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HYDROLOGIC CHARACTERISTICS AND WATER BUDGET FOR SWIFT CREEK RESERVOIR, VIRGINIA, 1997

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 98–4122

Prepared in cooperation with the
CHESTERFIELD COUNTY
DEPARTMENT OF UTILITIES

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Richmond, Virginia
1998

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square mile (mi^2)	259.0	hectare
square mile (mi^2)	2.590	square kilometer
	Volume	
cubic foot (ft^3)	0.02832	cubic meter
	Flow	
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
million gallons per day (Mgal/d)	0.04381	cubic meter per second

Temperature is reported in degree Fahrenheit (°F), which can be converted to degree Celsius (°C) by the following equation:

$$°C = (°F-32)/1.8$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Hydrologic Characteristics and Water Budget for Swift Creek Reservoir, Virginia, 1997

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Abstract

Residential development in Chesterfield County, Virginia, in areas adjacent to the Swift Creek Reservoir, an important public water supply, has prompted concern about the long-term effects of development on the water quality. This report presents hydrologic data and a water budget for the reservoir for 1997, information that will be needed to address the water-quality concerns associated with increased development.

In 1997, the total input to Swift Creek Reservoir was 1,429 million cubic feet (Mft^3), of which about 986 Mft^3 drained from monitored tributaries, an estimated 225 Mft^3 drained unmonitored areas adjacent to the reservoir, and about 218 Mft^3 fell directly on the reservoir as precipitation. Total output from Swift Creek Reservoir was about 1,916 Mft^3, of which about 1,454 Mft^3 flowed over the dam, 63 Mft^3 evaporated from the water surface of the reservoir, and 395 Mft^3 was withdrawn for public water supply and irrigation. The change in reservoir storage for 1997 was 97 Mft^3. The residual in the water-budget equation was about 390 Mft^3, including the net annual effects of ground water and the total of all errors associated with assumed, estimated, and measured hydrologic characteristics.

INTRODUCTION

Swift Creek Reservoir was constructed in 1965 as a public water supply for Chesterfield County, Va. (fig. 1). The Swift Creek Water Treatment Plant (SCWTP), which withdraws and treats water from the reservoir, has a production capacity of about 12 million gallons per day (Mgal/d), and currently supplies water to about 90,000 people in the county (George DuVal, Swift Creek Water Treatment Plant, oral commun., 1997). Chesterfield County has experienced rapid urban development within the last 10 years and a 14-percent increase in population between 1990 and 1995. Urban development within the Swift Creek Basin continues to spread from areas adjacent to the reservoir to outlying and previously undeveloped areas. Protection of the reservoir as a valuable economic and aesthetic resource is an important goal of the Chesterfield County Department of Utilities, and residents in the surrounding communities. County officials and residents are concerned about the effects of existing and future development within the Swift Creek Basin on the quality of water in the reservoir.

In 1995, the U.S. Geological Survey (USGS), in cooperation with the Chesterfield County Department of Utilities, began a study of the hydrologic characteristics and water budget of Swift Creek Reservoir. Knowledge of reservoir inflow and outflow is needed by the Chesterfield County Department of Utilities, for the formulation of a water-quality protection plan for the reservoir. Selected hydrologic characteristics and a water budget for the reservoir for the 1996 calendar year were described by Skrobialowski and Focazio (1997).

Purpose and Scope

The purpose of this report is to describe the hydrologic characteristics of Swift Creek Reservoir and to provide a water budget for January 1, 1997, through December 31, 1997. Precipitation, continuous

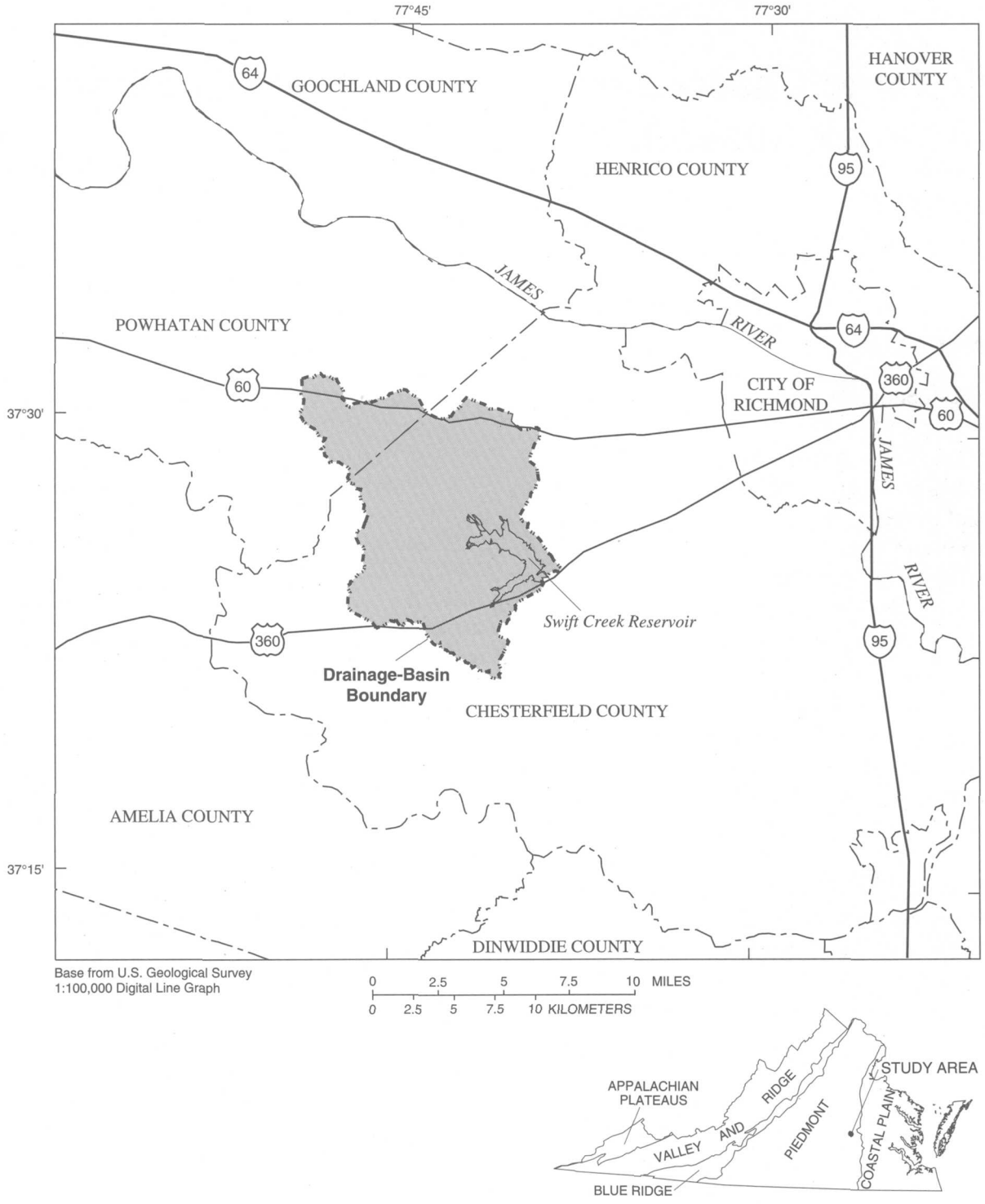

Figure 1. Location of the Swift Creek Reservoir drainage basin in Virginia.

stage (streamwater level), and discharge data were collected and used to characterize hydrologic input to the reservoir. Reservoir outflow, leakage, pan-evaporation, and public supply and irrigation-withdrawal data were collected and used to characterize hydrologic output from the reservoir. The change in storage for the reservoir also was computed. Ground-water inflow and outflow were not monitored, and the net annual effects of ground water are considered to be part of the residual in the water-budget equation. The effects of transpiration were not considered.

Description of Study Area

The Swift Creek drainage basin is located entirely within the southern Piedmont Physiographic Province, and the reservoir is located about 15 mi southwest of Richmond, Va. (fig. 1). The basin encompasses about 64 mi^2 upstream from the earthen dam that impounds Swift Creek to create the reservoir. Although residential development is common in areas adjacent to the reservoir, most of the land in the drainage basin is undeveloped.

Soil-drainage characteristics in the basin range from well drained to very poorly drained; however, most of the basin soils are either well drained or moderately well drained (Hodges and others, 1978; Reber and others, 1988). The climate of the area is classified as humid subtropical. Mean annual precipitation from 1961 through 1990 was about 43 in. for the closest climatological data-collection station located at Richmond, Va. Mean annual temperature for the same period was about 57°F (Dustin Hux, Virginia State Climatologist's Office, oral commun., 1997).

Acknowledgments

The author gratefully acknowledges the cooperation of Roy Covington and George DuVal from the Chesterfield County Department of Utilities; Weedon Cloe and other members of the Swift Creek Water Treatment Plant staff provided surface-water stage records, rainfall records, and water-supply withdrawal data for the study period. The author also wishes to acknowledge the residents of the Woodlake and Brandermill communities for their interest in the study and for allowing the installation of water-monitoring and water-control structures in their communities. Staff from the Brandermill Country Club recorded withdrawals for golf-course irrigation.

METHODS OF STUDY

Continuous stage data were collected at the nine main tributary sites, the two residential catchment sites, and the reservoir outflow site (fig. 2) using manometer and electronic data-logging equipment. Discharge measurements were made periodically to characterize base flow, and to document shifting control conditions that would affect the relation of stage to discharge (flows) of the tributaries. Additional discharge measurements were made at medium and high flows during or after periods of heavy rainfall to define stage-discharge relations or to confirm previous measurements.

Staff from SCWTP collected continuous stage, precipitation, evaporation, and withdrawal data. Staff from the Virginia District of the USGS made discharge measurements, and staff from the Brandermill Country Club recorded withdrawals for golf-course irrigation.

Daily discharge records were computed on the basis of stage data and discharge measurements and were judged to be "fair" to "poor" as a consequence of several conditions, including the following: (1) unstable sand channels; (2) poorly characterized peak discharge; and (3) the need to estimate discharge for periods with missing stage data. Swift Creek, Blackman Creek, Horsepen Creek, Otterdale Branch, Tomahawk Creek, Little Tomahawk Creek, Dry Creek, and West Branch (fig. 2) have unstable sand channels for which stage-discharge relations are not well defined and are difficult to determine at low and medium flows (Burkman and Dawdy, 1970; Rantz, 1982b). The stage-discharge relations for the main tributaries, residential catchments, and the dam are not well defined at high flows and are based on a small number of discharge measurements. Stage-discharge ratings for all the main tributary sites are not well defined at high stages because of insufficient peak-discharge data and the inability to measure discharge at some sites at high stages. Rating curves for sites with insufficient peak-discharge data were extended to cover the recorded range in stage. The extensions were based on considerations of channel, overflow, and flood-plain characteristics. Daily mean discharge was estimated for sites having periods of missing stage records based on comparison of discharge hydro-

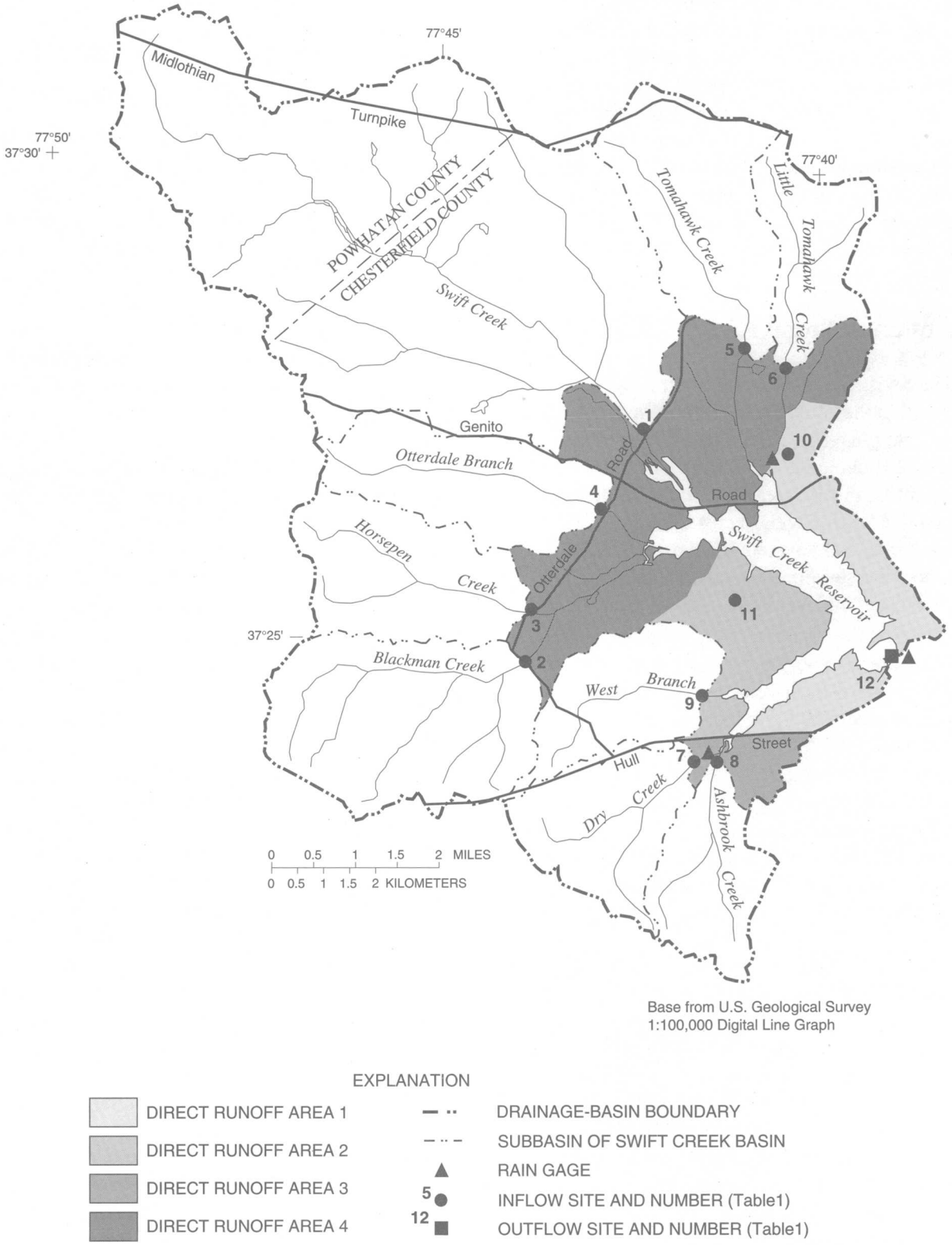

Figure 2. Subbasins and data-collection sites in the Swift Creek drainage basin, Virginia.

graphs, drainage area, and precipitation data. A rating of "fair" means that about 95 percent of the daily discharges is judged to be within 15 percent of the true discharge; "poor" means that the daily discharges have less than "fair" accuracy (Novak, 1985).

