0 ENGL          1.0     RCHRES  27     INFLOW NUIF1  1 1
*** PA Turnpike Comm. Service Plaza STP
WDM1   590 PTSQ   0 ENGL          1.0     RCHRES  35     EXTNL  IVOL   1 1
WDM1   591 TSSX   0 ENGL          1.0     RCHRES  35     INFLOW ISED   3 1
WDM1   592 BODX   0 ENGL          1.0     RCHRES  35     INFLOW OXIF   2 1
WDM1   593 NH3X   0 ENGL          1.0     RCHRES  35     INFLOW NUIF1  2 1
WDM1   594 PO4X   0 ENGL          1.0     RCHRES  35     INFLOW NUIF1  4 1
WDM1   596 HEAT   0 ENGL          1.0     RCHRES  35     INFLOW IHEAT  1 1
WDM1   597 NO3X   0 ENGL          1.0     RCHRES  35     INFLOW NUIF1  1 1
*** Phila Suburban Water Co. Water Treatment Backwash - Ingrams Mill
WDM1   680 PTSQ   0 ENGL          1.0     RCHRES  14     EXTNL  IVOL   1 1
WDM1   681 TSSX   0 ENGL          1.0     RCHRES  14     INFLOW ISED   3 1
WDM1   686 HEAT   0 ENGL          1.0     RCHRES  14     INFLOW IHEAT  1 1
***
*** Point Source Discharges to Main Stem Brandywine
*** Birmingham/Chadds Ford TWP STP
WDM1   700 PTSQ   0 ENGL          1.0     RCHRES  17     EXTNL  IVOL   1 1
WDM1   701 TSSX   0 ENGL          1.0     RCHRES  17     INFLOW ISED   3 1
WDM1   702 BODX   0 ENGL          1.0     RCHRES  17     INFLOW OXIF   2 1
WDM1   703 NH3X   0 ENGL          1.0     RCHRES  17     INFLOW NUIF1  2 1
WDM1   706 HEAT   0 ENGL          1.0     RCHRES  17     INFLOW IHEAT  1 1
WDM1   707 NO3X   0 ENGL          1.0     RCHRES  17     INFLOW NUIF1  1 1
*** Radley Run Mews STP
WDM1   710 PTSQ   0 ENGL          1.0     RCHRES  15     EXTNL  IVOL   1 1
WDM1   711 TSSX   0 ENGL          1.0     RCHRES  15     INFLOW ISED   3 1
WDM1   712 BODX   0 ENGL          1.0     RCHRES  15     INFLOW OXIF   2 1
WDM1   713 NH3X   0 ENGL          1.0     RCHRES  15     INFLOW NUIF1  2 1
WDM1   714 PO4X   0 ENGL          1.0     RCHRES  15     INFLOW NUIF1  4 1
WDM1   716 HEAT   0 ENGL          1.0     RCHRES  15     INFLOW IHEAT  1 1
WDM1   717 NO3X   0 ENGL          1.0     RCHRES  15     INFLOW NUIF1  1 1
*** Winterthur
WDM1   720 PTSQ   0 ENGL          1.0     RCHRES  19     EXTNL  IVOL   1 1
WDM1   721 TSSX   0 ENGL          1.0     RCHRES  19     INFLOW ISED   3 1
WDM1   722 BODX   0 ENGL          1.0     RCHRES  19     INFLOW OXIF   2 1
WDM1   726 HEAT   0 ENGL          1.0     RCHRES  19     INFLOW IHEAT  1 1
*** Knight’s Bridge Corp.
WDM1   730 PTSQ   0 ENGL          1.0     RCHRES  17     EXTNL  IVOL   1 1
WDM1   731 TSSX   0 ENGL          1.0     RCHRES  17     INFLOW ISED   3 1
WDM1   732 BODX   0 ENGL          1.0     RCHRES  17     INFLOW OXIF   2 1
WDM1   733 NH3X   0 ENGL          1.0     RCHRES  17     INFLOW NUIF1  2 1
WDM1   734 PO4X   0 ENGL          1.0     RCHRES  17     INFLOW NUIF1  4 1
WDM1   736 HEAT   0 ENGL          1.0     RCHRES  17     INFLOW IHEAT  1 1
WDM1   737 NO3X   0 ENGL          1.0     RCHRES  17     INFLOW NUIF1  1 1
*** Mendenhall Inn STP
WDM1   740 PTSQ   0 ENGL          1.0     RCHRES  17     EXTNL  IVOL   1 1
WDM1   741 TSSX   0 ENGL          1.0     RCHRES  17     INFLOW ISED   3 1
WDM1   742 BODX   0 ENGL          1.0     RCHRES  17     INFLOW OXIF   2 1
WDM1   743 NH3X   0 ENGL          1.0     RCHRES  17     INFLOW NUIF1  2 1
WDM1   746 HEAT   0 ENGL          1.0     RCHRES  17     INFLOW IHEAT  1 1
WDM1   747 NO3X   0 ENGL          1.0     RCHRES  17     INFLOW NUIF1  1 1
*** Radley Run Country Club STP
WDM1   750 PTSQ   0 ENGL          1.0     RCHRES  16     EXTNL  IVOL   1 1
WDM1   751 TSSX   0 ENGL          1.0     RCHRES  16     INFLOW ISED   3 1
WDM1   752 BODX   0 ENGL          1.0     RCHRES  16     INFLOW OXIF   2 1
WDM1   753 NH3X   0 ENGL          1.0     RCHRES  16     INFLOW NUIF1  2 1
WDM1   754 PO4X   0 ENGL          1.0     RCHRES  16     INFLOW NUIF1  4 1
WDM1   756 HEAT   0 ENGL          1.0     RCHRES  16     INFLOW IHEAT  1 1
WDM1   757 NO3X   0 ENGL          1.0     RCHRES  16     INFLOW NUIF1  1 1
*** Birmingham Twp STP
WDM1   760 PTSQ   0 ENGL          1.0     RCHRES  16     EXTNL  IVOL   1 1
WDM1   761 TSSX   0 ENGL          1.0     RCHRES  16     INFLOW ISED   3 1
WDM1   762 BODX   0 ENGL          1.0     RCHRES  16     INFLOW OXIF   2 1
WDM1   763 NH3X   0 ENGL          1.0     RCHRES  16     INFLOW NUIF1  2 1
WDM1   764 PO4X   0 ENGL          1.0     RCHRES  16     INFLOW NUIF1  4 1
WDM1   766 HEAT   0 ENGL          1.0     RCHRES  16     INFLOW IHEAT  1 1
WDM1   767 NO3X   0 ENGL          1.0     RCHRES  16     INFLOW NUIF1  1 1
*** Unionville-Chadds Ford Elem. School STP
WDM1   770 PTSQ   0 ENGL          1.0     RCHRES  16     EXTNL  IVOL   1 1
WDM1   771 TSSX   0 ENGL          1.0     RCHRES  16     INFLOW ISED   3 1
WDM1   772 BODX   0 ENGL          1.0     RCHRES  16     INFLOW OXIF   2 1
WDM1   776 HEAT   0 ENGL          1.0     RCHRES  16     INFLOW IHEAT  1 1
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*** Withdrawals from W.Br.Brandywine
