Evaluation of Alternative Statistical Methods for Estimating Frequency of Peak Flows in Maryland

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Final Report

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I. Introduction

This document summarizes the project entitled, "Evaluation of Alternative Statistical Methods for Estimating Frequency of Peak Flows in Maryland" performed for the Maryland State Highway Administration. The project was commenced in October 1999 and includes peak flow data through the hydrologic year ending September 30, 1999. Descriptive watershed characteristics were derived strictly from the GIS database included in GISHydro2000. The goal of this study was to develop peak flow regression equations for the state of Maryland with a particular emphasis given to watersheds less than 20 mi^2 in area. Three different methods for deriving these equations were investigated: fixed region, region of influence, and L-moments. This report presents the equations developed for each method and presents a comparison between these methods.

II. Determination of Watershed Properties for U.S. Geological Survey (USGS) Streamgages in Maryland

The GISHydro2000 database includes all the supporting GIS data needed to perform this study. The "usgsgages.shp" theme in GISHydro2000 shows the location of 378 gages in and around the State of Maryland. Because of the high quality and multiple representations of land use data strictly inside the State of Maryland, our study focused (with the exception of 9 gages in Delaware) on gages located inside the state. Ultimately, 136 gages (154 gages for the Fixed Region and Region of Influence Methods) were used in this study. Appendices A1 and A2 provide the derived watershed properties for these gages. The following list gives definitions for these reported properties.

- <u>GAGENO</u>: the station identification number as reported by the USGS.

- <u>Yrs of Rec</u>: the number of years of gage record, excluding those years of regulated gage record (range: 10 – 76 years)

- <u>MEAN</u>: the average value of the logarithmic peak flows in the years of record.

- <u>STD. DEV</u>: the standard deviation of the logarithmic peak flows in the years of record.

- <u>SKEW</u>: the skew of the logarithmic peak flows in the years of record.

- <u>AREA</u>: probably the single most important watershed characteristic for hydrologic design. It reflects the volume of water that can be generated from rainfall. GIS calculated variable equal to the number of pixels composing the watershed times the pixel's area or cell size (mi^2). (range: 0.1 – 820 mi^2)

- <u>PERIMETER</u>: GIS calculated variable equal to the length of the boundary of the watershed (mi). (range: 2.0 – 249.7 mi)

- LENGTH: GIS calculated variable equal to the distance measured along the main channel from the watershed outlet to the basin divide (mi). (range: 0.8 – 72.4 mi)

- SLOPE: the change of elevation with respect to distance along the principal flow path. The channel slope was calculated using GIS as the difference in elevation between two points located 10 and 85% of the distance along the main channel from the outlet divided by the distance between the two points (ft/mile). (range: 2.2 – 250.6 ft/mile)

- AVG_SLOPE: the average basin slope is the average of all neighborhood slopes determined along the steepest direction of flow. These are the local slopes determined from the upstream to downstream pixel for each pixel within the watershed (ft/ft). This quantity is represented by the symbol "LSLOPE" in the Fixed Region Method text. (range: 0.00378 – 0.22673 ft/ft)

- RELIEF: the average elevation of all points within the watershed minus the elevation at the outlet of the watershed (ft). (range: 16.2 – 1,363.4 ft)

- LIME: the percentage of limestone within the watershed (%). (range: 0 – 100 percent)

- HIGHELEV: the percentage of area within the watershed with elevation in excess of 2000 feet. (range: 0 – 100 percent)

- RES70: the percentage of the basin defined as residential by the USGS 1970's land use (%). (range: 0 – 82.6 percent)

- COM70: the percentage of the basin defined as commercial by the USGS 1970's land use (%). (range: 0 – 33.9 percent)

- AG70: the percentage of the basin defined as agricultural by the USGS 1970's land use (%). (range: 0 – 100 percent)

- FOR70: the percentage of the basin defined as forest by the USGS 1970's land use (%). (range: 0 – 100 percent)

- ST70: the percentage of the basin defined as storage by the USGS 1970's land use (%). (range: 0 – 16.9 percent)

- IA70: the percentage of the basin defined as impervious area by the USGS 1970's land use (%). Impervious area includes the following land use classifications: residential, commercial, industrial, transportation, industrial/commercial complexes, mixed urban or built-up land, dry salt flats, and bare exposed rock. Please see note on impervious area calculation at the end of this section. (range: 0 – 49.3 percent)

- CN70: the average runoff curve number for the basin as defined by the USGS 1970's land use. Soils data are from the NRCS STATSGO dataset. (range: 57 – 84.1 percent)

- RES85: the percentage of the basin defined as residential by the Ragan 1985 land use (%). (range: 0 – 68.7 percent)

- COM85: the percentage of the basin defined as commercial by the Ragan 1985 land use (%). (range: 0 – 27.2 percent)

- AG85: the percentage of the basin defined as agricultural by the Ragan 1985 land use (%). (range: not available)

- FOR85: the percentage of the basin defined as forest by the Ragan 1985 land use (%). (range: 2.7 – 100 percent)

- ST85: the percentage of the basin defined as storage by the Ragan 1985 land use (%). (range: 0 – 15.9 percent)

- IA85: the percentage of the basin defined as impervious area by the Ragan 1985 land use (%). Impervious area includes the following land use classifications: low density residential, medium density residential, high density residential, commercial, industrial, institutional, extractive, open urban land, bare exposed rock, and bare ground. Please see note on impervious area calculation at the end of this section. (range: 0 – 41.1 percent)

- RES90: the percentage of the basin defined as residential by the (Maryland Office of Planning (MOP) 1990 land use (%). (range: 0 – 69.2 percent)

- COM90: the percentage of the basin defined as commercial by the MOP 1990 land use (%). (range: 0 – 26.1 percent)

- AG90: the percentage of the basin defined as agricultural by the MOP 1990 land use (%). (range: 0 – 97.8 percent)

- FOR90: the percentage of the basin defined as forest by the MOP 1990 land use (%). (range: 0 – 98.8 percent)

- ST90: the percentage of the basin defined as storage by the MOP 1990 land use (%). (range: 0 – 16.0 percent)

- IA90: the percentage of the basin defined as impervious area by the MOP 1990 land use (%). Impervious area includes the following land use classifications: low density residential, medium density residential, high density residential, commercial, industrial, institutional, extractive, open urban land, bare exposed rock, and bare ground. Please see note on impervious area calculation at the end of this section. (range: 0 – 43.8 percent)

- RES97: the percentage of the basin defined as residential by the MOP 1997 land use (%). (range: 0 – 65.0 percent)

- COM97: the percentage of the basin defined as commercial by the MOP 1997 land use (%). (range: 0 – 33.9 percent)

- AG97: the percentage of the basin defined as agricultural by the MOP 1997 land use (%). (range: 0 – 96.3 percent)

- FOR97: the percentage of the basin defined as forest by the MOP 1997 land use (%). (range: 0 – 98.0 percent)

- ST97: the percentage of the basin defined as storage by the MOP 1997 land use (%). (range: 0 – 14.4 percent)

- IA97: the percentage of the basin defined as impervious area by the MOP 1997 land use (%). Please see note on impervious area calculation at the end of this section. (range: 0 – 45.0 percent)

- CN97: the average runoff curve number for the basin as defined by the MOP 1997 land use. Impervious area includes the following land use classifications: low density residential, medium density residential, high density residential, commercial, industrial, institutional, extractive, open urban land, bare exposed rock, bare ground, transportation, large lot agriculture, large lot forest, feeding operations, and agricultural buildings. (range: 57.1 – 84.6 percent)

- HYD_A: the percentage of the basin defined as hydrologic soil A, computed as the number of pixels of hydrologic soil A divided by the number of pixels in the basin (%). Soil percentages are based on the STATSGO soil dataset from the NRCS. (range: 0 – 84.5 percent)

- HYD_B: the percentage of the basin defined as hydrologic soil B, computed as the number of pixels of hydrologic soil B divided by the number of pixels in the basin (%). Soil percentages are based on the STATSGO soil dataset from the NRCS. (range: 0 – 100 percent)

- HYD_C: the percentage of the basin defined as hydrologic soil C, computed as the number of pixels of hydrologic soil C divided by the number of pixels in the basin (%). Soil percentages are based on the STATSGO soil dataset from the NRCS. (range: 0 – 95.7 percent)

- HYD_D: the percentage of the basin defined as hydrologic soil D, computed as the number of pixels of hydrologic soil D divided by the number of pixels in the basin (%). Soil percentages are based on the STATSGO soil dataset from the NRCS. (range: 0 – 85.7 percent)

- HYPSO: hypsometric area ratio, a single-valued index of the hypsometric curve, equal to the ratio of the area under the normalized hypsometric curve. (range: 0.18 – 0.74)

- FOSTREAM: the number of first order streams in the watershed as defined by the 1:250,000 mapping in the digitized National Hydrography Dataset. (range: 0 – 405)

- TSLENGTH: total length of streams in the watershed as defined by the 1:250,000 mapping in the digitized National Hydrography Dataset. (range: 0 – 1,546.9 mi)

- AREAFRAC: the fraction of the watershed that is within Maryland boundaries. (range: 0.005 – 1.0)

- 2-Year Prec: the 2-Year, 24-hour precipitation depth in hundredths of an inch (range: 2.243 – 3.760 inches)

- 100-Year Prec: the 100-Year, 24-hour precipitation depth in hundredths of an inch (range: 5.247 – 9.436 inches)

All properties were determined by using the 30m digital elevation models (DEMs) in GISHydro2000 and imposing the known drainage structure indicated by the National Hydrography Dataset to determine flow direction and ultimate delineate the watershed draining to each stream gage. The delineated watershed was then used as a "mask" to determine the properties exclusively within the watershed. In a number of cases, the watershed extends beyond the boundaries of the state. The AREAFRAC parameter indicates the fraction of the watershed area within the state boundaries. In cases where the quantity being determined is based on a GIS coverage that ends at state boundaries, (e.g land use from the Maryland Office of Planning) the percentage reported is the percentage based only on the area within the state. The potential for a poor measure of the watershed's composition is increased as AREAFRAC approaches zero. All watershed properties are provided in Appendices A1 and A2. GIS codes to determine these quantities are archived in Appendix B.

Impervious Area Calculation

Impervious area can be calculated many ways. Differences in data source and/or methods for calculating impervious area can result in estimates that vary by more than a factor of 2. For this reason, it is important that impervious area be calculated in a manner consistent with the methods used for developing the watershed dataset used in this report. For land use supplied by the Maryland Office of Planning, Table 1 below presents the fraction of imperviousness assigned to each land use category. The coefficients presented in this table are consistent with the values presented in TR-55 (SCS, 1986) which should be followed if land use is from a source other than the Maryland Office of Planning. The total impervious area was determined using:

$$IA = \frac{\sum_i C_i \cdot A_i}{\sum_i A_i} \cdot 100\% \qquad (1)$$

where the subscript, i, corresponds to the set of all land uses in the watershed, C_i is the fraction of imperviousness for land use, i, and A_i is the area of land use, i, in the watershed. Please note that estimating impervious area from other sources (notably the USGS National Land Cover Dataset or similar satellite derived imagery) will probably not produce imperviousness estimates consistent with those reported and used here.

Table 1. Impervious Fraction Coefficients for Maryland Office of Planning Generalized Land Use categories

MOP Code	**Classification**	**Fraction Impervious Area, C_i**
11	Low Density Residential	0.25
12	Medium Density Residential	0.38
13	High Density Residential	0.65
14	Commercial	0.85
15	Industrial	0.72
16	Institutional	0.50
17	Extractive	0.11
18	Open Urban Land	0.11
70	Barren Land	0.50
72	Bare Exposed Rock	1.00
73	Bare Ground	0.50
80	Transportation	0.75
191	Large Lot Agricultural	0.15
192	Large Lot Forest	0.15
241	Feeding Operations	0.10
242	Agricultural Buildings	0.10
various codes	All other land uses	0.00

III. Flood Frequency Analyses for USGS streamgages in Maryland

The magnitude and frequency of flood discharges for 154 gaging stations in Maryland (and Delaware) were defined using Bulletin 17B guidelines (Interagency Advisory Committee on Water Data (IACWD), 1982) and annual peak flow data through September 1999. The recommended approach in Bulletin 17B is to estimate flood discharges based on a weighted skew that is computed by weighting station and generalized (regional) skew by their respective mean square error.

The first step in the analysis was to evaluate if the generalized skew map in Bulletin 17B was applicable to Maryland. Station skews were computed at each gaging station using data through the 1999 water year by censoring low outliers and adjusting for high outliers and historical floods as described in Bulletin 17B. The station skew values were plotted on a map and compared to the skew map in Bulletin 17B. The new values were considered significantly different from the Bulletin 17B skew map and were used to define two regions of average skew.

Bulletin 17B guidelines recommends three approaches for defining generalized skew: a contour map of skew values (like Plate I in Bulletin 17B), a median or average skew value for a region, or a regression equation relating skew to watershed and climatic characteristics. For this study, there was no geographic or regional pattern in skew values, therefore, a contour map of skew values was not feasible. An attempt was made to relate the station skew values to many of the watershed and climatic variables described earlier in this report. None of the watershed or climatic characteristics were statistically significant in explaining the variability in the station skew values. Since there was not a lot of variation in station skew values across the State, an average value of skew was defined for two regions in Maryland.

The average skew for the Eastern Coastal Plains is 0.45 with a standard error of 0.41 and the average skew for the rest of the State was 0.55 with a standard error of 0.45. The new generalized skew values were weighted with station skew using the respective standard errors to compute the final flood discharges based on weighted skew. These computations were performed using the USGS Program PEAKFQ (Thomas and others, 1998) that implements Bulletin 17B guidelines (IACWD, 1982). The final flood discharges for the 154 stations are given in Appendices C1 and C2.