Continuous stage records for the two residential catchment sites, Little Tomahawk Creek Tributary (site 10) and Swift Creek Tributary (site 11), were available for the last 8 months of the study period (May-December 1997). Unmeasured runoff for January 1 through April 30 was estimated by multiplying the total precipitation for this period by the ratio of measured runoff to measured precipitation for September 1 through December 31. It was assumed that hydrologic conditions and characteristics were similar for the two periods.

Weirs were installed at each residential catchment site to provide accurate and consistent stage data and to simplify the stage-discharge rating process. Both are sharp-crested 90-degree V-notch weirs with a maximum depth of 1 ft. Discharge measurements were made to verify the theoretical rating for a 90-degree V-notch weir. Stage-discharge relations for these sites are not well defined at high stages because of insufficient peak-discharge measurement data and because gage heights during some storms exceeded the depth of the V-notch. Rating curves were extended to cover the recorded range in stage; extensions were based on channel, overflow, and flood-plain characteristics.

The following procedure was used to estimate the percent impervious area in the residential catchments. Impervious area drained was considered to be the ground area covered by homes, paved driveways, and paved road surface within the drainage area of each catchment. The mean ground area covered by each home was determined from the exterior dimensions of 10 homes selected at random within the drainage area of each residential catchment site. Paved driveways were assumed to be 75 ft long by 14 ft wide. The number of homes and paved driveways in each residential catchment was determined from areal photographs and verified in the field. Road length was determined from areal photographs, and road width was assumed to be 25 ft. Percent impervious area for each residential catchment was determined by dividing the total impervious area by the drainage area and multiplying by 100.

Annual runoff per unit area, in million cubic feet per square mile (Mft^3/mi^2), was determined for the main tributary sites and residential catchment sites to estimate discharge from four direct runoff areas surrounding the reservoir (fig. 2). Four direct runoff areas were delineated on the basis of land use, period of development, geographic position with respect to the reservoir, and local development restrictions. Runoff data for Little Tomahawk Creek Tributary (site 10) were used to estimate the total runoff from area 1. Runoff from Little Tomahawk Creek Tributary is included in the total annual discharge for area 1. Runoff data for Swift Creek Tributary (site 11) were used to estimate the total runoff from area 2. Runoff from Swift Creek Tributary is included in the total annual discharge for area 2. Runoff data for Dry Creek and Ashbrook Creek (sites 7 and 8) were weighted by drainage area to determine runoff from area 3. The mean runoff for Swift Creek, Blackman Creek, Horsepen Creek, Otterdale Branch, Tomahawk Creek, and Little Tomahawk Creek (sites 1-6) was weighted by drainage area to determine runoff from area 4.

The precipitation component of the water budget was determined by computing the arithmetic mean precipitation from data collected at three rain gages. The rain gages were located close to the reservoir, in areas that were clear of vegetation and structures, to reduce collection interference (fig. 2). The surface area of the reservoir was 2.49 mi^2 and was computed for a reservoir water-surface elevation of 177 ft, the elevation at which water begins to flow over the dam.

To estimate leakage through the dam, four discharge measurements were made about 800 ft downstream from the dam. The discharge measurements were made between June 1997 and January 1998, during periods of zero flow over the dam. Measured discharge was correlated with reservoir stage to estimate total annual leakage through the dam.

Evaporation from the reservoir was estimated by use of evaporation-pan data. Evaporation from a standard Class-A evaporation pan, located near the reservoir, was measured by staff from SCWTP throughout the study period. The total measured pan evaporation was converted to lake evaporation by multiplying the product of pan evaporation and lake area by a pan coefficient of 0.74, as described in Farnsworth and others (1982).

Withdrawal records for public supply were collected by staff from SCWTP. Withdrawals for golf-course irrigation between March and October 1997 were recorded by staff at the Brandermill Country Club. Withdrawals were recorded in gallons per day,

converted to cubic feet, and summed for the study period.

Methods used to collect and process inflow, outflow, and precipitation data and to determine drainage and surface areas are described by Skrobialowski and Focazio (1997). Rantz and others (1982a, 1982b), Kennedy (1983), and Buchanan and Somers (1984) described standard USGS stream-discharge data-collection and processing procedures used in this study.

The input and output of water to and from Swift Creek Reservoir were incorporated in an analysis of the water budget for the reservoir. A simplified water-budget equation for the Swift Creek Reservoir can be expressed as:

$$\text{Input} - \text{Output} = \Delta\text{storage} \pm \text{Residual}, \quad (1)$$

where:

Input = direct precipitation on the reservoir surface + measured and estimated reservoir inflows;

Output = sum of measured withdrawals + measured outflow + measured evaporation + estimated leakage through the dam;

Δstorage = measured change in storage in the reservoir; and

Residual = the sum of errors associated with assumed, estimated, and measured hydrologic characteristics.

HYDROLOGIC CHARACTERISTICS

Hydrologic input to the reservoir was determined from continuous stage data, discharge measurements, and precipitation data. Hydrologic output from the reservoir was calculated from reservoir outflow, public supply and irrigation withdrawals, leakage through the dam, and reservoir evaporation. Groundwater inflow and outflow were not investigated for this study and were assumed to be part of the residual.

Inputs

Surface-water inflow and precipitation were measured, and direct runoff was estimated to determine total input to the reservoir. More than 180 discharge measurements and continuous stage data were used to determine inflow for gaged sites (fig. 2). Total input from rainfall on the reservoir and runoff from ungaged developed areas adjacent to the reservoir were estimated.

Gaged Inflow Sites

The gaged inflow sites are divided into two groups—main tributaries and residential catchments. The main tributaries consist of nine inflow sites that drain mostly undeveloped or developing areas and encompass a minimum of 2 mi^2. The residential catchments include two inflow sites that drain mostly developed areas and encompass less than 2 mi^2.

Main Tributaries

The combined drainage area for the nine main tributaries is 49.1 mi^2 (table 1). West Branch drains the most developed land, and Little Tomahawk Creek subbasin has the smallest drainage area and the highest runoff per unit area. The Swift Creek subbasin has the largest drainage area, the highest annual discharge, and the lowest runoff per unit area.

Swift Creek.—Total annual discharge for Swift Creek (site 1) in 1997 was 248 Mft^3 (table 1), which is equal to about 25 percent of the measured total annual discharge for all main tributary sites. Runoff was 11.6 Mft^3/mi^2. Although the Swift Creek subbasin has the largest drainage area, it had the lowest computed runoff per unit area for the main tributary sites. The discharge hydrograph is presented in figure 3. During 1997, 17 discharge measurements were made, and 1 measurement was made in 1998. The highest measured discharge was 22.1 ft^3/s, and the highest instantaneous discharge was 174 ft^3/s. No daily mean discharges were estimated for the study period. Zero flow was reported for periods between August 8 and October 20.

Blackman Creek.—Total annual discharge for Blackman Creek (site 2) in 1997 was 180 Mft^3 (table 1), which is equal to about 18 percent of the measured total annual discharge for all main tributary sites. Runoff was 31.0 Mft^3/mi^2. The discharge hydrograph is presented in figure 4. During 1997, 16 discharge measurements were made, and 1 measurement was made in 1998. The highest measured discharge was 20.7 ft^3/s, and the highest instantaneous discharge was 366 ft^3/s. No daily mean

Table 1. Drainage area, discharge, and runoff data for main tributaries, residential catchments, and reservoir outfall in the Swift Creek Reservoir Basin, 1997

[mi^2, square mile; Mft^3, million cubic feet; Mft^3/mi^2, million cubic feet per square mile; ft^3/s, cubic feet per second; in., inches]

Site number	USGS station number	Stream name	Drainage area (mi^2)	Total annual discharge (Mft^3)	Daily mean discharge		Annual runoff[1]	
					Maximum (ft^3/s)	Minimum (ft^3/s)	(Mft^3/mi^2)	(in.)
			Main Tributaries					
1	02041810	Swift Creek	21.4	248	100	0	11.6	5.01
2	02041820	Blackman Creek	5.8	180	166	0	31.0	13.40
3	02041830	Horsepen Creek	3.72	87	77	0	23.4	10.08
4	02041840	Otterdale Branch	3.59	101	93	0	28.1	12.08
5	02041850	Tomahawk Creek	4.2	61.2	51	0	14.6	10.47
6	02041860	Little Tomahawk Creek	2.31	102	49	0	44.2	11.41
7	02041870	Dry Creek	2.96	78.2	79	0	26.4	11.24
8	02041880	Ashbrook Creek	2.37	64.3	43	0	27.1	11.76
9	02041890	West Branch	2.75	64.3	52	0	23.4	10.06
		Total	49.1	986				
			Residential Catchments					
10	02041862	Little Tomahawk Creek Tributary	.05	.44	.40	0	8.8	3.80
11	0204186350	Swift Creek Tributary	.19	3.85	4.0	0	20.3	8.74
			Reservoir Outfall					
12	02041900	Swift Creek Dam	64.4	1,454	1,390	0	22.6	9.72

[1] Runoff, in inches, is from daily values tables in the appendix and may differ from runoff, in million cubic feet per square mile, converted from annual discharge due to rounding.

discharges were estimated for the study period. Zero flow was reported for periods between June 17 and November 22.

Horsepen Creek.—Total annual discharge for Horsepen Creek (site 3) in 1997 was 87.0 Mft^3 (table 1), which is equal to about 9 percent of the measured total annual discharge for all main tributary sites. Runoff was 23.4 Mft^3/mi^2 . The discharge hydrograph is presented in figure 5. During 1997, 17 discharge measurements were made, and 1 measurement was made in 1998. The highest measured discharge was 32.5 ft^3/s, and the highest instantaneous discharge was 135 ft^3/s. No daily mean discharges were estimated for the study period. Zero flow was reported for periods between June 20 and November 7.

Otterdale Branch.—Total annual discharge for Otterdale Branch (site 4) in 1997 was 101 Mft^3 (table 1), which is equal to about 10 percent of the measured total annual discharge for all main tributary sites. Runoff was 28.1 Mft^3/mi^2. The discharge hydrograph is presented in figure 6. During 1997, 15 discharge measurements were made, and 1 measurement was made in 1998. The highest measured discharge was 25.2 ft^3/s, and the highest instantaneous discharge was 307 ft^3/s. No daily mean discharges were estimated for the study period. Zero flow was reported for periods between June 11 and November 21. Annual discharge was adjusted for returns; SCWTP returns about 0.22 ft^3/s at a flush site upstream from the monitoring site (Weedon Cloe, Swift Creek Water Treatment Plant, oral commun., 1997).

Tomahawk Creek.—Total annual discharge for Tomahawk Creek (site 5) in 1997 was 61.2 Mft^3 (table 1), which is equal to about 6 percent of the

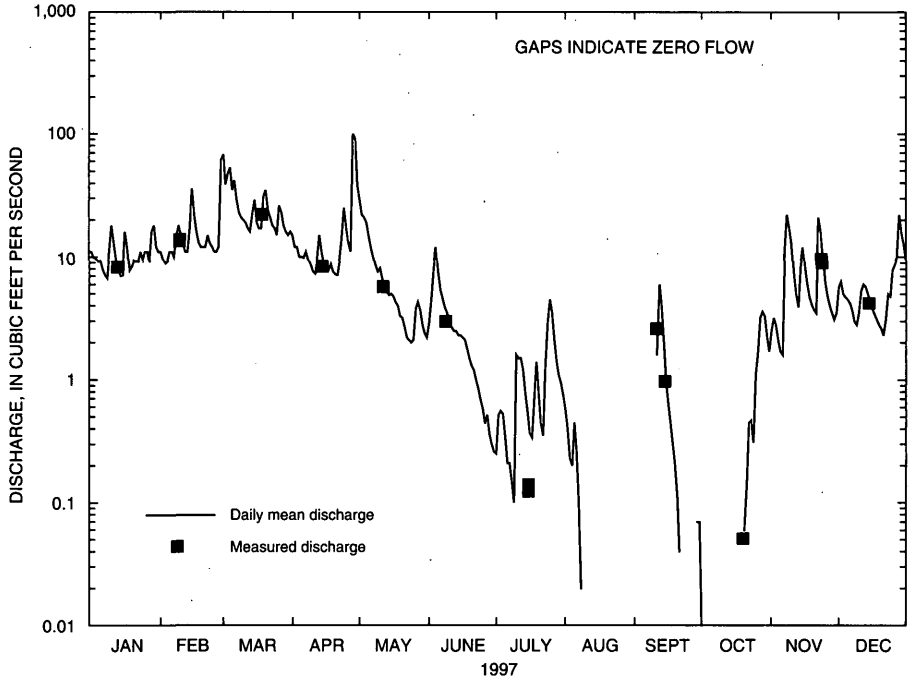

Figure 3. Daily mean and measured discharge in 1997 for Swift Creek, Virginia (USGS station no. 02041810).

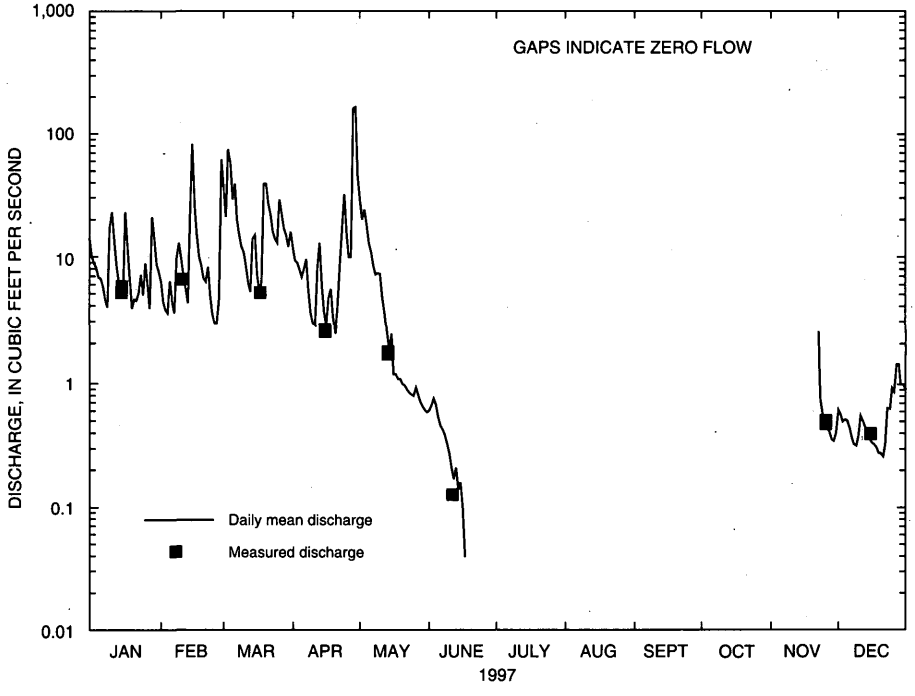

Figure 4. Daily mean and measured discharge in 1997 for Blackman Creek, Virginia (USGS station no. 02041820).