*** City of Coatesville, Rock Run Res.
WDM1   400 WITH   0 ENGL           1.0SAME RCHRES  33     EXTNL  OUTDGT 2 1
*** City of Coatesville, WB Brandywine Crk
WDM1   410 WITH   0 ENGL           1.0SAME RCHRES   3     EXTNL  OUTDGT 2 1
*** Lukens
WDM1   420 WITH   0 ENGL           1.0SAME RCHRES   5     EXTNL  OUTDGT 2 1
*** Sealed Air Corp.
WDM1   430 WITH   0 ENGL           1.0SAME RCHRES   6     EXTNL  OUTDGT 2 1
*** Embreeville Center
WDM1   440 WITH   0 ENGL           1.0SAME RCHRES   7     EXTNL  OUTDGT 2 1
***
*** Withdrawals from E.Br.Brandywine
*** Marsh Creek nr Downingtown - Reservoir release
WDM1   190 FLOW   0 ENGL           1.0SAME RCHRES  27     EXTNL  OUTDGT 1 1
*** Downingtown Municipal Water Auth.
WDM1   600 WITH   0 ENGL           1.0SAME RCHRES  12     EXTNL  OUTDGT 2 1
*** Milestone Materials
WDM1   610 WITH   0 ENGL           1.0SAME RCHRES  29     EXTNL  OUTDGT 2 1
*** Phila-Suburban Water - Ingrams Mill
WDM1   620 WITH   0 ENGL           1.0SAME RCHRES  14     EXTNL  OUTDGT 2 1
*** Sonoco Products
WDM1   630 WITH   0 ENGL           1.0SAME RCHRES  13     EXTNL  OUTDGT 2 1
*** Whitford Country Club
WDM1   640 WITH   0 ENGL           1.0SAME RCHRES  29     EXTNL  OUTDGT 3 1
*** Brandywine Paperboard
WDM1   650 WITH   0 ENGL           1.0SAME RCHRES  13     EXTNL  OUTDGT 3 1
***
*** Withdrawals from Main Stem Brandywine
*** Radley Run Country Club
WDM1   800 WITH   0 ENGL           1.0SAME RCHRES  16     EXTNL  OUTDGT 2 1
*** Brandywine Country Club
WDM1   810 WITH   0 ENGL           1.0SAME RCHRES  18     EXTNL  OUTDGT 2 1
*** Wilmington Country Club
WDM1   820 WITH   0 ENGL           1.0SAME RCHRES  19     EXTNL  OUTDGT 2 1
*** Dupont Country Club
WDM1   830 WITH   0 ENGL           1.0SAME RCHRES  19     EXTNL  OUTDGT 3 1
*** Wimington Finishing
WDM1   835 WITH   0 ENGL           1.0SAME RCHRES  34     EXTNL  OUTDGT 2 1

END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Aggr Amd ***
<Name>   x        <Name> x x<-factor->strg <Name>   x <Name>qf  tem strg strg***
***mult factor for rovol is 12/area
*** mult factor for others 1/area
*** Hydrologic output
RCHRES   1 ROFLOW ROVOL     .001019801     WDM   1170 FLOW     ENGL      REPL
RCHRES   1 HYDR   RO                       WDM   1179 FLOW     ENGL      REPL
COPY   100 OUTPUT MEAN   1  .000084983     WDM   1171 SURO     ENGL      REPL
COPY   100 OUTPUT MEAN   2  .000084983     WDM   1172 IFWO     ENGL      REPL
COPY   100 OUTPUT MEAN   3  .000084983     WDM   1173 AGWO     ENGL      REPL
COPY   100 OUTPUT MEAN   4  .000084983     WDM   1174 PREC     ENGL      REPL
COPY   100 OUTPUT MEAN   5  .000084983     WDM   1175 PETX     ENGL      REPL
COPY   100 OUTPUT MEAN   6  .000084983     WDM   1176 TAET     ENGL      REPL
COPY   100 OUTPUT MEAN   7  .000084983     WDM   1177 UZSX     ENGL      REPL
COPY   100 OUTPUT MEAN   8  .000084983     WDM   1178 LZSX     ENGL      REPL
COPY   100 OUTPUT MEAN   9  .000084983     WDM   9080 SOSED    ENGL      REPL
RCHRES   4 ROFLOW ROVOL     .000407553     WDM   1110 FLOW     ENGL      REPL
RCHRES   4 HYDR   RO                       WDM   1119 FLOW     ENGL      REPL
COPY   200 OUTPUT MEAN   1  .000033963     WDM   1111 SURO     ENGL      REPL
COPY   200 OUTPUT MEAN   2  .000033963     WDM   1112 IFWO     ENGL      REPL
COPY   200 OUTPUT MEAN   3  .000033963     WDM   1113 AGWO     ENGL      REPL
COPY   200 OUTPUT MEAN   4  .000033963     WDM   1114 PREC     ENGL      REPL
COPY   200 OUTPUT MEAN   5  .000033963     WDM   1115 PETX     ENGL      REPL
COPY   200 OUTPUT MEAN   6  .000033963     WDM   1116 TAET     ENGL      REPL
COPY   200 OUTPUT MEAN   7  .000033963     WDM   1117 UZSX     ENGL      REPL
COPY   200 OUTPUT MEAN   8  .000033963     WDM   1118 LZSX     ENGL      REPL
RCHRES   5 OFLOW  OVOL   1  .000341900     WDM   1200 FLOW     ENGL      REPL
RCHRES   5 HYDR   O      1                 WDM   1209 FLOW     ENGL      REPL
COPY   300 OUTPUT MEAN   1  .000028492     WDM   1201 SURO     ENGL      REPL
COPY   300 OUTPUT MEAN   2  .000028492     WDM   1202 IFWO     ENGL      REPL
COPY   300 OUTPUT MEAN   3  .000028492     WDM   1203 AGWO     ENGL      REPL
COPY   300 OUTPUT MEAN   4  .000028492     WDM   1204 PREC     ENGL      REPL
COPY   300 OUTPUT MEAN   5  .000028492     WDM   1205 PETX     ENGL      REPL
COPY   300 OUTPUT MEAN   6  .000028492     WDM   1206 TAET     ENGL      REPL
COPY   300 OUTPUT MEAN   7  .000028492     WDM   1207 UZSX     ENGL      REPL
COPY   300 OUTPUT MEAN   8  .000028492     WDM   1208 LZSX     ENGL      REPL
RCHRES  21 ROFLOW ROVOL     .001696113     WDM   1120 FLOW     ENGL      REPL
RCHRES  21 HYDR   RO                       WDM   1129 FLOW     ENGL      REPL
COPY   400 OUTPUT MEAN   1  .000141343     WDM   1121 SURO     ENGL      REPL
COPY   400 OUTPUT MEAN   2  .000141343     WDM   1122 IFWO     ENGL      REPL
COPY   400 OUTPUT MEAN   3  .000141343     WDM   1123 AGWO     ENGL      REPL
COPY   400 OUTPUT MEAN   4  .000141343     WDM   1124 PREC     ENGL      REPL
COPY   400 OUTPUT MEAN   5  .000141343     WDM   1125 PETX     ENGL      REPL
COPY   400 OUTPUT MEAN   6  .000141343     WDM   1126 TAET     ENGL      REPL
COPY   400 OUTPUT MEAN   7  .000141343     WDM   1127 UZSX     ENGL      REPL
COPY   400 OUTPUT MEAN   8  .000141343     WDM   1128 LZSX     ENGL      REPL
RCHRES  24 ROFLOW ROVOL     .031250000     WDM   1180 FLOW     ENGL      REPL
RCHRES  24 HYDR   RO                       WDM   1189 FLOW     ENGL      REPL
COPY   500 OUTPUT MEAN   1  .002604167     WDM   1181 SURO     ENGL      REPL
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COPY    500 OUTPUT MEAN    2  .002604167      WDM    1182 IFWO      ENGL       REPL
COPY    500 OUTPUT MEAN    3  .002604167      WDM    1183 AGWO      ENGL       REPL
COPY    500 OUTPUT MEAN    4  .002604167      WDM    1184 PREC      ENGL       REPL
COPY    500 OUTPUT MEAN    5  .002604167      WDM    1185 PETX      ENGL       REPL
COPY    500 OUTPUT MEAN    6  .002604167      WDM    1186 TAET      ENGL       REPL
COPY    500 OUTPUT MEAN    7  .002604167      WDM    1187 UZSX      ENGL       REPL
COPY    500 OUTPUT MEAN    8  .002604167      WDM    1188 LZSX      ENGL       REPL
RCHRES   26 ROFLOW ROVOL      .002227585      WDM    1160 FLOW      ENGL       REPL
RCHRES   26 HYDR   RO                         WDM    1169 FLOW      ENGL       REPL
COPY    600 OUTPUT MEAN    1  .000185632      WDM    1161 SURO      ENGL       REPL
COPY    600 OUTPUT MEAN    2  .000185632      WDM    1162 IFWO      ENGL       REPL
COPY    600 OUTPUT MEAN    3  .000185632      WDM    1163 AGWO      ENGL       REPL
COPY    600 OUTPUT MEAN    4  .000185632      WDM    1164 PREC      ENGL       REPL
COPY    600 OUTPUT MEAN    5  .000185632      WDM    1165 PETX      ENGL       REPL
COPY    600 OUTPUT MEAN    6  .000185632      WDM    1166 TAET      ENGL       REPL
COPY    600 OUTPUT MEAN    7  .000185632      WDM    1167 UZSX      ENGL       REPL
COPY    600 OUTPUT MEAN    8  .000185632      WDM    1168 LZSX      ENGL       REPL
COPY    600 OUTPUT MEAN    9  .000185632      WDM    9081 SOSED     ENGL       REPL
RCHRES   27 ROFLOW ROVOL      .000939408      WDM    1190 FLOW      ENGL       REPL
RCHRES   27 HYDR   RO                         WDM    1199 FLOW      ENGL       REPL
COPY    700 OUTPUT MEAN    1  .000078284      WDM    1191 SURO      ENGL       REPL
COPY    700 OUTPUT MEAN    2  .000078284      WDM    1192 IFWO      ENGL       REPL
COPY    700 OUTPUT MEAN    3  .000078284      WDM    1193 AGWO      ENGL       REPL
COPY    700 OUTPUT MEAN    4  .000078284      WDM    1194 PREC      ENGL       REPL
COPY    700 OUTPUT MEAN    5  .000078284      WDM    1195 PETX      ENGL       REPL
COPY    700 OUTPUT MEAN    6  .000078284      WDM    1196 TAET      ENGL       REPL
COPY    700 OUTPUT MEAN    7  .000078284      WDM    1197 UZSX      ENGL       REPL
COPY    700 OUTPUT MEAN    8  .000078284      WDM    1198 LZSX      ENGL       REPL
RCHRES   11 ROFLOW ROVOL      .000316347      WDM    1140 FLOW      ENGL       REPL
RCHRES   11 HYDR   RO                         WDM    1149 FLOW      ENGL       REPL
COPY    800 OUTPUT MEAN    1  .000026362      WDM    1141 SURO      ENGL       REPL
COPY    800 OUTPUT MEAN    2  .000026362      WDM    1142 IFWO      ENGL       REPL
COPY    800 OUTPUT MEAN    3  .000026362      WDM    1143 AGWO      ENGL       REPL
COPY    800 OUTPUT MEAN    4  .000026362      WDM    1144 PREC      ENGL       REPL
COPY    800 OUTPUT MEAN    5  .000026362      WDM    1145 PETX      ENGL       REPL
COPY    800 OUTPUT MEAN    6  .000026362      WDM    1146 TAET      ENGL       REPL
COPY    800 OUTPUT MEAN    7  .000026362      WDM    1147 UZSX      ENGL       REPL
COPY    800 OUTPUT MEAN    8  .000026362      WDM    1148 LZSX      ENGL       REPL
RCHRES   13 OFLOW  OVOL    1  .000210696      WDM    1130 FLOW      ENGL       REPL
RCHRES   13 HYDR   O       1                  WDM    1139 FLOW      ENGL       REPL
COPY    900 OUTPUT MEAN    1  .000017558      WDM    1131 SURO      ENGL       REPL
COPY    900 OUTPUT MEAN    2  .000017558      WDM    1132 IFWO      ENGL       REPL
COPY    900 OUTPUT MEAN    3  .000017558      WDM    1133 AGWO      ENGL       REPL
COPY    900 OUTPUT MEAN    4  .000017558      WDM    1134 PREC      ENGL       REPL
COPY    900 OUTPUT MEAN    5  .000017558      WDM    1135 PETX      ENGL       REPL
COPY    900 OUTPUT MEAN    6  .000017558      WDM    1136 TAET      ENGL       REPL
COPY    900 OUTPUT MEAN    7  .000017558      WDM    1137 UZSX      ENGL       REPL
COPY    900 OUTPUT MEAN    8  .000017558      WDM    1138 LZSX      ENGL       REPL
RCHRES   28 ROFLOW ROVOL      .007802341      WDM    1150 FLOW      ENGL       REPL
RCHRES   28 HYDR   RO                         WDM    1159 FLOW      ENGL       REPL
COPY    910 OUTPUT MEAN    1  .000650195      WDM    1151 SURO      ENGL       REPL
COPY    910 OUTPUT MEAN    2  .000650195      WDM    1152 IFWO      ENGL       REPL
COPY    910 OUTPUT MEAN    3  .000650195      WDM    1153 AGWO      ENGL       REPL
COPY    910 OUTPUT MEAN    4  .000650195      WDM    1154 PREC      ENGL       REPL
COPY    910 OUTPUT MEAN    5  .000650195      WDM    1155 PETX      ENGL       REPL
COPY    910 OUTPUT MEAN    6  .000650195      WDM    1156 TAET      ENGL       REPL
COPY    910 OUTPUT MEAN    7  .000650195      WDM    1157 UZSX      ENGL       REPL
COPY    910 OUTPUT MEAN    8  .000650195      WDM    1158 LZSX      ENGL       REPL
RCHRES   16 OFLOW  OVOL    1  .000064203      WDM    1100 FLOW      ENGL       REPL
RCHRES   16 HYDR   O       1                  WDM    1109 FLOW      ENGL       REPL
COPY    920 OUTPUT MEAN    1  .000005350      WDM    1101 SURO      ENGL       REPL
COPY    920 OUTPUT MEAN    2  .000005350      WDM    1102 IFWO      ENGL       REPL
COPY    920 OUTPUT MEAN    3  .000005350      WDM    1103 AGWO      ENGL       REPL
