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Selected Streamflow Statistics for Streamgaging Stations in Northeastern Maryland, 2006

Open-File Report 2006–1335

U.S. Department of the Interior
U.S. Geological Survey

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U.S. Geological Survey

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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Selected Streamflow Statistics for Streamgaging Stations in Northeastern Maryland, 2006

By Kernell G. Ries III

Abstract

Streamflow statistics were calculated for 47 U.S. Geological Survey (USGS) streamgaging stations in northeastern Maryland, in cooperation with (1) the University of Maryland, Baltimore County, Center for Urban Environmental Research and Education; (2) the Baltimore City Department of Public Works; and (3) the Baltimore County Department of Environmental Protection and Resource Management. The statistics include the mean, minimum, maximum, and standard deviation of the daily mean discharges for the periods of record at the stations, as well as flow-duration and low-flow frequency statistics. The flow-duration statistics include the 1-, 2-, 5-, 10-, 15-, 20-, 25-, 30-, 40-, 50-, 60-, 70-, 75-, 80-, 85-, 90-, 95-, 98-, and 99-percent duration discharges. The low-flow frequency statistics include the average discharges for 1, 7, 14, and 30 days that recur, on average, once in 1.01, 2, 5, 10, 20, 50, and 100 years. The statistics were computed only for the 25 stations with periods of record of 10 years or more. The statistics were computed from records available through September 30, 2004 using standard methods and computer software developed by the USGS.

A comparison between low-flow frequency statistics computed for this study and for a previous study that used data available through September 30, 1989 was done for seven stations. The comparison indicated that, for the 7-day mean low flow, the newer values were 19.8 and 15.3 percent lower for the 20- and 10-year recurrence intervals, respectively, and 2.1 percent higher for the 2-year recurrence interval, than the older values. For the 14-day mean low flow, the newer 20- and 10-year values were 25.2 and 15.5 percent lower, respectively, and the 2-year value was 2.9 percent higher than the older values. For the 30-day mean low flow, the newer 20-, 10-, and 2-year values were 10.8, 7.9, and 0.8 percent lower, respectively, than the older values. The newer values are generally lower than the older ones most likely because two major droughts have occurred since the older study was completed.

Introduction

Engineers, planners, land managers, biologists, and many others use streamflow statistics on a routine basis to help guide decision-making. Some uses of streamflow statistics include (1) flood-plain mapping for insurance underwriting and zoning, (2) bridge, culvert, and road design, (3) setting of water-quality standards, (4) water-supply planning and management, (5) wastewater-discharge permitting, and (6) protection of stream biota.

Streamflow statistics are computed for USGS streamgaging stations using the time series of discharge developed for the stations. Although the statistics are computed from actual data, they are considered estimates when they are used to represent long-term and future conditions for planning, management, and engineering purposes. This is because the statistics change over time as more data become available for use in the computations, and as extreme events influence the statistics. As a result, streamflow statistics for streamgaging stations should be updated periodically to reflect the longer record lengths available for the stations.

Low-flow and peak-flow statistics for streamgaging stations in Maryland were published previously in separate reports. Low-flow statistics for Maryland were last published by Carpenter and Hayes (1996). The statistics they published included the average 7-, 14-, and 30-consecutive-day low-flow discharges for recurrence intervals of 2, 10, and 20 years. Peak-flow statistics for Maryland were last published by Dillow (1996). The statistics published included the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence interval flood discharges.

The purposes of this report are to (1) provide updated streamflow statistics for 47 streamgaging stations in northeastern Maryland, (2) describe the methods used to determine the statistics, and (3) compare the low-flow frequency statistics provided in this report with those published previously by Carpenter and Hayes (1996). The statistics presented in this report include the mean, minimum, maximum, and standard deviation of the daily mean discharges for the periods of record at the stations, as well as flow-duration and low-flow frequency statistics. The flow-duration statistics give the percentage of time that flows are equaled or exceeded, and include the 1-, 2-, 5-, 10-, 15-, 20-, 25-, 30-, 40-, 50-, 60-, 70-, 75-, 80-, 85-, 90-, 95-, 98-, and 99-percent duration discharges. The low-flow frequency statistics include the average discharges for 1, 7, 14, and 30 days that recur, on average, once in 1.01, 2, 5, 10, 20, 50, and 100 years. This report and the analyses described in it were done in cooperation with (1) the University of Maryland, Baltimore County, Center for Urban Environmental Research and Education; (2) the Baltimore City Department of Public Works; and (3) the Baltimore County Department of Environmental Protection and Resource Management. The statistics provided in this report were selected to indicate the range of streamflows occurring at the stations and to provide information that would be useful for water-supply planning and protection of water quality.

Physical Setting

The State of Maryland is in the Mid-Atlantic coastal region of the United States. The study area consists of all of Baltimore City, Baltimore and Harford Counties, and the eastern part of Carroll County that drains into Baltimore County. The area is bordered on the north by the State of Pennsylvania, on the west by the western part of Carroll County, on the southwest by Howard County, on the south by Anne Arundel County, on the southeast by the Chesapeake Bay, and on the northeast by Cecil County (fig. 1). Baltimore City has a land area of 81 mi^2 (square miles) and the population was about 629,000 in 2003. Baltimore County has a land area of 599 mi^2 and the population was about 777,000 in 2003. Harford County has a land area of 440 mi^2 and the population was about 232,000 in 2003. Carroll County has a land area of 449 mi^2 and the population was about 163,000 in 2003 (FedStats, 2006).

The climate in the study area is temperate. Mean annual precipitation ranges from about 40 to 44 inches (Carpenter and Hayes, 1996). The precipitation is distributed fairly evenly throughout the year. The mean annual temperature at Baltimore is 55°F (degrees Fahrenheit), with monthly averages ranging from 32°F in January to 77°F in July (National Oceanographic and Atmospheric Administration, 2005).

The study area is in two major physiographic provinces, the Coastal Plain and the Piedmont (Fenneman, 1938). The provinces are separated by the Fall Line, which crosses diagonally from the northeast corner of Maryland, through Baltimore (fig. 1), and beyond. The Fall Line, along which numerous waterfalls occur, delineates the relatively sudden drop in elevation from the Piedmont to the Coastal Plain. The Piedmont, northwest of the Fall Line, consists of gently rolling landscape with maximum elevations generally less than 400 ft (feet) above sea level. Streams in this province have fairly steep gradients, and drain to the Chesapeake Bay (Dillow, 1996). The Coastal Plain, southeast of the Fall Line, consists of an area of low relief adjacent to the Chesapeake Bay, with elevations ranging from sea level to less than 100 ft. Streams in the Coastal Plain are often affected by tides for a substantial distance above their mouths. About 10 of the station locations are in the Coastal Plain, but most of the drainage areas for these stations are primarily in the Piedmont, and there are no apparent tidal effects.