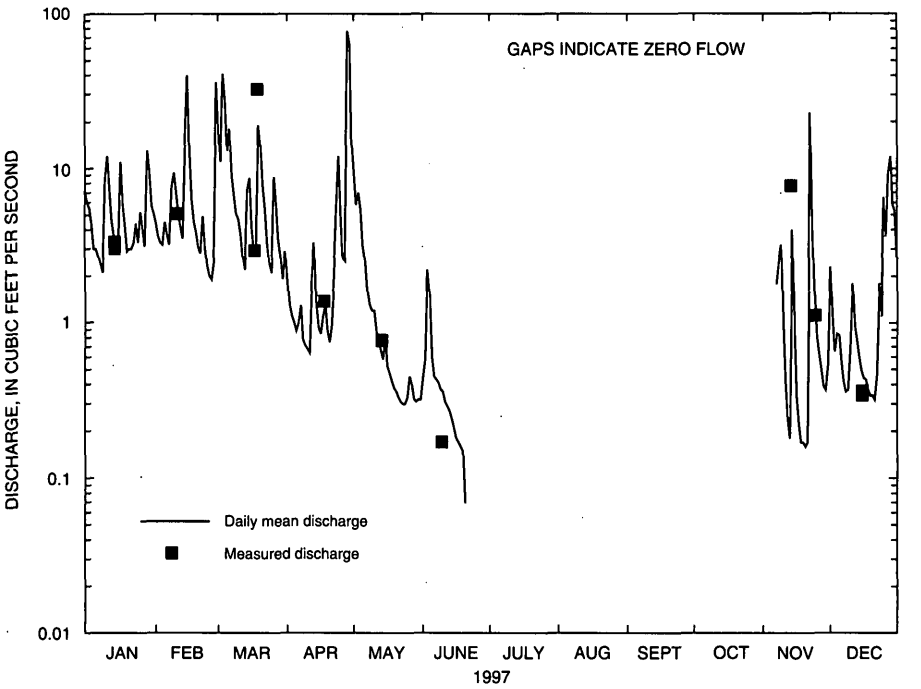

Figure 5. Daily mean and measured discharge in 1997 for Horsepen Creek, Virginia (USGS station no. 02041830).

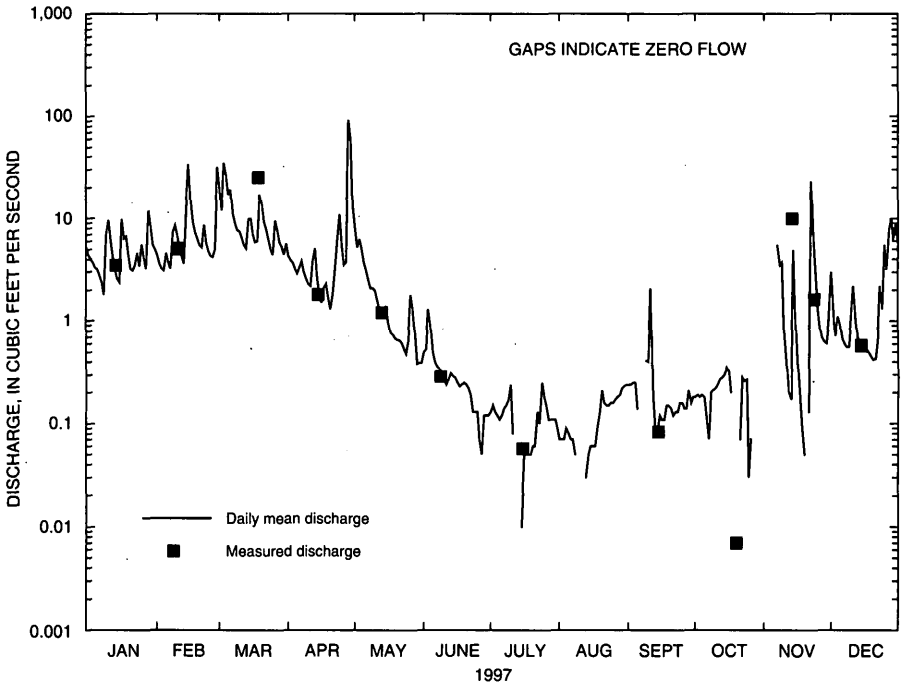

Figure 6. Daily mean and measured discharge in 1997 for Otterdale Branch, Virginia (USGS station no. 02041840).

measured total annual discharge for all main tributary sites. Runoff was 14.6 Mft^3/mi^2. The discharge hydrograph is presented in figure 7. During 1997, 17 discharge measurements were made, and 1 measurement was made in 1998. The highest measured discharge was 24.7 ft^3/s, and the highest instantaneous discharge was 88 ft^3/s. No daily mean discharges were estimated for the study period. Zero flow was reported for periods between June 25 and November 10.

Little Tomahawk Creek.—Total annual discharge for Little Tomahawk Creek (site 6) in 1997 was 102 Mft^3 (table 1), which is equal to about 10 percent of the measured total annual discharge for all main tributary sites. Runoff was 44.2 Mft^3/mi^2. Although Little Tomahawk Creek subbasin has the smallest drainage area, it had the highest computed runoff per unit area of the main tributary sites. The discharge hydrograph is presented in figure 8. During 1997, 17 discharge measurements were made, and 1 measurement was made in 1998. The highest measured discharge was 12.3 ft^3/s, and the highest instantaneous discharge was 93 ft^3/s. No daily mean discharges were estimated for the study period. Zero flow was reported for periods between June 27 and October 27.

Dry Creek.—Total annual discharge for Dry Creek (site 7) in 1997 was 78.2 Mft^3 (table 1), which is equal to about 8 percent of the measured total annual discharge for all main tributary sites. Runoff was 26.4 Mft^3/mi^2. The discharge hydrograph is presented in figure 9. During 1997, 15 discharge measurements were made, and 1 measurement was made in 1998. The highest measured discharge was 16.4 ft^3/s, and the highest instantaneous discharge was 420 ft^3/s. Daily mean discharge was estimated for February 6-10 because of power failure to the instrumentation. Zero flow was reported for periods between June 20 and November 7.

Ashbrook Creek.—Total annual discharge for Ashbrook Creek (site 8) in 1997 was 64.3 Mft^3 (table 1), which is equal to about 6 percent of the measured total annual discharge for all main tributary sites. Runoff was 27.1 Mft^3/mi^2. The discharge hydrograph is presented in figure 10. During 1997, six discharge measurements were made. The highest measured discharge was 0.096 ft^3/s, and the highest instantaneous discharge was 98 ft^3/s. No daily mean discharges were estimated for the study period. Zero flow was reported for periods between June 19 and November 8.

West Branch.—Total annual discharge for West Branch (site 9) in 1997 was 64.3 Mft^3 (table 1), which is equal to about 6 percent of the measured total annual discharge for all main tributary sites. Runoff was 23.4 Mft^3/mi^2. The discharge hydrograph is presented in figure 11. During 1997, 15 discharge measurements were made, and 1 measurement was made in 1998. The highest measured discharge was 18.6 ft^3/s, and the highest instantaneous discharge was 184 ft^3/s. No daily mean discharges were estimated for the study period. Zero flow was reported for periods between June 16 and October 14.

Residential Catchments

The combined drainage area of the residential catchments is 0.24 mi^2; Little Tomahawk Creek Tributary (site 10) drains about one-fourth the area drained by Swift Creek Tributary (site 11). Runoff for these sites was used to estimate discharge from direct runoff areas 1 and 2, respectively (fig. 2).

Little Tomahawk Creek Tributary.—Total annual discharge for Little Tomahawk Creek Tributary (site 10) in 1997 was 0.44 Mft^3 (table 1), and runoff was 8.8 Mft^3/mi^2. The discharge hydrograph is presented in figure 12. During 1997, 22 discharge measurements were made, and 1 measurement was made in 1998. The highest measured discharge during the study period was 2.17 ft^3/s, and the highest instantaneous discharge was 4.4 ft^3/s. Daily mean discharge was estimated for periods between May 1 and December 31, and total discharge was estimated between January 1 and May 1. Zero flow was reported for periods between May 20 and December 22. The drainage area of Little Tomahawk Creek is about 0.05 mi^2 and contains about 25 percent impervious area.

Swift Creek Tributary.—Total annual discharge for Swift Creek Tributary (site 11) in 1997 was 3.85 Mft^3 (table 1), and runoff was 20.3 Mft^3/mi^2. The discharge hydrograph is presented in figure 13. During 1997, 22 discharge measurements were made, and 1 measurement was made in 1998. The highest measured discharge during the study period was 9.31 ft^3/s, and the highest instantaneous discharge was 49 ft^3/s. Daily mean discharge was estimated for periods between May 1 and December 31, and total discharge was estimated between January 1 and May 1. Zero flow was reported for periods between July 3 and October 16. The drainage area of Swift Creek Tributary is about 0.19 mi^2 and contains about 31 percent impervious area.

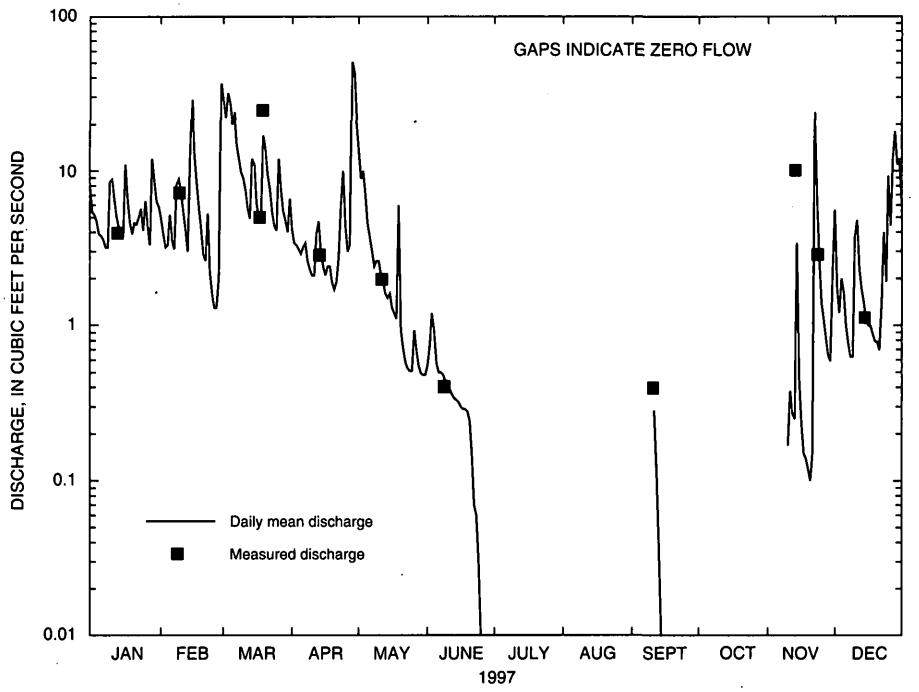

Figure 7. Daily mean and measured discharge in 1997 for Tomahawk Creek, Virginia (USGS station no. 02041850).

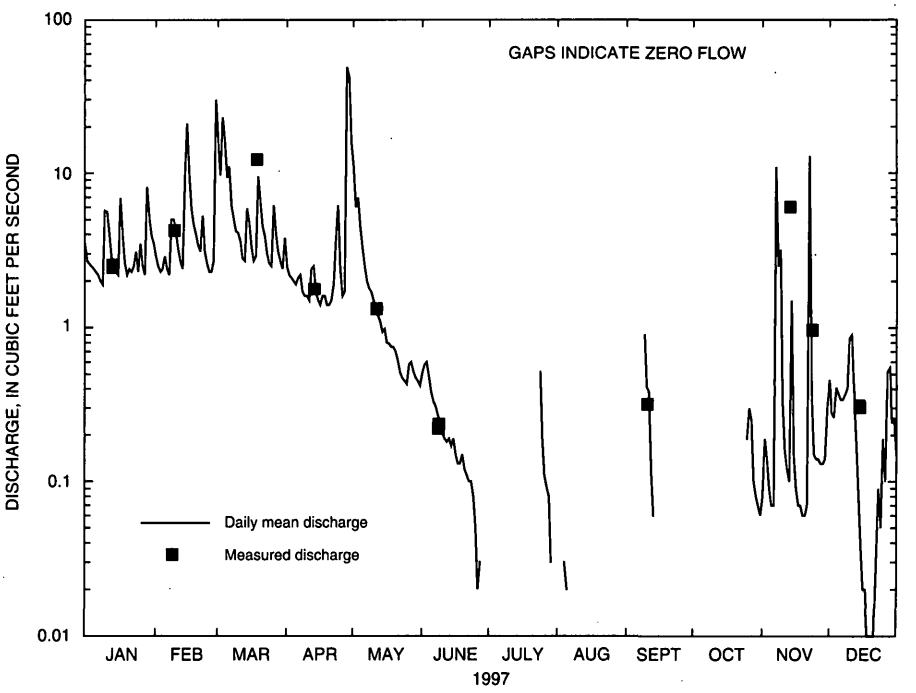

Figure 8. Daily mean and measured discharge in 1997 for Little Tomahawk Creek, Virgina (USGS station no. 02041860).

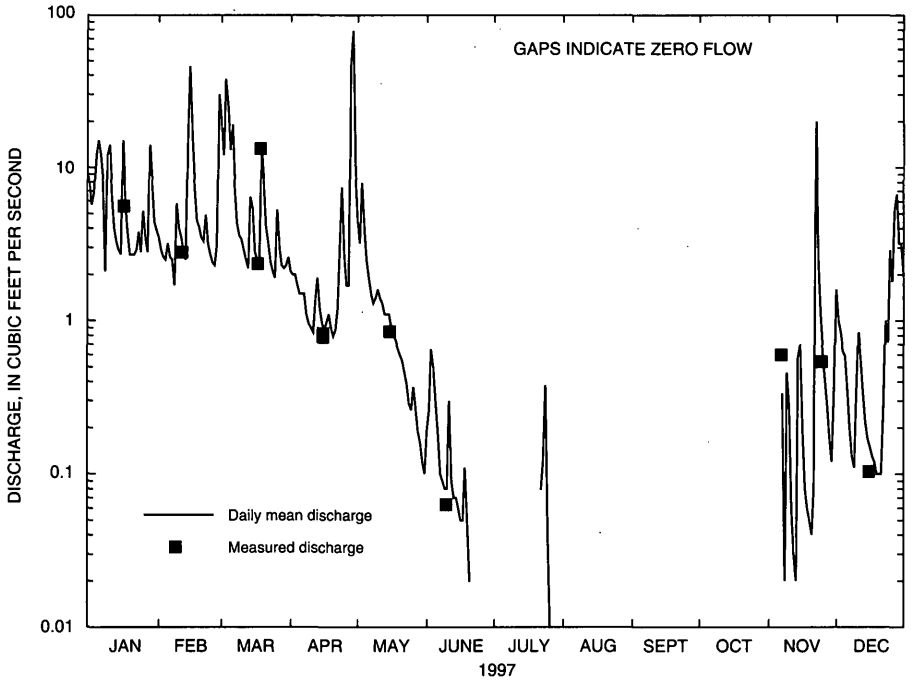

Figure 9. Daily mean and measured discharge in 1997 for Dry Creek, Virginia (USGS station no. 02041870).