COPY    920 OUTPUT MEAN    4  .000005350      WDM    1104 PREC      ENGL       REPL
COPY    920 OUTPUT MEAN    5  .000005350      WDM    1105 PETX      ENGL       REPL
COPY    920 OUTPUT MEAN    6  .000005350      WDM    1106 TAET      ENGL       REPL
COPY    920 OUTPUT MEAN    7  .000005350      WDM    1107 UZSX      ENGL       REPL
COPY    920 OUTPUT MEAN    8  .000005350      WDM    1108 LZSX      ENGL       REPL
*** total load outputs from land areas for reach 16
COPY    920 OUTPUT MEAN    9  1.00000000      WDM    9095 SOSED     ENGL       REPL
COPY    920 OUTPUT MEAN   10  1.00000000      WDM    9120 PONO3     ENGL       REPL
COPY    920 OUTPUT MEAN   11  1.00000000      WDM    9121 PONH4     ENGL       REPL
COPY    920 OUTPUT MEAN   12  1.00000000      WDM    9122 POPHOS    ENGL       REPL
COPY    920 OUTPUT MEAN   13  1.00000000      WDM    9130 IONO3     ENGL       REPL
COPY    920 OUTPUT MEAN   14  1.00000000      WDM    9131 IONH4     ENGL       REPL
COPY    920 OUTPUT MEAN   15  1.00000000      WDM    9132 IOPHOS    ENGL       REPL
COPY    920 OUTPUT MEAN   16  1.00000000      WDM    9133 SOSLD     ENGL       REPL
*** reach 19
RCHRES   19 OFLOW  OVOL    1  .000058024      WDM    1210 FLOW      ENGL       REPL
RCHRES   19 HYDR   O       1                  WDM    1219 FLOW      ENGL       REPL
COPY    930 OUTPUT MEAN    1  .000004835      WDM    1211 SURO      ENGL       REPL
COPY    930 OUTPUT MEAN    2  .000004835      WDM    1212 IFWO      ENGL       REPL
COPY    930 OUTPUT MEAN    3  .000004835      WDM    1213 AGWO      ENGL       REPL
COPY    930 OUTPUT MEAN    4  .000004835      WDM    1214 PREC      ENGL       REPL
COPY    930 OUTPUT MEAN    5  .000004835      WDM    1215 PETX      ENGL       REPL
COPY    930 OUTPUT MEAN    6  .000004835      WDM    1216 TAET      ENGL       REPL
COPY    930 OUTPUT MEAN    7  .000004835      WDM    1217 UZSX      ENGL       REPL
COPY    930 OUTPUT MEAN    8  .000004835 ***  WDM    1218 LZSX      ENGL       REPL
*** total load outputs from land areas for reach 19
COPY    930 OUTPUT MEAN    9  1.00000000      WDM    9090 SOSED     ENGL       REPL
COPY    930 OUTPUT MEAN   10  1.00000000      WDM    9125 PONO4     ENGL       REPL
COPY    930 OUTPUT MEAN   11  1.00000000      WDM    9126 PONH4     ENGL       REPL
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COPY   930 OUTPUT MEAN  12  1.00000000     WDM   9127 POPHOS   ENGL      REPL
COPY   930 OUTPUT MEAN  13  1.00000000     WDM   9135 IONO3    ENGL      REPL
COPY   930 OUTPUT MEAN  14  1.00000000     WDM   9136 IONH4    ENGL      REPL
COPY   930 OUTPUT MEAN  15  1.00000000     WDM   9137 IOPHOS   ENGL      REPL
COPY   930 OUTPUT MEAN  16  1.00000000     WDM   9138 SOSLD    ENGL      REPL
*** water temperature output
RCHRES   1 HTRCH  TW                       WDM   1740 WTEM     METR      REPL
RCHRES   4 HTRCH  TW                       WDM   1760 WTEM     METR      REPL
RCHRES   5 HTRCH  TW                       WDM   1780 WTEM     METR      REPL
RCHRES  21 HTRCH  TW                       WDM   1800 WTEM     METR      REPL
RCHRES   8 HTRCH  TW                       WDM   1840 WTEM     METR      REPL
RCHRES  24 HTRCH  TW                       WDM   1820 WTEM     METR      REPL
RCHRES  26 HTRCH  TW                       WDM   1860 WTEM     METR      REPL
RCHRES  11 HTRCH  TW                       WDM   1880 WTEM     METR      REPL
RCHRES  13 HTRCH  TW                       WDM   1900 WTEM     METR      REPL
RCHRES  28 HTRCH  TW                       WDM   1920 WTEM     METR      REPL
RCHRES  14 HTRCH  TW                       WDM   1940 WTEM     METR      REPL
RCHRES  16 HTRCH  TW                       WDM   1960 WTEM     METR      REPL
RCHRES  19 HTRCH  TW                       WDM   2000 WTEM     METR      REPL
*** suspended sediment output
RCHRES   1 SEDTRN SSED   4                 WDM   1742 SEDC     METR      REPL
RCHRES   4 SEDTRN SSED   4                 WDM   1762 SEDC     METR      REPL
RCHRES  21 SEDTRN SSED   4                 WDM   1802 SEDC     METR      REPL
RCHRES  24 SEDTRN SSED   4                 WDM   1822 SEDC     METR      REPL
RCHRES   8 SEDTRN SSED   4                 WDM   1862 SEDC     METR      REPL
RCHRES  28 SEDTRN SSED   4                 WDM   1922 SEDC     METR      REPL
RCHRES  16 SEDTRN SSED   4                 WDM   1962 SEDC     METR      REPL
RCHRES  19 SEDTRN SSED   4                 WDM   2002 SEDC     METR      REPL
RCHRES  21 HYDR   TAU                      WDM   9000 TAU      ENGL      REPL
RCHRES  24 HYDR   TAU                      WDM   9001 TAU      ENGL      REPL
RCHRES  28 HYDR   TAU                      WDM   9002 TAU      ENGL      REPL
RCHRES  19 HYDR   TAU                      WDM   9003 TAU      ENGL      REPL
RCHRES  16 HYDR   TAU                      WDM   9004 TAU      ENGL      REPL
RCHRES  26 HYDR   TAU                      WDM   9005 TAU      ENGL      REPL
RCHRES   1 HYDR   TAU                      WDM   9006 TAU      ENGL      REPL
RCHRES   3 HYDR   TAU                      WDM   9007 TAU      ENGL      REPL
RCHRES   4 HYDR   TAU                      WDM   9008 TAU      ENGL      REPL
RCHRES  11 HYDR   TAU                      WDM   9009 TAU      ENGL      REPL
RCHRES  12 HYDR   TAU                      WDM   9010 TAU      ENGL      REPL
RCHRES  23 HYDR   TAU                      WDM   9011 TAU      ENGL      REPL
RCHRES  30 HYDR   TAU                      WDM   9012 TAU      ENGL      REPL
RCHRES  32 HYDR   TAU                      WDM   9013 TAU      ENGL      REPL
RCHRES  33 HYDR   TAU                      WDM   9014 TAU      ENGL      REPL
RCHRES  34 HYDR   TAU                      WDM   9015 TAU      ENGL      REPL
RCHRES  35 HYDR   TAU                      WDM   9016 TAU      ENGL      REPL
PERLND 102 SEDMNT DETS                     WDM   9020 DETS     ENGL      REPL
PERLND 103 SEDMNT DETS                     WDM   9021 DETS     ENGL      REPL
PERLND 104 SEDMNT DETS                     WDM   9022 DETS     ENGL      REPL
PERLND 105 SEDMNT DETS                     WDM   9023 DETS     ENGL      REPL
PERLND 108 SEDMNT DETS                     WDM   9024 DETS     ENGL      REPL
PERLND 109 SEDMNT DETS                     WDM   9025 DETS     ENGL      REPL
PERLND 202 SEDMNT DETS                     WDM   9026 DETS     ENGL      REPL
PERLND 203 SEDMNT DETS                     WDM   9027 DETS     ENGL      REPL
PERLND 204 SEDMNT DETS                     WDM   9028 DETS     ENGL      REPL
PERLND 205 SEDMNT DETS                     WDM   9029 DETS     ENGL      REPL
PERLND 208 SEDMNT DETS                     WDM   9030 DETS     ENGL      REPL
PERLND 209 SEDMNT DETS                     WDM   9031 DETS     ENGL      REPL
PERLND 302 SEDMNT DETS                     WDM   9032 DETS     ENGL      REPL
PERLND 303 SEDMNT DETS                     WDM   9033 DETS     ENGL      REPL
PERLND 304 SEDMNT DETS                     WDM   9034 DETS     ENGL      REPL
PERLND 305 SEDMNT DETS                     WDM   9035 DETS     ENGL      REPL
PERLND 308 SEDMNT DETS                     WDM   9036 DETS     ENGL      REPL
PERLND 309 SEDMNT DETS                     WDM   9037 DETS     ENGL      REPL
PERLND 402 SEDMNT DETS                     WDM   9038 DETS     ENGL      REPL
PERLND 403 SEDMNT DETS                     WDM   9039 DETS     ENGL      REPL
PERLND 404 SEDMNT DETS                     WDM   9040 DETS     ENGL      REPL
PERLND 405 SEDMNT DETS                     WDM   9041 DETS     ENGL      REPL
PERLND 408 SEDMNT DETS                     WDM   9042 DETS     ENGL      REPL
PERLND 409 SEDMNT DETS                     WDM   9043 DETS     ENGL      REPL
*** Water-quality output
RCHRES   1 OXRX   DOX                      WDM   1741 DOXX     METR      REPL
*** Dissolved NO3
RCHRES   1 NUTRX  DNUST  1                 WDM   1743 NO3X     METR      REPL
*** Dissolved NH3
RCHRES   1 NUTRX  DNUST  2                 WDM   1744 NH4X     METR      REPL
*** Dissolved PO4
RCHRES   1 NUTRX  DNUST  4                 WDM   1745 PO4X     METR      REPL
*** BOD
RCHRES   1 OXRX   BOD                      WDM   1746 BODX     METR      REPL
COPY    10 OUTPUT MEAN   1                 WDM   1747 NH4P     METR      REPL
COPY    10 OUTPUT MEAN   2                 WDM   1748 PO4P     METR      REPL
RCHRES   1 PLANK  PKST3  4                 WDM   1749 TORN     METR      REPL
RCHRES   1 PLANK  PHYCLA 1                 WDM   1750 PHCA     METR      REPL
RCHRES   4 NUTRX  DNUST  1                 WDM   1763 NO3X     METR      REPL
RCHRES   4 NUTRX  DNUST  2                 WDM   1764 NH4X     METR      REPL
RCHRES   4 NUTRX  DNUST  4                 WDM   1765 PO4X     METR      REPL
RCHRES   5 OXRX   DOX                      WDM   1781 DOXX     METR      REPL
RCHRES   5 NUTRX  DNUST  1                 WDM   1783 NO3X     METR      REPL
RCHRES   5 NUTRX  DNUST  2                 WDM   1784 NH4X     METR      REPL
RCHRES   5 NUTRX  DNUST  4                 WDM   1785 PO4X     METR      REPL
RCHRES   5 OXRX   BOD                      WDM   1786 BODX     METR      REPL
RCHRES  21 OXRX   DOX                      WDM   1801 DOXX     METR      REPL
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RCHRES  21 NUTRX  DNUST  1                   WDM   1803 NO3X     METR      REPL
RCHRES  21 NUTRX  DNUST  2                   WDM   1804 NH4X     METR      REPL
RCHRES  21 NUTRX  DNUST  4                   WDM   1805 PO4X     METR      REPL
RCHRES  21 OXRX   BOD                        WDM   1806 BODX     METR      REPL
COPY    11 OUTPUT MEAN   1                   WDM   1807 NH4P     METR      REPL
COPY    11 OUTPUT MEAN   2                   WDM   1808 PO4P     METR      REPL
RCHRES  21 PLANK  PKST3  4                   WDM   1809 TORN     METR      REPL
RCHRES  21 PLANK  PHYCLA 1                   WDM   1810 PHCA     METR      REPL
RCHRES  24 OXRX   DOX                        WDM   1821 DOXX     METR      REPL
RCHRES  24 NUTRX  DNUST  1                   WDM   1823 NO3X     METR      REPL
RCHRES  24 NUTRX  DNUST  2                   WDM   1824 NH4X     METR      REPL
RCHRES  24 NUTRX  DNUST  4                   WDM   1825 PO4X     METR      REPL
RCHRES  24 OXRX   BOD                        WDM   1826 BODX     METR      REPL
COPY    12 OUTPUT MEAN   1                   WDM   1827 NH4P     METR      REPL
COPY    12 OUTPUT MEAN   2                   WDM   1828 PO4P     METR      REPL
RCHRES  12 PLANK  PKST3  4                   WDM   1829 TORN     METR      REPL
RCHRES  12 PLANK  PHYCLA 1                   WDM   1830 PHCA     METR      REPL
RCHRES  26 OXRX   DOX                        WDM   1861 DOXX     METR      REPL
RCHRES  26 NUTRX  DNUST  1                   WDM   1863 NO3X     METR      REPL
RCHRES  26 NUTRX  DNUST  2                   WDM   1864 NH4X     METR      REPL
RCHRES  26 NUTRX  DNUST  4                   WDM   1865 PO4X     METR      REPL