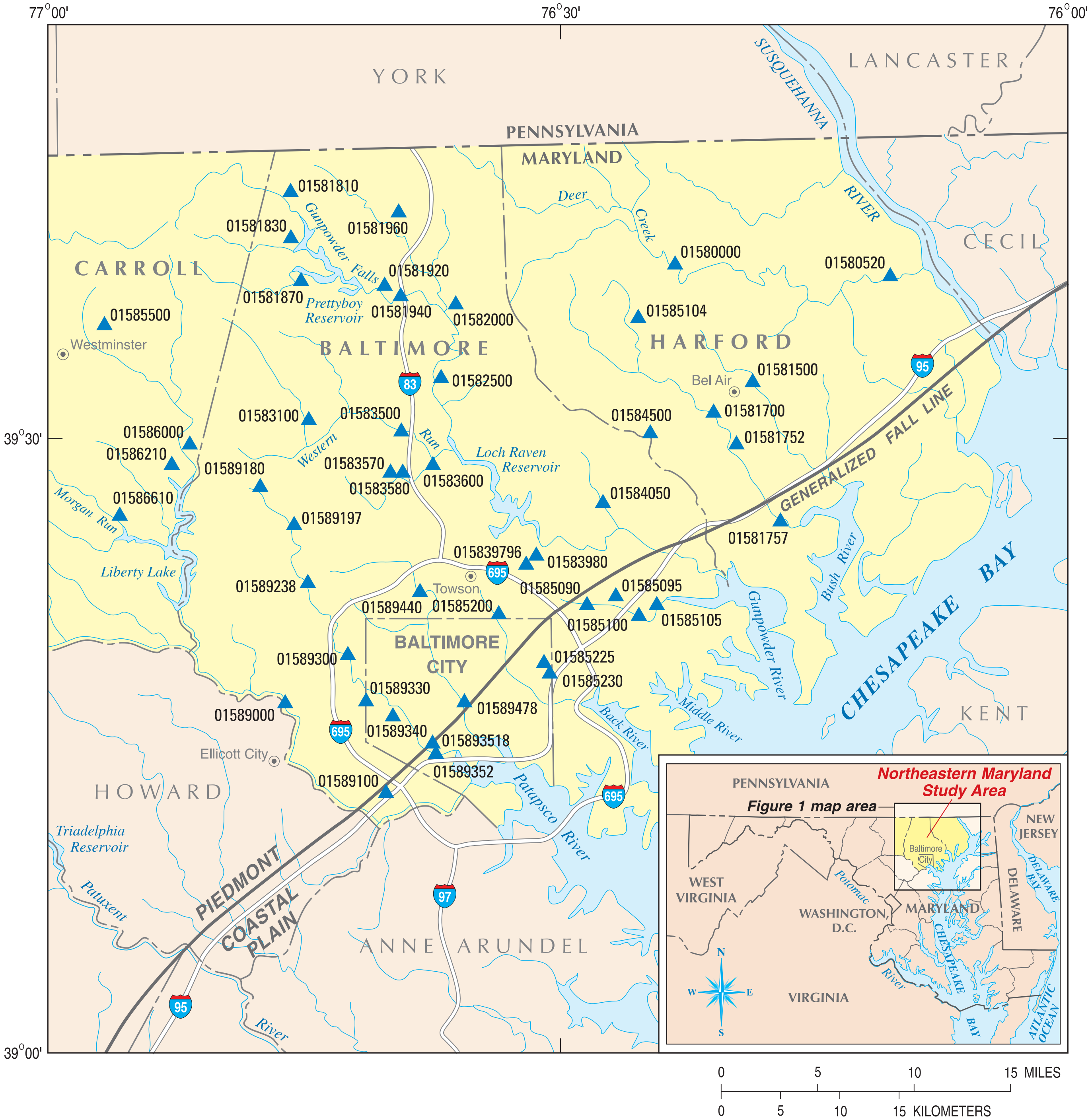
Computation of Statistics

The low-flow frequency statistics presented in the report by Carpenter and Hayes (1996) were based on data through the 1989 water year. A water year begins on October 1 of the previous year and ends on September 30 of the given year. The 47 stations (fig. 1) selected for inclusion in this study were either active streamgaging stations at the end of the 2004 water year (46 stations), or they were discontinued but had additional data since the previous report was released (station 01585105). Periods of record for the stations ranged from 2 to 78 years, with an average record length of 21 years. Daily mean discharges needed to compute the statistics were downloaded from the USGS NWIS-Web database. Surface-water data for the Nation can be accessed through NWIS-Web at *http://waterdata.usgs.gov/nwis/sw*.

Descriptive information for the streamgaging stations included in this study is presented in table 1. The information provided for each station includes station name, identification number, latitude, longitude, the city or county in which the station is located, drainage area, and remarks. As noted in the remarks, seven of the stations are affected to some extent by regulations, diversions, or both. As a result, the streamflow statistics computed for the affected stations do not reflect natural conditions. No attempt was made to adjust the streamflow records for the regulation patterns or to limit the periods of record for the analyses to unregulated periods.

Computer programs used to calculate the statistics were developed by the USGS, and can be downloaded from the web at no cost. The programs included ANNIE, which was used for binary database management; IOWDM, which was used for input and output of data to the database; and SWSTAT, which was used to compute the statistics presented in this report. The ANNIE program and accompanying documentation can be downloaded at *http://water.usgs.gov/software/annie.html*. The IOWDM program and accompanying documentation can be downloaded at *http://water.usgs.gov/software/iowdm.html*. The SWSTAT program and documentation for it can be downloaded at *http://water.usgs.gov/software/swstat.html*.

The SWSTAT program incorporates standard USGS methods for computing flow-duration and low-flow frequency statistics. Standard methods for computing flow-duration statistics were described in Searcy (1959). Standard methods for computing low-flow frequency statistics were described in Riggs (1972).



EXPLANATION

NORTHEASTERN MARYLAND STUDY AREA

01589100 LOCATION OF STREAMGAGING STATION AND U.S. GEOLOGICAL SURVEY IDENTIFICATION NUMBER

Figure 1. Locations of streamgaging stations in northeastern Maryland (including Baltimore City, Baltimore and Harford Counties, and a part of Carroll County).

Table 1. Summary of streamgaging stations in northeastern Maryland for which streamflow statistics were computed.