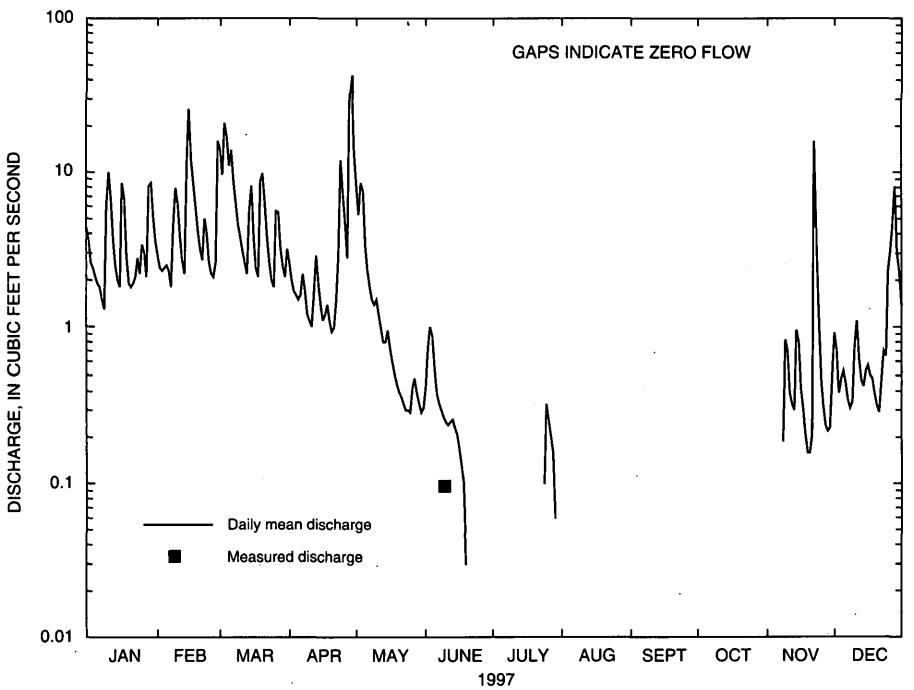

Figure 10. Daily mean and measured discharge in 1997 for Ashbrook Creek, Virginia (USGS station no. 02041880).

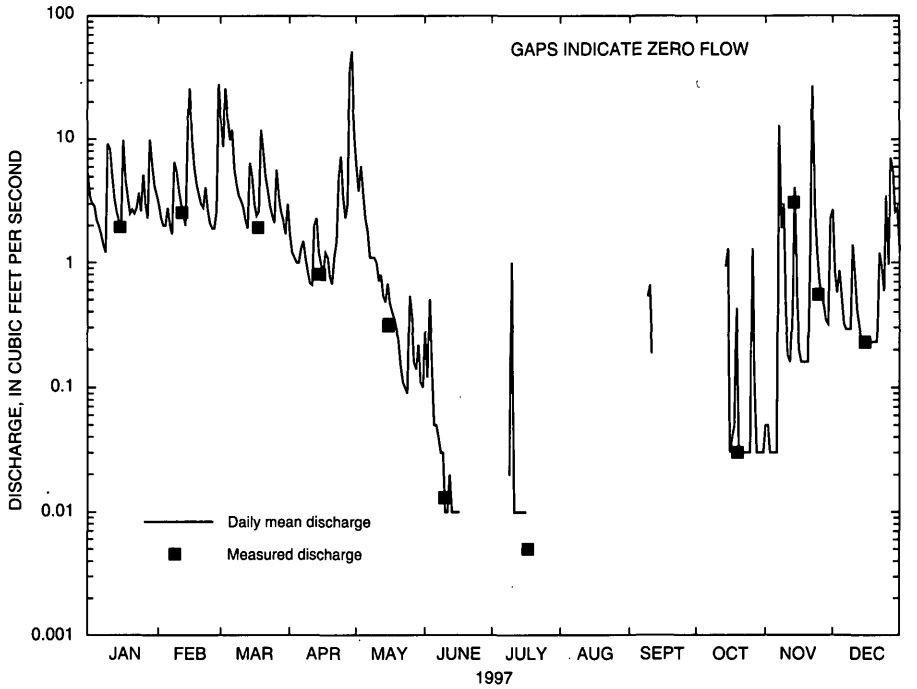

Figure 11. Daily mean and measured discharge in 1997 for West Branch, Virginia (USGS station no. 02041890).

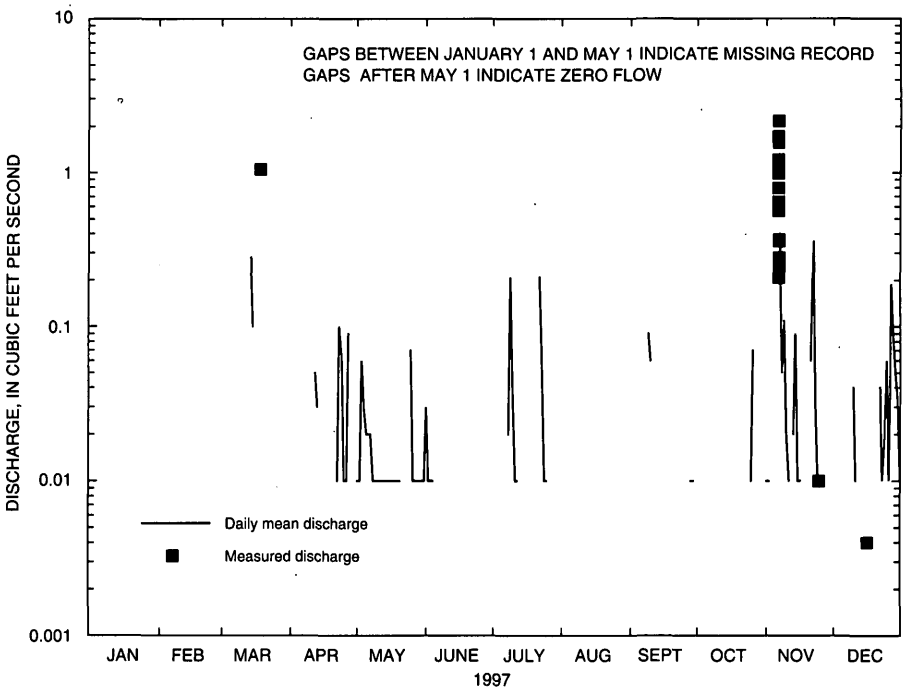

Figure 12. Daily mean and measured discharge in 1997 for Little Tomahawk Creek Tributary, Virginia (USGS station no. 02041862).

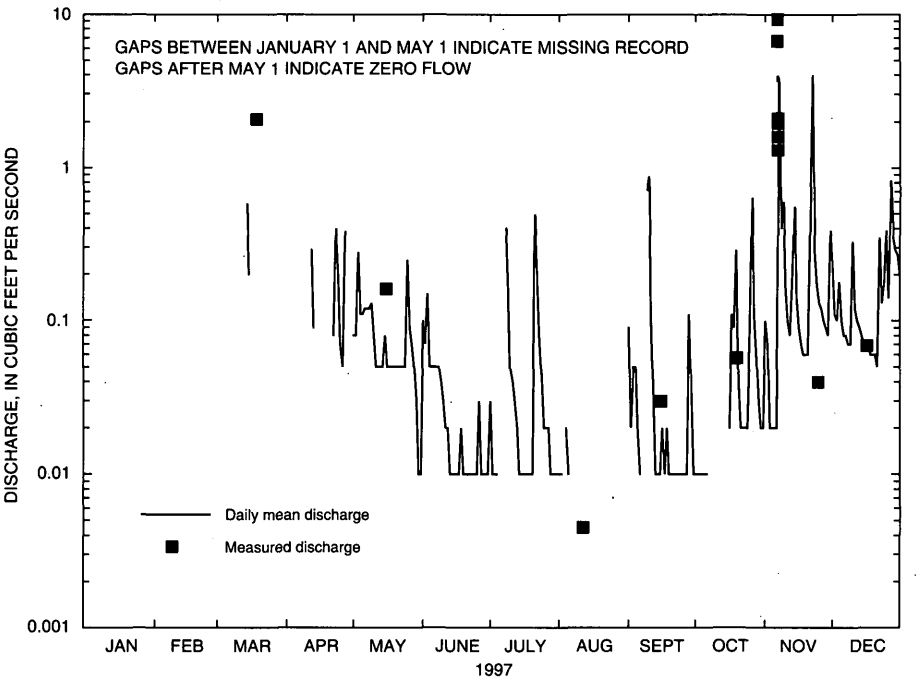

Figure 13. Daily mean and measured discharge in 1997 for Swift Creek Tributary, Virginia (USGS station no. 0204186350).

Direct Runoff Areas

Direct runoff is the volume of water discharged to the reservoir from ungaged areas adjacent to the reservoir (fig. 2). Runoff for inflow sites near or within the direct runoff areas was weighted by drainage area and used to estimate discharge from the direct runoff areas (table 2).

Total annual direct runoff from area 1 was 22.8 Mft^3 and was estimated on the basis of measured runoff for Little Tomahawk Tributary (site 10). The entire area drained by Little Tomahawk Creek Tributary is within area 1 (fig. 2). The total annual discharge for Little Tomahawk Creek Tributary is included in the total annual direct runoff from area 1. Land is used mostly for residences, schools, shopping centers, parks, a golf course, and recreation. For this study, land use, soil properties, and percent impervious area for Little Tomahawk Creek Tributary were assumed to be representative of area 1, although land use in area 1 is more diverse than the drainage area for Little Tomahawk Creek Tributary.

Total annual direct runoff from area 2 was 43.0 Mft^3 and was estimated on the basis of measured runoff for Swift Creek Tributary (site 11). The entire area drained by Swift Creek Tributary is within area 2 (fig. 2). The total annual discharge for Swift Creek Tributary is included in the total annual direct runoff from area 2. Land is used mostly for residences, schools, shopping centers, and parks. For this study, land use, soil properties, and percent impervious area for Swift Creek Tributary were assumed to be representative of area 2, although land use in area 2 is more diverse than the drainage area for Swift Creek Tributary.

Total annual direct runoff from area 3 was 20.3 Mft^3 and was estimated on the basis of measured runoff for Dry Creek and Ashbrook Creek (sites 7, 8) weighted by drainage area. Area 3 mostly is undeveloped and was assumed to have land use, soil properties, and percent impervious area similar to the Dry Creek and Ashbrook Creek drainages.

Total annual direct runoff from area 4 was 139 Mft^3 and was estimated on the basis of measured runoff for the main tributaries—Swift Creek, Blackman Creek, Horsepen Creek, Otterdale Branch, Tomahawk Creek, and Little Tomahawk Creek—weighted by drainage area. The area mostly is

Table 2. Drainage area, discharge, and runoff data for direct runoff areas in the Swift Creek Reservoir Basin, Virginia, 1997

[mi^2, square miles; Mft^3, million cubic feet; Mft^3/mi^2, million cubic feet per square mile; in., inches]

Direct runoff area number	Drainage area (mi^2)	Total annual discharge (Mft^3)	Runoff	
			(Mft^3/mi^2)	(in.)
1	2.54	22.8	8.8	3.88
2	2.12	43	20.3	8.74
3	.76	20.3	26.7	11.49
4	7.34	139	18.9	8.14
TOTAL	12.76	225.1		

undeveloped and was assumed to have land use, soil properties, and percent impervious area similar to that encompassed by the main tributary sites.

Direct Precipitation

Mean annual precipitation, between 1961 and 1990, at Richmond, Va., was about 43 in. In 1997, the total annual precipitation was about 34 in. (Steve Gautry, Virginia State Climatologist Office, oral commun., 1997). The mean precipitation computed for the reservoir was 37.6 in., and total direct precipitation onto the reservoir surface was about 218 Mft^3.

Outputs

Discharge from the reservoir, leakage through the dam, evaporation, and reservoir withdrawals were measured output components for the Swift Creek Reservoir water budget. Reservoir-stage data were collected near the dam and applied to the dam stage-discharge relation to determine discharge at the dam. Discharge measurements were made downstream from the dam to determine leakage through the dam. Daily evaporation was measured and recorded by staff from SCWTP using a standard Class-A evaporation pan. Public supply and irrigation withdrawals were recorded by personnel at SCWTP and the Brandermill Country Club.

Outflow

Total annual discharge at the dam (site 12) was 1,454 Mft^3 (table 1). Reservoir-stage data and a stage-discharge relation were used to determine discharge at the dam. The discharge hydrograph is shown in figure 14. The highest instantaneous discharge determined from the stage-discharge rating was 1,390 ft^3/s on April 29, 1997. No daily mean discharges were estimated for the study period. Flow over the dam occurred between January 1 and May 17, 1997 (fig. 14), and zero flow was reported for the remainder of the study period.

Leakage, Evaporation, and Withdrawals

In 1997, leakage through the reservoir dam was 4 Mft^3 (table 3), and evaporation from the reservoir was 63 Mft^3. The total volume of water withdrawn from the reservoir was 392 Mft^3 for public supply and 3 Mft^3 for golf course irrigation.

Change in Reservoir Storage

Data from a reservoir bathymetric survey were provided by SCWTP and processed to develop an elevation-storage rating. The rating was used to determine the relation of storage capacity to reservoir stage. The change in reservoir storage indicated a loss of 97 Mft^3 (table 3) of water from the reservoir for the study period.

RESERVOIR WATER BUDGET FOR 1997

Calculation of Water Budget

The measured and estimated water-budget input, output, and storage values were substituted in

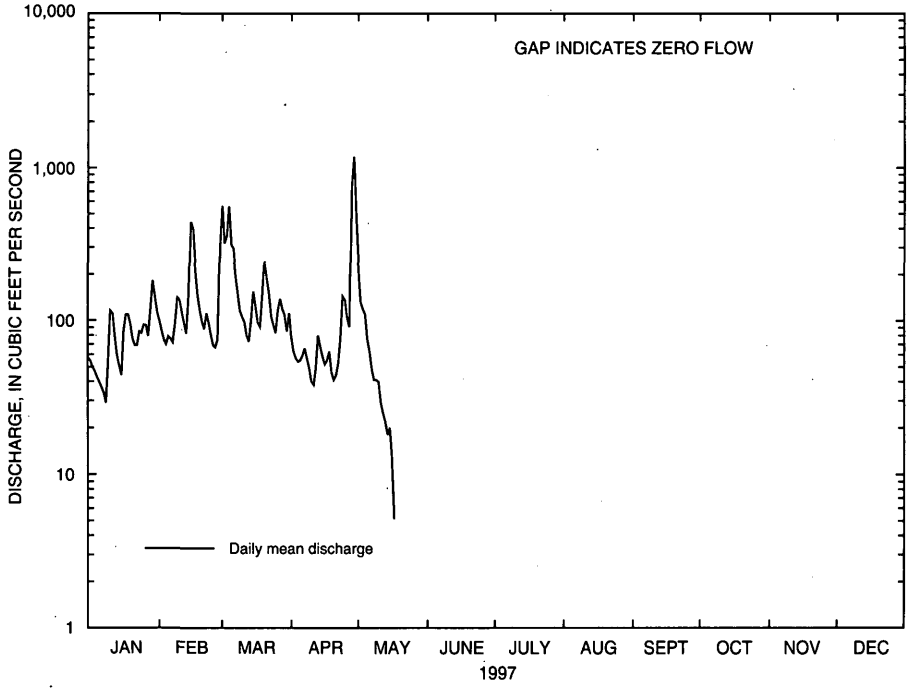

Figure 14. Daily mean discharge in 1997 for Swift Creek Reservoir Dam (USGS station no. 02041900).

the water-budget equation for Swift Creek Reservoir (eq. 1). Total input was 1,429 Mft^3, and total output was 1,916 Mft^3 (table 3). After applying the change in reservoir storage, 97 Mft^3, to the difference between total inputs and total outputs, the residual was 390 Mft^3.