RCHRES  26 OXRX   BOD                        WDM   1866 BODX     METR      REPL
COPY    13 OUTPUT MEAN   1                   WDM   1867 NH4P     METR      REPL
COPY    13 OUTPUT MEAN   2                   WDM   1868 PO4P     METR      REPL
RCHRES  26 PLANK  PKST3  4                   WDM   1869 TORN     METR      REPL
RCHRES  26 PLANK  PHYCLA 1                   WDM   1870 PHCA     METR      REPL
RCHRES  28 OXRX   DOX                        WDM   1921 DOXX     METR      REPL
RCHRES  28 NUTRX  DNUST  1                   WDM   1923 NO3X     METR      REPL
RCHRES  28 NUTRX  DNUST  2                   WDM   1924 NH4X     METR      REPL
RCHRES  28 NUTRX  DNUST  4                   WDM   1925 PO4X     METR      REPL
RCHRES  28 OXRX   BOD                        WDM   1926 BODX     METR      REPL
COPY    14 OUTPUT MEAN   1                   WDM   1927 NH4P     METR      REPL
COPY    14 OUTPUT MEAN   2                   WDM   1928 PO4P     METR      REPL
RCHRES  28 PLANK  PKST3  4                   WDM   1929 TORN     METR      REPL
RCHRES  28 PLANK  PHYCLA 1                   WDM   1930 PHCA     METR      REPL
RCHRES  11 NUTRX  DNUST  1                   WDM   1303 NO3X     METR      REPL
RCHRES  11 NUTRX  DNUST  2                   WDM   1304 NH4X     METR      REPL
RCHRES  11 NUTRX  DNUST  4                   WDM   1305 PO4X     METR      REPL
RCHRES  13 OXRX   DOX                        WDM   1325 DOXX     METR      REPL
RCHRES  13 OXRX   BOD                        WDM   1326 BODX     METR      REPL
RCHRES  13 NUTRX  DNUST  1                   WDM   1327 NO3X     METR      REPL
RCHRES  13 NUTRX  DNUST  2                   WDM   1328 NH4X     METR      REPL
RCHRES  13 NUTRX  DNUST  4                   WDM   1329 PO4X     METR      REPL
RCHRES  16 OXRX   DOX                        WDM   1961 DOXX     METR      REPL
RCHRES  16 NUTRX  DNUST  1                   WDM   1963 NO3X     METR      REPL
RCHRES  16 NUTRX  DNUST  2                   WDM   1964 NH4X     METR      REPL
RCHRES  16 NUTRX  DNUST  4                   WDM   1965 PO4X     METR      REPL
RCHRES  16 OXRX   BOD                        WDM   1966 BODX     METR      REPL
COPY    15 OUTPUT MEAN   1                   WDM   1967 NH4P     METR      REPL
COPY    15 OUTPUT MEAN   2                   WDM   1968 PO4P     METR      REPL
RCHRES  16 PLANK  PKST3  4                   WDM   1969 TORN     METR      REPL
RCHRES  16 PLANK  PHYCLA 1                   WDM   1970 PHCA     METR      REPL
RCHRES  16 NUTRX  NUCF1  4                   WDM   1971 PLDD     METR      REPL
RCHRES  16 NUTRX  NUCF2  4 2                 WDM   1972 PLDP     METR      REPL
END EXT TARGETS

SCHEMATIC
<-Source->                  <--Area-->    <-Target->   <ML>  ***
<Name>   #                  <-factor->    <Name>   #      #  ***
*** Note: All PLS-RCH and ILS-RCH multiplication factors are acres.
***       Conversion factors, where applicable, are in Mass-Link.
***
*** Segment 1 (W.Br.Brandywine)
*** Tributary to Reach 1 (W.Br. to Honeybrook)
PERLND 102                    478.8400    RCHRES   1      1
PERLND 103                     168.160    RCHRES   1      1
PERLND 104                      72.980    RCHRES   1      1
PERLND 105                    5363.665    RCHRES   1      1
PERLND 106                     2641.81    RCHRES   1      1
PERLND 107                           0    RCHRES   1      1
PERLND 108                    2361.190    RCHRES   1      1
PERLND 109                     317.880    RCHRES   1      1
PERLND 110                      57.280    RCHRES   1      1
PERLND 111                     100.200    RCHRES   1      1
IMPLND 101                     125.270    RCHRES   1      2
IMPLND 102                      79.540    RCHRES   1      2
*** Tributary to Reach 2 (W.Br to Birch Run/Hibernia)
PERLND 102                     816.240    RCHRES   2      1
PERLND 103                      29.660    RCHRES   2      1
PERLND 104                      84.370    RCHRES   2      1
PERLND 105                     441.670    RCHRES   2      1
PERLND 106                     896.720    RCHRES   2      1
PERLND 107                           0    RCHRES   2      1
PERLND 108                    2189.170    RCHRES   2      1
PERLND 109                      25.340    RCHRES   2      1
PERLND 110                      38.860    RCHRES   2      1
PERLND 111                      11.080    RCHRES   2      1
IMPLND 101                     103.400    RCHRES   2      2
IMPLND 102                      84.370    RCHRES   2      2
*** Tributary to Reach 32 (Birch Run)
PERLND 102                     337.710    RCHRES  32      1
PERLND 103                           0    RCHRES  32      1
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PERLND 104                     23.540     RCHRES  32      1
PERLND 105                    471.960     RCHRES  32      1
PERLND 106                    471.960     RCHRES  32      1
PERLND 107                          0     RCHRES  32      1
PERLND 108                   1577.110     RCHRES  32      1
PERLND 109                     27.730     RCHRES  32      1
PERLND 110                      2.460     RCHRES  32      1
PERLND 111                      8.460     RCHRES  32      1
IMPLND 101                     37.520     RCHRES  32      2
IMPLND 102                     23.540     RCHRES  32      2
*** Tributary to Reach 9 (E.Br.Brandywine near Struble Lake)
PERLND 102                   574.4000     RCHRES   9      1
PERLND 103                     46.630     RCHRES   9      1
PERLND 104                     34.650     RCHRES   9      1
PERLND 105                   2537.335     RCHRES   9      1
PERLND 106                   2537.335     RCHRES   9      1
PERLND 107                          0     RCHRES   9      1
PERLND 108                   3065.560     RCHRES   9      1
PERLND 109                    202.190     RCHRES   9      1
PERLND 110                    258.330     RCHRES   9      1
PERLND 111                     21.810     RCHRES   9      1
IMPLND 101                     83.810     RCHRES   9      2
IMPLND 102                     35.500     RCHRES   9      2

    Reach Connections ***
RCHRES   1                                RCHRES   2      3


***
*** Segment 2 (WBrBrandywine below Hibernia)
*** Tributary to Reach 3 (W.Br. to Rock Run)
PERLND 202                    962.690     RCHRES   3      1
PERLND 203                     13.190     RCHRES   3      1
PERLND 204                     51.210     RCHRES   3      1
PERLND 205                    325.180     RCHRES   3      1
PERLND 206                    975.540     RCHRES   3      1
PERLND 207                          0     RCHRES   3      1
PERLND 208                   1721.420     RCHRES   3      1
PERLND 209                     87.220     RCHRES   3      1
PERLND 210                     23.050     RCHRES   3      1
PERLND 211                      1.450     RCHRES   3      1
IMPLND 201                    112.620     RCHRES   3      2
IMPLND 202                     51.370     RCHRES   3      2
*** Tributary to Reach 33 (Rock Run)
PERLND 202                    624.740     RCHRES  33      1
PERLND 203                    181.830     RCHRES  33      1
PERLND 204                     65.000     RCHRES  33      1
PERLND 205                    216.840     RCHRES  33      1
PERLND 206                   1951.590     RCHRES  33      1
PERLND 207                          0     RCHRES  33      1
PERLND 208                   1531.880     RCHRES  33      1
PERLND 209                    228.510     RCHRES  33      1
PERLND 210                    106.300     RCHRES  33      1
PERLND 211                     19.020     RCHRES  33      1
IMPLND 201                    147.340     RCHRES  33      2
IMPLND 202                     66.000     RCHRES  33      2
*** Tributary to Reach 4 (W.Br. to Coatesville)
PERLND 202                          0     RCHRES   4      1
PERLND 203                     36.650     RCHRES   4      1
PERLND 204                     10.920     RCHRES   4      1
PERLND 205                          0     RCHRES   4      1
PERLND 206                     77.650     RCHRES   4      1
PERLND 207                          0     RCHRES   4      1
PERLND 208                    357.730     RCHRES   4      1
PERLND 209                      0.740     RCHRES   4      1
PERLND 210                      8.740     RCHRES   4      1
PERLND 211                      0.810     RCHRES   4      1
IMPLND 201                     15.710     RCHRES   4      2
IMPLND 202                     11.040     RCHRES   4      2
*** Tributary to Reach 5 (W.Br. to Modena)
PERLND 202                     82.000     RCHRES   5      1
PERLND 203                    622.830     RCHRES   5      1
PERLND 204                    591.820     RCHRES   5      1
PERLND 205                          0     RCHRES   5      1
PERLND 206                   1076.980     RCHRES   5      1
PERLND 207                          0     RCHRES   5      1
PERLND 208                   1963.630     RCHRES   5      1
PERLND 209                    203.990     RCHRES   5      1
PERLND 210                     85.050     RCHRES   5      1
PERLND 211                    137.180     RCHRES   5      1
IMPLND 201                    276.040     RCHRES   5      2
IMPLND 202                    604.620     RCHRES   5      2
*** Tributary to Reach 6 (W.Br. to Buck Run)
PERLND 202                    883.470     RCHRES   6      1
PERLND 203                     27.220     RCHRES   6      1
PERLND 204                     75.070     RCHRES   6      1
PERLND 205                    204.260     RCHRES   6      1
PERLND 206                   1838.310     RCHRES   6      1
PERLND 207                          0     RCHRES   6      1
PERLND 208                   1828.280     RCHRES   6      1
PERLND 209                     91.900     RCHRES   6      1
PERLND 210                     25.830     RCHRES   6      1
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PERLND 211                         0.490     RCHRES   6      1
IMPLND 201                       109.830     RCHRES   6      2
IMPLND 202                        75.070     RCHRES   6      2
*** Tributary to Reach 20 (Buck Run to Doe Run)
PERLND 202                      1251.790     RCHRES  20      1
PERLND 203                       294.070     RCHRES  20      1
PERLND 204                       175.410     RCHRES  20      1
PERLND 205                       960.500     RCHRES  20      1
PERLND 206                      8644.491     RCHRES  20      1
PERLND 207                             0     RCHRES  20      1
PERLND 208                      4172.560     RCHRES  20      1
PERLND 209                       206.770     RCHRES  20      1
PERLND 210                        60.710     RCHRES  20      1
PERLND 211                       137.310     RCHRES  20      1
IMPLND 201                       265.120     RCHRES  20      2
IMPLND 202                       175.410     RCHRES  20      2