IV. Case Study Watershed

To illustrate the application of the equations that will be developed we will present a sample watershed as a case study. The watershed chosen is Dorsey Run at a point approximately 1.6 km downstream of the bridge at US Route 1. This watershed is located in Howard County, Maryland and straddles the fall line such that 35 percent of its area is in the Piedmont region, and the remaining 65 percent of its area is in the Western Coastal Plain region. The following table is the direct output from GISHydro's Basin Statistics menu choice for this watershed:

```
Watershed Statistics for: Dorsey Run at U.S. Route 1
Data Selected:
     Quadrangles Used: savage
     DEM Coverage: NED DEMs
     Land Use Coverage: 2002 MOP Landuse
     Soil Coverage: SSURGO Soils
     Hydrologic Condition: (see Lookup Table)
     Impose NHD stream Locations: Yes
     Outlet Easting:        418030 m. (MD Stateplane, NAD 1983)
     Outlet Northing:       165250 m. (MD Stateplane, NAD 1983)

Findings:
     Outlet Location:       Western Coastal Plain
     Outlet State:          Maryland
     Drainage Area          5.9 square miles
       -Piedmont (34.8% of area)
       -Western Coastal Plain (65.2% of area)
     Channel Slope:         50.4 feet/mile
     Land Slope:            0.052 ft/ft
     Urban Area:            54.6%
```

```
     Impervious Area:       35.5%
****************************************************
     URBAN DEVELOPMENT IN WATERSHED EXCEEDS 15%.
     Calculated discharges from USGS Regression
     Equations may not be appropriate.
****************************************************
     Time of Concentration: 5.2 hours  [W.O. Thomas, Jr. Equation]
     Time of Concentration: 3.3 hours  [From SCS Lag Equation * 1.67]
     Longest Flow Path:     5.02 miles
     Basin Relief:          140.5 feet
     Average CN:            79
     % Forest Cover:        39.5
     % Storage:             0.0
     % Limestone:           0.0
     % A Soils:             0.8
     % B Soils:             29.9
     % C Soils:             10.3
     % D Soils:             59.0
     2-Year,24-hour Prec.:  3.20 inches
     Mean Annual Prec.:     44.60 inches
```

The predicted discharges for this watershed will be presented for each method to illustrate the application of that method to this watershed.

V. Development of Regression Equations

Regression equations were developed using three distinctly different approaches: a Fixed Region Method (similar to that used by Carpenter (1980) and Dillow (1996) in previous studies), the Region of Influence Method (Burn, 1990), and the L-Moments Method (Hosking and Wallis, 1993; 1997). Our hope was that in approaching the task of developing predictive equations for flood frequency behavior in Maryland that this range of approaches would provide useful contrasts in methodologies and ultimately in the resulting equations. As is generally the case, our objective was to determine the

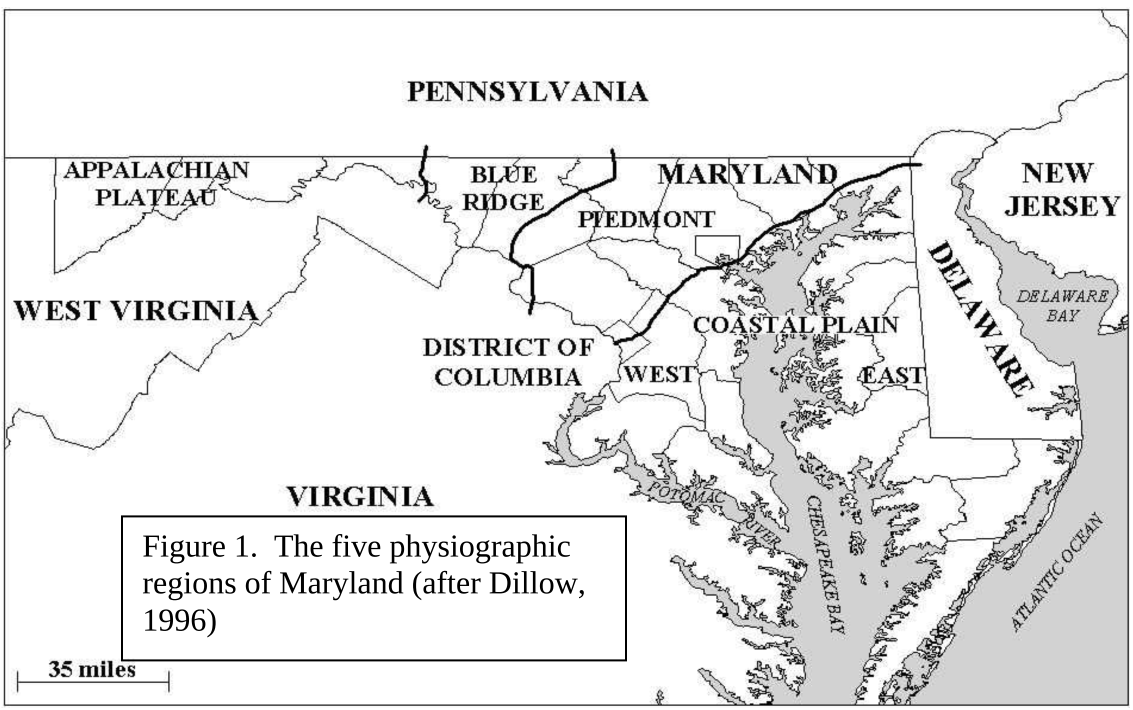

Figure 1. The five physiographic regions of Maryland (after Dillow, 1996)

predictive equations that would have the smallest standard errors possible while still being easy to determine given readily available GIS data such as that found in GISHydro.

Comparison of equation performance will be conducted on a region-by-region basis, using the physiographic regions defined in Dillow's (1996) report. The regions he identified were: the Appalachian Plateau, the Blue Ridge, the Piedmont, the Western Coastal Plain, and the Eastern Coastal Plain, shown in Figure 1, above.

Fixed Region Method

The current regional regression equations being used by the Maryland State Highway Administration were developed by Dillow (1996). Dillow (1996) defined regression equations for five hydrologic (fixed) regions: Appalachian Plateaus and Allegheny Ridges, Blue Ridge and Great Valley, Piedmont, Western Coastal Plain and Eastern Coastal Plain. These regions are shown in Figure 1. The fixed region analysis used in this study is based on the predefined regions of Dillow (1996) since these regions are based on physiographic regions.

Eastern Coastal Plains Region

The fixed region equations are based on 15 stations in Maryland and 9 stations in Delaware with drainage area (*DA*) ranging from 2.27 to 112.20 square miles, basin relief (*BR*) ranging from 5.1 to 43.5 feet, and percent A soils (S_A) ranging from 0.0 to 49.4 percent. Basin relief is not statistically significant for discharges less than the 5-year event but is included in the equations for consistency. The standard errors range from 33.7 percent (0.142 log units) for $Q_{1.50}$ to 50.8 percent (0.208 log units) for Q_{500}.

	Standard error (percent)	Equivalent Years of Record	Equation Number
$Q_{1.25} = 19.85\ DA^{0.796}\ BR^{0.066}\ (S_A+1)^{-0.106}$	34.2	4.5	(2)
$Q_{1.50} = 20.48\ DA^{0.795}\ BR^{0.156}\ (S_A+1)^{-0.140}$	33.7	4.1	(3)
$Q_{1.75} = 20.81\ DA^{0.799}\ BR^{0.197}\ (S_A+1)^{-0.146}$	34.2	4.1	(4)
$Q_{2} = 20.95\ DA^{0.803}\ BR^{0.222}\ (S_A+1)^{-0.144}$	34.9	4.1	(5)
$Q_{5} = 25.82\ DA^{0.793}\ BR^{0.368}\ (S_A+1)^{-0.190}$	36.9	6.8	(6)
$Q_{10} = 31.17\ DA^{0.777}\ BR^{0.439}\ (S_A+1)^{-0.215}$	38.2	9.5	(7)
$Q_{25} = 40.26\ DA^{0.751}\ BR^{0.511}\ (S_A+1)^{-0.242}$	40.0	13	(8)
$Q_{50} = 50.00\ DA^{0.732}\ BR^{0.549}\ (S_A+1)^{-0.261}$	41.7	16	(9)
$Q_{100} = 63.44\ DA^{0.711}\ BR^{0.576}\ (S_A+1)^{-0.279}$	44.0	18	(10)

$Q_{200} = 79.81\ DA^{0.689}\ BR^{0.601}\ (S_A+1)^{-0.296}$	46.5	19	(11)
$Q_{500} = 108.7\ DA^{0.660}\ BR^{0.628}\ (S_A+1)^{-0.316}$	50.8	21	(12)

The percent A soils (S_A) is estimated using the "STATSGO Soils" layer obtained from the NRCS. S_A measured from the "Ragan soils" developed from the SCS County Soil Series publications by Robert Ragan at the University of Maryland and available in digital form through GISHydro2000 and from SSURGO soils data obtained from the NRCS can (in some cases) vary widely from the estimate determined from the "STATSGO Soils"-derived measure. For this reason, it is preferable to use S_A estimated from the "STATSGO Soils" when using these regression equations.

The equations should be used within the range of data used to develop them. The range of data used in developing the above equations were given in Section II. "Determination of Watershed Properties for USGS streamgages in Maryland."

Western Coastal Plain Region

The fixed region equations are based on 22 stations in the Western Coastal Plain. Five stations were deleted as outliers: 01585100 and 01585300 (highly urban stations partly in the Piedmont), 01589500 and 01594800 (very low peaks), and 01661050 (data do not fit a Pearson Type III distribution well). The drainage area (*DA*) ranges from 0.10 to 349.50 square miles, the 1985 impervious area (*IA*) ranges from 0.0 to 36.8 percent, and percent D soils (S_D) ranges from 2.4 to 26.4 percent. Although the 1985 impervious area was used to develop the equations, the current impervious area should be used when estimating flood discharges (Please see earlier note on how impervious area was determined in this study. Consistency in calculating impervious area is important for correct application of these equations.)

The standard errors range from 35.4 percent (0.149 log units) for Q_2 to 65.7 percent (0.260 log units) for Q_{100}. The standard error for Q_{500} is 89.8 percent (0.334 log units) because there is one station that is an outlier at the 500-year recurrence interval but reasonable for other recurrence intervals.

Forest cover and impervious area are about equally significant, have a correlation of -0.63, and are not both significant in the same equation. Impervious area was used because it is more related to ultimate development. Drainage area has a correlation of 0.86 with basin relief, and -0.72 with channel slope. Therefore, neither basin relief nor channel slope was used as significant parameters in this region. Land slope is not statistically significant either.

	Standard error (percent)	Equivalent Years of Record	Equation Number
$Q_{1.25} = 18.62\ DA^{0.611}\ (IA+1)^{0.419}\ (S_D+1)^{0.165}$	38.9	3.2	(13)

$Q_{1.50} = 21.97\, DA^{0.612}\, (IA+1)^{0.399}\, (S_D+1)^{0.226}$	36.3	3.2	(14)
$Q_{1.75} = 24.42\, DA^{0.612}\, (IA+1)^{0.391}\, (S_D+1)^{0.246}$	35.6	3.4	(15)
$Q_{2} = 26.32\, DA^{0.612}\, (IA+1)^{0.386}\, (S_D+1)^{0.256}$	35.4	3.7	(16)
$Q_{5} = 42.64\, DA^{0.607}\, (IA+1)^{0.347}\, (S_D+1)^{0.340}$	36.3	6.8	(17)
$Q_{10} = 58.04\, DA^{0.603}\, (IA+1)^{0.323}\, (S_D+1)^{0.382}$	40.6	8.4	(18)
$Q_{25} = 86.25\, DA^{0.582}\, (IA+1)^{0.295}\, (S_D+1)^{0.421}$	48.9	9.3	(19)
$Q_{50} = 111.50\, DA^{0.584}\, (IA+1)^{0.270}\, (S_D+1)^{0.457}$	54.7	9.9	(20)
$Q_{100} = 143.56\, DA^{0.586}\, (IA+1)^{0.260}\, (S_D+1)^{0.469}$	65.7	9.0	(21)
$Q_{200} = 185.15\, DA^{0.580}\, (IA+1)^{0.243}\, (S_D+1)^{0.488}$	75.5	8.7	(22)
$Q_{500} = 256.02\, DA^{0.573}\, (IA+1)^{0.222}\, (S_D+1)^{0.510}$	89.8	8.3	(23)

The percent D soils (S_D) is estimated using the “STATSGO Soils” layer obtained from the NRCS. S_D measured from the “Ragan soils” developed from the SCS County Soil Series publications by Robert Ragan at the University of Maryland and available in digital form through GISHydro2000 and from SSURGO soils data obtained from the NRCS can (in some cases) vary widely from the estimate determined from the “STATSGO Soils”-derived measure. For this reason, it is preferable to use S_D estimated from the “STATSGO Soils” when using these regression equations.

The equations should be used within the range of data used to develop them. The range of data used in developing the above equations were given in Section II. “Determination of Watershed Properties for USGS streamgages in Maryland.”