Input to the reservoir from the main tributaries accounted for about 69 percent of the total inflow, direct runoff about 16 percent, and direct precipitation about 15 percent (fig. 15). The area drained by the main tributaries accounts for about 76 percent of the total area of the Swift Creek Reservoir Basin, direct-runoff areas account for about 20 percent, and the reservoir accounts for about 4 percent.

Discharge at the reservoir outfall accounted for about 76 percent of the total output from the reservoir. Combined supply and irrigation withdrawals accounted for about 21 percent of the total output, evaporation accounted for about 3 percent, and leakage accounted for less than 1 percent (fig. 16).

Discussion of Errors in Water-Budget Components

The residual in the water-budget equation represents the sum of all errors associated with assumed, estimated, and measured hydrologic characteristics. If the components investigated for the water budget were determined accurately without errors or if the errors balanced, then it may be assumed that the residual is accounted for entirely by the net effects of ground water. Winter (1981, p. 110) concluded, however, that significant errors may result if one or more of the water-budget "components are calculated as the residual term, and the errors in the measured components are not considered in the interpretation of that residual term." The purpose of this discussion is not to explore several error-analysis scenarios but to recognize potential sources of error in the determination of input and output components.

The net annual effect of ground water was the only component entirely accounted for by assuming it to be part of the residual. Other assumptions were made in the determination of specific input and output

Table 3. Hydrologic inputs and outputs of Swift Creek Reservoir

[Mft^3, million cubic feet]

Component	Value (Mft^3)
Inputs	
Inflow from main tributaries	986
Inflow from direct runoff areas	225
Direct precipitation	218
Total	1,429
Outputs	
Discharge at dam	1,454
Leakage	4
Evaporation	63
Withdrawals	395
Total	1,916

components, including the assumption that land-use characteristics in the residential catchments represented the respective direct runoff areas. Leakage through the dam was estimated on the basis of periodic discharge measurements and reservoir-stage data, and direct runoff was estimated from discharge at the main tributary and residential catchment sites.

Ground-water inflow and outflow may occur in significant volumes to warrant additional investigation in the Swift Creek Reservoir Basin. Winter (1981) suggests that the knowledge of geologic boundaries, hydraulic gradient, hydraulic conductivity, seepage, and the configuration and fluctuation of the water table is critical to understanding the importance of the ground-water components of inflow, outflow, and flow-through in the hydrologic budget. Nelms and others (1997) determined summary statistics for base-flow characteristics for more than 100 streams in the southern Piedmont Physiographic Province of Virginia. Mean base flows ranged from 0.11 to 0.78 $(ft^3/s)/mi^2$ for drainage areas that ranged in size between 0.33 and 7,320 mi^2. The minimum mean base flow for streams in the southern Piedmont Physiographic Province is equal to about one-half the residual determined for the Swift Creek water budget and suggests that ground water may significantly contribute to the water budget for Swift Creek.

Additional investigation may determine the validity of using the residential catchments to represent the developed direct runoff areas and the validity of using drainage-area weighted runoff to estimate discharge from undeveloped areas. Land use, impervious area, and soil characteristics were assumed to be similar between the inflow sites and the respective direct runoff areas. The developed direct runoff areas have residential, recreational, and light commercial land uses compared to the residential catchments that are used primarily for residential land use. The actual percent impervious area for the direct runoff areas may be different. Because runoff for Swift Creek was used to compute direct runoff from area 4, the discharge estimated for area 4 may be low. Swift Creek has the lowest runoff per unit area and the largest drainage area of all the measured inflow sites; therefore, the drainage-area runoff value determined for area 4 may have been disproportionately weighted.

Daily mean discharge for the residential catchments was estimated for about one-third of the study period. The residential catchments were assumed to represent ungaged areas adjacent to the reservoir with respect to land use, impervious area, soil properties, and runoff. Annual runoff from the residential catchments may be described more accurately using continuous stage data collected throughout the study period.

Annual discharge was computed from stage-discharge ratings for each of the measured inflow sites. Rantz and others (1982b) suggested that stage-discharge ratings for sand-channel streams at low flow

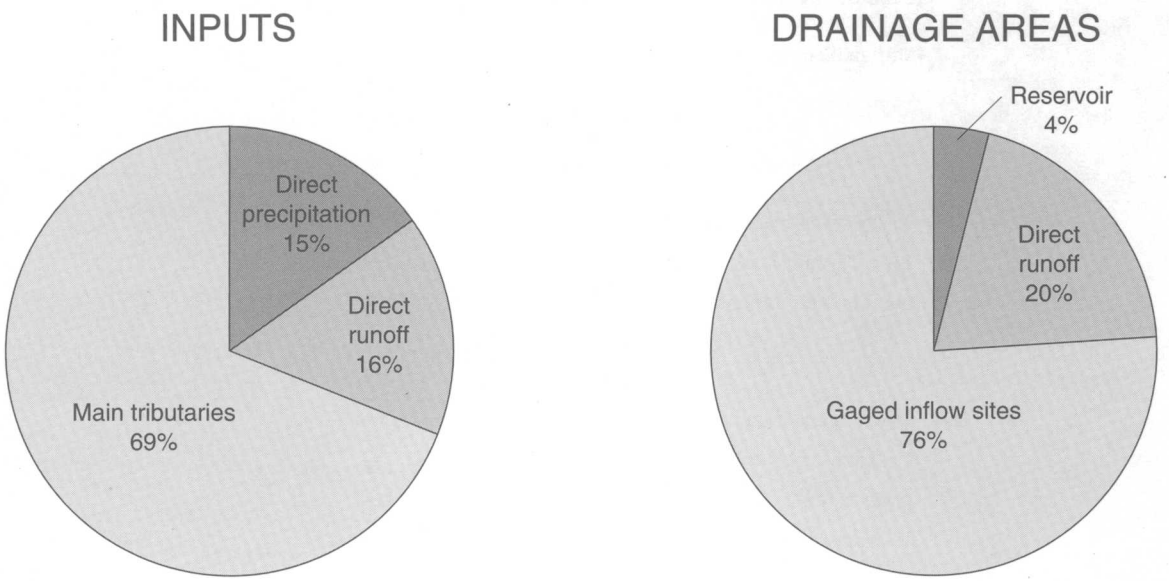

Figure 15. Comparison of percent input to contributing drainage area for input components of the Swift Creek Reservoir water budget, 1997.

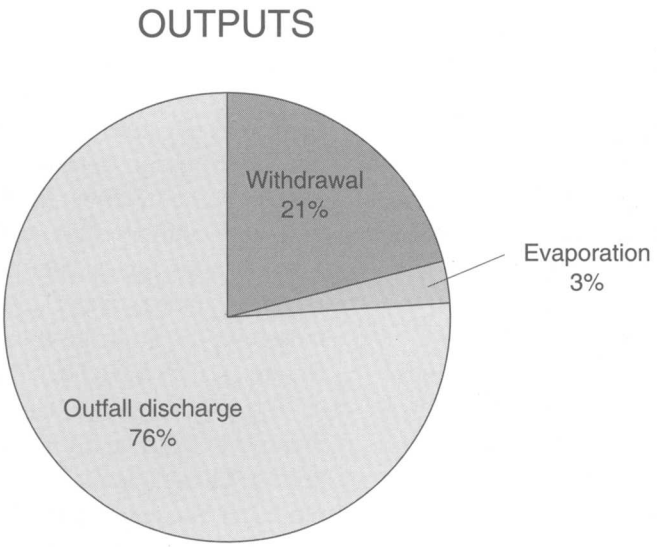

Figure 16. Distribution of percent output for components of the Swift Creek Reservoir water budget, 1997.

may be difficult to define even if discharge measurements are made daily. Ratings may not be well defined, owing to the sand-channel controls, the lack of sufficient high-flow measurements, or the inability to measure high flows at some sites.

Stage data collected for this study were dependent on the reliability and accuracy of recording and sensing equipment. Sensor drift and fouling and power failure were a few of the problems associated with the recording and sensing equipment used for this study. Although standard methods were used to correct data for sensor drift and fouling and to estimate discharge for periods of missing records, these corrections and estimates may not accurately represent the periods for which they were applied.

Winter (1981) concluded that errors associated with measuring rainfall include (1) mechanical speed and calibration of equipment, (2) use of wind shields, and (3) height of gage above ground and exposure angle and that errors in precipitation measurement due to instrument errors may be as large as 75 percent for specific storms. Rainfall data were used to determine atmospheric input directly to the reservoir for the entire study period and to estimate discharge for the residential catchments during the first 4 months of the study period. Rainfall in 1996 was about 10 in. above normal and in 1997 about 10 in. below normal. The effects of rainfall extremes on components of the water budget are beyond the scope of this study and may require additional investigation.

Reservoir evaporation was determined from evaporation-pan data. The effects of transpiration were not considered. Actual reservoir evaporation may have been less than the 63 Mft^3 reported for this study because a stage-surface-area relation was not developed. The surface area of the reservoir was computed for a water-surface elevation of 177 ft, but the water-surface elevation was less than 177 ft between May 18 and December 31. Winter (1981) suggests that (1) wind and heat advection are the two main sources of error for determining lake evaporation from evaporation-pan data, (2) evaporation determined from the energy-budget method may be the most accurate method of determining evaporation from lakes, and (3) transpiration by aquatic plants may significantly contribute to the output of water from lakes to the atmosphere.

The percent error associated with precipitation, evaporation, and streamflow for the computation of hydrologic budgets was described by Winter (1981), and examples are shown in table 4. The percent errors in table 4 do not necessarily apply to the water-budget components for Swift Creek Reservoir, and additional errors for the Swift Creek water budget may be associated with measurements or estimates of direct runoff and with public supply and irrigation withdrawals. Winter (1981, p. 109) stated that, "To relate these estimates of error to calculation of the residual of the budget equation, numerous possible combinations of the magnitude and sign of the errors are possible." It is beyond the scope of this investigation to explore the computation scenarios associated with water-budget components and respective errors.

Table 4. Examples of percent error associated with selected components of a hydrologic budget (modified from Winter, 1981)

Component	Percent error
Precipitation[1]	
Gage	2
Placement	5
Areal averaging	10
Gage density	13
Evaporation[2]	
National Weather Service Class-A evaporation pan	10
Pan to lake coefficient	15
Areal averaging	15
Streamflow and Leakage[3]	
Current meter measurement	5
Stage discharge relation	5
Channel bias	5

[1] Using National Weather Service data from the nearest gages.
[2] Using National Weather Service Class-A pan data from nearest gages.
[3] Using recording stage gages.

SUMMARY

Hydrologic inputs and outputs were measured or estimated to determine a water budget for the Swift Creek Reservoir for 1997. Total input to the reservoir was 1,429 Mft^3 and total output was 1,916 Mft^3. The measured change in reservoir storage was 97 Mft^3, and the residual that was computed from the water-budget

equation was 390 Mft^3. Total inputs to the reservoir were determined from the total annual discharge for nine main tributaries, estimated runoff from ungaged areas adjacent to the reservoir, and mean precipitation at three rainfall sites. The total output from the reservoir was determined from the total annual discharge at the dam, leakage through the dam, measured evaporation, and public supply and irrigation withdrawals. Ground-water effects were considered a part of the residual and the effects of transpiration were not considered.

Input from the main tributaries accounted for 69 percent of the total inflow, direct runoff accounted for 16 percent, and direct precipitation accounted for 15 percent. Discharge at the dam accounted for about 76 percent of the total output from the reservoir. Evaporation and withdrawals accounted for about 21 percent and 3 percent of the output from the reservoir, respectively. Leakage through the dam was estimated to be less than 1 percent of the total output from the reservoir.

Additional data collection may better define stage-discharge relations used to determine discharge at gaged inflow sites. Additional investigation of ground water and direct runoff also may improve the accuracy of the water budget and may improve the ability of resource managers and scientists to better understand the hydrologic processes affecting the reservoir.

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APPENDIXES

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for Swift Creek at Route 667 near Hallsboro, VA, station number 02041810												
1	11	11	68	15	29	2.9	.25	.57	.00	.01	2.5	5.7
2	9.9	9.6	39	12	22	4.6	.52	.40	.00	.00	3.2	6.3
3	9.7	8.9	47	12	21	7.8	.56	.23	.00	.00	2.8	5.0
4	9.2	9.2	53	10	19	12	.53	.20	.00	.00	2.1	4.7
5	9.3	11	35	10	15	7.5	.35	.45	.00	.00	1.7	4.5
6	7.9	11	42	9.8	12	5.4	.21	.26	.00	.00	1.6	4.2
7	7.1	10	29	11	10	4.6	.21	.10	.00	.00	11	3.7
8	6.7	14	23	9.5	8.6	3.9	.15	.02	.00	.00	22	3.0
9	11	18	21	8.7	7.6	3.5	.10	.00	.00	.00	17	2.8
10	18	15	20	7.6	8.1	3.0	1.6	.00	.00	.00	13	3.5
11	13	13	19	7.3	6.6	2.7	1.5	.00	1.6	.00	7.4	5.3
12	9.6	11	17	9.4	5.7	2.5	1.5	.00	6.0	.00	5.0	6.0
13	7.9	11	16	15	5.2	2.5	1.2	.00	4.0	.00	3.9	5.7
14	7.0	17	22	11	4.9	2.3	.80	.00	1.9	.00	8.2	5.0
15	7.1	36	29	8.7	5.0	2.3	.56	.00	.95	.00	12	4.3
16	16	22	19	7.8	4.8	2.2	.37	.00	.66	.00	8.1	3.8
17	12	16	17	7.8	4.3	2.1	.34	.00	.43	.00	5.9	3.4
18	7.8	13	17	8.8	4.0	1.8	.66	.00	.30	.00	4.7	3.1
19	8.4	12	31	7.6	3.3	1.5	1.4	.00	.21	.00	4.1	2.8
20	9.4	12	35	7.2	3.2	1.3	.76	.00	.11	.06	3.7	2.6
21	9.2	12	24	7.1	2.7	1.2	.45	.00	.04	.14	3.5	2.3
22	9.2	15	21	9.5	2.2	1.0	.35	.00	.00	.45	21	3.1
23	11	13	18	14	2.1	.85	1.3	.00	.00	.47	16	5.0
24	9.5	12	17	25	2.0	.69	2.9	.00	.00	.31	9.8	4.8
25	11	11	15	17	2.1	.58	4.5	.00	.00	1.1	6.1	7.8
26	11	11	26	13	3.8	.44	3.5	.00	.00	1.7	4.8	8.7
27	9.1	12	23	11	4.3	.52	2.1	.00	.00	3.2	4.0	9.9
28	16	61	18	100	3.7	.36	1.4	.00	.00	3.6	3.5	22
29	18	---	16	91	2.8	.30	1.1	.00	.07	3.3	3.1	16
30	12	---	15	39	2.4	.26	.94	.00	.07	2.3	3.5	13
31	11	---	16	---	2.2	---	.74	.00	---	1.7	---	9.7
TOTAL	325.0	427.7	808	522.8	229.6	82.60	32.85	2.23	16.34	18.34	215.2	187.7
MEAN	10.5	15.3	26.1	17.4	7.41	2.75	1.06	.072	.54	.59	7.17	6.05
MAX	18	61	68	100	29	12	4.5	.57	6.0	3.6	22	22
MIN	6.7	8.9	15	7.1	2.0	.26	.10	.00	.00	.00	1.6	2.3
CFSM	.49	.71	1.22	.81	.35	.13	.05	.00	.03	.03	.34	.28
IN.	.56	.74	1.40	.91	.40	.14	.06	.00	.03	.03	.37	.33
CAL YR 1997		TOTAL 2,868.36		MEAN 7.86		MAX 100		MIN .00	CFSM .37		IN. 4.99	