*** Tributary to Reach 21 (Doe Run to Springdell)
PERLND 202                       248.770     RCHRES  21      1
PERLND 203                             0     RCHRES  21      1
PERLND 204                        28.720     RCHRES  21      1
PERLND 205                       539.420     RCHRES  21      1
PERLND 206                      4854.760     RCHRES  21      1
PERLND 207                             0     RCHRES  21      1
PERLND 208                      1226.230     RCHRES  21      1
PERLND 209                        76.530     RCHRES  21      1
PERLND 210                         9.120     RCHRES  21      1
PERLND 211                        34.480     RCHRES  21      1
IMPLND 201                        27.640     RCHRES  21      2
IMPLND 202                        28.720     RCHRES  21      2
*** Tributary to Reach 22 (Doe Run to Buck Run)
PERLND 202                        46.170     RCHRES  22      1
PERLND 203                             0     RCHRES  22      1
PERLND 204                        61.920     RCHRES  22      1
PERLND 205                       555.930     RCHRES  22      1
PERLND 206                      5003.370     RCHRES  22      1
PERLND 207                             0     RCHRES  22      1
PERLND 208                      1241.900     RCHRES  22      1
PERLND 209                             0     RCHRES  22      1
PERLND 210                        23.800     RCHRES  22      1
PERLND 211                        13.000     RCHRES  22      1
IMPLND 201                         5.130     RCHRES  22      2
IMPLND 202                        61.920     RCHRES  22      2
*** Tributary to Reach 23 (Buck Run to W.Br. Brandywine)
PERLND 202                             0     RCHRES  23      1
PERLND 203                             0     RCHRES  23      1
PERLND 204                           0.1     RCHRES  23      1
PERLND 205                        61.460     RCHRES  23      1
PERLND 206                       553.122     RCHRES  23      1
PERLND 207                             0     RCHRES  23      1
PERLND 208                       615.550     RCHRES  23      1
PERLND 209                             0     RCHRES  23      1
PERLND 210                        15.540     RCHRES  23      1
PERLND 211                             0     RCHRES  23      1
IMPLND 201                             0     RCHRES  23      2
IMPLND 202                           0.1     RCHRES  23      2
*** Tributary to Reach 7 (W.Br. to Broad Run)
PERLND 202                       505.330     RCHRES   7      1
PERLND 203                             0     RCHRES   7      1
PERLND 204                       131.840     RCHRES   7      1
PERLND 205                             0     RCHRES   7      1
PERLND 206                      4219.310     RCHRES   7      1
PERLND 207                             0     RCHRES   7      1
PERLND 208                      3290.770     RCHRES   7      1
PERLND 209                       166.360     RCHRES   7      1
PERLND 210                       104.550     RCHRES   7      1
PERLND 211                        10.390     RCHRES   7      1
IMPLND 201                        56.150     RCHRES   7      2
IMPLND 202                       131.840     RCHRES   7      2
*** Tributary to Reach 24 (Little Broad Run)
PERLND 202                       280.860     RCHRES  24      1
PERLND 203                        18.910     RCHRES  24      1
PERLND 204                             0     RCHRES  24      1
PERLND 205                             0     RCHRES  24      1
PERLND 206                        13.230     RCHRES  24      1
PERLND 207                             0     RCHRES  24      1
PERLND 208                        31.370     RCHRES  24      1
PERLND 209                             0     RCHRES  24      1
PERLND 210                             0     RCHRES  24      1
PERLND 211                             0     RCHRES  24      1
IMPLND 201                        39.310     RCHRES  24      2
IMPLND 202                             0     RCHRES  24      2
*** Tributary to Reach 25 (Broad Run to W.Br. Brandywine)
PERLND 202                       568.610     RCHRES  25      1
PERLND 203                       139.350     RCHRES  25      1
PERLND 204                        83.980     RCHRES  25      1
PERLND 205                             0     RCHRES  25      1
PERLND 206                      1518.030     RCHRES  25      1
PERLND 207                             0     RCHRES  25      1
PERLND 208                      1134.750     RCHRES  25      1
PERLND 209                        64.490     RCHRES  25      1
PERLND 210                         4.890     RCHRES  25      1
PERLND 211                        12.300     RCHRES  25      1
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IMPLND 201                     122.900     RCHRES  25      2
IMPLND 202                      84.400     RCHRES  25      2
*** Tributary to Reach 8 (W.Br. to confluence E.Br.)
PERLND 202                     211.910     RCHRES   8      1
PERLND 203                           0     RCHRES   8      1
PERLND 204                      13.480     RCHRES   8      1
PERLND 205                           0     RCHRES   8      1
PERLND 206                    1448.780     RCHRES   8      1
PERLND 207                           0     RCHRES   8      1
PERLND 208                     575.400     RCHRES   8      1
PERLND 209                           0     RCHRES   8      1
PERLND 210                      26.710     RCHRES   8      1
PERLND 211                       1.110     RCHRES   8      1
IMPLND 201                      23.550     RCHRES   8      2
IMPLND 202                      13.480     RCHRES   8      2

    Reach Connections ***
RCHRES   2                                 RCHRES   3      3
RCHRES  32                                 RCHRES   3      3
RCHRES   3                                 RCHRES   4      4
RCHRES  33                                 RCHRES   4      4
RCHRES   4                                 RCHRES   5      3
RCHRES   5                                 RCHRES   6      4
RCHRES   6                                 RCHRES   7      4
RCHRES  20                                 RCHRES  23      3
RCHRES  21                                 RCHRES  22      3
RCHRES  22                                 RCHRES  23      3
RCHRES  23                                 RCHRES   7      3
RCHRES   7                                 RCHRES   8      4
RCHRES  24                                 RCHRES  25      3
RCHRES  25                                 RCHRES   8      3

*** Segment 3 E.Br above Wawaset
*** Tributary to Reach 35 (Marsh Creek to Lyons Creek)
PERLND 302                     234.540     RCHRES  35      1
PERLND 303                           0     RCHRES  35      1
PERLND 304                      39.440     RCHRES  35      1
PERLND 305                      449.08     RCHRES  35      1
PERLND 306                    1347.248     RCHRES  35      1
PERLND 307                           0     RCHRES  35      1
PERLND 308                    1267.800     RCHRES  35      1
PERLND 309                      11.810     RCHRES  35      1
PERLND 310                     290.000     RCHRES  35      1
PERLND 311                       8.050     RCHRES  35      1
IMPLND 301                      26.060     RCHRES  35      2
IMPLND 302                      39.440     RCHRES  35      2
*** Tributary to Reach 26 (Marsh Creek to Glenmoore gage)
PERLND 302                     135.500     RCHRES  26      1
PERLND 303                           0     RCHRES  26      1
PERLND 304                      37.640     RCHRES  26      1
PERLND 305                      109.54     RCHRES  26      1
PERLND 306                     328.628     RCHRES  26      1
PERLND 307                           0     RCHRES  26      1
PERLND 308                     994.930     RCHRES  26      1
PERLND 309                       4.850     RCHRES  26      1
PERLND 310                       8.230     RCHRES  26      1
PERLND 311                       1.330     RCHRES  26      1
IMPLND 301                      15.060     RCHRES  26      2
IMPLND 302                      37.640     RCHRES  26      2
*** Tributary to Reach 27 (Marsh Creek Reservoir)
PERLND 302                    1586.590     RCHRES  27      1
PERLND 303                       4.650     RCHRES  27      1
PERLND 304                      64.210     RCHRES  27      1
PERLND 305                     653.500     RCHRES  27      1
PERLND 306                    1524.830     RCHRES  27      1
PERLND 307                           0     RCHRES  27      1
PERLND 308                    2501.180     RCHRES  27      1
PERLND 309                     178.360     RCHRES  27      1
PERLND 310 ***                 549.530     RCHRES  27      1
PERLND 311                      82.030     RCHRES  27      1
IMPLND 301                     178.280     RCHRES  27      2
IMPLND 302                      64.210     RCHRES  27      2
*** Tributary to Reach 10 (EBrBrandywine below dam near Glenmoore)
PERLND 302                    1995.080     RCHRES  10      1
PERLND 303                      27.220     RCHRES  10      1
PERLND 304                     140.810     RCHRES  10      1
PERLND 305                           0     RCHRES  10      1
PERLND 306                    4247.410     RCHRES  10      1
PERLND 307                           0     RCHRES  10      1
PERLND 308                    4707.030     RCHRES  10      1
PERLND 309                     134.070     RCHRES  10      1
PERLND 310                      72.990     RCHRES  10      1
PERLND 311                      22.060     RCHRES  10      1
IMPLND 301                     233.340     RCHRES  10      2
IMPLND 302                     141.030     RCHRES  10      2
*** Tributary to Reach 11 (EBr Brandywine to Dowlins)
PERLND 302                     189.180     RCHRES  11      1
PERLND 303                     468.230     RCHRES  11      1
PERLND 304                      75.190     RCHRES  11      1
PERLND 305                           0     RCHRES  11      1
PERLND 306                    1338.030     RCHRES  11      1
PERLND 307                           0     RCHRES  11      1
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PERLND 308                   1438.480     RCHRES  11       1
PERLND 309                    189.960     RCHRES  11       1
PERLND 310                     20.210     RCHRES  11       1
PERLND 311                     22.560     RCHRES  11       1
IMPLND 301                    221.690     RCHRES  11       2
IMPLND 302                     76.360     RCHRES  11       2
*** Tributary to Reach 12 (EBrBrandywine to Beaver Ck)
PERLND 302                    199.300     RCHRES  12       1
PERLND 303                    441.890     RCHRES  12       1
PERLND 304                    103.530     RCHRES  12       1
PERLND 305                          0     RCHRES  12       1