Piedmont Region

The fixed region equations are based on 34 rural stations and 16 urban stations in the Piedmont region. Two sets of regression equations were developed for the rural and urban stations with urban stations having 10 percent or greater impervious area and rural stations less than 10 percent. Across the two data sets, 9 stations were deleted as outliers: 01582510, 01583000, 01583495, 01583600, 01589000, 01589240, 01592000, 01650050, and 01650085. Therefore, 50 of the 59 stations in the Piedmont Region were used in developing the following two sets of equations. For rural equations, the drainage area (*DA*) ranges from 0.28 to 258.07 square miles and forest cover (*FOR*) ranges from 4.4 to 75.3 percent. For the urban equations, drainage area (*DA*) ranges from 0.39 to 102.05 square miles and impervious area (*IA*) ranges from 10.9 to 42.8 percent. Basin relief and channel slope are highly correlated with drainage area. Therefore, neither basin relief nor channel slope was used as significant parameters in this region.

Rural Equations

Standard errors range from 24.3 percent (0.104 log units for Q_{10} to 39.7 percent (0.166 log units) for Q_{500}.

	Standard error (percent)	Equivalent Years of Record	Equation Number
$Q_{1.25} = 202.9\ DA^{0.682}\ (FOR+1)^{-0.222}$	39.0	3.3	(24)
$Q_{1.50} = 262.0\ DA^{0.683}\ (FOR+1)^{-0.217}$	33.8	3.8	(25)
$Q_{1.75} = 308.9\ DA^{0.679}\ (FOR+1)^{-0.219}$	32.1	4.3	(26)
$Q_{2} = 349.0\ DA^{0.674}\ (FOR+1)^{-0.224}$	31.3	4.8	(27)
$Q_{5} = 673.8\ DA^{0.659}\ (FOR+1)^{-0.228}$	25.6	14	(28)
$Q_{10} = 992.6\ DA^{0.649}\ (FOR+1)^{-0.230}$	24.3	23	(29)
$Q_{25} = 1556\ DA^{0.635}\ (FOR+1)^{-0.231}$	25.3	33	(30)
$Q_{50} = 2146\ DA^{0.624}\ (FOR+1)^{-0.235}$	27.5	37	(31)
$Q_{100} = 2897\ DA^{0.613}\ (FOR+1)^{-0.238}$	30.6	37	(32)
$Q_{200} = 3847\ DA^{0.603}\ (FOR+1)^{-0.239}$	34.2	37	(33)
$Q_{500} = 5519\ DA^{0.589}\ (FOR+1)^{-0.242}$	39.7	35	(34)

The equations should be used within the range of data used to develop them. The range of data used in developing the above equations were given in Section II. “Determination of Watershed Properties for USGS streamgages in Maryland”.

Urban Equations

For the urban equations (10 percent or greater impervious area), the standard errors range from 26.0 percent (0.111 log units) for Q_{25} to 41.7 percent (0.174 log units) for $Q_{1.25}$.

	Standard error (percent)	Equivalent Years of Record	Equation Number

$Q_{1.25} = 17.85\ DA^{0.652}\ (IA{+}1)^{0.635}$	41.7	3.3	(35)
$Q_{1.50} = 24.66\ DA^{0.648}\ (IA{+}1)^{0.631}$	36.9	3.8	(36)
$Q_{1.75} = 30.82\ DA^{0.643}\ (IA{+}1)^{0.611}$	35.6	4.1	(37)
$Q_{2} = 37.01\ DA^{0.635}\ (IA{+}1)^{0.588}$	35.1	4.5	(38)
$Q_{5} = 94.76\ DA^{0.624}\ (IA{+}1)^{0.499}$	28.5	13	(39)
$Q_{10} = 169.2\ DA^{0.622}\ (IA{+}1)^{0.435}$	26.2	24	(40)
$Q_{25} = 341.0\ DA^{0.619}\ (IA{+}1)^{0.349}$	26.0	38	(41)
$Q_{50} = 562.4\ DA^{0.619}\ (IA{+}1)^{0.284}$	27.7	44	(42)
$Q_{100} = 898.3\ DA^{0.619}\ (IA{+}1)^{0.222}$	30.7	45	(43)
$Q_{200} = 1413\ DA^{0.621}\ (IA{+}1)^{0.160}$	34.8	44	(44)
$Q_{500} = 2529\ DA^{0.623}\ (IA{+}1)^{0.079}$	41.2	40	(45)

The equations should be used within the range of data used to develop them. The range of data used in developing the above equations were given in Section II. "Determination of Watershed Properties for USGS streamgages in Maryland".

Blue Ridge Region

The fixed region equations are based on 20 stations in Maryland with drainage area (*DA*) ranging from 0.11 to 820 square miles and percent limestone (*LIME*) ranging from 0.0 to 100 percent. Basin relief, land slope, forest cover, and soils characteristics were all investigated as explanatory variables but were not statistically significant across all recurrence intervals in the regression equations.

The standard errors range from 51.6 percent (0.211 log units) for Q_{25} to 74.6 percent (0.289 log units) for $Q_{1.25}$.

	Standard error (percent)	Equivalent Years of Record	Equation Number
$Q_{1.25} = 57.39\ DA^{0.784}\ (LIME{+}1)^{-0.190}$	74.6	1.0	(46)
$Q_{1.50} = 81.45\ DA^{0.764}\ (LIME{+}1)^{-0.193}$	67.1	1.1	(47)

$Q_{1.75} = 96.33\ DA^{0.755}\ (LIME+1)^{-0.194}$	65.2	1.2	(48)
$Q_{2} = 107.20\ DA^{0.750}\ (LIME+1)^{-0.194}$	64.0	1.3	(49)
$Q_{5} = 221.28\ DA^{0.710}\ (LIME+1)^{-0.202}$	55.4	3.0	(50)
$Q_{10} = 336.84\ DA^{0.687}\ (LIME+1)^{-0.207}$	52.5	4.9	(51)
$Q_{25} = 545.62\ DA^{0.660}\ (LIME+1)^{-0.214}$	51.6	8.8	(52)
$Q_{50} = 759.45\ DA^{0.641}\ (LIME+1)^{-0.219}$	52.5	9.7	(53)
$Q_{100} = 1034.7\ DA^{0.624}\ (LIME+1)^{-0.224}$	54.4	11	(54)
$Q_{200} = 1387.6\ DA^{0.608}\ (LIME+1)^{-0.229}$	57.4	13	(55)
$Q_{500} = 2008.6\ DA^{0.587}\ (LIME+1)^{-0.235}$	62.3	13	(56)

The equations should be used within the range of data used to develop them. The range of data used in developing the above equations were given in Section II. "Determination of Watershed Properties for USGS streamgages in Maryland".

Appalachian Plateaus Region

The fixed region equations are based on 23 stations in Maryland with drainage area (*DA*) ranging from 0.52 to 293.7 square miles and land slope (*LSLOPE*) ranging from 0.06632 to 0.22653 ft/ft. One station, 03076505, was an outlier and eliminated from the regression analysis. Basin relief, channel slope, and basin shape have relatively high correlations with drainage area (0.78, 0.77, and 0.62, respectively) and were not statistically significant in the regression equations.

The standard error range from 20.7 percent (0.089 log units) for Q_2 to 48.0 percent (0.198 log units) for Q_{500}.

	Standard error (percent)	Equivalent Years of Record	Equation Number
$Q_{1.25} = 70.25\ DA^{0.837}\ LSLOPE^{0.327}$	23.6	5.7	(57)
$Q_{1.50} = 87.42\ DA^{0.837}\ LSLOPE^{0.321}$	21.9	5.9	(58)
$Q_{1.75} = 96.37\ DA^{0.836}\ LSLOPE^{0.307}$	21.2	6.4	(59)
$Q_{2} = 101.41\ DA^{0.834}\ LSLOPE^{0.300}$	20.7	7.1	(60)

$$Q_5 = 179.13\, DA^{0.826}\, LSLOPE^{0.314} \qquad 21.6 \qquad 12 \qquad (61)$$

$$Q_{10} = 255.75\, DA^{0.821}\, LSLOPE^{0.340} \qquad 24.2 \qquad 14 \qquad (62)$$

$$Q_{25} = 404.22\, DA^{0.812}\, LSLOPE^{0.393} \qquad 29.1 \qquad 15 \qquad (63)$$

$$Q_{50} = 559.80\, DA^{0.806}\, LSLOPE^{0.435} \qquad 33.1 \qquad 16 \qquad (64)$$

$$Q_{100} = 766.28\, DA^{0.799}\, LSLOPE^{0.478} \qquad 37.4 \qquad 15 \qquad (65)$$

$$Q_{200} = 1046.9\, DA^{0.793}\, LSLOPE^{0.525} \qquad 41.8 \qquad 15 \qquad (66)$$

$$Q_{500} = 1565.0\, DA^{0.784}\, LSLOPE^{0.589} \qquad 48.0 \qquad 15 \qquad (67)$$

The equations should be used within the range of data used to develop them. The range of data used in developing the above equations were given in Section II. “Determination of Watershed Properties for USGS streamgages in Maryland”.

Application of Fixed Region Method to Case Study Watershed

The fixed region method developed distinct equations for the Piedmont and Western Coastal Plain regions so it will be necessary to apply the generated equations twice, once for each region, and then develop an area weighted average for the peak flow estimates in this watershed.

Applying the 2-year peak discharge equation for the Piedmont region, we get:

$$Q_{2,P} = 37.01 \cdot (5.9)^{0.635} \cdot (35.5+1)^{0.588} = 947.2 \text{ ft}^3\text{/s} \qquad (68)$$

similarly, applying the 2-year peak discharge equation for the Western Coastal Plain region, we get:

$$Q_{2,WCP} = 26.32 \cdot (5.9)^{0.612} \cdot (35.5+1)^{0.386} \cdot (59.0+1)^{0.256} = 891.9 \text{ ft}^3\text{/s} \qquad (69)$$

The area weighted discharge is then calculated:

$$Q_2 = 0.348 \cdot (947.2) + 0.652 \cdot (891.9) = 911.1 \text{ ft}^3\text{/s} \qquad (70)$$

Region of Influence Method

The concept behind the Region of Influence (ROI) method is to develop regression models based on the flood frequency information of the *n* most similar gaged sites to the ungaged watershed in question. Regression models are thus unique to every ungaged location. Similarity is asserted by examining such watershed properties as those that appeared in the earlier section on determining watershed properties. The ROI method uses as input the ungaged watershed properties and then determines a "distance" function that reflects the similarity of the ungaged site to all gaged sites in the database. The *n* gaged sites that are the most similar (i.e. have the smallest "distance") to the ungaged site are used to develop a multiple-predictor power law regression model for each return period from 2 to 500 years.

To determine the best predictors to use in this method, two-, three-, and four-parameter models were examined with the smallest standard errors associated with the higher parameter models. Testing of models was performed by treating the data from each gage as if it were an ungaged location and then using the remaining gages to predict the flood frequency distribution at this gage. Gages were grouped according to the physiographic provinces identified by Dillow (1996). The standard error within each physiographic province was then calculated using the Bulletin 17b discharges at each gage as the "observed" discharges and the ROI determined regression equations as the "predicted" discharges.

The original ROI code was obtained from Gary Tasker at the USGS for the State of North Carolina and was modified to work for the State of Maryland. The original code set *n* (the number of most similar gages used to develop a regression equation) at 30. A small analysis confirmed that *n* = 30 produced the smallest standard errors representing the tradeoff between gaining more information from larger sample sizes and having that information be of lower quality because it corresponds to less similar gages.
Model development was a lengthy undertaking, proceeding largely by a trial-and-error process. The models that were examined all included drainage area as a predictor by default. The remaining predictors were allowed to vary although it was expected that a blend of predictors reflecting structural properties of the watershed (e.g. relief, soil type) and dynamic properties of the watershed (e.g. forest cover, imperviousness) would ultimately produce the best regression models. Ultimately, after trying a great number of potential models, we found that that the most effective watershed predictors were drainage area, land slope, basin relief, percent imperviousness, and forest cover. Table 1 below shows the precise best predictive models found, grouped by physiographic province.

The reader will note that Table 1 indicates that the models that were ultimately found to produce the smallest standard errors also contained highly correlated predictors (e.g. [land slope and basin relief] or [impervious area and forest cover]). These

Table 1. Best predictors for Region of Influence Method – by geographic province

Physiographic Province	Predictor 1	Predictor 2	Predictor 3	Predictor 4
Appalachian	Drainage area	Basin relief	A soils	Forest cover (1985)
Blue Ridge*	Drainage area	Limestone	Forest cover (1985)	Impervious area (1985)
Piedmont*	Drainage area	Limestone	Forest cover (1985)	Impevious area (1985)
Western Coastal	Drainage area	Land slope	Impervious area (1990)	D soils
Eastern Coastal	Drainage area	Basin relief	A soils	Forest Cover (1985)

correlated predictors resulted in regression models with irrational exponents (e.g. a negative exponent on land slope or basin relief). We subsequently searched for the best regression model with more independent predictors. The resulting best four predictor model was found to be dependent on drainage area, basin relief, percent imperviousness, and percent hydrologic soil group D. The exponents associated with this model were rational in sign and were rational in their trends with increasing return period (e.g. the exponent on percent imperviousness decreases as return period increases.) Although there is a small sacrifice in the magnitude of the standard errors during the calibration step using this new model, we feel the rationality of the exponents is ultimately more important when using these equations to make predictions at ungaged sites.

The asterisk (*) next to the Blue Ridge and Piedmont regions indicates a slight difference in treatment of the Region of Influence methods for these two regions with regards to the limestone predictor. The presence of an underlying limestone geology in these areas has been found by others to be significant for both low flows (Carpenter and Hayes, 1996) and for floods (Dillow, 1996). For the two indicated regions, the limestone predictor was handled as follows. If the percent limestone was greater than zero, then all four predictors were used. If no limestone was present then the initial set of calibrated models did not include limestone as a predictor.