[Datum of latitude and longitude is North American Datum of 1983; drainage area is in square miles]

Station number	Name	Latitude	Longitude	Location	Drainage area	Remarks
01580000	Deer Creek at Rocks, MD	39.62997	-76.40331	Harford County	94.4	Low-flow regulation prior to 1965.
01580520	Deer Creek near Darlington, MD	39.61744	-76.19186	Harford County	168	
01581500	Bynum Run at Bel Air, MD	39.54147	-76.33011	Harford County	8.52	
01581700	Winters Run near Benson, MD	39.51994	-76.36914	Harford County	34.8	
01581752	Plumtree Run near Bel Air, MD	39.49650	-76.34746	Harford County	2.50	
01581757	Otter Point Creek near Edgewood, MD	39.43928	-76.30603	Harford County	55.6	
01581810	Gunpowder Falls at Hoffmanville, MD	39.68981	-76.78147	Baltimore County	27.0	
01581830	Grave Run near Beckleysville, MD	39.65481	-76.78092	Baltimore County	7.68	
01581870	Georges Run near Beckleysville, MD	39.62589	-76.77253	Baltimore County	15.8	
01581920	Gunpowder Falls near Parkton, MD	39.61889	-76.69031	Baltimore County	81.5	Upstream diversions and regulation.
01581940	Mingo Branch near Hereford, MD	39.61125	-76.67522	Baltimore County	0.78	Slight diurnal fluctuation at low flow.
01581960	Beetree Run at Bentley Springs, MD	39.67308	-76.67519	Baltimore County	9.72	
01582000	Little Falls at Blue Mount, MD	39.60408	-76.62047	Baltimore County	52.9	
01582500	Gunpowder Falls at Glencoe, MD	39.54969	-76.63611	Baltimore County	160	Upstream diversions and regulation.
01583100	Piney Run at Dover, MD	39.52061	-76.76689	Baltimore County	12.3	
01583500	Western Run at Western Run, MD	39.51078	-76.67650	Baltimore County	59.8	
01583570	Pond Branch at Oregon Ridge, MD	39.48031	-76.68750	Baltimore County	0.12	
01583580	Baisman Run at Broadmoor, MD	39.47947	-76.67803	Baltimore County	1.47	
01583600	Beaverdam Run at Cockeysville, MD	39.48558	-76.64572	Baltimore County	20.9	
0158397967	Minebank Run at Glen Arm, MD	39.41011	-76.55608	Baltimore County	2.06	
01583980	Minebank Run at Loch Raven, MD	39.41667	-76.54631	Baltimore County	2.90	
01584050	Long Green Creek at Glen Arm, MD	39.45469	-76.47889	Baltimore County	9.40	
01584500	Little Gunpowder Falls at Laurel Brook, MD	39.50536	-76.43178	Baltimore County	36.1	
01585090	Whitemarsh Run near Fullerton, MD	39.37958	-76.49581	Baltimore County	2.73	
01585095	North Fork Whitemarsh Run near White Marsh, MD	39.38589	-76.46886	Baltimore County	1.34	

Table 1. Summary of streamgaging stations in northeastern Maryland for which streamflow statistics were computed.—Continued

[Datum of latitude and longitude is North American Datum of 1983; drainage area is in square miles]

Station number	Name	Latitude	Longitude	Location	Drainage area	Remarks
01585100	Whitemarsh Run at White Marsh, MD	39.37053	-76.44592	Baltimore County	7.61	Low-flow affected by sand and gravel plant.
01585104	Honeygo Run near White Marsh, MD	39.59111	-76.44083	Baltimore County	2.5	
01585105	Honeygo Run at White Marsh, MD	39.37816	-76.42913	Baltimore County	2.65	
01585200	West Branch Herring Run at Idlewylde, MD	39.37364	-76.58433	Baltimore County	2.13	
01585225	Moores Run Tributary near Todd Avenue at Baltimore, MD	39.33669	-76.54061	Baltimore City	0.21	
01585230	Moores Run Tributary at Radeke Avenue at Baltimore, MD	39.33008	-76.53489	Baltimore City	3.52	
01585500	Cranberry Branch near Westminster, MD	39.59333	-76.96753	Carroll County	3.29	
01586000	North Branch Patapsco River at Cedarhurst, MD	39.50367	-76.88486	Carroll County	56.6	Numerous regulations and diversions.
01586210	Beaver Run near Finksburg, MD	39.48944	-76.90294	Carroll County	14.0	
01586610	Morgan Run near Louisville, MD	39.45189	-76.95531	Carroll County	28.0	
01589000	Patapsco River at Holofield, MD	39.31031	-76.79242	Baltimore County	285	
01589100	East Branch Herbert Run at Arbutus, MD	39.24000	-76.69219	Baltimore County	2.47	
01589180	Gwynns Falls at Glyndon, MD	39.47169	-76.81689	Baltimore County	0.32	
01589197	Gwynns Falls near Delight, MD	39.44294	-76.78342	Baltimore County	4.23	
01589238	Gwynns Falls Tributary at McDonogh, MD	39.40044	-76.77044	Baltimore County	0.03	
01589300	Gwynns Falls at Villa Nova, MD	39.34589	-76.73319	Baltimore County	32.5	Slight regulations and diversions.
01589330	Dead Run at Franklintown, MD	39.31122	-76.71664	Baltimore County	5.52	Occasional low-flow regulation.
01589340	Rognel Heights Storm Sewer Outfall at Baltimore, MD	39.29986	-76.69014	Baltimore County	0.03	
0158935180	Gwynns Run at Baltimore, MD	39.27825	-76.65169	Baltimore City	2.50	
01589352	Gwynns Falls at Washington Boulevard at Baltimore, MD	39.27150	-76.64856	Baltimore City	65.9	
01589440	Jones Falls at Sorrento, MD	39.39172	-76.66094	Baltimore County	25.2	
01589478	Jones Falls at Maryland Avenue at Baltimore, MD	39.30931	-76.61942	Baltimore City	58.3	

Descriptive statistics, including means, minimums, maximums, and standard deviations, were computed from all available daily flow records for the stations, including incomplete water years. The mean streamflow is indicative of long-term normal conditions. The minimum and maximum streamflows are the extremes of daily streamflows during the period of record. The standard deviation is indicative of the variability of streamflows, as about two-thirds of all daily streamflows are within plus and minus one standard deviation value from the mean streamflow. The descriptive statistics are presented in table 2, along with the beginning and ending dates of available data and the number of days from which the statistics were calculated.