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for Blackman Creek at Route 667 near Hallsboro, Va., station number 02041820												
1	10	6.3	35	12	29	.61	.00	.00	.00	.00	.00	.62
2	8.9	4.3	21	9.4	20	.67	.00	.00	.00	.00	.00	.57
3	8.2	3.7	75	9.0	24	.76	.00	.00	.00	.00	.00	.50
4	6.8	3.5	57	7.9	18	.68	.00	.00	.00	.00	.00	.52
5	6.7	6.4	29	6.9	13	.54	.00	.00	.00	.00	.00	.51
6	5.8	4.3	39	8.0	11	.46	.00	.00	.00	.00	.00	.44
7	4.5	3.5	20	9.6	8.5	.43	.00	.00	.00	.00	.00	.37
8	3.9	9.8	15	5.4	7.2	.39	.00	.00	.00	.00	.00	.33
9	17	13	12	3.5	7.4	.33	.00	.00	.00	.00	.00	.32
10	23	9.7	11	2.9	7.3	.28	.00	.00	.00	.00	.00	.39
11	14	7.0	8.5	2.8	4.7	.21	.00	.00	.00	.00	.00	.56
12	8.7	5.6	6.2	7.7	3.6	.17	.00	.00	.00	.00	.00	.50
13	6.4	4.2	5.2	13	2.5	.21	.00	.00	.00	.00	.00	.45
14	5.2	24	14	5.9	1.8	.14	.00	.00	.00	.00	.00	.41
15	4.8	83	15	3.6	2.4	.16	.00	.00	.00	.00	.00	.36
16	23	26	7.2	2.8	1.2	.10	.00	.00	.00	.00	.02	.34
17	12	15	5.3	4.6	1.2	.04	.00	.00	.00	.00	.00	.33
18	6.7	10	6.3	5.5	1.1	.00	.00	.00	.00	.00	.00	.31
19	3.8	8.6	39	3.4	1.1	.00	.00	.00	.00	.00	.00	.28
20	4.5	6.7	39	2.4	1.0	.00	.00	.00	.00	.00	.00	.28
21	4.4	6.3	27	3.8	.97	.00	.00	.00	.00	.00	.00	.26
22	5.1	8.3	22	8.4	.90	.00	.00	.00	.00	.00	2.5	.33
23	7.2	4.9	16	16	.85	.00	.00	.00	.00	.00	.75	.64
24	4.9	3.4	14	32	.82	.00	.00	.00	.00	.00	.58	.63
25	8.9	2.9	13	16	.80	.00	.00	.00	.00	.00	.48	.93
26	5.9	2.9	29	10	.93	.00	.00	.00	.00	.00	.45	.87
27	3.8	4.5	22	10	.82	.00	.00	.00	.00	.00	.42	1.4
28	21	62	17	162	.72	.00	.00	.00	.00	.00	.36	1.4
29	14	---	15	166	.66	.00	.00	.00	.00	.00	.35	1.0
30	8.7	---	12	46	.62	.00	.00	.00	.00	.00	.40	1.0
31	7.6	---	16	---	.59	---	.00	.00	---	.00	---	.92
TOTAL	275.4	349.8	662.7	596.5	174.68	6.18	.00	.00	.00	.00	6.31	17.77
MEAN	8.88	12.5	21.4	19.9	5.63	.21	.000	.000	.000	.000	.21	.57
MAX	23	83	75	166	29	.76	.00	.00	.00	.00	2.5	1.4
MIN	3.8	2.9	5.2	2.4	.59	.00	.00	.00	.00	.00	.00	.26
CFSM	1.53	2.15	3.69	3.43	.97	.04	.00	.00	.00	.00	.04	.10
IN.	1.77	2.24	4.25	3.83	1.12	.04	.00	.00	.00	.00	.04	.11
CAL YR 1997		TOTAL 2,089.34		MEAN 5.72		MAX 166		MIN .00	CFSM .99		IN. 13.40	

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for Horsepen Creek near Hallsboro, Va., station number 02041830												
1	6.0	4.4	18	1.9	9.3	.44	.00	.00	.00	.00	.00	2.3
2	5.5	3.6	11	1.3	5.8	.58	.00	.00	.00	.00	.00	1.1
3	4.3	3.3	41	1.1	7.0	2.2	.00	.00	.00	.00	.00	.65
4	3.0	3.2	27	1.0	5.4	1.5	.00	.00	.00	.00	.00	.85
5	3.0	4.5	13	.89	3.2	.61	.00	.00	.00	.00	.00	.83
6	2.7	3.7	18	1.0	2.5	.45	.00	.00	.00	.00	.00	.56
7	2.4	3.2	9.0	1.3	1.6	.43	.00	.00	.00	.00	1.8	.42
8	2.1	7.5	6.8	.78	1.3	.41	.00	.00	.00	.00	2.5	.36
9	8.2	9.4	5.1	.72	1.2	.37	.00	.00	.00	.00	3.2	.37
10	12	7.0	4.7	.68	1.2	.36	.00	.00	.00	.00	1.0	.67
11	7.4	5.1	3.8	.64	.88	.31	.00	.00	.00	.00	.42	1.8
12	4.6	4.2	2.7	1.8	.76	.29	.00	.00	.00	.00	.24	.96
13	3.7	3.5	2.2	3.3	.67	.27	.00	.00	.00	.00	.18	.76
14	3.2	15	7.3	1.3	.58	.24	.00	.00	.00	.00	4.0	.60
15	2.9	40	8.7	.93	.80	.21	.00	.00	.00	.00	.90	.49
16	11	13	4.2	.85	.52	.18	.00	.00	.00	.00	.33	.44
17	5.9	6.3	3.0	1.1	.47	.17	.00	.00	.00	.00	.22	.43
18	4.3	4.5	3.1	1.3	.42	.16	.00	.00	.00	.00	.17	.37
19	2.9	3.9	19	.90	.38	.15	.00	.00	.00	.00	.17	.34
20	3.0	3.1	14	.75	.36	.07	.00	.00	.00	.00	.16	.34
21	3.0	2.8	7.8	.97	.33	.00	.00	.00	.00	.00	.17	.32
22	3.3	4.9	5.4	2.0	.31	.00	.00	.00	.00	.00	23	.46
23	4.4	3.1	3.3	5.2	.30	.00	.00	.00	.00	.00	4.2	1.8
24	3.3	2.3	2.4	12	.30	.00	.00	.00	.00	.00	1.5	1.1
25	5.2	2.0	2.1	5.2	.33	.00	.00	.00	.00	.00	.81	6.5
26	4.0	1.9	8.8	2.6	.45	.00	.00	.00	.00	.00	.63	3.6
27	3.1	2.5	5.8	2.5	.40	.00	.00	.00	.00	.00	.50	9.2
28	13	36	3.5	77	.32	.00	.00	.00	.00	.00	.39	12
29	9.3	---	2.7	64	.31	.00	.00	.00	.00	.00	.37	5.9
30	5.7	---	1.9	15	.32	.00	.00	.00	.00	.00	.53	5.3
31	5.1	---	2.9	---	.32	---	.00	.00	---	.00	---	2.6
TOTAL	157.5	203.9	268.2	210.01	48.03	9.40	.00	.00	.00	.00	47.39	63.42
MEAN	5.08	7.28	8.65	7.00	1.55	.31	.000	.000	.000	.000	1.58	2.05
MAX	13	40	41	77	9.3	2.2	.00	.00	.00	.00	23	12
MIN	2.1	1.9	1.9	.64	.30	.00	.00	.00	.00	.00	.00	.32
CFSM	1.37	1.96	2.33	1.88	.42	.08	.00	.00	.00	.00	.42	.55
IN.	1.58	2.04	2.68	2.10	.48	.09	.00	.00	.00	.00	.47	.63

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for Otterdale Branch near Hallsboro, Va., station number 02041840												
1	4.4	4.4	20	4.3	8.0	.50	.13	.07	.24	.18	.00	3.0
2	4.0	3.6	12	3.9	5.2	.53	.15	.07	.24	.19	.00	1.4
3	3.7	3.2	35	3.7	6.3	1.3	.13	.07	.25	.18	.00	.72
4	3.3	3.1	26	3.2	4.9	.88	.12	.09	.25	.19	.00	1.1
5	3.2	4.6	17	2.9	3.7	.50	.11	.08	.14	.18	.00	.94
6	2.8	3.7	19	3.3	3.1	.40	.12	.07	.00	.12	.00	.67
7	2.4	3.2	11	3.8	2.5	.36	.14	.07	.00	.07	5.4	.60
8	1.8	7.4	8.9	3.0	2.1	.34	.15	.05	.00	.20	3.5	.56
9	6.9	8.6	7.7	2.6	2.1	.31	.17	.00	.41	.21	3.7	.56
10	9.7	6.8	7.5	2.3	2.0	.28	.24	.00	.40	.22	.80	1.1
11	6.1	5.1	6.5	2.2	1.6	.24	.08	.00	2.1	.24	.39	2.2
12	4.2	4.3	5.5	3.8	1.3	.27	.00	.00	.19	.27	.20	1.0
13	3.2	3.6	5.1	5.1	1.2	.31	.00	.03	.09	.28	.17	.68
14	2.6	13	9.9	2.6	1.2	.29	.00	.05	.09	.30	4.9	.61
15	2.4	34	10	1.8	1.4	.28	.01	.06	.12	.35	1.1	.54
16	9.9	15	7.0	1.5	.96	.25	.05	.06	.11	.32	.37	.52
17	6.4	9.2	5.9	2.1	.77	.23	.05	.06	.11	.20	.18	.53
18	6.7	7.3	6.0	2.3	.74	.24	.05	.09	.15	.00	.09	.49
19	4.4	6.4	17	1.7	.68	.25	.05	.13	.15	.08	.05	.45
20	3.2	5.5	14	1.3	.66	.24	.06	.21	.14	.00	.00	.42
21	3.1	5.2	9.3	1.8	.65	.22	.06	.16	.12	.07	.13	.43
22	3.5	8.7	7.8	3.2	.61	.19	.13	.15	.13	.28	23	.68
23	4.6	5.8	6.2	6.1	.54	.13	.10	.15	.13	.26	6.7	2.2
24	3.4	4.8	5.0	11	.48	.13	.25	.16	.16	.27	3.3	1.3
25	5.6	4.3	4.4	5.5	.65	.13	.18	.16	.16	.03	1.3	5.5
26	4.1	4.2	9.6	3.5	1.8	.07	.15	.17	.14	.07	.85	3.2
27	3.2	5.0	7.6	3.7	1.3	.05	.11	.18	.14	.00	.69	7.8
28	12	32	5.9	93	.74	.12	.11	.19	.21	.00	.63	10
29	8.2	---	5.3	59	.38	.12	.11	.22	.16	.00	.61	6.2
30	5.5	---	4.4	13	.39	.12	.11	.23	.18	.00	.95	9.0
31	5.0	---	5.7	---	.39	---	.09	.24	---	.00	---	5.9
TOTAL	149.5	222.0	322.2	257.2	58.34	9.28	3.21	3.27	6.71	4.76	59.01	70.30
PUMPAGE	5.94	5.06	5.50	4.62	4.84	4.36	3.16	3.24	5.17	4.17	3.46	5.50
MEAN*	4.63	7.75	10.2	8.42	1.72	.16	.00	.00	.05	.02	1.85	2.09
MAX	12	34	35	93	8.0	1.3	.25	.24	2.1	.35	23	10
MIN	1.8	3.1	4.4	1.3	.38	.05	.00	.00	.00	.00	.00	.42
CFSM*	1.28	2.16	2.84	2.34	.48	.04	.00	.00	.01	.00	.51	.58
IN.*	1.49	2.25	3.28	2.62	.55	.05	.00	.00	.02	.01	.58	.67

*ADJUSTED FOR PUMPAGE

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for Tomahawk Creek near Hallsboro, Va., station number 02041850												
1	5.4	4.9	28	4.2	14	.56	.00	.00	.00	.00	.00	5.6
2	5.2	3.9	22	3.4	8.9	.75	.00	.00	.00	.00	.00	1.8
3	4.7	3.2	32	3.3	10	1.2	.00	.00	.00	.00	.00	1.2
4	3.9	3.3	27	3.1	7.0	.90	.00	.00	.00	.00	.00	2.0
5	3.8	5.2	20	2.9	4.6	.57	.00	.00	.00	.00	.00	1.6
6	3.6	3.5	24	3.2	3.7	.50	.00	.00	.00	.00	.00	.99
7	3.2	3.1	15	3.4	3.0	.50	.00	.00	.00	.00	.00	.77
8	3.2	8.1	12	2.6	2.4	.48	.00	.00	.00	.00	.00	.63
9	8.5	8.8	9.8	2.3	2.6	.44	.00	.00	.00	.00	.00	.63
10	8.8	7.2	9.0	2.1	2.6	.41	.00	.00	.00	.00	.17	3.7
11	6.5	5.4	7.5	2.1	2.1	.39	.00	.00	.28	.00	.38	4.8
12	5.0	4.2	5.7	3.9	1.9	.36	.00	.00	.11	.00	.27	2.3
13	4.3	3.0	4.9	4.7	1.6	.34	.00	.00	.04	.00	.25	1.7
14	3.9	12	12	2.9	1.5	.33	.00	.00	.01	.00	3.4	1.4
15	3.9	29	11	2.4	1.6	.32	.00	.00	.00	.00	.46	1.1
16	11	13	6.2	2.1	1.3	.30	.00	.00	.00	.00	.24	1.0
17	6.5	8.4	5.0	2.4	1.2	.29	.00	.00	.00	.00	.15	.99
18	4.6	5.8	5.3	2.4	1.1	.29	.00	.00	.00	.00	.14	.88
19	3.9	4.3	17	1.9	6.0	.28	.00	.00	.00	.00	.12	.79
20	4.6	2.9	14	1.7	.94	.24	.00	.00	.00	.00	.10	.78
21	4.5	2.6	9.5	1.9	.71	.14	.00	.00	.00	.00	.15	.69
22	5.0	5.3	7.6	2.8	.58	.07	.00	.00	.00	.00	24	1.4
23	5.7	2.2	5.4	5.8	.53	.06	.00	.00	.00	.00	7.1	4.0
24	4.1	1.6	4.4	10	.51	.03	.00	.00	.00	.00	2.7	1.9
25	6.4	1.3	4.1	4.5	.51	.01	.00	.00	.00	.00	1.4	9.3
26	4.4	1.3	12	3.0	.93	.00	.00	.00	.00	.00	1.1	4.4
27	3.3	2.0	7.5	3.3	.69	.00	.00	.00	.00	.00	.83	12
28	12	37	5.5	51	.55	.00	.00	.00	.00	.00	.64	18
29	8.5	---	4.8	43	.49	.00	.00	.00	.00	.00	.59	11
30	6.3	---	4.0	21	.48	.00	.00	.00	.00	.00	2.1	12
31	5.9	---	6.6	---	.48	---	.00	.00	---	.00	---	6.1
TOTAL	170.6	192.5	358.8	203.3	84.50	9.76	.00	.00	.44	.00	46.29	115.45
MEAN	5.50	6.88	11.6	6.78	2.73	.33	.000	.000	.015	.000	1.54	3.72
MAX	12	37	32	51	14	1.2	.00	.00	.28	.00	24	18
MIN	3.2	1.3	4.0	1.7	.48	.00	.00	.00	.00	.00	.00	.63
CFSM	1.31	1.64	2.76	1.61	.65	.08	.00	.00	.00	.00	.37	.89
IN.	1.51	1.71	3.18	1.80	.75	.09	.00	.00	.00	.00	.41	1.02
CAL YR 1997		TOTAL 1,181.64		MEAN 3.64		MAX 51		MIN .00	CFSM .77		IN. 10.47	