A final wrinkle we added beyond the standard region of influence method was a test for rationality of all exponents in the calibrated regression equations. If an irrational exponent (e.g. a negative exponent on land slope or a positive exponent on forest cover) was determined for any predictor for any return period, that predictor was removed from the set of predictors and the region of influence method was repeated with the reduced predictor set. For the calibration of a set of equations for a given region, this process was repeated, starting with the four predictors indicated in Table 1 until all calibrated exponents were rational for all return periods.

Application of Region of Influence Method to Case Study Watershed

The region of influence method develops a unique set of regression equations for each watershed it is applied to based on the 30 most similar watersheds to the watershed under study. Using the "Hydro: Export ROI Equations" menu choice in GISHydro, we find that the following regression equations were developed for the study watershed:

```
Region of Influence Equations for Piedmont
Q2 = 368.553 * (area) ^ 0.7055 * (forest85 + 0.1) ^-0.7074 * (ia85 + 0.1) ^ 0.5013
Q5 = 1089.68 * (area) ^ 0.7083 * (forest85 + 0.1) ^-0.8221 * (ia85 + 0.1) ^ 0.4629
Q10 = 2042.21 * (area) ^ 0.7094 * (forest85 + 0.1) ^-0.8817 * (ia85 + 0.1) ^ 0.4329
Q25 = 4236.43 * (area) ^ 0.7093 * (forest85 + 0.1) ^-0.9462 * (ia85 + 0.1) ^ 0.3922
Q50 = 7212.74 * (area) ^ 0.7301 * (forest85 + 0.1) ^-0.9861 * (ia85 + 0.1) ^ 0.3239
Q100 = 11478.9 * (area) ^ 0.7060 * (forest85 + 0.1) ^-1.0267 * (ia85 + 0.1) ^ 0.3269
Q200 = 18281 * (area) ^ 0.7035 * (forest85 + 0.1) ^-1.0625 * (ia85 + 0.1) ^ 0.2947
Q500 = 33059.8 * (area) ^ 0.6996 * (forest85 + 0.1) ^-1.1070 * (ia85 + 0.1) ^ 0.2525

Region of Influence Equations for Western Coastal Plain
Q2 = 47.2498 * (area) ^ 0.5762 * (ia90 + 0.1) ^ 0.3835 * (hyd_d + 0.1) ^ 0.1288
Q5 = 101.088 * (area) ^ 0.5812 * (ia90 + 0.1) ^ 0.3193 * (hyd_d + 0.1) ^ 0.1411
Q10 = 164.248 * (area) ^ 0.5814 * (ia90 + 0.1) ^ 0.2764 * (hyd_d + 0.1) ^ 0.1417
Q25 = 314.485 * (area) ^ 0.5567 * (ia90 + 0.1) ^ 0.2287 * (hyd_d + 0.1) ^ 0.1259
Q50 = 447.507 * (area) ^ 0.5954 * (ia90 + 0.1) ^ 0.1539 * (hyd_d + 0.1) ^ 0.1427
Q100 = 706.48 * (area) ^ 0.5669 * (ia90 + 0.1) ^ 0.1508 * (hyd_d + 0.1) ^ 0.1128
Q200 = 1064.63 * (area) ^ 0.5604 * (ia90 + 0.1) ^ 0.1174 * (hyd_d + 0.1) ^ 0.0994
Q500 = 1803.85 * (area) ^ 0.5509 * (ia90 + 0.1) ^ 0.0751 * (hyd_d + 0.1) ^ 0.0805
```

where “area” is the drainage area in square miles, “forest85” is the percent forest cover measured by the 1985 land use, “ia85” is the percent impervious area measured by the 1985 land use, “ia90” is the percent impervious area measured by the 1990 land use, and “hyd_d” is the percent D soils. Notice that since no limestone was present in the study watershed limestone does not appear as a predictor in the calibrated Piedmont region equations. Similarly, notice that land slope does not appear as a predictor in the calibrated Western Coastal plane equations. This is because the calibrated exponent on the land slope predictor was negative for one or more return period examined.

Applying the 2-year peak discharge equation to the Dorsey Run watershed in the Piedmont region we get:

$$Q_{2,P} = 368.553 \cdot (5.9)^{0.7055} \cdot (39.5 + 01)^{-0.7074} \cdot (35.5 + 0.1)^{0.5013} = 572.6 \text{ ft}^3/\text{s} \qquad (71)$$

Likewise, for the Western Coastal Plain region we get:

$$Q_{2,WCP} = 47.2498 \cdot (5.9)^{0.5762} \cdot (35.5 + 01)^{0.3835} \cdot (59.0 + 0.1)^{0.1288} = 874.4 \text{ ft}^3/\text{s} \qquad (72)$$

The area weighted discharge is then calculated:

$$Q_2 = 0.348 \cdot (572.6) + 0.652 \cdot (874.4) = 769.4 \text{ ft}^3/\text{s} \qquad (73)$$

L-Moment Method

The Method of L-Moments has been developed by (Wallis and Hosking, 1993). This method was applied to flood frequency estimation in the State of Maryland. The first, and possibly most difficult step in the development of predictive equations using this method is the determination of homogeneous regions. Using codes published by Wallis and Hosking, (1998), we determined the existence of five homogeneous regions over the State of Maryland that corresponded well with the framework established previously by Dillow (1996). These regions are: Appalachian, Blue Ridge / Piedmont (<20 mi^2), Blue Ridge / Piedmont (> 20 mi^2), Western Coastal Plain, and Eastern Coastal Plain. These regions agree well with those established by Dillow with the difference being the merger of the Blue Ridge and Piedmont provinces but with this merged province divided based on whether the drainage area is greater or less than 20 mi^2.

The output from the L-moment methods is an equation for determining the L-mean and a set of quantiles that correspond to the various return periods one may wish to estimate a flood discharge for. This is basically an index flood procedure in which the discharge for any given return period is the product of the L-mean determined for that watershed (and region) and the quantile for the return period and region.

The equations for the L-means for each region are given below in equations 38-42. Table 2 provides the corresponding quantiles for each region.

Table 2. Quantiles for L-moment method by region and return period

Region	Return Period										
	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Appalachian	0.55	0.67	0.76	0.83	1.31	1.70	2.32	2.89	3.55	4.34	5.61
Piedmont/Blue Ridge < 20 mi^2	0.36	0.49	0.60	0.69	1.34	1.96	3.03	4.12	5.52	7.34	10.60
Piedmont/Blue Ridge > 20 mi^2	0.48	0.61	0.70	0.78	1.32	1.80	2.58	3.33	4.26	5.4	7.32
Western Coastal	0.40	0.53	0.62	0.70	1.30	1.88	2.90	3.95	5.33	7.14	10.43
Eastern Coastal	0.45	0.60	0.71	0.80	1.38	1.86	2.60	3.26	4.03	4.93	6.37

For the Appalachian Region:

$$L_A = 18.4606 \cdot (DA)^{0.8234} \cdot (S_c + 10)^{0.3186} \quad (74)$$

For the Blue Ridge / Piedmont Region less than 20 mi^2:

$$L_{BR-P<20} = 1551.203 \cdot (DA)^{0.5202} \cdot (LI + 10)^{-0.7158} \quad (75)$$

For the Blue Ridge / Piedmont Region more than 20 mi^2:

$$L_{BR-P>20} = 1035.085 \cdot (DA)^{0.6489} \cdot (LI + 10)^{-0.6525} \quad (76)$$

For the Western Coastal Plain Region:

$$L_W = 0.0107 \cdot (BR)^{1.9} \cdot (S_d + 10)^{0.7446} \quad (77)$$

For the Eastern Coastal Plain Region:

$$L_E = 3.5742 \cdot (DA)^{0.6189} \cdot (BR)^{0.9183} \quad (78)$$

where S_c is the percent C soils and all other predictors have been used in earlier equations.

Application of L-Moment Method to Case Study Watershed

Returning to the Dorsey Run watershed, it is necessary to determine the discharge twice: once with the Blue Ridge / Piedmont region less than 20 square miles equation, and once with the Western Coastal Plain equation. For the Blue Ridge / Piedmont region the L-mean for Dorsey Run is thus:

$$L_{BR-P<20} = 1551.203 \cdot (5.9)^{0.5202} \cdot (0 + 10)^{-0.7158} = 751.4 \text{ ft}^3/\text{s} \quad (79)$$

For the Western Coastal Plain region the L-mean is:

$$L_W = 0.0107 \cdot (140.5)^{1.9} \cdot (59.0 + 10)^{0.7446} = 3{,}014 \text{ ft}^3/\text{s} \quad (80)$$

Then, for instance, the quantile for the 2-year flood in the Blue Ridge / Piedmont region for watersheds less than 20 mi^2 is 0.69. The quantile for the 2-year flood in the Western Coastal Plain region is 0.70. The resulting estimates of the 2-year floods in the two different regions are:

$$(751.4) \cdot (0.69) = 518.5 \text{ ft}^3/\text{s} \quad \text{(Piedmont)} \quad (81)$$

$$(3{,}014) \cdot (0.70) = 2{,}110 \text{ ft}^3/\text{s} \quad \text{(Western Coastal Plain)} \quad (82)$$

The area weighted discharge is then calculated:

$$Q_2 = 0.348 \cdot (518.5) + 0.652 \cdot (2{,}110) = 1{,}556 \text{ ft}^3/\text{s} \quad (83)$$

VI. Results – Comparison of Methods

Summary of Findings for Case Study Watershed

We have demonstrated the application of three new approaches for estimation of peak discharges at different frequencies for our case study watershed. Table 3 below summarizes these findings and, for perspective, also provides the resultant estimates based on the equations developed earlier by Carpenter (1980) and Dillow (1996).

Table 3. Summary of 2-year peak discharge estimates for Dorsey Run near U.S. Route 1 watershed.

Method	**2-year Peak Discharge (ft^3/s)**
USGS, 1980 – Carpenter	258
USGS, 1995 – Dillow	338
Fixed Region Method	911
Region of Influence Method	769
L-Moment Method	1556

Thus the three new methods uniformly predict significantly bigger 2-year peak discharges than do the two earlier USGS regression equations. This trend continues across all return periods for this watershed as indicated by Table 4 which summarizes the 1.25 through 500 year peak discharge estimates across all five prediction methods.

Table 4: Summary of peak flow estimates (in ft^3/s) for Dorsey Run watershed across all return periods using all methods. The 2-year estimates are highlighted.

OVERALL Calculated Discharges

Return_Period	Carpenter	Carpenter+1SE	Dillow	Dillow+1SE	Thomas	Thomas+1SE	L-Moment	L-Moment+1SE	ROI	ROI+1SE
1.25 Year	-999.0	-999.0	-999.0	-999.0	511.0	808.0	883.0	1880.0	-999.0	-999.0
1.50 Year	-999.0	-999.0	-999.0	-999.0	711.0	1090.0	1170.0	2490.0	-999.0	-999.0
1.75 Year	-999.0	-999.0	-999.0	-999.0	828.0	1260.0	1380.0	2890.0	-999.0	-999.0
2 Year	258.0	457.0	338.0	531.0	911.0	1370.0	1560.0	3210.0	769.0	1250.0
5 Year	495.0	868.0	636.0	965.0	1750.0	2610.0	2910.0	5940.0	1370.0	2280.0
10 Year	726.0	1290.0	913.0	1380.0	2540.0	3900.0	4200.0	8600.0	1900.0	3250.0
25 Year	1130.0	2050.0	1370.0	2120.0	3820.0	6300.0	6490.0	13100.0	2730.0	4930.0
50 Year	1550.0	2860.0	1790.0	2860.0	4840.0	8390.0	8830.0	18300.0	3380.0	6320.0
100 Year	2080.0	4000.0	2310.0	3820.0	6690.0	12900.0	11900.0	25400.0	4450.0	8670.0
200 Year	-999.0	-999.0	-999.0	-999.0	8610.0	18000.0	15900.0	34600.0	5560.0	11300.0
500 Year	-999.0	-999.0	3980.0	7340.0	11800.0	27800.0	23200.0	52400.0	7350.0	16000.0

The process of automating this type of comparison across all methods and return periods has been automated within GISHydro and Table 4 is actually a "screen capture" from within GISHydro. Also shown in Table 4 are the peak flow estimates plus one standard error – this quantification of error will be discussed in the next section.

Quantifying Performance of Methods

In a manner similar to the way the best ROI models were determined, all models from the three new developed methods were tested against the gage database developed and used throughout this project. For purposes of comparison, the equations developed by Carpenter (1980) and Dillow (1995) were also tested. The results are shown in the Tables 5 through 9 which show the relative standard error (standard error divided by standard deviation) for each model and return period grouped by physiographic region identified by Dillow. The exact value shown in Tables 5-9 is given by the following equation:

$$\frac{S_e}{S_y} = \frac{\left[\frac{1}{n-p-1}\sum_{i=1}^{n}(y_i-\hat{y}_i)^2\right]^{0.5}}{\left[\frac{1}{n-1}\sum_{i=1}^{n}(y_i-\bar{y}_i)^2\right]^{0.5}} \tag{84}$$

where S_e is the standard error, S_y is the standard deviation, n is the number of observations, p is the number of predictor variables, y is the observed discharge for a given return period, $\hat{y}$ is the estimated discharge from one of the regression equations presented for a given method and return period, and $\bar{y}$ is the mean of the observed discharges for a given return period.

Table 5. Relative Standard Error as a function of return period and method in the Appalachian Region. (Lowest standard error is shown in **bold**.)