Flow-duration statistics indicate the percentage of time that daily mean streamflows are equaled or exceeded at the stations. For example, if the streamflow at the 90-percent duration is given for a station as 5 ft^3/s (cubic feet per second), then the streamflow at that station was greater than or equal to 5 ft^3/s 90 percent of the time during the period of record analyzed. The flow-duration statistics are presented in table 3, and were computed using data for only complete water years.

Low-flow frequency statistics indicate the magnitude and frequency of the occurrence of low streamflows at the streamgaging stations, and are useful for a variety of planning and design purposes. Low-flow frequency analyses were only done for the 25 stations in the study area with at least 10 complete climatic years of record. Use of climatic years, which begin on April 1 of the given year and end on March 31 of the following year, is standard practice for low-flow frequency analysis because low-flow periods occur most often in the summer and fall. Use of climatic years makes it highly unlikely that the lowest low-flow period in a given year will be split between 2 consecutive climatic years, as could sometimes happen if water years were used for this type of analysis.

Low-flow frequency statistics were computed for the 25 stations from annual series of minimum n-day mean flows, where n = 1, 7, 14, and 30 days. For example, computing the annual series of minimum 7-day mean flows for a streamgaging station requires identifying the 7-day period during each climatic year with the lowest mean flow. Mann-Kendall nonparametric tests for monotonic trends in the annual 7-day low-flow series were done to determine if changes (increases or decreases) in the annual series were occurring over time (Helsel and Hirsch, 1992). No statistically significant trends were found.

The standard USGS method incorporated into SWSTAT for computing low-flow frequency statistics for a streamgaging station is to fit the logarithms of the annual n-day streamflows for the station to a log-Pearson, Type III frequency distribution to determine recurrence intervals (1.01, 2, 5, 10, 20, 50, and 100 years) for the n-day streamflows. The streamflows equal to or less than those given for a specific recurrence interval can be expected to occur, on average, once during the time interval. For instance, the 7-day, 2- and 10-year recurrence interval flows were computed from annual series of minimum 7-day average flows. Flows equal to or less than the 7-day, 2-year flow occur on average once every 2 years, whereas flows equal to or less than the 7-day, 10-year flow occur on average once every 10 years. These flows have a 50 percent [(1 year/2 years) × 100] and 10 percent [(1 year/10 years) × 100] chance of not being exceeded in any given year, respectively. The 1.01-year recurrence interval is given because it corresponds with the 99-percent chance of occurrence in any given year. The low-flow frequency statistics are presented in table 4.

The 7-day low-flow statistics are not available for West Branch Herring Run at Idlewylde, MD, station 01585200, because the computed skew of the logarithms of the annual 7-day minimum flows was -3.73. The SWSTAT program does not compute low-flow frequencies when skew values exceed the absolute value of 3.3. The large negative skew at this station was caused primarily by the 2003 7-day low-flow value, which was only 0.001 ft^3/s. On a logarithmic scale, the 2003 value was more than an order of magnitude lower than the other values in the time series.

There is the potential that low-flow frequency statistics and improved flow-duration statistics could be estimated for many of the stations for which low-flow frequency statistics were not provided in this report because of record lengths that are less than 10 years. Correlations developed between the daily flows or n-day low flows at the short-term stations and those for nearby long-term stations could be used as a basis for extending or augmenting the records for the short-term stations, enabling estimation of streamflow statistics that represent a longer-term period. Correlations such as these, however, were beyond the scope of this study.

Table 2. Descriptive statistics of the mean daily discharges for the period of record for streamgaging stations in northeastern Maryland.

[Mean, minimum, maximum, and standard deviation are in units of cubic feet per second]

Station number	Mean	Minimum	Maximum	Standard deviation	Begin date	End date	Number of days
01580000	126	4.0	6,610	148	10/1/1926	9/30/2004	28,490
01580520	213	6.3	2,480	216	10/1/1999	9/30/2004	1,735
01581500	11.2	0.01	2,320	35.4	10/1/1943	9/30/2004	10,020
01581700	52.5	.38	3,000	78.0	8/1/1967	9/30/2004	13,576
01581752	4.49	.07	101	9.12	10/1/2001	9/30/2004	1,096
01581757	79.4	.27	1,760	136	1/1/2000	9/30/2005	2,058
01581810	34.9	2.0	536	38.1	5/1/2000	9/30/2004	1,614
01581830	10.3	.54	130	9.52	3/25/2000	9/30/2004	1,651
01581870	21.4	.95	353	25.4	3/25/2000	9/30/2004	1,651
01581920	107	12	1,000	87.6	7/17/2000	9/30/2004	1,535
01581940	0.99	0	28	1.21	10/1/1999	9/30/2004	1,827
01581960	13.7	1.1	290	16.0	10/1/1999	9/30/2004	1,827
01582000	68.9	4.5	4,730	77.7	7/1/1944	9/30/2004	22,007
01582500	207	31	4,500	187	10/1/1977	9/30/2004	8,943
01583100	14.6	.96	599	17.5	5/9/1982	9/30/2004	5,044
01583500	69.4	2.5	7,000	95.5	9/1/1944	9/30/2004	21,945
01583570	0.14	0	1.8	0.11	1/1/1983	9/30/2004	3,729
01583580	1.29	0	41	1.41	8/1/1964	9/30/2004	3,714
01583600	30.3	3.0	903	39.6	10/1/1982	9/30/2004	8,036
0158397967	3.25	.04	61	6.21	10/1/2001	9/30/2004	1,096
01583980	3.51	.13	150	6.59	10/1/1996	9/30/2004	2,922
01584050	11.3	.76	408	16.6	10/1/1975	9/30/2004	10,593
01584500	44.5	.90	2,800	65.9	11/1/1926	9/30/2004	18,232
01585090	5.16	0	418	15.2	1/1/1995	9/30/2004	3,561
01585095	2.22	0	140	5.95	4/17/1992	9/30/2004	4,545
01585100	12.3	.10	980	34.8	2/1/1959	9/30/2004	15,791
01585104	3.42	.02	74	6.90	10/1/1999	9/30/2004	1,827
01585105	3.84	.19	130	9.26	8/1/1990	9/30/1993	1,157
01585200	2.64	0	137	5.63	7/1/1957	9/30/2004	13,757
01585225	0.22	0	13	0.56	7/25/1996	9/30/2004	2,990

Table 2. Descriptive statistics of the mean daily discharges for the period of record for streamgaging stations in northeastern Maryland.—Continued

[Mean, minimum, maximum, and standard deviation are in units of cubic feet per second]