PERLND 306                    270.930     RCHRES  12       1
PERLND 307                          0     RCHRES  12       1
PERLND 308                    922.160     RCHRES  12       1
PERLND 309                     52.290     RCHRES  12       1
PERLND 310                     31.590     RCHRES  12       1
PERLND 311                     29.780     RCHRES  12       1
IMPLND 301                    211.520     RCHRES  12       2
IMPLND 302                    106.540     RCHRES  12       2
*** Tributary to Reach 30 (Beaver Creek)
PERLND 302                   1406.820     RCHRES  30       1
PERLND 303                    764.380     RCHRES  30       1
PERLND 304                    548.280     RCHRES  30       1
PERLND 305                          0     RCHRES  30       1
PERLND 306                   3742.940     RCHRES  30       1
PERLND 307                          0     RCHRES  30       1
PERLND 308                   3465.160     RCHRES  30       1
PERLND 309                    249.200     RCHRES  30       1
PERLND 310                     21.790     RCHRES  30       1
PERLND 311                    311.740     RCHRES  30       1
IMPLND 301                    483.910     RCHRES  30       2
IMPLND 302                    573.890     RCHRES  30       2
*** Tributary to Reach 13 (EBrBrandywine to below Downingtown)
PERLND 302                    329.470     RCHRES  13       1
PERLND 303                    515.350     RCHRES  13       1
PERLND 304                    218.120     RCHRES  13       1
PERLND 305                          0     RCHRES  13       1
PERLND 306                    725.260     RCHRES  13       1
PERLND 307                          0     RCHRES  13       1
PERLND 308                   2437.510     RCHRES  13       1
PERLND 309                    157.850     RCHRES  13       1
PERLND 310                     70.370     RCHRES  13       1
PERLND 311                    139.200     RCHRES  13       1
IMPLND 301                    257.470     RCHRES  13       2
IMPLND 302                    233.590     RCHRES  13       2
*** Tributary to Reach 28 (Uwchlan Run to Exton)
PERLND 302                       0.92     RCHRES  28       1
PERLND 303                     578.43     RCHRES  28       1
PERLND 304                      99.68     RCHRES  28       1
PERLND 305                          0     RCHRES  28       1
PERLND 306                      46.74     RCHRES  28       1
PERLND 307                          0     RCHRES  28       1
PERLND 308                     315.57     RCHRES  28       1
PERLND 309                      87.24     RCHRES  28       1
PERLND 310                       0.44     RCHRES  28       1
PERLND 311                      54.65     RCHRES  28       1
IMPLND 301                     248.00     RCHRES  28       2
IMPLND 302                     105.93     RCHRES  28       2
*** Tributary to Reach 29 (W.Valley Ck)
PERLND 302                    501.070     RCHRES  29       1
PERLND 303                   1505.950     RCHRES  29       1
PERLND 304                    746.170     RCHRES  29       1
PERLND 305                          0     RCHRES  29       1
PERLND 306                   2434.310     RCHRES  29       1
PERLND 307                          0     RCHRES  29       1
PERLND 308                   4095.190     RCHRES  29       1
PERLND 309                    228.270     RCHRES  29       1
PERLND 310                    288.210     RCHRES  29       1
PERLND 311                    367.900     RCHRES  29       1
IMPLND 301                    701.080     RCHRES  29       2
IMPLND 302                    785.210     RCHRES  29       2
*** Tributary to Reach 14 (EBrBrandywine to Wawaset)
PERLND 302                    724.890     RCHRES  14       1
PERLND 303                    889.920     RCHRES  14       1
PERLND 304                    289.000     RCHRES  14       1
PERLND 305                          0     RCHRES  14       1
PERLND 306                   2637.650     RCHRES  14       1
PERLND 307                          0     RCHRES  14       1
PERLND 308                   2498.730     RCHRES  14       1
PERLND 309                    267.210     RCHRES  14       1
PERLND 310                     84.070     RCHRES  14       1
PERLND 311                    114.290     RCHRES  14       1
IMPLND 301                    461.940     RCHRES  14       2
IMPLND 302                    300.460     RCHRES  14       2
*** Reach Connections
RCHRES   9                                RCHRES  10       3
RCHRES  10                                RCHRES  11       3
RCHRES  35                                RCHRES  26       3
RCHRES  26                                RCHRES  27       3
RCHRES  27    *** Not simulated           RCHRES  11       3
RCHRES  11                                RCHRES  12       3
RCHRES  12                                RCHRES  13       4
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RCHRES  30                              RCHRES  13      3
RCHRES  13                              RCHRES  14      4
RCHRES  28                              RCHRES  29      3
RCHRES  29                              RCHRES  14      4

*** Segment 4 (Brandywine below Wawaset)
*** Tributary to Reach 15
PERLND 402                  1168.130    RCHRES  15      1
PERLND 403                   475.030    RCHRES  15      1
PERLND 404                   127.370    RCHRES  15      1
PERLND 405                         0    RCHRES  15      1
PERLND 406                  2700.240    RCHRES  15      1
PERLND 407                         0    RCHRES  15      1
PERLND 408                  1112.360    RCHRES  15      1
PERLND 409                   459.770    RCHRES  15      1
PERLND 410                    63.320    RCHRES  15      1
PERLND 411                    63.320    RCHRES  15      1
IMPLND 401                   333.370    RCHRES  15      2
IMPLND 402                   128.430    RCHRES  15      2
*** Tributary to Reach 31 (Pocopson Ck)
PERLND 402                  1335.040    RCHRES  31      1
PERLND 403                         0    RCHRES  31      1
PERLND 404                    46.570    RCHRES  31      1
PERLND 405                         0    RCHRES  31      1
PERLND 406                  2868.580    RCHRES  31      1
PERLND 407                         0    RCHRES  31      1
PERLND 408                  1299.400    RCHRES  31      1
PERLND 409                   106.460    RCHRES  31      1
PERLND 410                    15.570    RCHRES  31      1
PERLND 411                    16.970    RCHRES  31      1
IMPLND 401                   148.340    RCHRES  31      2
IMPLND 402                    46.570    RCHRES  31      2
*** Tributary to Reach 16 (Main stem Chadds Ford)
PERLND 402                  2244.360    RCHRES  16      1
PERLND 403                         0    RCHRES  16      1
PERLND 404                   219.300    RCHRES  16      1
PERLND 405                         0    RCHRES  16      1
PERLND 406                  2308.780    RCHRES  16      1
PERLND 407                         0    RCHRES  16      1
PERLND 408                  3485.380    RCHRES  16      1
PERLND 409                   139.970    RCHRES  16      1
PERLND 410                    82.370    RCHRES  16      1
PERLND 411                    47.910    RCHRES  16      1
IMPLND 401                   249.370    RCHRES  16      2
IMPLND 402                   219.300    RCHRES  16      2
*** Tributary to Reach 17 (Main stem Smiths Bridge)
PERLND 402                   702.170    RCHRES  17      1
PERLND 403                         0    RCHRES  17      1
PERLND 404                     9.660    RCHRES  17      1
PERLND 405                         0    RCHRES  17      1
PERLND 406                  1297.660    RCHRES  17      1
PERLND 407                         0    RCHRES  17      1
PERLND 408                  2333.410    RCHRES  17      1
PERLND 409                   293.680    RCHRES  17      1
PERLND 410                    61.540    RCHRES  17      1
PERLND 411                    19.110    RCHRES  17      1
IMPLND 401                    78.020    RCHRES  17      2
IMPLND 402                     9.660    RCHRES  17      2
*** Tributary to Reach 18 (Main stem Rockland)
PERLND 402                   609.280    RCHRES  18      1
PERLND 403                   233.340    RCHRES  18      1
PERLND 404                   108.190    RCHRES  18      1
PERLND 405                   140.981    RCHRES  18      1
PERLND 406                  1268.829    RCHRES  18      1
PERLND 407                         0    RCHRES  18      1
PERLND 408                  2536.280    RCHRES  18      1
PERLND 409                   968.060    RCHRES  18      1
PERLND 410                    73.110    RCHRES  18      1
PERLND 411                   386.670    RCHRES  18      1
IMPLND 401                   167.700    RCHRES  18      2
IMPLND 402                   143.890    RCHRES  18      2
*** Tributary to Reach 19 (Main stem to Wilm. gage)
PERLND 402                   586.860    RCHRES  19      1
PERLND 403                   568.870    RCHRES  19      1
PERLND 404                   186.200    RCHRES  19      1
PERLND 405                         0    RCHRES  19      1
PERLND 406                   228.800    RCHRES  19      1
PERLND 407                         0    RCHRES  19      1
PERLND 408                   913.200    RCHRES  19      1
PERLND 409                  2227.580    RCHRES  19      1
PERLND 410                    55.830    RCHRES  19      1
PERLND 411                   256.780    RCHRES  19      1
IMPLND 401                   309.010    RCHRES  19      2
IMPLND 402                   201.050    RCHRES  19      2
*** Tributary to Reach 34 (Main stem to Christina)
PERLND 402                    73.390    RCHRES  34      1
PERLND 403                    96.220    RCHRES  34      1
PERLND 404                  1228.460    RCHRES  34      1
PERLND 405                         0    RCHRES  34      1
PERLND 406                    60.270    RCHRES  34      1
PERLND 407                         0    RCHRES  34      1
PERLND 408                   536.480    RCHRES  34      1
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PERLND 409                     210.500     RCHRES  34       1
PERLND 410                     100.280     RCHRES  34       1
PERLND 411                     282.150     RCHRES  34       1
IMPLND 401                      49.390     RCHRES  34       2
IMPLND 402                    1236.000     RCHRES  34       2

*** Reach Connections
RCHRES   8                                 RCHRES  15       3
RCHRES  14                                 RCHRES  15       4
RCHRES  15                                 RCHRES  16       3
RCHRES  31                                 RCHRES  16       3
RCHRES  16                                 RCHRES  17       4
RCHRES  17                                 RCHRES  18       3
RCHRES  18                                 RCHRES  19       4