Appalachian Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.270	0.408	0.503	0.611	0.684	0.744	---	---
Dillow	---	---	---	0.225	0.327	0.387	0.460	0.510	0.554	---	0.644
Fixed Region	**0.180**	**0.172**	**0.172**	0.181	**0.235**	**0.286**	**0.346**	**0.386**	**0.421**	**0.451**	**0.487**
L-Moments	0.181	0.194	0.186	**0.175**	0.250	0.318	0.393	0.442	0.487	0.525	0.568
ROI	---	---	---	0.251	0.369	0.446	0.532	0.586	0.633	0.672	0.716

Table 6. Relative Standard Error as a function of return period and method in the Blue Ridge Region. (Lowest standard error is shown in **bold**.)

Blue Ridge Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.694	0.749	0.798	0.878	0.937	1.000	---	---
Dillow	---	---	---	0.508	0.716	0.868	1.043	1.147	1.234	---	1.268
Fixed Region	0.526	0.477	0.456	0.442	**0.338**	**0.285**	**0.266**	**0.297**	**0.354**	**0.424**	**0.526**
L-Moments	**0.466**	**0.436**	**0.426**	**0.426**	0.431	0.470	0.550	0.626	0.708	0.786	0.877
ROI	---	---	---	0.518	0.513	0.481	0.467	0.480	0.512	0.559	0.632

Table 7. Relative Standard Error as a function of return period and method in the Piedmont Region (rural and urban). (Lowest standard error is shown in **bold**.)

Piedmont Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	**0.310**	0.302	0.368	0.500	0.607	0.709	---	---
Dillow	---	---	---	0.468	0.423	0.437	0.499	0.572	0.653	---	0.818
Fixed Region	**0.449**	**0.384**	**0.359**	0.352	**0.264**	**0.261**	**0.331**	0.414	0.506	0.612	0.740
L-Moments	0.531	0.493	0.468	0.442	0.372	0.369	0.427	0.500	0.581	0.660	0.753
ROI	---	---	---	0.389	0.354	0.343	0.347	**0.373**	**0.415**	**0.474**	**0.573**

Table 8. Relative Standard Error as a function of return period and method in the Western Coastal Plain Region. (Lowest standard error is shown in **bold**.)

Western Coastal Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.793	0.735	0.710	0.703	0.719	0.756	---	---
Dillow	---	---	---	0.451	0.580	0.687	0.869	0.911	0.997	---	1.127
Fixed Region	**0.391**	**0.376**	**0.370**	**0.366**	**0.342**	**0.351**	**0.427**	**0.467**	**0.542**	**0.616**	**0.710**
L-Moments	0.768	0.760	0.747	0.728	0.708	0.708	0.673	0.749	0.788	0.828	0.886
ROI	---	---	---	0.488	0.533	0.585	0.697	0.709	0.759	0.800	0.841

Table 9. Relative Standard Error as a function of return period and method in the Eastern Coastal Plain Region. (Lowest standard error is shown in **bold**.)

Eastern Coastal Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.683	0.635	0.582	0.547	0.554	0.589	---	---
Dillow	---	---	---	0.734	0.676	0.647	0.716	0.614	0.626	---	0.672
Fixed Region	0.356	0.361	0.361	0.368	0.391	0.394	0.401	**0.413**	**0.437**	**0.472**	**0.534**
L-Moments	**0.335**	**0.289**	**0.268**	**0.258**	**0.266**	**0.314**	**0.400**	0.476	0.560	0.648	0.767
ROI	---	---	---	0.405	0.441	0.449	0.469	0.467	0.484	0.510	0.560

It is now possible to summarize our findings by reporting the method that achieved the lowest standard error across all equations/methods considered. These results are shown in Table 10.

Table 10. Method with smallest relative standard error as a function of return period and region.

Method with smallest S_e/S_y	Return Period										
Region	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Appalachian	FR	FR	FR	L	FR	FR	FR	FR	FR	FR	FR
Blue Ridge	L	L	L	L	FR	FR	FR	FR	FR	FR	FR
Piedmont	FR	FR	FR	C	FR	FR	FR	ROI	ROI	ROI	ROI
Western Coastal	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR	FR
Eastern Coastal	L	L	L	L	L	L	L	FR	FR	FR	FR

Notes: “C” is Carpenter equations, “FR” is fixed region method, “L” is L-moments method, and ROI is the region of influence method. “Piedmont” is both rural and urban gages combined.

The most successful methods were the Fixed Region (producing the lowest S_e/S_y in 38 cases), the L-moments method (producing the lowest S_e/S_y in 12 cases), and the Region of Influence method a distant third (producing the lowest S_e/S_y in 4 cases). Surprisingly the Carpenter equations, calibrated long ago, still produced the lowest S_e/S_y in 1 case. The Dillow equations did not produce the lowest S_e/S_y in any instance.

Tables of standard error as a fraction of the mean discharge

The hydrology panel convened by the Maryland State Highway Administration recommends that calibration of TR-20 simulations be based on simulated peak discharges between the *n*-year peak discharge estimate and this same estimate plus one standard error. Tables 11-15 present values of the standard error as a percentage of the mean discharge using equation 85 for each method and return period to aid in this calibration step.

$$\frac{S_e}{\bar{y}} = \frac{\left[\frac{1}{n-p-1}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2\right]^{0.5}}{\frac{1}{n}\sum_{i=1}^{n} y_i} \tag{85}$$

Table 11. Standard Error as a fraction of the mean discharge by return period and method in the Appalachian Region.

Appalachian Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.325	0.487	0.604	0.746	0.849	0.941	---	---
Dillow	---	---	---	0.271	0.390	0.465	0.561	0.632	0.701	---	0.856
Fixed Region	0.228	0.215	0.215	0.226	0.290	0.355	0.437	0.495	0.550	0.601	0.668
L-Moments	0.214	0.227	0.216	0.211	0.299	0.381	0.480	0.549	0.616	0.677	0.754
ROI	---	---	---	0.312	0.456	0.555	0.672	0.752	0.827	0.896	0.982

Table 12. Standard Error as a fraction of the mean discharge by return period and method in the Blue Ridge Region.

Blue Ridge Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.985	0.948	0.947	0.978	1.008	1.055	---	---
Dillow	---	---	---	0.721	0.906	1.030	1.161	1.235	1.301	---	1.331
Fixed Region	0.819	0.705	0.658	0.628	0.430	0.340	0.297	0.321	0.375	0.446	0.555
L-Moments	0.726	0.643	0.613	0.605	0.545	0.557	0.612	0.674	0.747	0.822	0.921
ROI	---	---	---	0.822	0.651	0.573	0.523	0.519	0.543	0.587	0.667

Table 13. Standard Error as a fraction of the mean discharge by return period and method in the Piedmont Region (rural and urban).

Piedmont Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.489	0.419	0.477	0.610	0.721	0.834	---	---
Dillow	---	---	---	0.738	0.587	0.567	0.608	0.679	0.767	---	0.987
Fixed Region	0.802	0.646	0.589	0.568	0.369	0.333	0.379	0.438	0.499	0.569	0.647
L-Moments	0.929	0.811	0.750	0.696	0.517	0.479	0.521	0.593	0.682	0.779	0.909
ROI	---	---	---	0.627	0.495	0.437	0.397	0.395	0.410	0.441	0.501

Table 14. Standard Error as a fraction of the mean discharge by return period and method in the Western Coastal Western Region.

Western Coastal Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.909	0.790	0.733	0.701	0.710	0.737	---	---
Dillow	---	---	---	0.517	0.622	0.710	0.867	0.900	0.972	---	1.119
Fixed Region	0.520	0.487	0.474	0.467	0.402	0.392	0.449	0.480	0.540	0.606	0.695
L-Moments	0.917	0.884	0.861	0.834	0.761	0.731	0.672	0.740	0.768	0.810	0.880
ROI	---	---	---	0.621	0.627	0.652	0.734	0.730	0.756	0.786	0.824

Table 15. Standard Error as a fraction of the mean discharge by return period and method in the Eastern Coastal Region.

Eastern Coastal Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.762	0.680	0.601	0.539	0.527	0.542	---	---
Dillow	---	---	---	0.818	0.724	0.668	0.705	0.584	0.577	---	0.591
Fixed Region	0.390	0.402	0.404	0.413	0.432	0.425	0.416	0.416	0.429	0.455	0.508
L-Moments	0.379	0.323	0.299	0.288	0.285	0.324	0.393	0.453	0.516	0.582	0.674
ROI	---	---	---	0.454	0.488	0.485	0.487	0.470	0.475	0.491	0.533

We should comment on the $S_e/\bar{y}$ values presented here and their comparability to values presented in other publications. The standard error (S_e) is calculated here in the arithmetic (rather than logarithmic) space in units of ft^3/s. Other documents report this quantity in the logarithmic space and use a different transform to determine the standard error as a fraction of the mean which may tend to reduce the apparent magnitude of $S_e/\bar{y}$. Additionally, the values reported in this document apply for the test data set of gages appearing in Appendices A1, A2, C1, and C2 from Maryland and Delaware. Both Dillow (1996) and Carpenter (1980) had different sets of streamgages over which these quantities were calculated. We have tabulated the values analogous to Tables 11-15 but using USGS methods in Appendix E (Tables E1-E5) so that the results of the new methods presented in this document can be compared directly to these other studies.

Standard Error Calculation for Case Study Watershed

Tables E1-E5 above can be used to determine an estimate of the uncertainty surrounding a prediction from the methods considered in this report. The discharge plus one standard error estimate is computed by simply multiplying the estimated discharge by the appropriate tabulated value plus one. In the case of a watershed that straddles more than one region (such as in our case study), the standard error is calculated as the area weighted average of the standard errors for the regions in which the watershed is located.

Region of Influence Method – Estimating Discharge Plus One Standard Error

Table E3 (Piedmont Region) shows the fraction of standard error is 0.445 for the 2-year discharge. Thus, the estimate plus one standard error is (compare to equation 71):

$$Q_{2,P+1SE} \cdot (1+0.445) = 572.6 \cdot (1.445) = 827.4 \text{ ft}^3/\text{s} \qquad (86)$$

Likewise, from Table E4 (Western Coastal Region), the fraction of standard error is 0.682 for the 2-year discharge. The estimate plus one standard error is (compare to equation 72):

$$Q_{2,WCP+1SE} \cdot (1+0.682) = 874.4 \cdot (1.682) = 1{,}470.7 \text{ ft}^3/\text{s} \qquad (87)$$

The overall estimate of the discharge plus one standard error is then the area weighted average:

$$Q_{2+1SE} = 0.348 \cdot (827.4) + 0.652 \cdot (1{,}470.7) = 1{,}246.8 \text{ ft}^3/\text{s} \qquad (88)$$

Table 4 shows the equivalent entry for equation 88 under the column heading, "*ROI + 1SE*". The slight difference (1,246.8 ft^3/s here versus 1,250 ft^3/s in Table 4) is due to rounding differences present in the hand calculations of equations 71-73 and 86-88.

L-Moment Method – Estimating Discharge Plus One Standard Error

Table E3 (Piedmont Region) shows the fraction of standard error is 0.402 for the 2-year discharge. Thus, the estimate plus one standard error is (compare to equation 81):

$$Q_{2,P+1SE} \cdot (1+0.402) = 518.5 \cdot (1.402) = 726.9 \text{ ft}^3/\text{s} \qquad (89)$$

Likewise, from Table E4 (Western Coastal Region), the fraction of standard error is 1.152 for the 2-year discharge. The estimate plus one standard error is (compare to equation 82):

$$Q_{2,WCP+1SE} \cdot (1+1.152) = 2{,}110 \cdot (1.152) = 4{,}541 \text{ ft}^3/\text{s} \qquad (90)$$

The overall estimate of the discharge plus one standard error is then the area weighted average (compare to equation 45):

$$Q_{2+1SE} = 0.348 \cdot (726.9) + 0.652 \cdot (4{,}541) = 3{,}214 \text{ ft}^3/\text{s} \qquad (91)$$

Table 4 shows the equivalent entry for equation 91 under the column heading, "*L-Moment + 1SE*". The slight difference (3,214 ft^3/s here versus 3,210 ft^3/s in Table 4) is due to rounding differences present in the hand calculations of equations 79-82 and 89-91.

Fixed Region Method – Estimating Discharge Plus One Standard Error

In the case of the Fixed Region method, the tabulated standard error values can be improved upon by using a computer program originally developed by Gary Tasker at the USGS and modified by the authors for the fixed region equations developed in this study. This program (and associated data files) is available for download from the GISHydro web site at:

http://www.gishydro.umd.edu/documents/mdsha_reports/fixedregion.zip

Executing this program for the study watershed in the Piedmont Region produces the following value the +1SE estimate:

$$Q_{2,P+1SE} = 1{,}330 \text{ ft}^3/\text{s} \qquad (92)$$

Likewise, this program produces the following value for the +1SE estimate in the Western Coastal Region:

$$Q_{2,WCP+1SE} = 1{,}390 \text{ ft}^3/\text{s} \qquad (93)$$

The overall estimate of the discharge plus one standard error is then the area weighted average (compare to equation 36):

$$Q_{2+1SE} = 0.348 \cdot (1{,}330) + 0.652 \cdot (1{,}390) = 1{,}369 \text{ ft}^3/\text{s} \qquad (94)$$

Table 4 shows the equivalent entry for equation 94 under the column heading, "*Thomas + 1SE* " (which means "Fixed Reion + 1SE"). The slight difference (1,369 ft^3/s here versus 1,370 ft^3/s in Table 4) is due to rounding differences present in the hand calculations of equations 68-70 and 92-94.

To summarize these findings, both of the best estimate of the discharge and the discharge plus one standard deviation, Table 3 can be updated as shown below in Table 16.

Table 16. Summary of 2-year peak discharge estimates and estimates plus one Standard Error for Dorsey Run at U.S. Route 1 watershed.