Station number	Mean	Minimum	Maximum	Standard deviation	Begin date	End date	Number of days
01585230	4.19	.17	310	12.7	7/17/1996	9/30/2004	2,992
01585500	3.27	.01	440	6.58	10/1/1949	9/30/2004	20,089
01586000	64.9	.83	6,000	102	9/17/1945	9/30/2004	21,553
01586210	16.6	.27	528	20.4	10/1/1982	9/30/2004	8,036
01586610	34.7	.73	1370	49.1	10/1/1982	9/30/2004	8,036
01589000	196	5.9	30,000	407	5/17/1944	9/30/2004	19,694
01589100	3.34	.21	200	7.97	8/1/1957	9/30/2004	13,941
01589180	0.33	0	20	1.02	10/1/1998	9/30/2004	2,192
01589197	5.04	.25	161	10.4	10/1/1998	9/30/2004	2,192
01589238	0.03	0	0.9	0.05	10/1/1999	9/30/2004	1,827
01589300	40.1	1.7	5,000	89.4	2/1/1957	9/30/2004	14,487
01589330	8.03	.17	800	25.2	10/1/1959	9/30/2004	12,503
01589340	0.03	0	4.7	0.13	10/1/1998	9/30/2004	2,192
0158935180	8.81	.85	230	13.7	10/1/2001	9/30/2004	1,096
01589352	91.4	8.7	3,520	180	10/1/1998	9/30/2004	2,192
01589440	31.7	1.4	2,600	53.5	4/1/1966	9/30/2004	11,141
01589478	76.0	7.8	1,970	132	5/1/1981	9/30/2004	2,258

Table 3. Flow-duration statistics for streamgaging stations in northeastern Maryland.

Station number	Discharge, in cubic feet per second, exceeded given percentage of the time																		
	99	98	95	90	85	80	75	70	60	50	40	30	25	20	15	10	5	2	1
01580000	25.2	28.9	35.6	43.7	50.9	57.1	62.9	68.7	81.5	96.2	111	134	145	165	191	217	299	489	724
01580520	14.6	20.3	36.3	56.4	67.1	77.9	89.7	101	133	169	205	249	273	298	341	403	558	815	1187
01581500	0.51	0.66	1.13	1.62	2.02	2.41	2.79	3.17	4.10	5.16	6.32	8.08	9.05	11.2	14.3	20.4	37.6	76.7	127
01581649	2.36	2.44	2.70	3.12	3.59	4.09	4.58	5.49	7.11	8.39	10.1	12.8	15.0	17.3	20.3	24.9	36.8	132	238
01581700	7.50	9.28	12.5	15.8	18.4	21.0	23.8	26.6	29.4	37.9	45.2	53.9	59.5	65.2	76.0	89.1	133	228	334
01581752	.14	.20	0.29	0.48	0.68	0.87	1.05	1.27	1.75	2.30	2.83	3.44	3.95	4.46	5.78	8.45	18.3	34.7	49.7
01581757	3.82	5.81	10.5	14.3	17.4	20.7	24.4	28.5	38.7	50.2	62.6	75.2	85.8	97.1	108	139	238	481	778
01581810	2.38	3.46	6.46	9.50	11.0	12.6	14.5	16.5	21.4	27.3	33.5	40.4	44.8	49.2	54.9	67.5	92.0	141	195
01581830	.85	1.41	2.44	3.27	3.76	4.24	4.77	5.49	6.99	8.74	10.5	12.2	13.2	15.1	17.0	18.9	25.4	36.4	48.1
01581870	1.86	2.88	4.50	6.27	7.46	8.53	9.69	11.1	14.0	17.0	20.2	23.8	25.6	28.1	32.8	37.5	52.3	88.9	126
01581920	13.5	14.1	15.8	18.8	29.5	38.0	44.5	51.0	71.0	90.6	110	137	150	171	191	211	265	331	428
01581940	.02	.04	.09	.19	.25	.30	0.35	0.41	0.57	0.78	1.05	1.31	1.44	1.57	1.80	2.06	2.41	3.18	4.09
01581960	1.87	2.35	3.70	4.77	5.3	5.83	6.36	7.06	8.72	11.0	13.5	16.0	17.2	18.5	21.1	24.6	31.9	51.2	78.8
01582000	13.8	16.2	20.6	24.8	28.6	31.7	34.9	38.0	45.4	52.7	63.6	74.7	84.0	94.5	105	125	163	245	344
01582500	44.7	52.2	62.8	78.4	89.7	101	112	122	141	167	196	230	256	282	308	377	494	699	860
01583100	2.86	3.47	4.42	5.20	5.89	6.57	7.26	7.96	9.38	11.2	13.2	16.4	18.0	20.1	23.1	26.2	35.0	51.5	77.7
01583500	12.7	14.5	19.1	23.1	27.2	30.6	34.0	37.4	45.0	52.6	63.4	74.4	83.4	93.9	104	124	166	255	357
01583570	0	0	.01	.02	.04	.05	.06	.07	.09	.12	0.14	0.17	0.19	0.22	0.25	0.28	0.36	0.47	0.55
01583580	.05	.10	.27	.42	.48	.54	.60	.67	.79	.99	1.22	1.47	1.59	1.91	2.23	2.73	3.28	4.47	6.17
01583600	5.70	6.79	8.24	10.3	12.2	13.7	14.9	16.2	18.7	22.0	25.4	30.5	34.0	37.4	44.7	52.9	79.7	134	193
0158397967	.03	.07	0.14	.26	.38	.51	.66	.83	1.2.	1.50	1.90	2.43	2.92	3.57	4.85	7.12	14.2	27.1	35.7
01583980	.29	.35	.46	.61	.71	.82	.97	1.13	1.43	1.83	2.36	3.16	3.71	4.35	5.45	7.15	12.3	22.8	32.4
01584050	1.65	2.04	2.61	3.27	3.81	4.34	4.93	5.57	6.86	8.25	9.78	11.8	12.8	14.7	16.7	18.8	26.8	51.8	79.4
01584500	6.71	8.44	12.2	15.2	17.7	20.0	22.1	24.3	28.6	33.2	37.8	45.6	49.6	54.4	64.7	75.0	107	181	270
01585090	.05	.11	.27	.40	.50	.62	.77	.97	1.30	1.59	2.04	2.69	3.15	4.06	5.87	11.1	23.2	47.8	71.4

Table 3. Flow-duration statistics for streamgaging stations in northeastern Maryland.—Continued