RCHRES  19                                 RCHRES  34       4

*** HSPEXP ***
    Honeybrook - Output from Reach 1 ***
PERLND 102                     478.840     COPY   100      91
PERLND 103                     168.160     COPY   100      91
PERLND 104                      72.980     COPY   100      91
PERLND 105                    5363.665     COPY   100      91
PERLND 106                    2641.810     COPY   100      91
PERLND 107                           0     COPY   100      91
PERLND 108                    2361.190     COPY   100      91
PERLND 109                     317.880     COPY   100      91
PERLND 110                      57.280     COPY   100      91
PERLND 111                     100.280     COPY   100      91
IMPLND 101                     125.270     COPY   100      92
IMPLND 102                      79.540     COPY   100      92
    Coatesville - Output from Reach 4 ***
PERLND 102                     1632.79     COPY   200      91
PERLND 103                      197.82     COPY   200      91
PERLND 104                      180.89     COPY   200      91
PERLND 105                    6277.295     COPY   200      91
PERLND 106                     4010.49     COPY   200      91
PERLND 107                           0     COPY   200      91
PERLND 108                     6127.47     COPY   200      91
PERLND 109                      370.95     COPY   200      91
PERLND 110                        98.6     COPY   200      91
PERLND 111                      119.74     COPY   200      91
IMPLND 101                      266.19     COPY   200      92
IMPLND 102                      187.45     COPY   200      92
PERLND 202                     1578.43     COPY   200      91
PERLND 203                      231.67     COPY   200      91
PERLND 204                      127.13     COPY   200      91
PERLND 205                      542.02     COPY   200      91
PERLND 206                     3004.78     COPY   200      91
PERLND 207                           0     COPY   200      91
PERLND 208                     3611.03     COPY   200      91
PERLND 209                      316.47     COPY   200      91
PERLND 210                      138.09     COPY   200      91
PERLND 211                       21.28     COPY   200      91
IMPLND 201                      275.67     COPY   200      92
IMPLND 202                      128.41     COPY   200      92
    Modena - Output from Reach 5 ***
PERLND 102                     1632.79     COPY   300      91
PERLND 103                      197.82     COPY   300      91
PERLND 104                      180.89     COPY   300      91
PERLND 105                    6277.295     COPY   300      91
PERLND 106                     4010.49     COPY   300      91
PERLND 107                           0     COPY   300      91
PERLND 108                     6127.47     COPY   300      91
PERLND 109                      370.95     COPY   300      91
PERLND 110                        98.6     COPY   300      91
PERLND 111                      119.74     COPY   300      91
IMPLND 101                      266.19     COPY   300      92
IMPLND 102                      187.45     COPY   300      92
PERLND 202                     1669.43     COPY   300      91
PERLND 203                      854.50     COPY   300      91
PERLND 204                      718.95     COPY   300      91
PERLND 205                      542.02     COPY   300      91
PERLND 206                     4081.76     COPY   300      91
PERLND 207                           0     COPY   300      91
PERLND 208                     5574.66     COPY   300      91
PERLND 209                      520.46     COPY   300      91
PERLND 210                      223.14     COPY   300      91
PERLND 211                      158.46     COPY   300      91
IMPLND 201                      551.71     COPY   300      92
IMPLND 202                      733.03     COPY   300      92
    Springdell - Output from Reach 21 ***
PERLND 202                     248.770     COPY   400      91
PERLND 203                           0     COPY   400      91
PERLND 204                      28.720     COPY   400      91
PERLND 205                     539.420     COPY   400      91
PERLND 206                    4854.760     COPY   400      91
PERLND 207                           0     COPY   400      91
PERLND 208                    1226.230     COPY   400      91
PERLND 209                      76.530     COPY   400      91
PERLND 210                       9.120     COPY   400      91
PERLND 211                      34.480     COPY   400      91
IMPLND 201                      27.640     COPY   400      92
```

```
IMPLND 202                    28.720     COPY   400      92
    Marshallton - Output from Reach 24 ***
PERLND 202                   280.860     COPY   500      91
PERLND 203                    18.910     COPY   500      91
PERLND 204                         0     COPY   500      91
PERLND 205                         0     COPY   500      91
PERLND 206                    13.230     COPY   500      91
PERLND 207                         0     COPY   500      91
PERLND 208                    31.370     COPY   500      91
PERLND 209                         0     COPY   500      91
PERLND 210                         0     COPY   500      91
PERLND 211                         0     COPY   500      91
IMPLND 201                    39.310     COPY   500      92
IMPLND 202                         0     COPY   500      92
    Glenmoore - Output from Reach 26 ***
PERLND 302                    370.05     COPY   600      91
PERLND 303                         0     COPY   600      91
PERLND 304                     77.07     COPY   600      91
PERLND 305                    670.35     COPY   600      91
PERLND 306                  1564.150     COPY   600      91
PERLND 307                         0     COPY   600      91
PERLND 308                   2527.19     COPY   600      91
PERLND 309                     16.66     COPY   600      91
PERLND 310                     33.77     COPY   600      91
PERLND 311                      9.38     COPY   600      91
IMPLND 301                     41.12     COPY   600      92
IMPLND 302                     77.07     COPY   600      92
    nr Downingtown - Output from Reach 11 ***
PERLND 102                    574.40     COPY   800      91
PERLND 103                     46.63     COPY   800      91
PERLND 104                     34.65     COPY   800      91
PERLND 105                  2537.335     COPY   800      91
PERLND 106                  2537.335     COPY   800      91
PERLND 107                         0     COPY   800      91
PERLND 108                   3065.56     COPY   800      91
PERLND 109                    202.19     COPY   800      91
PERLND 110                    258.33     COPY   800      91
PERLND 111                     21.81     COPY   800      91
IMPLND 101                     83.81     COPY   800      92
IMPLND 102                     35.50     COPY   800      92
PERLND 302                   4140.90     COPY   800      91
PERLND 303                    500.10     COPY   800      91
PERLND 304                    357.28     COPY   800      91
PERLND 305                   1323.85     COPY   800      91
PERLND 306                  8674.420     COPY   800      91
PERLND 307                         0     COPY   800      91
PERLND 308                   11173.9     COPY   800      91
PERLND 309                    519.05     COPY   800      91
PERLND 310                    676.55     COPY   800      91
PERLND 310                    136.03     COPY   800      91
IMPLND 301                    674.43     COPY   800      92
IMPLND 302                    358.67     COPY   800      92
    bl Downington - Output from Reach 13 ***
PERLND 102                    574.40     COPY   900      91
PERLND 103                     46.63     COPY   900      91
PERLND 104                     34.65     COPY   900      91
PERLND 105                  2537.335     COPY   900      91
PERLND 106                  2537.335     COPY   900      91
PERLND 107                         0     COPY   900      91
PERLND 108                   3065.56     COPY   900      91
PERLND 109                    202.19     COPY   900      91
PERLND 110                    258.33     COPY   900      91
PERLND 111                     21.81     COPY   900      91
IMPLND 101                     83.81     COPY   900      92
IMPLND 102                     35.50     COPY   900      92
PERLND 302                   6076.49     COPY   900      91
PERLND 303                   2221.72     COPY   900      91
PERLND 304                   1227.21     COPY   900      91
PERLND 305                   1323.85     COPY   900      91
PERLND 306                  13413.55     COPY   900      91
PERLND 307                         0     COPY   900      91
PERLND 308                  17998.71     COPY   900      91
PERLND 309                    978.39     COPY   900      91
PERLND 310                    800.25     COPY   900      91
PERLND 311                    616.75     COPY   900      91
IMPLND 301                   1627.33     COPY   900      92
IMPLND 302                   1272.69     COPY   900      92
     Exton - Output from Reach 28 ***
PERLND 302                      0.92     COPY   910      91
PERLND 303                    578.43     COPY   910      91
PERLND 304                     99.68     COPY   910      91
PERLND 305                         0     COPY   910      91
PERLND 306                     46.74     COPY   910      91
PERLND 307                         0     COPY   910      91
PERLND 308                    315.57     COPY   910      91
PERLND 309                     87.24     COPY   910      91
PERLND 310                      0.44     COPY   910      91
PERLND 311                     54.65     COPY   910      91
IMPLND 301                    248.00     COPY   910      92
IMPLND 302                    105.93     COPY   910      92
     Chadds Ford - Output from Reach 16 ***
PERLND 102                   2207.19     COPY   920      91
```

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PERLND 103                      244.45     COPY   920      91
PERLND 104                      215.54     COPY   920      91
PERLND 105                     8814.63     COPY   920      91
PERLND 106                    6547.825     COPY   920      91
PERLND 107                           0     COPY   920      91
PERLND 108                     9193.03     COPY   920      91
PERLND 109                      573.14     COPY   920      91
PERLND 110                      356.93     COPY   920      91
PERLND 111                      141.55     COPY   920      91
IMPLND 101                      350.00     COPY   920      92
IMPLND 102                      222.10     COPY   920      92
PERLND 202                     5666.34     COPY   920      91