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for Little Tomahawk Creek near Hallsboro, Va., station number 02041860												
1	2.7	2.9	16	2.5	11	.51	.00	.00	.00	.00	.08	.46
2	2.6	2.5	9.6	2.2	6.0	.58	.00	.00	.00	.00	.19	.28
3	2.5	2.3	23	2.1	6.9	.60	.00	.00	.00	.00	.14	.26
4	2.4	2.4	16	2.0	4.4	.48	.00	.03	.00	.00	.09	.41
5	2.3	2.9	9.3	1.9	3.3	.38	.00	.02	.00	.00	.07	.37
6	2.2	2.4	11	2.1	2.5	.33	.00	.00	.00	.00	.07	.34
7	2.0	2.2	6.1	2.2	2.0	.31	.00	.00	.00	.00	11	.34
8	1.9	5.0	5.0	1.7	1.8	.27	.00	.00	.00	.00	2.5	.37
9	5.7	5.0	4.2	1.6	1.7	.24	.00	.00	.90	.00	3.2	.41
10	5.6	4.1	4.1	1.6	1.5	.21	.00	.00	.41	.00	.33	.86
11	4.0	3.2	3.6	1.5	1.3	.19	.00	.00	.39	.00	.16	.90
12	2.8	2.7	2.8	2.4	1.2	.18	.00	.00	.11	.00	.12	.39
13	2.4	2.4	2.7	2.5	1.1	.19	.00	.00	.06	.00	.10	.18
14	2.3	9.3	5.9	1.7	.94	.17	.00	.00	.00	.00	1.5	.09
15	2.2	21	4.7	1.5	.98	.19	.00	.00	.00	.00	.15	.04
16	6.9	9.8	3.3	1.4	.80	.15	.00	.00	.00	.00	.09	.02
17	3.9	5.8	2.7	1.6	.79	.13	.00	.00	.00	.00	.07	.02
18	2.6	4.6	2.9	1.6	.75	.13	.00	.00	.00	.00	.07	.01
19	2.2	4.0	9.5	1.4	.75	.15	.00	.00	.00	.00	.06	.01
20	2.4	3.4	6.5	1.4	.70	.12	.00	.00	.00	.00	.06	.01
21	2.3	3.1	4.5	1.5	.61	.11	.00	.00	.00	.00	.07	.01
22	2.5	5.3	3.9	1.9	.51	.10	.00	.00	.00	.00	13	.03
23	3.1	3.1	3.0	3.6	.47	.10	.00	.00	.00	.00	.38	.09
24	2.3	2.6	2.6	6.2	.45	.08	.52	.00	.00	.00	.15	.05
25	3.5	2.3	2.5	2.4	.43	.05	.19	.00	.00	.19	.14	.19
26	2.5	2.3	6.2	1.6	.58	.02	.11	.00	.00	.30	.14	.10
27	2.2	2.7	4.0	1.7	.60	.03	.09	.00	.00	.25	.13	.52
28	8.1	30	3.1	49	.52	.00	.08	.00	.00	.10	.13	.55
29	5.1	---	2.7	42	.47	.00	.03	.00	.00	.08	.14	.24
30	3.9	---	2.4	16	.45	.00	.00	.00	.00	.07	.29	.26
31	3.5	---	3.8	---	.42	---	.00	.00	---	.06	---	.15
TOTAL	100.6	149.3	187.6	162.8	55.92	6.00	1.02	0.05	1.87	1.05	34.62	7.96
MEAN	3.25	5.33	6.05	5.43	1.80	.20	.033	.002	.062	.034	1.15	.26
MAX	8.1	30	23	49	11	.60	.52	.03	.90	.30	13	.90
MIN	1.9	2.2	2.4	1.4	.42	.00	.00	.00	.00	.00	.06	.01
CFSM	1.40	2.31	2.62	2.35	.78	.09	.01	.00	.03	.01	.50	.11
IN.	1.62	2.40	3.02	2.62	.90	.10	.02	.00	.03	.02	.56	.13
CAL YR 1997		TOTAL 708.79		MEAN 1.94		MAX 49		MIN .00	CFSM .84		IN. 11.41	

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for Little Tomahawk Creek Tributary Near Hallsboro, Va., station number 02041862												
1	---	---	---	---	.01	.03	.00	.00	.00	.00	.01	.00
2	---	---	---	---	.01	.01	.00	.00	.00	.00	.01	.01
3	---	---	---	---	.06	.01	.00	.00	.00	.00	.00	.00
4	---	---	---	---	.03	.01	.00	.03	.00	.00	.00	.01
5	---	---	---	.01	.02	.00	.00	.00	.00	.00	.00	.00
6	---	---	---	---	.02	.00	.00	.00	.00	.00	.00	.00
7	---	---	---	---	.02	.00	.00	.00	.00	.00	.40	.00
8	---	---	---	---	.01	.00	.02	.00	.00	.00	.05	.00
9	---	---	---	---	.01	.00	.21	.00	.09	.00	.11	.00
10	---	---	---	---	.01	.00	.04	.00	.06	.00	.02	.04
11	---	---	---	---	.01	.00	.01	.00	.00	.00	.01	.01
12	---	---	---	.05	.01	.00	.01	.00	.00	.00	.00	.00
13	---	---	---	.03	.01	.00	.00	.00	.00	.00	.02	.00
14	---	---	.28	---	.01	.00	.00	.00	.00	.00	.09	.00
15	---	---	.10	---	.01	.00	.00	.00	.00	.05	.01	.00
16	---	---	---	---	.01	.00	.00	.00	.00	.00	.01	.00
17	---	---	---	---	.01	.00	.00	.00	.00	.00	.00	.00
18	---	---	---	---	.01	.00	.00	.00	.00	.00	.00	.00
19	---	---	.27	---	.01	.00	.00	.00	.00	.02	.00	.00
20	---	---	---	---	.01	.00	.00	.01	.00	.00	.00	.00
21	---	---	---	---	.00	.00	.00	.00	.00	.00	.06	.00
22	---	---	---	.01	.00	.00	.21	.00	.00	.00	.36	.04
23	---	---	---	.10	.00	.00	.07	.00	.00	.00	.03	.01
24	---	---	---	.06	.00	.00	.01	.00	.00	.00	.01	.02
25	---	---	---	.01	.07	.00	.01	.00	.00	.01	.01	.06
26	---	---	---	.01	.01	.00	.00	.00	.00	.07	.01	.01
27	---	---	---	.09	.01	.00	.00	.00	.00	.00	.01	.19
28	---	---	---	---	.01	.00	.00	.00	.01	.00	.00	.08
29	---	---	---	---	.01	.00	.00	.00	.01	.00	.00	.05
30	---	---	---	---	.01	.00	.00	.00	.00	.00	.10	.03
31	---	---	---	---	.01	---	.00	.00	---	.00	---	.01
TOTAL	---	---	---	---	.43	.06	.59	.04	.17	.15	1.33	.57
MEAN	---	---	---	---	.014	.002	.019	.001	.006	.005	.044	.018
MAX	---	---	---	---	.07	.03	.21	.03	.09	.07	.40	.19
MIN	---	---	---	---	.00	.00	.00	.00	.00	.00	.00	.00

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for Swift Creek Tributary near Hallsboro, Va., station number 0204186350												
1	---	---	---	---	e.08	.10	.03	.01	.09	.01	.10	e.22
2	---	---	---	---	e.08	.07	e.01	.01	.02	.01	.07	.11
3	---	---	---	---	.28	.15	e.01	.00	.05	.01	.02	.10
4	---	---	---	---	.11	.05	e.01	.02	.05	.01	.02	.18
5	---	---	---	---	.11	.05	e.00	.01	.02	.01	.02	.10
6	---	---	---	---	.12	.05	e.00	.00	.01	.01	.02	.08
7	---	---	---	---	.12	.05	e.00	.00	.00	.00	3.8	.08
8	---	---	---	---	.12	.05	e.40	.00	.00	.00	.40	.07
9	---	---	---	---	.13	e.04	e.18	.00	.72	.00	.60	.07
10	---	---	---	---	.08	e.03	e.05	.00	.88	.00	.17	.33
11	---	---	---	---	.05	e.02	e.04	.00	.11	.00	.10	.12
12	---	---	---	.29	.05	e.02	e.03	.00	.03	.00	.08	.10
13	---	---	---	.09	.05	.01	e.02	.00	.01	.00	.19	.09
14	---	---	.58	---	.05	.01	e.01	.00	.01	e.00	.56	.08
15	---	---	.20	---	.08	.01	e.01	.00	.01	e.00	.14	.07
16	---	---	---	---	.05	e.01	e.01	.00	.02	.02	.09	.07
17	---	---	---	---	.05	e.01	e.01	.00	.01	.11	.07	.07
18	---	---	---	---	.05	.02	e.01	.00	.02	.09	.06	.06
19	---	---	.89	---	.05	.01	e.01	.00	.01	.29	.06	.06
20	---	---	---	---	.05	.01	e.01	.13	.01	.04	.06	.06
21	---	---	---	---	.05	.01	e.50	.00	.01	.02	.43	.05
22	---	---	---	.08	.05	.01	e.18	.00	.01	.02	4.0	.35
23	---	---	---	.40	.05	.01	e.08	.00	.01	.02	.28	.13
24	---	---	---	.19	.05	.01	e.04	.00	.01	.02	.17	.18
25	---	---	---	.07	.25	.01	e.02	.00	.01	.08	.13	.39
26	---	---	---	.05	.09	.03	e.02	.00	.01	.64	.12	.14
27	---	---	---	.38	e.07	.01	e.02	.00	.01	e.11	.10	.83
28	.96	---	---	---	e.05	.01	e.01	.00	.11	e.06	.09	.35
29	---	---	---	---	e.03	.01	.01	.00	.03	e.03	.08	.29
30	---	---	---	---	.01	.01	.01	.00	.01	.02	.39	e.27
31	---	---	---	---	.01	---	.01	.00	---	.02	---	.20
TOTAL	---	---	---	---	2.47	.89	1.75	.18	2.30	1.65	12.42	5.30
MEAN	---	---	---	---	.080	.030	.056	.006	.077	.053	.41	.17
MAX	---	---	---	---	.28	.15	.50	.13	.88	.64	4.0	.83
MIN	---	---	---	---	.01	.01	.00	.00	.00	.00	.02	.05

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for Dry Creek near Winterpock, Va., station number 02041870												
1	7.8	3.5	20	2.1	4.7	.19	.00	.00	.00	.00	.00	1.6
2	5.7	2.9	12	2.0	3.2	.26	.00	.00	.00	.00	.00	1.0
3	6.9	2.6	38	2.0	7.9	.65	.00	.00	.00	.00	.00	.84
4	12	2.5	25	1.7	4.0	.49	.00	.00	.00	.00	.00	.63
5	15	3.2	13	1.5	2.5	.29	.00	.00	.00	.00	.00	.59
6	12	e2.6	19	1.5	1.9	.18	.00	.00	.00	.00	.00	.35
7	8.0	e2.5	7.3	1.5	1.5	.10	.00	.00	.00	.00	.33	.20
8	2.1	e1.7	4.3	1.1	1.3	.09	.00	.00	.00	.00	.02	.13
9	12	e5.8	3.6	.96	1.4	.08	.00	.00	.00	.00	.46	.11
10	14	e4.0	3.4	.90	1.6	.08	.33	.00	.00	.00	.28	.33
11	6.5	3.5	2.9	.84	1.4	.30	.00	.00	.00	.00	.06	.84
12	4.0	2.9	2.5	1.3	1.3	.09	.00	.00	.00	.00	.03	.55
13	3.3	2.5	2.2	1.9	1.1	.07	.00	.00	.00	.00	.02	.33
14	2.9	17	6.4	1.2	1.1	.07	.00	.00	.00	.00	.57	.22
15	2.7	46	5.4	.96	1.1	.06	.00	.00	.00	.00	.70	.17
16	15	16	2.8	.88	.89	.05	.00	.00	.00	.00	.19	.15
17	5.9	7.4	2.5	.97	.81	.05	.00	.00	.00	.00	.08	.13
18	3.8	4.5	2.4	1.1	.74	.11	.00	.00	.00	.00	.06	.12
19	2.7	4.1	13	.90	.66	.05	.00	.00	.00	.00	.05	.10
20	2.7	3.5	8.0	.79	.60	.02	.00	.00	.00	.00	.04	.10
21	2.7	3.3	4.1	.87	.55	.00	.00	.00	.00	.00	.08	.10
22	2.9	4.9	3.2	1.2	.46	.01	.08	.00	.00	.00	20	.25
23	3.8	3.2	2.4	2.9	.39	.00	.12	.00	.00	.00	2.5	1.0
24	2.8	2.7	2.1	7.4	.29	.00	.38	.00	.00	.00	1.1	.72
25	5.2	2.4	1.9	2.7	.26	.00	.04	.00	.00	.00	.62	2.9
26	3.5	2.3	5.3	1.7	.37	.00	.01	.00	.00	.00	.42	1.8
27	2.8	3.1	3.0	1.7	.27	.00	.00	.00	.00	.00	.28	5.2
28	14	30	2.3	47	.19	.00	.00	.00	.00	.00	.17	6.7
29	7.9	---	2.2	79	.16	.00	.00	.00	.00	.00	.12	3.2
30	4.4	---	2.3	9.8	.12	.00	.00	.00	.00	.00	.34	3.2
31	3.9	---	2.6	---	.10	---	.00	.00	---	.00	---	2.0
TOTAL	198.9	190.6	225.1	180.37	42.86	3.29	.96	.00	.00	.00	28.52	35.56
MEAN	6.42	6.81	7.26	6.01	1.38	.11	.031	.000	.000	.000	.95	1.15
MAX	15	46	38	79	7.9	.65	.38	.00	.00	.00	20	6.7
MIN	2.1	1.7	1.9	.79	.10	.00	.00	.00	.00	.00	.00	.10
CFSM	2.17	2.30	2.45	2.03	.47	.04	.01	.00	.00	.00	.32	.39
IN.	2.50	2.40	2.83	2.27	.54	.04	.01	.00	.00	.00	.36	.45
CAL YR 1997		TOTAL 906.16		MEAN 2.48		MAX 79		MIN .00	CFSM .84		IN. 11.39	