Station number	Discharge, in cubic feet per second, exceeded given percentage of the time																		
	99	98	95	90	85	80	75	70	60	50	40	30	25	20	15	10	5	2	1
01585095	.02	.03	.08	.14	.18	.23	.28	.34	.48	.63	.80	1.15	1.45	1.93	2.86	5.08	11.0	21.2	30.2
01585100	.56	.71	1.10	1.47	1.78	2.06	2.35	2.68	3.34	4.22	5.39	6.97	8.38	10.5	14.9	24.1	50.6	105	169
01585104	.03	.06	.14	.28	.42	.57	.71	.85	1.11	1.38	1.73	2.29	2.83	3.56	4.84	7.74	15.7	29.4	40.2
01585105	.22	.26	.32	.40	.53	.68	.84	1.03	1.37	1.73	2.14	2.92	3.48	4.24	5.34	6.98	12.8	31.6	46.6
01585200	.15	.21	.28	.39	.48	.57	.65	.72	.92	1.16	1.47	1.94	2.22	2.76	3.51	5.54	11.0	21.0	28.3
01585225	0	0	.01	.02	.02	.03	.04	.05	.07	.08	.10	.13	.16	.20	.32	.49	1.00	1.96	2.85
01585230	.18	.22	.31	.42	.48	.54	.60	.68	.84	1.08	1.38	1.81	2.17	2.91	4.34	8.52	18.6	43.4	66.9
01585500	.22	.27	.36	.54	.80	1.11	1.31	1.51	1.88	2.24	2.74	3.27	3.75	4.26	5.00	6.17	8.94	15.9	22.7
01586000	10.3	12.7	15.3	19.3	22.2	25.1	28.1	31.3	37.6	45.5	54.0	67.5	74.2	86.0	99.6	119	171	283	407
01586210	2.36	2.72	3.64	4.78	5.56	6.33	7.15	7.98	9.85	12.5	15.4	18.4	20.6	23.4	26.3	32.7	44.5	66.7	92.0
01586610	3.46	4.84	6.84	9.00	10.7	12.4	14.1	15.8	19.4	24.1	29.7	36.9	42.2	48.3	55.9	69.6	97.2	144	203
01589000	18.3	21.7	29.4	39.1	47.5	55.7	63.8	71.8	91.1	113	143	190	216	264	321	414	597	970	1,315
01589100	.36	.42	.51	.63	.72	.82	.97	1.11	1.31	1.51	1.82	2.22	2.60	3.10	4.05	6.17	12.8	25.8	37.4
01589180	0	0	.01	.02	.02	.03	.04	.04	.07	.11	.16	.22	.25	.30	.39	.66	1.30	2.90	4.80
01589197	.58	.76	1.10	1.32	1.55	1.72	1.88	2.03	2.38	2.92	3.52	4.27	4.69	5.47	6.25	8.1	13.8	31.6	55.3
01589238	0	0	.01	.01	.02	.02	.03	.03	.04	005	.06	.07	.08	.08	.09	.09	.10	.14	.23
01589300	4.57	5.48	7.51	9.87	11.6	13.4	14.9	16.4	19.6	23.6	27.9	34.5	37.8	44.7	51.9	70.6	122	238	365
01589330	.32	.40	.52	.68	.82	1.00	1.16	1.31	1.62	2.06	2.63	3.47	4.31	5.8	8.92	16.4	36.2	75.1	113
01589340	0	0	.01	.01	.02	.02	.03	.03	.04	.05	.06	.07	.08	.09	.09	.10	.13	.27	.38
0158935180	.96	1.11	1.58	2.48	2.80	3.13	3.45	3.77	4.41	5.16	5.96	7.08	8.32	10.0	13.6	18.5	30.1	51.9	72.2
01589352	13.3	14.5	18.0	21.8	25.2	28.4	31.6	34.7	41.2	48.1	56.8	70.2	78.4	97.6	124	178	300	588	857
01589440	3.88	5.21	7.24	9.28	10.8	12.3	13.8	15.5	18.7	22.6	26.7	32.8	35.9	40.2	46.7	53.8	76.1	141	217
01589478	9.98	12.3	16.3	20.5	23.2	26.0	28.9	32.0	38.1	45.8	53.8	67.3	74.0	87.8	105	138	219	460	684

Table 4. Low-flow frequency statistics for streamgaging stations in northeastern Maryland.

[Discharges are in units of cubic feet per second]

Station number	Period of record	Number of days	Recurrence interval						
			100	50	20	10	5	2	1.01
01580000	1928–2004	1	7.0	9.4	14.1	19.4	27.0	43.7	74.8
		7	8.6	11.4	16.7	22.5	30.6	48.0	79.0
		14	10.2	13	18.3	23.9	31.9	49.6	90.2
		30	15.3	18.1	22.8	27.8	34.9	51.7	118
01581500	1945–2004	1	0	0	0.1	0.2	0.4	1.2	2.5
		7	0	0.1	.1	.2	.5	1.2	3.5
		14	0.1	.1	.2	.3	.6	1.4	4.4
		30	.4	.5	.6	.8	1.0	1.7	7.7
01581700	1968–2004	1	.6	1.1	2.5	4.6	8.2	16.4	23.9
		7	.9	1.5	3.1	5.4	9.2	17.8	26.4
		14	1.3	2.1	3.8	6.1	9.8	18.4	30.9
		30	3.5	4.4	6.1	8.1	11.0	18.7	52.4
01582000	1945–2004	1	5.3	6.5	8.8	11.2	14.7	22.9	51.2
		7	5.9	7.3	9.8	12.4	16.2	25.1	54.8
		14	6.7	8.1	10.6	13.3	17.2	26.4	61.5
		30	9.2	10.6	13.0	15.5	19.1	28.1	73.8
01582500	1979–2004	1	24.3	27.9	34.1	40.6	50.0	73.3	194
		7	26.2	29.8	36.2	42.8	52.5	77.3	218
		14	29.8	33.3	39.5	46.1	55.7	80.7	241
		30	35.8	39.4	45.8	52.5	62.4	88.5	266
01583100	1983–2004	1	0.6	0.8	1.3	1.8	2.6	4.8	11.6
		7	0.7	1.0	1.5	2.0	2.9	5.0	12.7
		14	0.8	1.1	1.6	2.2	3.1	5.3	13
		30	1.6	1.9	2.4	2.9	3.6	5.6	16.3
01583500	1945–2004	1	3.4	4.6	6.8	9.4	13.3	22.8	49.6
		7	4.4	5.6	7.9	10.6	14.5	24.1	57.1
		14	4.8	6.1	8.6	11.3	15.4	25.4	60.9
		30	6.8	8.1	10.6	13.3	17.2	27.1	73.8
01583570	1984–2004	1	0	0	0	0	0	0	.2
		7	0	0	0	0	0	0	.2
		14	0	0	0	0	0	0	.3
		30	0	0	0	0	0	.1	.2
01583580	1965–2004	1	0	0	0	0	0	.4	1.5
		7	0	0	0	0	0	.4	1.6
		14	0	0	0	0	0	.4	1.3
		30	0	0	0	.1	.1	.4	2.4