PERLND 203                     1334.05     COPY   920      91
PERLND 204                     1289.47     COPY   920      91
PERLND 205                     2863.59     COPY   920      91
PERLND 206                    32175.16     COPY   920      91
PERLND 207                           0     COPY   920      91
PERLND 208                    19691.47     COPY   920      91
PERLND 209                     1126.51     COPY   920      91
PERLND 210                      494.29     COPY   920      91
PERLND 211                      367.54     COPY   920      91
IMPLND 201                     1201.34     COPY   920      92
IMPLND 202                     1303.97     COPY   920      92
PERLND 302                     7303.37     COPY   920      91
PERLND 303                     5196.02     COPY   920      91
PERLND 304                     2362.06     COPY   920      91
PERLND 305                     1323.85     COPY   920      91
PERLND 306                    18532.25     COPY   920      91
PERLND 307                           0     COPY   920      91
PERLND 308                    24908.20     COPY   920      91
PERLND 309                     1561.11     COPY   920      91
PERLND 310                     1172.97     COPY   920      91
PERLND 311                     1153.59     COPY   920      91
IMPLND 301                     3038.35     COPY   920      92
IMPLND 302                     2464.29     COPY   920      92
PERLND 402                     4747.53     COPY   920      91
PERLND 403                      475.03     COPY   920      91
PERLND 404                      393.24     COPY   920      91
PERLND 405                           0     COPY   920      91
PERLND 406                      7877.6     COPY   920      91
PERLND 407                           0     COPY   920      91
PERLND 408                     5897.14     COPY   920      91
PERLND 409                       706.2     COPY   920      91
PERLND 410                      161.26     COPY   920      91
PERLND 411                      128.20     COPY   920      91
IMPLND 401                      731.08     COPY   920      92
IMPLND 402                      394.30     COPY   920      92

     Wilmington - Output from Reach 19 ***
COPY   920                                 COPY   930      93
PERLND 402                     1971.70     COPY   930      91
PERLND 403                      898.43     COPY   930      91
PERLND 404                     1387.51     COPY   930      91
PERLND 405                     140.981     COPY   930      91
PERLND 406                    2855.559     COPY   930      91
PERLND 407                           0     COPY   930      91
PERLND 408                     6319.37     COPY   930      91
PERLND 409                     3989.82     COPY   930      91
PERLND 410                      290.76     COPY   930      91
IMPLND 401                      604.12     COPY   930      92
IMPLND 402                     1445.60     COPY   930      92
END SCHEMATIC

MASS-LINK
  MASS-LINK        1
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
PERLND     PWATER PERO       0.0833333     RCHRES         INFLOW IVOL
PERLND     SEDMNT SOSED           0.10     RCHRES         INFLOW ISED   1
PERLND     SEDMNT SOSED           0.40     RCHRES         INFLOW ISED   2
PERLND     SEDMNT SOSED           0.50     RCHRES         INFLOW ISED   3
PERLND     PWTGAS POHT                     RCHRES         INFLOW IHEAT
PERLND     PWTGAS PODOXM                   RCHRES         INFLOW OXIF   1
PERLND     PQUAL  POQUAL 1                 RCHRES         INFLOW NUIF1  1
PERLND     PQUAL  POQUAL 2                 RCHRES         INFLOW NUIF1  2
PERLND     PQUAL  POQUAL 3                 RCHRES         INFLOW NUIF1  4
PERLND     PQUAL  POQUAL 4                 RCHRES         INFLOW OXIF   2
PERLND     PQUAL  POQUAL 5                 RCHRES         INFLOW PKIF   3
  END MASS-LINK    1

  MASS-LINK        2
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
IMPLND     IWATER SURO       0.0833333     RCHRES         INFLOW IVOL
IMPLND     SOLIDS SOSLD           0.10     RCHRES         INFLOW ISED   1
IMPLND     SOLIDS SOSLD           0.40     RCHRES         INFLOW ISED   2
IMPLND     SOLIDS SOSLD           0.50     RCHRES         INFLOW ISED   3
IMPLND     IWTGAS SOHT                     RCHRES         INFLOW IHEAT
IMPLND     IWTGAS SODOXM                   RCHRES         INFLOW OXIF   1
IMPLND     IQUAL  SOQUAL 1                 RCHRES         INFLOW NUIF1  1
IMPLND     IQUAL  SOQUAL 2                 RCHRES         INFLOW NUIF1  2
IMPLND     IQUAL  SOQUAL 3                 RCHRES         INFLOW NUIF1  4
```

```
IMPLND     IQUAL  SOQUAL 4                 RCHRES         INFLOW OXIF   2
  END MASS-LINK    2

  MASS-LINK        3
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
RCHRES     ROFLOW                          RCHRES         INFLOW
  END MASS-LINK    3

  MASS-LINK        4
<Srce>     <-Grp> <-Member-><--Mult-->     <Targ>         <-Grp> <-Member-> ***
<Name>     <Name> <Name> # #<-factor->     <Name>         <Name> <Name> # # ***
RCHRES     OFLOW         1                 RCHRES         INFLOW
  END MASS-LINK    4

  MASS-LINK       91
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
PERLND     PWATER SURO                     COPY           INPUT  MEAN   1
PERLND     PWATER IFWO                     COPY           INPUT  MEAN   2
PERLND     PWATER AGWO                     COPY           INPUT  MEAN   3
PERLND     PWATER PET                      COPY           INPUT  MEAN   5
PERLND     PWATER TAET                     COPY           INPUT  MEAN   6
PERLND     PWATER UZS                      COPY           INPUT  MEAN   7
PERLND     PWATER LZS                      COPY           INPUT  MEAN   8
PERLND     SEDMNT SOSED                    COPY           INPUT  MEAN   9
PERLND     PQUAL  POQUAL 1                 COPY           INPUT  MEAN  10
PERLND     PQUAL  POQUAL 2                 COPY           INPUT  MEAN  11
PERLND     PQUAL  POQUAL 3                 COPY           INPUT  MEAN  12
  END MASS-LINK   91

  MASS-LINK       92
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
IMPLND     IWATER SURO                     COPY           INPUT  MEAN   1
IMPLND     IWATER PET                      COPY           INPUT  MEAN   5
IMPLND     IWATER IMPEV                    COPY           INPUT  MEAN   6
IMPLND     SOLIDS SOSLD                    COPY           INPUT  MEAN  16
IMPLND     IQUAL  SOQUAL 1                 COPY           INPUT  MEAN  13
IMPLND     IQUAL  SOQUAL 2                 COPY           INPUT  MEAN  14
IMPLND     IQUAL  SOQUAL 3                 COPY           INPUT  MEAN  15
  END MASS-LINK   92

  MASS-LINK       93
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>            <Name> x x<-factor->strg <Name>                <Name> x x  ***
COPY       OUTPUT MEAN   1                 COPY           INPUT  MEAN   1
COPY       OUTPUT MEAN   2                 COPY           INPUT  MEAN   2
COPY       OUTPUT MEAN   3                 COPY           INPUT  MEAN   3
COPY       OUTPUT MEAN   4                 COPY           INPUT  MEAN   4
COPY       OUTPUT MEAN   5                 COPY           INPUT  MEAN   5
COPY       OUTPUT MEAN   6                 COPY           INPUT  MEAN   6
COPY       OUTPUT MEAN   7                 COPY           INPUT  MEAN   7
COPY       OUTPUT MEAN   8                 COPY           INPUT  MEAN   8
COPY       OUTPUT MEAN   9                 COPY           INPUT  MEAN   9
COPY       OUTPUT MEAN  10                 COPY           INPUT  MEAN  10
COPY       OUTPUT MEAN  11                 COPY           INPUT  MEAN  11
COPY       OUTPUT MEAN  12                 COPY           INPUT  MEAN  12
COPY       OUTPUT MEAN  13                 COPY           INPUT  MEAN  13
COPY       OUTPUT MEAN  14                 COPY           INPUT  MEAN  14
COPY       OUTPUT MEAN  15                 COPY           INPUT  MEAN  15
COPY       OUTPUT MEAN  16                 COPY           INPUT  MEAN  16
  END MASS-LINK   93

END MASS-LINK

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
*** Results for calibration
     PARTICULATE N (ADSORBED NH3 + ORG N) ***
RCHRES   1 NUTRX  RSNH4  4                 GENER    1     INPUT  ONE
RCHRES   1 HYDR   VOL                      GENER    1     INPUT  TWO
GENER    1 OUTPUT TIMSER       0.368       COPY    10     INPUT  MEAN   1
RCHRES  21 NUTRX  RSNH4  4                 GENER    3     INPUT  ONE
RCHRES  21 HYDR   VOL                      GENER    3     INPUT  TWO
GENER    3 OUTPUT TIMSER       0.368       COPY    11     INPUT  MEAN   1
RCHRES  24 NUTRX  RSNH4  4                 GENER    5     INPUT  ONE
RCHRES  24 HYDR   VOL                      GENER    5     INPUT  TWO
GENER    5 OUTPUT TIMSER       0.368       COPY    12     INPUT  MEAN   1
RCHRES  26 NUTRX  RSNH4  4                 GENER    7     INPUT  ONE
RCHRES  26 HYDR   VOL                      GENER    7     INPUT  TWO
GENER    7 OUTPUT TIMSER       0.368       COPY    13     INPUT  MEAN   1
RCHRES  28 NUTRX  RSNH4  4                 GENER    9     INPUT  ONE
RCHRES  28 HYDR   VOL                      GENER    9     INPUT  TWO
GENER    9 OUTPUT TIMSER       0.368       COPY    14     INPUT  MEAN   1
RCHRES  16 NUTRX  RSNH4  4                 GENER   11     INPUT  ONE
RCHRES  16 HYDR   VOL                      GENER   11     INPUT  TWO
GENER   11 OUTPUT TIMSER       0.368       COPY    15     INPUT  MEAN   1
     PARTICULATE P (ADSORBED PO4 + ORG P) ***
RCHRES   1 NUTRX  RSPO4  4                 GENER    2     INPUT  ONE
RCHRES   1 HYDR   VOL                      GENER    2     INPUT  TWO
```

```
GENER    2 OUTPUT TIMSER       0.368       COPY    10      INPUT  MEAN   2
RCHRES  21 NUTRX  RSPO4  4                 GENER    4      INPUT  ONE
RCHRES  21 HYDR   VOL                      GENER    4      INPUT  TWO
GENER    4 OUTPUT TIMSER       0.368       COPY    11      INPUT  MEAN   2
RCHRES  24 NUTRX  RSPO4  4                 GENER    6      INPUT  ONE
RCHRES  24 HYDR   VOL                      GENER    6      INPUT  TWO
GENER    6 OUTPUT TIMSER       0.368       COPY    12      INPUT  MEAN   2
RCHRES  26 NUTRX  RSPO4  4                 GENER    8      INPUT  ONE
RCHRES  26 HYDR   VOL                      GENER    8      INPUT  TWO
GENER    8 OUTPUT TIMSER       0.368       COPY    13      INPUT  MEAN   2
RCHRES  28 NUTRX  RSPO4  4                 GENER   10      INPUT  ONE
RCHRES  28 HYDR   VOL                      GENER   10      INPUT  TWO
GENER   10 OUTPUT TIMSER       0.368       COPY    14      INPUT  MEAN   2
RCHRES  16 NUTRX  RSPO4  4                 GENER   12      INPUT  ONE
RCHRES  16 HYDR   VOL                      GENER   12      INPUT  TWO
GENER   12 OUTPUT TIMSER       0.368       COPY    15      INPUT  MEAN   2
END NETWORK

GENER
  OPCODE
    #thru# code ***
    1   12   19
  END OPCODE
END GENER

END RUN
```