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for Ashbrook Creek near Winterpock, Va., station number 02041880												
1	3.6	2.9	14	2.6	8.4	.43	.00	.00	.00	.00	.00	.92
2	2.6	2.4	9.6	2.0	5.3	.73	.00	.00	.00	.00	.00	.71
3	2.4	2.3	21	1.7	8.5	1.0	.00	.00	.00	.00	.00	.39
4	2.1	2.4	17	1.6	7.5	.87	.00	.00	.00	.00	.00	.48
5	1.9	2.5	11	1.5	3.4	.54	.00	.00	.00	.00	.00	.53
6	1.8	2.3	14	1.6	2.3	.38	.00	.00	.00	.00	.00	.45
7	1.5	1.8	8.7	2.2	1.8	.33	.00	.00	.00	.00	.00	.35
8	1.3	4.5	6.3	1.7	1.5	.30	.00	.00	.00	.00	.19	.31
9	6.0	7.9	4.6	1.2	1.4	.27	.00	.00	.00	.00	.83	.34
10	10	6.2	3.8	1.1	1.5	.25	.00	.00	.00	.00	.71	.73
11	6.7	3.8	3.1	1.0	1.2	.24	.00	.00	.00	.00	.39	1.1
12	3.6	2.7	2.6	1.6	.99	.25	.00	.00	.00	.00	.33	.62
13	2.5	2.2	2.2	2.9	.80	.26	.00	.00	.00	.00	.30	.47
14	2.0	11	5.4	1.9	.80	.23	.00	.00	.00	.00	.96	.43
15	1.8	26	8.2	1.4	.95	.21	.00	.00	.00	.00	.80	.53
16	8.5	12	3.8	1.1	.74	.17	.00	.00	.00	.00	.42	.57
17	6.7	8.4	2.4	1.2	.60	.13	.00	.00	.00	.00	.30	.50
18	2.9	5.9	2.1	1.4	.51	.10	.00	.00	.00	.00	.21	.48
19	1.9	4.2	8.7	1.1	.45	.03	.00	.00	.00	.00	.16	.38
20	1.8	3.2	9.8	.93	.40	.00	.00	.00	.00	.00	.16	.32
21	1.9	2.7	6.3	.99	.37	.00	.00	.00	.00	.00	.21	.29
22	2.1	5.0	3.8	1.5	.33	.00	.00	.00	.00	.00	16	.47
23	2.8	4.0	2.6	2.9	.30	.00	.00	.00	.00	.00	3.8	.70
24	2.2	2.6	2.0	12	.30	.00	.10	.00	.00	.00	1.2	.65
25	3.4	2.2	1.8	7.1	.29	.00	.33	.00	.00	.00	.48	2.3
26	3.0	2.1	5.6	4.7	.42	.00	.26	.00	.00	.00	.32	3.1
27	2.1	2.6	5.5	2.8	.48	.00	.20	.00	.00	.00	.24	4.6
28	8.1	16	3.3	32	.39	.00	.16	.00	.00	.00	.22	8.1
29	8.5	---	2.5	43	.33	.00	.06	.00	.00	.00	.23	3.1
30	5.1	---	2.1	14	.29	.00	.00	.00	.00	.00	.51	2.3
31	3.6	---	3.2	---	.31	---	.00	.00	---	.00	---	1.4
TOTAL	114.4	151.8	197.0	152.72	52.85	6.72	1.11	.00	.00	.00	28.97	37.62
MEAN	3.69	5.42	6.35	5.09	1.70	.22	.036	.000	.000	.000	.97	1.21
MAX	10	26	21	43	8.5	1.0	.33	.00	.00	.00	16	8.1
MIN	1.3	1.8	1.8	.93	.29	.00	.00	.00	.00	.00	.00	.29
CFSM	1.56	2.29	2.68	2.15	.72	.09	.02	.00	.00	.00	.41	.51
IN.	1.80	2.38	3.09	2.40	.83	.11	.02	.00	.00	.00	.45	.59
CAL YR 1997		TOTAL 743.19		MEAN 2.04		MAX 43		MIN .00	CFSM .86		IN. 11.67	

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Discharge for West Branch near Winterpock, Va., station number 02041890												
1	3.4	3.0	14	1.7	6.1	.28	.00	.00	.00	.00	.05	2.7
2	3.0	2.3	8.7	1.2	3.8	.12	.00	.00	.00	.00	.05	.85
3	2.9	2.0	26	1.1	6.1	.51	.00	.00	.00	.00	.03	.57
4	2.2	2.0	15	1.0	3.6	.16	.00	.00	.00	.00	.03	.86
5	2.0	2.8	9.9	1.0	2.3	.05	.00	.00	.00	.00	.03	.53
6	1.7	2.0	12	1.3	1.8	.05	.00	.00	.00	.00	.03	.32
7	1.4	1.7	5.8	1.5	1.1	.04	.00	.00	.00	.00	13	.29
8	1.2	6.6	4.3	1.1	1.1	.03	.00	.00	.00	.00	1.9	.29
9	9.2	5.5	3.5	.85	1.1	.03	.02	.00	.54	.00	3.0	.29
10	8.3	3.9	3.2	.68	.99	.01	1.0	.00	.66	.00	.40	1.4
11	5.1	3.0	2.8	.66	.71	.01	.01	.00	.19	.00	.18	.77
12	3.3	2.5	2.2	2.0	.80	.02	.01	.00	.00	.00	.16	.41
13	2.6	2.0	1.9	2.3	.54	.01	.01	.00	.00	.00	.40	.30
14	2.2	12	6.5	1.2	.48	.01	.01	.00	.00	.94	4.1	.24
15	2.0	26	5.0	.97	.68	.01	.01	.00	.00	1.3	.54	.23
16	9.9	9.9	3.0	.82	.47	.01	.01	.00	.00	.03	.20	.23
17	4.7	5.9	2.4	1.2	.40	.00	.00	.00	.00	.04	.16	.23
18	3.4	4.3	2.6	1.1	.35	.00	.00	.00	.00	.05	.16	.23
19	2.5	3.6	12	.78	.29	.00	.00	.00	.00	.43	.16	.23
20	2.7	3.0	8.2	.67	.24	.00	.00	.00	.00	.03	.16	.23
21	2.5	2.8	5.1	1.1	.15	.00	.00	.00	.00	.03	1.5	.23
22	2.8	4.1	3.9	1.5	.11	.00	.42	.00	.00	.03	27	1.2
23	3.7	2.7	2.9	4.7	.10	.00	.00	.00	.00	.03	2.8	.93
24	2.6	2.1	2.4	7.3	.09	.00	.54	.00	.00	.03	1.2	.59
25	5.2	1.9	2.1	3.4	.54	.00	.00	.00	.00	.03	.69	3.5
26	3.0	1.9	5.7	2.3	.36	.00	.00	.00	.00	1.3	.55	.96
27	2.3	2.6	3.4	3.0	.16	.00	.00	.00	.00	.12	.45	7.1
28	10	28	2.6	36	.14	.00	.00	.00	.00	.03	.34	5.5
29	6.2	---	2.2	52	.22	.00	.00	.00	.00	.03	.32	2.6
30	4.2	---	1.7	11	.11	.00	.00	.00	.00	.03	2.3	2.8
31	3.6	---	3.0	---	.10	---	.00	.00	---	.03	---	1.3
TOTAL	119.8	150.1	184.0	145.43	35.03	1.35	2.04	.00	1.39	4.51	61.89	37.91
MEAN	3.86	5.36	5.94	4.85	1.13	.045	.066	.000	.046	.15	2.06	1.22
MAX	10	28	26	52	6.1	.51	1.0	.00	.66	1.3	27	7.1
MIN	1.2	1.7	1.7	.66	.09	.00	.00	.00	.00	.00	.03	.23
CFSM	1.41	1.95	2.16	1.76	.41	.02	.02	.00	.02	.05	.75	.44
IN.	1.62	2.03	2.49	1.97	.47	.02	.03	.00	.02	.06	.84	.51

Appendix 1. Daily mean discharges (in cubic feet per second) for selected sites in the Swift Creek Basin, Virginia, 1997—Continued

[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
					Discharge for Swift Creek Reservoir at dam, station number 02041900							
1	55	100	563	79	233	.00	.00	.00	.00	.00	.00	.00
2	50	86	319	63	133	.00	.00	.00	.00	.00	.00	.00
3	47	75	357	57	119	.00	.00	.00	.00	.00	.00	.00
4	43	70	559	54	110	.00	.00	.00	.00	.00	.00	.00
5	40	79	312	55	76	.00	.00	.00	.00	.00	.00	.00
6	37	76	295	59	63	.00	.00	.00	.00	.00	.00	.00
7	34	72	200	66	48	.00	.00	.00	.00	.00	.00	.00
8	29	95	152	57	41	.00	.00	.00	.00	.00	.00	.00
9	52	141	116	49	41	.00	.00	.00	.00	.00	.00	.00
10	116	136	106	40	40	.00	.00	.00	.00	.00	.00	.00
11	111	113	98	38	29	.00	.00	.00	.00	.00	.00	.00
12	79	97	80	49	25	.00	.00	.00	.00	.00	.00	.00
13	60	82	73	80	22	.00	.00	.00	.00	.00	.00	.00
14	51	147	100	67	18	.00	.00	.00	.00	.00	.00	.00
15	44	442	155	58	20	.00	.00	.00	.00	.00	.00	.00
16	86	392	122	52	13	.00	.00	.00	.00	.00	.00	.00
17	109	219	97	55	5.2	.00	.00	.00	.00	.00	.00	.00
18	109	148	91	63	.00	.00	.00	.00	.00	.00	.00	.00
19	94	118	147	46	.00	.00	.00	.00	.00	.00	.00	.00
20	76	99	243	41	.00	.00	.00	.00	.00	.00	.00	.00
21	69	88	192	44	.00	.00	.00	.00	.00	.00	.00	.00
22	69	112	152	53	.00	.00	.00	.00	.00	.00	.00	.00
23	85	97	106	76	.00	.00	.00	.00	.00	.00	.00	.00
24	83	81	93	144	.00	.00	.00	.00	.00	.00	.00	.00
25	94	69	83	136	.00	.00	.00	.00	.00	.00	.00	.00
26	93	67	118	104	.00	.00	.00	.00	.00	.00	.00	.00
27	79	75	139	91	.00	.00	.00	.00	.00	.00	.00	.00
28	119	298	119	737	.00	.00	.00	.00	.00	.00	.00	.00
29	183	---	109	1180	.00	.00	.00	.00	.00	.00	.00	.00
30	142	---	85	484	.00	.00	.00	.00	.00	.00	.00	.00
31	114	---	112	---	.00	---	.00	.00	---	.00	---	.00
TOTAL	2,452	3,674	5,493	4,177	1,036.20	.00	.00	.00	.00	.00	.00	.00
MEAN	79.1	131	177	139	33.4	.000	.000	.000	.000	.000	.000	.000
MAX	183	442	563	1180	233	.00	.00	.00	.00	.00	.00	.00
MIN	29	67	73	38	.00	.00	.00	.00	.00	.00	.00	.00
CFSM	1.23	2.04	2.75	2.16	.52	.00	.00	.00	.00	.00	.00	.00
IN.	1.42	2.12	3.17	2.41	.60	.00	.00	.00	.00	.00	.00	.00
CAL YR 1997		TOTAL 16,832.20		MEAN 46.1		MAX 1,180		MIN .00	CFSM .72		IN. 9.72	

Appendix 2. Daily withdrawals (in cubic feet per second) at Swift Creek Water Treatment Plant, Virginia, 1997

[MAX, maximum; MIN, minimum]

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	11	10	12	12	12	14	14	14	15	10	11	11
2	11	11	11	12	15	13	14	15	13	11	10	11
3	12	11	11	12	11	12	17	16	11	11	10	11
4	11	10	11	12	12	13	19	16	11	11	10	11
5	12	10	11	12	12	13	17	13	11	15	9.6	11
6	11	11	10	12	12	13	19	13	14	15	11	11
7	11	8.6	11	14	13	14	18	15	18	13	10	11
8	10	11	11	15	14	14	19	12	18	14	11	11
9	11	6.9	12	15	12	16	18	14	12	15	9.7	11
10	11	9.9	9.6	15	13	16	14	14	11	14	11	11
11	12	10	10	12	14	18	15	15	9.2	16	11	11
12	12	10	11	12	14	16	17	15	10	16	8.9	11
13	12	11	9.8	13	13	15	17	14	10	14	10	11
14	9.9	11	8.9	14	16	14	18	12	11	11	11	9.9
15	11	11	9.1	15	13	16	19	15	11	11	11	11
16	10	12	9.2	15	14	18	19	18	10	9.5	10	10
17	12	11	9.3	14	15	17	16	18	9.9	11	10	11
18	11	11	9.1	14	16	16	19	13	10	10	11	11
19	11	10	9.0	14	17	17	19	10	11	10	11	12
20	11	11	9.0	14	16	18	18	9.8	11	11	11	11
21	12	11	9.1	14	17	18	17	10	13	11	11	10
22	11	10	9.1	14	17	19	14	10	11	11	11	11
23	11	12	9.1	11	18	19	12	10	11	11	11	11
24	10	11	9.0	11	17	17	11	10	10	11	11	11
25	11	11	9.0	11	15	18	12	11	9.8	11	11	11
26	11	12	9.1	11	14	17	13	11	11	11	11	10
27	12	11	8.9	13	12	13	13	12	11	11	11	9.8
28	10	10	9.0	11	14	16	15	13	10	11	10	9.9
29	11	---	9.0	12	14	17	13	17	10	11	11	11
30	11	---	9.1	12	16	18	15	16	9.6	10	11	11
31	10	---	8.8	---	16	---	16	15	---	11	---	11
TOTAL	342.9	295.4	303.2	388	444	475	497	416.8	343.5	368.5	317.2	335.6
MEAN	11.1	10.6	9.78	12.9	14.3	15.8	16.0	13.4	11.4	11.9	10.6	10.8
CAL YR 1997		TOTAL 4,527.1		MEAN 12.4		MAX 19.1		MIN 6.9				

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