Table 4. Low-flow frequency statistics for streamgaging stations in northeastern Maryland.—Continued

[Discharges are in units of cubic feet per second]

Station number	Period of record	Number of days	Recurrence interval						
			100	50	20	10	5	2	1.01
01583600	1984–2004	1	2.9	3.3	4.1	4.9	6.1	9.1	23.9
		7	3.6	4.1	4.9	5.7	7.0	10.1	28.3
		14	4.1	4.6	5.4	6.3	7.5	10.6	29.8
		30	5.6	6.0	6.8	7.5	8.7	12.0	38.8
01584050	1977–2004	1	.7	.9	1.1	1.4	1.9	3.1	10.5
		7	.8	1.0	1.2	1.5	2.0	3.2	11.2
		14	.9	1.1	1.3	1.7	2.1	3.4	11.6
		30	1.1	1.3	1.6	1.9	2.4	3.7	13.9
01584500	1928–2004	1	1.4	2.2	3.8	5.7	8.7	15.2	23.4
		7	1.8	2.6	4.3	6.3	9.4	16.2	25.8
		14	2.2	3.0	4.8	6.9	9.9	16.9	29.6
		30	3.4	4.4	6.2	8.2	11	17.9	39.3
01585095	1993–2004	1	0	0	0	0	0	.1	.5
		7	0	0	0	0	0	.1	.8
		14	0	0	0	0	.1	.1	.8
		30	0	0	.1	.1	.1	.2	1.9
01585100	1960–2099	1	.1	.1	.2	.3	.5	.8	2.1
		7	.2	.3	.4	.5	.6	1.0	3.1
		14	.3	.4	.5	.6	.8	1.3	3.6
		30	.6	.7	.8	1.0	1.2	1.8	6.6
01585200	1958–2004	1	0	0	.1	.1	.1	.2	1.0
		7	Absolute value of skew is greater than 3.3. Estimates not computed.						
		14	.1	.1	.2	.2	.3	.4	1.3
		30	.1	.2	.2	.3	.4	.6	1.6
01585500	1951–2004	1	0	0	.1	.1	.2	.6	1.4
		7	0	0	.1	.2	.3	.8	1.7
		14	.1	.1	.2	.2	.4	.9	2.4
		30	.1	.1	.2	.3	.5	1.0	3.3
01586000	1946–2004	1	1.7	2.6	4.6	7.0	10.7	18.4	26.1
		7	2.9	3.9	5.9	8.2	11.4	18.9	35.3
		14	3.5	4.6	6.6	8.9	12.1	19.8	40.4
		30	6.0	7.1	8.9	10.9	13.8	21.2	58.2
01586210	1984–2004	1	.2	.4	.8	1.2	2.0	4.1	8.3
		7	.4	.5	.9	1.4	2.2	4.5	10.3
		14	.5	.7	1.1	1.7	2.5	4.7	11.7
		30	1.3	1.5	1.9	2.4	3.1	5.0	19.3

Table 4. Low-flow frequency statistics for streamgaging stations in northeastern Maryland.—Continued

[Discharges are in units of cubic feet per second]

Station number	Period of record	Number of days	Recurrence interval						
			100	50	20	10	5	2	1.01
01586610	1984–2004	1	.7	1.0	1.6	2.5	3.9	7.9	21.8
		7	.8	1.2	1.9	2.8	4.2	8.4	26.7
		14	1.0	1.3	2.1	3.0	4.6	8.9	28.0
		30	1.9	2.3	3.1	4.0	5.4	9.5	41.4
01589000	1945–2004	1	5.8	7.3	10.1	13.5	18.9	35.5	174
		7	6.8	8.4	11.7	15.5	21.6	40.3	197
		14	7.9	9.7	13.1	17.2	23.6	43.2	215
		30	10.5	12.5	16.2	20.4	27.3	48.2	261
01589100	1958–2004	1	.2	.2	.3	.3	.4	.5	1.5
		7	.2	.2	.3	.4	.4	.6	1.6
		14	.2	.3	.3	.4	.5	.7	1.9
		30	.3	.4	.4	.5	.6	.9	2.4
01589300	1958–2004	1	1.6	1.9	2.5	3.3	4.3	7.2	22.4
		7	1.7	2.1	2.9	3.7	4.9	8.2	23.4
		14	2.0	2.4	3.2	4.2	5.6	9.2	26.4
		30	3.3	3.8	4.7	5.7	7.1	10.9	35
01589330	1961–2004	1	.1	.1	.2	.2	.3	.5	1.4
		7	.2	.2	.2	.3	.4	.6	1.8
		14	.2	.2	.3	.3	.4	.7	2.6
		30	.2	.3	.3	.5	.6	1.1	3.8
01589440	1967–2004	1	1.4	1.8	2.5	3.3	4.6	7.8	22
		7	1.4	1.8	2.6	3.6	5.0	8.7	23.6
		14	1.5	1.9	2.8	3.8	5.3	9.4	25.8
		30	2.3	2.8	3.7	4.7	6.2	10.3	32.9
01589478	1982–2004	1	3.5	4.2	5.7	7.3	9.9	17.5	75.8
		7	3.5	4.4	6.0	7.9	10.9	19.3	73.2
		14	3.7	4.5	6.2	8.1	11.2	19.9	83.4
		30	11.1	11.5	12.4	13.5	15.6	23.1	196

Comparison With Previously Published Statistics

Two significant droughts have occurred since the data for the previous study were analyzed; one that spanned the 1999 and 2000 climatic years, and another that spanned the 2002 and 2003 climatic years. Seventeen of the stations analyzed for this study have periods of record of 25 years or greater. Of these stations, the 2003 1-day and 7-day low flows were the lowest for the period of record for 10 stations, and the second lowest for 5 of them. The 2003 low flows were substantially lower than any previous low flows at most of the 10 stations. The 2000 1-day and 7-day low flows were the lowest for the period of record for two of the stations.

Low-flow frequency statistics for seven of the stations included in this study were published previously by Carpenter and Hayes (1996). As 15 years of additional data were available to analyze low-flow frequency statistics since the previous study was completed, and as substantial droughts have occurred since that study, it is useful to understand how this new information has affected the low-flow frequency analyses.