Method	**2-year Peak Discharge (ft^3/s)**	**2-year Peak Discharge plus one S_e (ft^3/s)**
USGS, 1980 – Carpenter	258	457
USGS, 1995 – Dillow	338	531
Fixed Region Method	911	1,370
Region of Influence Method	769	1,250
L-Moment Method	1,560	3,210

The results of this case study may be summarized by observing that the three new methods developed in this study each predict a much greater discharge than those resulting from the either set of USGS equations. We attribute this to the fact that both sets of USGS equations were for "rural" watersheds where imperviousness was used as a criterion in selecting which watersheds would contribute to the calibration of the equations. In contrast, all watersheds were used in this study, regardless of extent of development. Because of a large sampling of urban watersheds in the Piedmont and Western Coastal Plain, equations developed in this study may be applied to these regions to estimate the current or future discharge without the need to apply the USGS urban equations (Sauer et al., 1983) after the fact. (The USGS urban equations are still necessary in the Appalachian Plateau, Blue Ridge, and Eastern Coastal Plain regions where an urbanization parameter is not present.) Standard errors, while larger in absolute magnitude than those from either set of USGS equations, are a comparable percentage of the estimated discharge.

VII. Summary, Conclusions, and Recommendations

In an earlier draft of this report, we wrote:

> How do we make sense of these results? In some cases, there is a clear course of action. For instance, the Fixed Region method achieves the lowest S_e/S_y values across all return periods in the Western Coastal region and all but one return period in the Appalachian region. It would be a simple matter to adopt the Fixed Region equations for these regions and be done with it. At the other end are the results for the Blue Ridge, Piedmont, and Eastern Coastal regions which each have at least two different methods produce lowest S_e/S_y values across 11 different return periods. Can/should methods be mixed across different return periods for a given region? Should multiple methods be used in a region and their estimates averaged (or otherwise interpreted) in some way to produce a discharge estimate?

Since that time the Maryland Hydrology Panel has examined the findings from this study and considered how to best apply statistical methods for peak discharge estimation across the State of Maryland. Results from specific MSHA analyses from across the state were examined over the course of several years of meetings. Their ultimate recommendation was, "The Fixed Region regression equations are the recommended statistical approach for ungaged watersheds in Maryland and supercede the regression equations developed by Dillow (1996)."

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Appendix A1: Watershed Properties for USGS Stream Gages in Maryland

Station Number	Station Name	Years of Record	Area (mi^2)	Perimeter (mi)	Length (mi)	Channel Slope (ft/mi)	Watershed Slope (ft/ft)	Basin Relief (ft)	Lime (%)	High Elev. (%)	Hypso
1485000	Pocomoke River near Willards, MD	50	44.11	82.5	15.9	2.2	0.00530	22.0	0.0	0.0	0.42
1485500	Nassawango Creek near Snow Hill, MD	49	48.64	64.6	15.7	2.5	0.00494	29.4	0.0	0.0	0.39
1486000	Manokin Branch near Princess Anne, MD	46	6.68	23.4	7.1	3.7	0.00378	21.1	0.0	0.0	0.59
1489000	Faulkner Branch near Federalsburg, MD	42	8.66	25.3	6.7	5.9	0.01062	25.7	0.0	0.0	0.60
1490000	Chicamacomico River near Salem, MD	29	15.87	31.6	8.4	6.3	0.00692	26.5	0.0	0.0	0.54
1490800	Oldtown Branch at Goldsboro, MD	10	4.04	20.2	4.7	7.5	0.00553	16.2	0.0	0.0	0.62
1491000	Choptank River near Greensboro, MD	52	112.20	94.9	21.7	3.2	0.00708	44.6	0.0	0.0	0.44
1491050	Spring Branch near Greensboro, MD	10	4.44	17.3	4.9	5.3	0.00390	16.2	0.0	0.0	0.61
1492000	Beaverdam Branch at Matthews, MD	32	6.22	20.0	5.7	10.0	0.00811	34.0	0.0	0.0	0.74
1492050	Gravel Run at Beulah, MD	10	8.28	22.5	5.0	10.9	0.01315	37.3	0.0	0.0	0.67
1492500	Sallie Harris Creek near Carmicheal, MD	30	7.30	23.7	7.4	8.8	0.01118	36.5	0.0	0.0	0.62
1492550	Mill Creek near Skipton, MD	11	4.88	16.3	4.9	12.5	0.00750	40.4	0.0	0.0	0.62
1493500	Morgan Creek near Kennedyville, MD	49	12.03	28.1	7.6	7.5	0.01155	40.8	0.0	0.0	0.62
1494000	Southeast Creek at Church Hill, DE	14	12.15	25.4	7.3	9.5	0.01006	43.3	0.0	0.0	0.69
1495000	Big Elk Creek at Elk Mills, MD	68	53.49	64.4	23.9	17.6	0.08607	329.9	0.0	0.0	0.57
1495500	Little Elk Creek at Childs, MD	10	26.46	42.7	16.8	24.2	0.06752	294.1	0.0	0.0	0.58
1496000	Northeast River at Leslie, MD	37	24.87	42.5	14.3	24.5	0.04863	288.5	0.0	0.0	0.57
1496200	Principio Creek near Principio Furnace, MD	27	9.00	22.1	6.7	33.2	0.06388	165.6	0.0	0.0	0.58
1577940	Broad Creek tributary at Whiteford, MD	15	0.67	5.8	1.7	175.7	0.07430	107.7	0.0	0.0	0.35
1578500	Octoraro Creek near Rising Sun, MD	19	191.66	99.7	43.6	10.8	0.08256	422.8	0.0	0.0	0.50
1580000	Deer Creek at Rocks, MD	73	94.18	77.9	31.3	17.5	0.09710	379.1	0.0	0.0	0.48
1580200	Deer Creek at Kalmia, MD	11	127.16	103.8	43.8	14.2	0.09671	424.0	0.0	0.0	0.47
1581500	Bynum Run at Bel Air, MD	25	8.32	20.2	7.1	38.1	0.05467	144.4	0.0	0.0	0.47
1581700	Winter Run near Benson, MD	32	34.66	42.2	17.4	30.4	0.07969	315.5	0.0	0.0	0.55
1582000	Little Falls at Blue Mount, MD	56	53.63	53.4	18.6	18.8	0.10669	364.1	0.0	0.0	0.54
1582510	Piney Creek near Hereford, MD	14	1.39	7.3	2.4	92.5	0.07866	139.0	0.0	0.0	0.62
1583000	Slade Run near Glyndon, MD	34	2.04	10.0	2.8	96.5	0.09968	180.2	0.0	0.0	0.51
1583100	Piney Run at Dover, MD	10	12.44	28.3	9.0	51.1	0.09213	274.3	0.0	0.0	0.50
1583495	Western Run tributary at Western Run, MD	10	0.23	3.1	1.2	168.8	0.08274	110.5	0.0	0.0	0.53
1583500	Western Run at Western Run, MD	55	60.32	56.1	18.8	24.2	0.09060	282.2	0.0	0.0	0.43

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	# First Order Streams	Total Stream Length	Area in MD	2-Year Prec. (in x 100)	100-Year Prec. (in x100)	Res70 (%)	Com70 (%)	Ag70 (%)	For70 (%)	St70 (%)	IA70 (%)	Res85 (%)
1485000	Pocomoke River near Willards, MD	27	99.8	0.334	333.9	858.8	0.6	0.0	53.1	29.4	16.9	0.2	0.2
1485500	Nassawango Creek near Snow Hill, MD	9	54.5	1.000	355.6	914.4	0.8	0.5	18.1	79.4	1.2	0.8	1.2
1486000	Manokin Branch near Princess Anne, MD	2	7.9	1.000	338.0	869.0	0.1	0.0	24.1	75.7	0.0	0.0	0.6
1489000	Faulkner Branch near Federalsburg, MD	5	14.6	1.000	359.0	921.0	1.7	0.0	75.4	22.9	0.0	0.6	1.5
1490000	Chicamacomico River near Salem, MD	9	26.7	1.000	334.1	859.7	0.4	0.1	51.1	48.1	0.3	0.2	0.2
1490800	Oldtown Branch at Goldsboro, MD	3	8.0	1.000	337.0	865.0	1.1	0.0	65.4	29.8	3.6	0.4	1.1
1491000	Choptank River near Greensboro, MD	68	232.7	0.316	330.5	848.1	2.6	0.1	52.7	37.1	7.1	1.1	2.5
1491050	Spring Branch near Greensboro, MD	2	6.3	0.998	337.0	865.0	1.9	0.0	76.7	21.4	0.0	0.7	0.0
1492000	Beaverdam Branch at Matthews, MD	3	10.9	1.000	317.0	814.0	1.2	0.0	67.9	31.0	0.0	0.4	0.0
1492050	Gravel Run at Beulah, MD	7	13.7	1.000	359.0	921.0	1.0	0.0	87.3	11.0	0.0	0.4	0.2
1492500	Sallie Harris Creek near Carmicheal, MD	3	11.9	1.000	345.0	887.0	4.7	0.0	64.5	30.8	0.0	1.8	0.5
1492550	Mill Creek near Skipton, MD	2	7.0	0.995	345.0	887.0	0.0	0.0	91.7	8.3	0.0	0.0	0.0
1493500	Morgan Creek near Kennedyville, MD	7	17.0	1.000	315.8	810.4	1.2	0.0	93.3	5.4	0.2	0.4	1.0
1494000	Southeast Creek at Church Hill, DE	6	20.4	1.000	340.0	874.1	0.5	0.0	77.9	17.4	4.2	0.2	0.4
1495000	Big Elk Creek at Elk Mills, MD	22	85.6	0.201	318.9	802.7	2.4	3.0	80.2	14.2	0.0	3.7	5.4
1495500	Little Elk Creek at Childs, MD	12	42.1	0.533	328.4	834.2	6.1	2.0	75.7	15.9	0.1	4.0	6.3
1496000	Northeast River at Leslie, MD	9	34.8	0.693	325.6	824.7	2.0	2.4	78.8	15.3	0.0	3.0	4.4
1496200	Principio Creek near Principio Furnace, MD	4	13.4	1.000	315.8	799.9	0.0	0.0	95.7	4.2	0.0	0.0	2.9
1577940	Broad Creek tributary at Whiteford, MD	1	0.9	1.000	348.0	872.0	2.0	0.8	42.9	54.3	0.0	1.3	5.4
1578500	Octoraro Creek near Rising Sun, MD	88	345.8	0.083	317.1	794.5	1.5	0.7	79.3	17.6	0.5	1.3	5.2
1580000	Deer Creek at Rocks, MD	42	175.4	0.734	339.4	850.4	0.9	0.4	71.8	26.7	0.1	0.7	2.6
1580200	Deer Creek at Kalmia, MD	55	232.5	0.803	335.3	840.3	0.8	0.4	71.7	27.0	0.0	0.6	3.2
1581500	Bynum Run at Bel Air, MD	3	12.8	1.000	322.8	809.0	16.2	5.2	67.0	10.5	0.0	10.8	20.5
1581700	Winter Run near Benson, MD	13	61.5	1.000	323.0	809.6	6.6	0.3	71.1	20.6	0.0	2.8	14.2
1582000	Little Falls at Blue Mount, MD	22	96.6	0.919	334.6	839.0	0.2	0.9	67.2	31.6	0.0	1.0	4.5
1582510	Piney Creek near Hereford, MD	1	2.6	1.000	321.0	806.0	0.0	0.6	74.4	25.0	0.0	0.6	9.7
1583000	Slade Run near Glyndon, MD	3	5.5	1.000	328.0	822.0	5.4	0.0	45.4	49.2	0.0	2.1	3.3
1583100	Piney Run at Dover, MD	3	19.8	1.000	322.2	808.7	1.0	0.1	74.1	24.6	0.1	0.5	4.8
1583495	Western Run tributary at Western Run, MD	1	0.0	1.000	321.0	806.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
1583500	Western Run at Western Run, MD	32	107.4	1.000	321.8	807.7	0.8	0.1	71.8	27.2	0.1	0.4	4.5