The new and previous estimates of the 7-, 14-, and 30-day low flows for the 2-, 10-, and 20-year recurrence intervals for the seven stations, the percentage change in the statistics, and the average percentage change for each of the statistics are presented in table 5. The magnitude of the changes varies substantially among the stations, but the table generally indicates that the effects of the recent droughts on the low-flow frequency estimates increase with increasing recurrence interval. Changes in the 2-year recurrence interval estimates have been small, but the 10- and 20-year estimates have changed substantially at most stations.

The increase in percentage change with increasing recurrence interval can be partly explained by the fact that flow magnitude decreases with increasing recurrence interval. As the flow magnitude decreases, the percentage change for a given change in magnitude increases. For example, a change in flow of 0.1 ft^3/s from a previous flow of 2.0 ft^3/s is only a 5-percent change, whereas a change in flow of 0.1 ft^3/s from a previous flow of 0.2 ft^3/s is a 50-percent change.

The addition of the two recent droughts to the annual low-flow time series probably accounts for most the changes in the low-flow statistics since the previous report. It is possible, however, that the changes are partly due to increased urbanization within the drainage basins for the stations. Some investigators have shown that increased urbanization can lead to decreased low flows in streams (U.S. Environmental Protection Agency, 2006). Much of the study area has been developing rapidly since the previous study was completed. Attempts to quantify the extent of change in urbanization and possible effects on low flows for the stations were beyond the scope of this study. The overall effect of the new computations is that generally there is less flow in the streams of Northeastern Maryland during times of drought than was thought to be available when the previous analysis was completed. As a result, State and local water-resource planners and managers may need to change their water-management plans and policies to accommodate the lower flows.

Summary

This report and the analyses it describes were done in cooperation with (1) the University of Maryland, Baltimore County, Center for Urban Environmental Research and Education; (2) the Baltimore City Department of Public Works; and (3) the Baltimore County Department of Environmental Protection and Resource Management. Means, minimums, maximums, and standard deviations of the mean daily discharges and flow-duration statistics were calculated for 47 streamgaging stations in northeastern Maryland. The flow-duration statistics include the 1-, 2-, 5-, 10-, 20-, 30-, 40-, 50-, 60-, 70-, 80-, 90-, 95-, 98-, and 99-percent duration discharges. Low-flow frequency statistics were computed for 25 of the stations with periods of record of 10 or more years. The low-flow frequency statistics include the average discharges for 1, 7, 14, and 30 days that recur, on average, once in 1.01, 2, 5, 10, 20, 50, and 100 years. The statistics were computed using mean daily discharge data through September 30, 2004 and the U.S. Geological Survey ANNIE, IOWDM, and SWSTAT computer programs. The 7-day low flow annual series were tested for trends and none were found.

A comparison between low-flow frequency statistics computed for this study and for a previous study that used data available through September 30, 1989 was done for seven stations. The comparison indicated that, for the 7-day mean low flow, the newer values were 19.8 and 15.3 percent lower for the 20- and 10-year recurrence intervals, respectively, and 2.1 percent higher for the 2-year recurrence interval, than the older values. For the 14-day mean low flow, the newer 20- and 10- year values were 25.2 and 15.5 percent lower, respectively, and the 2-year value was 2.9 percent higher than the older values. For the 30-day mean low streamflow, the newer 20-, 10-, and 2-year values were 10.8, 7.9, and 0.8 percent lower, respectively, than the older values. The newer values are lower than the older values most likely because of the occurrence of two major droughts since the older values were computed; however, it is also possible that increased urbanization within the drainage basins for the stations may be causing part of the reductions. The lower streamflows during times of drought may require State and local water-resource planners and managers to adjust their water-management plans and policies.

Table 5. Comparison of low-flow frequency statistics computed from data available through climatic years 1989 and 2004 for streamgaging stations in northeastern Maryland with greater than 25 years of record.

[Discharges are in units of cubic feet per second]

Station number	20-year recurrence interval			10-year recurrence interval			2-year recurrence interval		
	2004 estimate	1989 estimate	Percent change	2004 estimate	1989 estimate	Percent change	2004 estimate	1989 estimate	Percent change
7-day low flow									
01580000	16.7	20.5	-18.5	22.5	25.4	-11.4	48	46.3	3.7
01581500	0.1	0.1	0.0	0.25	0.3	-16.7	1.2	1.3	-7.7
01581700	3.1	7.7	-59.7	5.37	8.9	-39.7	17.8	15.5	14.8
01582000	9.8	10.4	-5.8	12.4	13.1	-5.3	25.1	25.2	-0.4
01583500	8	8.4	-4.8	10.6	11	-3.6	24.1	23.7	1.7
01584500	4.3	6	-28.3	6.3	7.6	-15.8	16.2	15.2	6.6
01589440	2.6	3.3	-21.2	3.6	4.2	-14.3	8.73	9.1	-4.1
Average percent change			-19.8			-15.3			2.1
14-day low flow									
01580000	18.3	21.8	-16.1	23.9	26.7	-10.5	49.6	48.3	2.7
01581500	0.2	0.2	-50.0	0.3	0.4	-25.0	1.4	1.4	0.0
01581700	3.8	8.4	-54.8	6.1	9.6	-36.5	18.4	16.1	14.3
01582000	10.6	11.2	-5.4	13.3	14	-5.0	26.4	26.6	-0.8
01583500	8.6	9.1	-5.5	11.3	11.7	-3.4	25.4	24.9	2.0
01584500	4.8	6.4	-25.0	6.9	8.1	-14.8	16.9	16.2	4.3
01589440	2.8	3.5	-20.0	3.8	4.4	-13.6	9.4	9.6	-2.1
Average percent change			-25.2			-15.5			2.9
30-day low flow									
01580000	22.8	24.8	-8.1	27.8	29.6	-6.1	51.7	51.6	0.2
01581500	0.6	0.6	0.0	0.8	0.8	0.0	1.7	1.8	-5.6
01581700	6.1	9.6	-36.5	8.1	10.9	-25.7	18.7	18.1	3.3
01582000	13	13.1	-0.8	15.5	15.9	-2.5	28.1	28.4	-1.1
01583500	10.6	10.8	-1.9	13.3	13.4	-0.7	27.1	26.5	2.3
01584500	6.2	7.4	-16.2	8.2	9.2	-10.9	17.9	17.8	0.6
01589440	3.7	4.2	-11.9	4.7	5.2	-9.6	10.3	10.9	-5.5
Average percent change			-10.8			-7.9			-0.8

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