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Com85 (%)	Ag85 (%)	For85 (%)	St85 (%)	IA85 (%)	Res90 (%)	Com90 (%)	Ag90 (%)	For90 (%)	St90 (%)	IA90 (%)	Res97 (%)
1485000	Pocomoke River near Willards, MD	1.8	0.0	34.2	0.0	1.5	0.3	0.1	57.8	34.7	0.0	0.5	1.5
1485500	Nassawango Creek near Snow Hill, MD	1.6	0.0	65.6	0.3	1.7	1.5	0.9	20.4	64.5	0.3	1.3	3.1
1486000	Manokin Branch near Princess Anne, MD	1.6	0.0	57.4	0.0	1.5	1.4	0.0	22.4	57.7	0.0	0.6	2.2
1489000	Faulkner Branch near Federalsburg, MD	3.2	0.0	18.6	0.0	3.0	2.1	0.3	75.4	19.6	0.0	1.4	4.5
1490000	Chicamacomico River near Salem, MD	0.0	0.0	46.4	0.1	0.2	0.5	0.0	51.8	39.6	3.1	0.4	1.5
1490800	Oldtown Branch at Goldsboro, MD	0.6	0.0	33.1	0.0	0.7	6.0	0.4	62.0	31.5	0.0	2.0	9.4
1491000	Choptank River near Greensboro, MD	0.1	0.0	41.0	0.3	0.8	5.4	0.1	51.7	38.0	0.3	1.6	6.9
1491050	Spring Branch near Greensboro, MD	0.0	0.0	20.4	0.0	0.0	1.2	0.0	77.3	19.8	0.0	0.3	2.3
1492000	Beaverdam Branch at Matthews, MD	0.6	0.0	27.9	0.0	0.6	1.1	0.0	65.6	29.1	0.0	0.4	3.1
1492050	Gravel Run at Beulah, MD	1.3	0.0	15.0	0.3	1.3	0.4	0.0	71.0	15.0	0.4	0.5	4.6
1492500	Sallie Harris Creek near Carmicheal, MD	0.0	0.0	30.4	0.0	0.1	1.4	0.0	66.8	31.8	0.0	0.3	2.3
1492550	Mill Creek near Skipton, MD	0.0	0.0	12.2	0.0	0.0	0.0	0.0	93.1	7.4	0.0	0.0	0.5
1493500	Morgan Creek near Kennedyville, MD	0.4	0.0	8.9	0.2	0.6	0.9	0.3	89.8	8.5	0.6	0.6	1.1
1494000	Southeast Creek at Church Hill, DE	0.4	0.0	26.3	0.0	0.6	0.6	0.1	72.8	25.4	0.2	0.7	1.2
1495000	Big Elk Creek at Elk Mills, MD	5.7	0.0	36.3	0.0	6.4	5.2	0.3	58.8	36.2	0.0	2.1	5.8
1495500	Little Elk Creek at Childs, MD	1.1	0.0	30.9	0.0	2.5	12.5	0.8	58.9	27.1	0.3	4.2	18.7
1496000	Northeast River at Leslie, MD	0.7	0.0	22.8	0.0	1.9	6.7	0.4	68.5	23.1	0.0	2.5	7.7
1496200	Principio Creek near Principio Furnace, MD	0.0	0.0	14.8	0.0	1.0	4.4	0.0	78.6	17.0	0.0	1.2	9.7
1577940	Broad Creek tributary at Whiteford, MD	0.3	0.0	28.0	0.0	1.6	8.5	1.1	49.9	39.5	0.0	3.0	10.4
1578500	Octoraro Creek near Rising Sun, MD	0.6	0.0	33.6	0.2	1.9	10.3	0.6	59.3	31.7	0.3	3.5	14.2
1580000	Deer Creek at Rocks, MD	0.3	0.0	35.8	0.0	1.0	6.4	0.5	58.1	34.3	0.1	2.4	8.8
1580200	Deer Creek at Kalmia, MD	0.3	0.0	34.7	0.0	1.2	7.2	0.5	58.0	33.5	0.0	2.6	10.2
1581500	Bynum Run at Bel Air, MD	6.3	0.0	22.3	0.0	12.9	31.7	7.8	34.7	18.4	0.2	19.6	38.1
1581700	Winter Run near Benson, MD	0.7	0.0	29.3	0.0	4.6	19.0	0.4	49.1	27.6	0.0	6.4	25.4
1582000	Little Falls at Blue Mount, MD	0.2	0.0	41.0	0.0	1.3	7.6	0.2	51.7	39.4	0.0	2.6	10.4
1582510	Piney Creek near Hereford, MD	0.0	0.0	31.2	0.0	2.4	10.8	0.0	54.2	35.0	0.0	3.3	13.6
1583000	Slade Run near Glyndon, MD	0.4	0.0	46.2	0.0	1.2	5.9	0.2	50.0	42.9	0.0	2.5	4.5
1583100	Piney Run at Dover, MD	0.8	0.0	29.1	0.1	1.9	3.7	0.4	62.5	30.4	0.0	1.9	6.3
1583495	Western Run tributary at Western Run, MD	0.0	0.0	27.5	0.0	0.0	0.0	0.0	97.8	2.0	0.0	0.0	11.0
1583500	Western Run at Western Run, MD	0.4	0.0	34.0	0.0	1.5	6.1	0.1	59.8	31.9	0.0	2.1	8.3

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Com97 (%)	Ag97 (%)	For97 (%)	St97 (%)	IA97 (%)	CN70	CN97	Hyd. A (%)	Hyd. B (%)	Hyd. C (%)	Hyd. D (%)
1485000	Pocomoke River near Willards, MD	0.0	57.0	33.7	0.0	0.7	81.8	79.4	4.6	6.3	3.4	85.7
1485500	Nassawango Creek near Snow Hill, MD	1.3	19.5	64.6	0.3	2.0	70.1	70.9	10.8	9.4	5.6	74.2
1486000	Manokin Branch near Princess Anne, MD	0.0	22.1	51.3	0.0	0.8	74.4	74.5	0.4	10.1	6.4	83.1
1489000	Faulkner Branch near Federalsburg, MD	0.8	73.2	18.7	0.0	2.1	78.3	81.4	0.0	38.6	20.9	40.6
1490000	Chicamacomico River near Salem, MD	0.1	50.9	41.9	0.5	0.8	74.3	77.2	4.3	33.0	17.6	45.1
1490800	Oldtown Branch at Goldsboro, MD	0.3	61.2	28.9	0.0	2.9	78.7	80.4	0.0	31.0	7.7	61.3
1491000	Choptank River near Greensboro, MD	0.3	50.9	36.3	0.3	2.2	77.1	77.1	9.9	30.9	9.6	49.6
1491050	Spring Branch near Greensboro, MD	0.0	75.9	19.7	0.0	0.6	78.2	81.6	2.0	55.3	7.4	35.4
1492000	Beaverdam Branch at Matthews, MD	0.0	66.0	26.8	0.0	1.0	76.3	79.1	0.0	54.4	25.2	20.5
1492050	Gravel Run at Beulah, MD	0.2	74.9	13.5	0.6	2.0	76.7	80.5	5.2	77.1	12.0	5.7
1492500	Sallie Harris Creek near Carmicheal, MD	0.0	68.1	29.6	0.0	0.6	75.2	78.7	0.0	43.9	32.4	23.7
1492550	Mill Creek near Skipton, MD	0.0	91.8	8.2	0.0	0.1	80.3	84.4	0.0	59.9	20.5	19.6
1493500	Morgan Creek near Kennedyville, MD	0.4	87.9	10.0	0.5	0.8	76.9	81.0	1.4	31.4	57.6	9.5
1494000	Southeast Creek at Church Hill, DE	0.3	74.9	22.5	0.2	0.9	77.5	80.1	0.2	58.9	14.8	26.1
1495000	Big Elk Creek at Elk Mills, MD	0.4	58.4	34.9	0.0	2.4	73.6	72.9	0.0	81.9	11.6	6.5
1495500	Little Elk Creek at Childs, MD	1.1	53.4	24.9	0.2	6.3	75.0	75.0	0.0	67.6	22.1	10.3
1496000	Northeast River at Leslie, MD	0.5	66.4	22.6	0.1	3.2	75.3	76.4	0.0	60.9	19.7	19.5
1496200	Principio Creek near Principio Furnace, MD	0.1	73.5	16.4	0.0	2.8	75.8	78.0	0.0	72.3	15.0	12.7
1577940	Broad Creek tributary at Whiteford, MD	1.2	49.0	38.3	0.0	3.8	67.5	70.5	1.2	83.8	15.0	0.0
1578500	Octoraro Creek near Rising Sun, MD	1.7	54.6	29.7	0.3	5.5	73.5	76.8	0.0	71.7	19.5	8.8
1580000	Deer Creek at Rocks, MD	0.3	56.1	32.7	0.1	2.6	70.7	72.1	0.1	86.8	10.2	2.9
1580200	Deer Creek at Kalmia, MD	0.4	55.4	32.2	0.0	3.1	71.3	72.6	0.0	82.6	14.1	3.3
1581500	Bynum Run at Bel Air, MD	8.1	29.1	17.6	0.2	21.8	77.8	78.7	0.0	70.5	5.3	24.2
1581700	Winter Run near Benson, MD	0.8	45.8	26.0	0.0	7.9	72.7	73.1	0.0	77.8	14.6	7.6
1582000	Little Falls at Blue Mount, MD	0.4	49.5	37.4	0.0	3.3	70.6	71.0	0.0	87.7	9.2	3.1
1582510	Piney Creek near Hereford, MD	0.0	54.2	32.1	0.0	3.4	71.5	72.1	0.0	94.4	5.6	0.0
1583000	Slade Run near Glyndon, MD	0.9	51.1	42.3	0.0	2.7	67.7	70.0	0.0	99.9	0.1	0.0
1583100	Piney Run at Dover, MD	0.4	59.5	29.2	0.0	3.1	71.4	73.3	0.2	87.7	8.7	3.3
1583495	Western Run tributary at Western Run, MD	0.0	86.7	2.3	0.0	2.7	75.0	77.7	0.0	100.0	0.0	0.0
1583500	Western Run at Western Run, MD	0.2	58.7	30.4	0.0	2.7	71.2	72.8	0.2	85.4	10.3	4.1

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Years of Record	Area (mi^2)	Perimeter (mi)	Length (mi)	Channel Slope (ft/mi)	Watershed Slope (ft/ft)	Basin Relief (ft)	Lime (%)	High Elev. (%)	Hypso
1583600	Beaverdam Run at Cockeysville, MD	16	20.68	30.1	11.8	36.7	0.08073	292.3	0.0	0.0	0.55
1584050	Long Green Creek at Glen Arm, MD	24	9.30	19.4	5.4	54.0	0.07196	167.0	0.0	0.0	0.47
1584500	Little Gunpowder Falls at Laurel Brook, MD	59	36.03	48.2	15.5	21.7	0.08010	251.5	0.0	0.0	0.50
1585100	White Marsh Run at White Marsh, MD	28	7.63	23.0	6.7	53.7	0.06653	159.8	0.0	0.0	0.38
1585200	West Branch Herring Run at Idlewylde, MD	31	2.16	8.8	2.5	62.5	0.06275	127.9	0.0	0.0	0.60
1585300	Stemmers Run at Rossville, MD	29	4.52	15.1	5.4	63.1	0.06403	167.2	0.0	0.0	0.46
1585400	Brien Run at Stemmers Run, MD	29	1.95	8.3	2.3	37.0	0.03603	62.3	0.0	0.0	0.38
1585500	Cranberry Branch near Westminster, MD	51	3.43	12.0	4.1	47.0	0.08999	164.9	0.0	0.0	0.46
1586000	North Branch Patapsco River at Cedarhurst, MD	54	56.27	48.8	16.2	28.2	0.09223	340.1	0.0	0.0	0.49
1586210	Beaver Run near Finksburg, MD	17	14.09	25.9	10.1	44.3	0.08905	297.5	0.0	0.0	0.57
1586610	Morgan Run near Louisville, MD	17	27.84	38.0	10.7	35.4	0.10010	285.6	0.0	0.0	0.54
1587000	North Branch Patapsco River near Marriottsville, MD	26	164.23	95.3	51.9	6.1	0.09138	413.3	0.0	0.0	0.48
1587050	Hay Meadow Branch tributary at Poplar Springs, MD	11	0.49	4.1	1.1	136.4	0.08716	82.4	0.0	0.0	0.52
1587500	South Branch Patapsco River at Henryton, MD	31	64.26	66.8	19.7	24.0	0.09709	349.9	0.0	0.0	0.55
1588000	Piney Run near Sykesville, MD	43	11.40	26.6	8.6	39.6	0.07545	216.8	0.0	0.0	0.49
1588500	Patapsco River at Woodstock, MD	10	258.07	122.7	57.2	7.7	0.09329	496.7	0.0	0.0	0.52
1589000	Patapsco River at Hollofield, MD	23	284.71	138.0	63.7	7.4	0.09301	475.6	0.0	0.0	0.49
1589100	East Branch Herbert Run at Arbutus, MD	34	2.42	10.5	3.6	97.4	0.05790	116.2	0.0	0.0	0.33
1589200	Gwynns Falls near Owings Mills, MD	17	4.89	14.0	4.7	34.2	0.05587	131.4	0.0	0.0	0.58
1589240	Gwynns Falls at McDonough, MD	12	19.27	28.0	9.6	28.8	0.06318	180.8	0.0	0.0	0.56
1589300	Gwynns Falls at Villa Nova, MD	36	32.61	40.0	15.9	19.4	0.06068	198.4	0.0	0.0	0.51
1589330	Dead Run at Franklintown, MD	29	5.47	16.7	3.9	45.9	0.05263	122.2	0.0	0.0	0.48
1589440	Jones Fall at Sorrento, MD	34	25.26	32.3	10.6	32.2	0.08167	237.5	0.0	0.0	0.49
1589500	Sawmill Creek at Glen Burnie, MD	30	4.92	14.7	4.7	30.1	0.02750	75.5	0.0	0.0	0.40
1590000	North River near Annapolis, MD	42	8.73	23.7	6.0	24.4	0.08665	110.7	0.0	0.0	0.55
1590500	Bacon Ridge Branch at Chesterfield, MD	35	6.88	19.6	5.3	24.9	0.11030	115.1	0.0	0.0	0.57
1591000	Patuxent River near Unity, MD	55	34.85	46.3	13.2	30.1	0.10645	259.7	0.0	0.0	0.46
1591400	Cattail Creek near Glenwood, MD	21	22.94	32.6	9.6	30.4	0.09419	212.3	0.0	0.0	0.45
1591500	Cattail Creek at Roxbury Mills, MD	12	27.72	37.1	10.2	31.3	0.09381	211.7	0.0	0.0	0.44

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	# First Order Streams	Total Stream Length	Area in MD	2-Year Prec. (in x 100)	100-Year Prec. (in x100)	Res70 (%)	Com70 (%)	Ag70 (%)	For70 (%)	St70 (%)	IA70 (%)	Res85 (%)
1583600	Beaverdam Run at Cockeysville, MD	8	34.0	1.000	310.7	779.0	9.5	12.6	36.7	33.7	0.2	14.5	21.4
1584050	Long Green Creek at Glen Arm, MD	9	20.8	1.000	313.5	785.7	4.0	1.7	80.1	14.2	0.0	2.9	11.8
1584500	Little Gunpowder Falls at Laurel Brook, MD	14	60.8	1.000	320.4	803.2	2.9	0.0	74.8	22.0	0.0	1.1	11.1
1585100	White Marsh Run at White Marsh, MD	4	13.9	1.000	323.0	809.5	27.5	9.4	19.2	29.8	0.7	18.9	38.5
1585200	West Branch Herring Run at Idlewylde, MD	2	4.2	1.000	330.0	827.0	73.9	16.0	0.0	0.0	0.0	41.4	66.3
1585300	Stemmers Run at Rossville, MD	3	7.0	1.000	330.0	827.0	35.3	17.9	25.0	15.6	0.0	30.4	41.4
1585400	Brien Run at Stemmers Run, MD	1	1.7	1.000	330.0	827.0	26.5	24.7	7.9	18.6	0.0	31.1	32.5
1585500	Cranberry Branch near Westminster, MD	1	3.8	1.000	328.0	822.0	2.4	0.0	75.0	21.7	0.8	0.9	10.9
1586000	North Branch Patapsco River at Cedarhurst, MD	19	84.3	1.000	328.0	822.0	2.9	1.9	74.3	20.5	0.1	2.6	11.3
1586210	Beaver Run near Finksburg, MD	6	25.6	1.000	328.0	822.0	5.5	1.2	74.0	18.8	0.0	3.1	14.2
1586610	Morgan Run near Louisville, MD	20	56.6	1.000	326.4	818.2	1.1	0.3	77.1	21.1	0.0	0.7	10.7
1587000	North Branch Patapsco River near Marriottsville, MD	80	302.6	1.000	324.9	814.2	3.3	0.9	66.2	26.6	2.6	2.0	12.3
1587050	Hay Meadow Branch tributary at Poplar Springs, MD	1	1.1	1.000	310.3	778.5	0.0	0.6	99.4	0.0	0.0	0.6	26.2
1587500	South Branch Patapsco River at Henryton, MD	36	125.4	1.000	310.8	780.0	2.9	1.2	75.3	20.6	0.0	2.2	11.2
1588000	Piney Run near Sykesville, MD	5	21.2	1.000	312.9	784.9	2.7	0.5	84.7	10.2	1.9	1.5	13.6
1588500	Patapsco River at Woodstock, MD	130	485.5	1.000	320.0	802.1	3.3	1.1	68.0	25.6	1.8	2.1	12.2
1589000	Patapsco River at Hollofield, MD	145	533.9	1.000	319.2	800.3	3.9	1.1	65.9	27.0	1.6	2.4	12.4
1589100	East Branch Herbert Run at Arbutus, MD	1	3.9	1.000	331.5	852.6	48.5	33.9	0.2	9.9	0.0	49.3	45.4
1589200	Gwynns Falls near Owings Mills, MD	2	7.1	1.000	313.8	786.4	31.4	4.3	49.1	11.9	0.0	15.5	33.7
1589240	Gwynns Falls at McDonough, MD	8	33.1	1.000	312.4	783.1	21.5	7.2	40.0	28.6	0.0	14.2	26.0
1589300	Gwynns Falls at Villa Nova, MD	11	52.0	1.000	312.4	782.9	34.3	7.7	30.3	24.4	0.0	19.7	37.1
1589330	Dead Run at Franklintown, MD	4	11.6	1.000	322.5	819.8	36.5	33.1	16.2	9.2	0.0	43.1	41.6
1589440	Jones Fall at Sorrento, MD	13	44.0	1.000	323.1	809.7	22.6	3.8	34.4	34.2	0.0	12.1	33.3
1589500	Sawmill Creek at Glen Burnie, MD	4	11.4	1.000	319.0	820.0	16.0	20.2	27.4	31.7	0.0	26.0	13.6
1590000	North River near Annapolis, MD	4	14.4	1.000	339.2	871.2	5.3	0.0	30.1	64.6	0.0	2.0	9.8
1590500	Bacon Ridge Branch at Chesterfield, MD	4	14.3	1.000	328.7	844.0	5.6	2.8	28.1	63.5	0.0	4.5	5.8
1591000	Patuxent River near Unity, MD	16	67.7	1.000	315.3	790.7	1.0	0.1	77.7	21.2	0.0	0.4	4.9
1591400	Cattail Creek near Glenwood, MD	14	46.9	1.000	321.2	806.2	0.4	1.9	81.3	16.2	0.1	2.0	8.4
1591500	Cattail Creek at Roxbury Mills, MD	16	53.1	1.000	321.9	807.8	1.7	1.7	82.7	13.7	0.2	2.3	10.0

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Com85 (%)	Ag85 (%)	For85 (%)	St85 (%)	IA85 (%)	Res90 (%)	Com90 (%)	Ag90 (%)	For90 (%)	St90 (%)	IA90 (%)	Res97 (%)
1583600	Beaverdam Run at Cockeysville, MD	11.9	0.0	34.4	0.1	18.0	26.0	11.3	24.3	28.4	0.3	18.9	33.5
1584050	Long Green Creek at Glen Arm, MD	3.2	0.0	19.7	0.0	5.6	12.9	0.9	67.2	18.3	0.0	5.8	15.5
1584500	Little Gunpowder Falls at Laurel Brook, MD	0.9	0.0	28.2	0.0	3.5	14.5	0.2	56.4	28.3	0.0	4.3	17.7
1585100	White Marsh Run at White Marsh, MD	7.2	0.0	26.5	0.0	21.6	44.6	8.3	10.2	23.6	0.0	25.8	52.1
1585200	West Branch Herring Run at Idlewylde, MD	10.5	0.0	7.0	0.0	37.5	65.8	9.8	0.0	7.2	0.0	37.8	65.0
1585300	Stemmers Run at Rossville, MD	9.5	0.0	29.9	0.0	25.3	42.4	9.1	9.2	28.3	0.0	25.4	44.4
1585400	Brien Run at Stemmers Run, MD	27.2	0.0	21.4	0.0	36.8	33.5	25.4	2.8	25.2	0.0	39.4	34.4
1585500	Cranberry Branch near Westminster, MD	1.8	0.0	19.5	1.2	4.2	18.5	0.7	57.6	21.3	1.9	5.5	20.3
1586000	North Branch Patapsco River at Cedarhurst, MD	2.9	0.0	23.0	0.3	5.4	13.6	3.5	57.9	23.3	0.3	6.6	17.9
1586210	Beaver Run near Finksburg, MD	2.3	0.0	26.6	0.0	6.0	18.4	1.8	52.1	26.0	0.1	7.0	26.1
1586610	Morgan Run near Louisville, MD	0.3	0.0	31.6	0.0	3.0	14.0	0.4	54.9	30.1	0.0	4.0	17.5
1587000	North Branch Patapsco River near Marriottsville, MD	1.5	0.0	31.5	2.8	4.6	14.5	1.7	47.1	31.2	3.4	5.5	18.8
1587050	Hay Meadow Branch tributary at Poplar Springs, MD	4.3	0.0	5.9	0.0	10.0	29.7	3.5	60.5	6.3	0.0	10.3	33.5
1587500	South Branch Patapsco River at Henryton, MD	1.2	0.0	31.4	0.1	4.0	13.7	0.8	53.0	29.8	0.1	4.7	20.7
1588000	Piney Run near Sykesville, MD	1.0	0.0	20.5	4.0	4.6	13.9	0.4	56.6	20.8	4.0	4.7	22.0
1588500	Patapsco River at Woodstock, MD	1.3	0.0	32.0	2.0	4.5	14.1	1.3	47.9	31.5	2.3	5.4	19.3
1589000	Patapsco River at Hollofield, MD	1.4	0.0	33.3	1.8	4.7	14.2	1.4	46.4	32.8	2.1	5.6	19.4
1589100	East Branch Herbert Run at Arbutus, MD	17.0	0.0	24.5	0.0	33.8	44.8	21.8	0.0	21.4	0.0	39.0	43.0
1589200	Gwynns Falls near Owings Mills, MD	2.5	0.0	26.5	0.0	14.6	36.2	2.5	27.8	23.4	0.0	17.5	55.9
1589240	Gwynns Falls at McDonough, MD	5.8	0.0	35.1	0.0	16.6	28.7	6.1	18.4	32.6	0.0	19.3	39.2
1589300	Gwynns Falls at Villa Nova, MD	5.2	0.0	30.7	0.0	19.5	38.5	5.6	14.1	28.5	0.0	21.6	46.5
1589330	Dead Run at Franklintown, MD	25.6	0.0	8.4	0.0	41.1	47.7	26.1	5.5	3.1	0.0	43.8	41.3
1589440	Jones Fall at Sorrento, MD	0.5	0.0	35.9	0.0	11.4	38.7	0.5	21.6	30.6	0.0	13.7	41.3
1589500	Sawmill Creek at Glen Burnie, MD	5.4	0.0	47.1	0.0	11.5	23.3	18.1	9.3	43.9	0.0	23.5	28.1
1590000	North River near Annapolis, MD	0.0	0.0	60.3	0.0	2.7	11.3	0.0	28.5	58.6	0.0	3.0	18.2
1590500	Bacon Ridge Branch at Chesterfield, MD	0.4	0.0	66.1	0.0	1.9	6.0	0.6	26.8	62.6	0.0	3.7	12.4
1591000	Patuxent River near Unity, MD	0.1	0.0	33.3	0.0	1.4	6.6	0.1	56.1	33.1	0.0	2.1	6.7
1591400	Cattail Creek near Glenwood, MD	0.8	0.0	26.1	0.0	2.9	10.5	0.2	61.1	26.1	0.0	3.0	13.3
1591500	Cattail Creek at Roxbury Mills, MD	0.9	0.0	24.6	0.0	3.5	11.9	0.2	61.7	23.9	0.0	3.4	16.3

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Com97 (%)	Ag97 (%)	For97 (%)	St97 (%)	IA97 (%)	CN70	CN97	Hyd. A (%)	Hyd. B (%)	Hyd. C (%)	Hyd. D (%)
1583600	Beaverdam Run at Cockeysville, MD	11.2	19.7	25.3	0.1	21.2	72.8	74.0	0.0	84.4	8.9	6.7
1584050	Long Green Creek at Glen Arm, MD	1.0	64.5	18.0	0.0	5.6	73.5	74.8	0.0	83.2	12.2	4.6
1584500	Little Gunpowder Falls at Laurel Brook, MD	0.3	54.6	26.6	0.0	5.0	71.7	72.1	0.0	82.6	12.0	5.4
1585100	White Marsh Run at White Marsh, MD	13.0	6.9	16.6	0.0	34.9	79.2	81.3	8.9	23.9	64.5	2.7
1585200	West Branch Herring Run at Idlewylde, MD	10.0	0.0	4.4	0.0	37.6	78.5	78.9	0.0	62.3	36.3	1.3
1585300	Stemmers Run at Rossville, MD	11.1	2.7	22.0	0.0	29.3	80.3	78.5	1.9	16.3	80.5	1.3
1585400	Brien Run at Stemmers Run, MD	33.9	2.1	20.2	0.0	45.0	84.1	84.6	4.1	20.2	66.8	9.0
1585500	Cranberry Branch near Westminster, MD	0.7	58.8	19.1	1.1	5.9	72.0	73.5	30.8	58.1	5.0	6.1
1586000	North Branch Patapsco River at Cedarhurst, MD	4.1	51.5	24.4	0.2	8.6	72.2	73.8	21.0	67.6	5.9	5.5
1586210	Beaver Run near Finksburg, MD	2.1	42.4	26.8	0.1	9.4	72.5	72.8	32.4	58.4	3.7	5.6
1586610	Morgan Run near Louisville, MD	0.3	53.2	28.5	0.0	4.8	69.6	70.1	52.2	37.4	4.5	6.0
1587000	North Branch Patapsco River near Marriottsville, MD	2.3	42.4	30.8	3.2	7.2	72.0	72.7	23.5	65.8	6.5	4.2
1587050	Hay Meadow Branch tributary at Poplar Springs, MD	1.5	53.1	6.9	0.0	10.9	73.5	74.0	0.0	94.1	5.9	0.0
1587500	South Branch Patapsco River at Henryton, MD	1.5	47.7	27.5	0.0	7.1	68.7	68.7	27.8	64.0	4.6	3.6
1588000	Piney Run near Sykesville, MD	0.5	48.8	19.8	4.0	6.9	73.1	73.1	18.7	71.0	5.5	4.8
1588500	Patapsco River at Woodstock, MD	2.0	43.0	30.5	2.2	7.2	71.0	71.5	22.9	66.6	6.4	4.1
1589000	Patapsco River at Hollofield, MD	1.9	41.5	31.7	2.0	7.4	71.0	71.4	20.8	66.6	8.3	4.3
1589100	East Branch Herbert Run at Arbutus, MD	24.6	0.0	8.9	0.0	41.7	83.1	82.5	2.7	14.7	81.1	1.5
1589200	Gwynns Falls near Owings Mills, MD	6.8	14.7	16.5	0.0	26.7	73.8	75.2	0.0	86.4	5.9	7.7
1589240	Gwynns Falls at McDonough, MD	11.2	12.4	25.9	0.1	27.4	72.6	75.0	0.0	76.8	18.6	4.6
1589300	Gwynns Falls at Villa Nova, MD	9.3	9.0	23.9	0.1	27.7	73.7	75.2	0.0	66.8	25.1	8.2
1589330	Dead Run at Franklintown, MD	24.9	3.0	8.1	0.0	42.8	83.5	83.4	0.0	17.4	30.4	52.2
1589440	Jones Fall at Sorrento, MD	0.9	20.6	26.5	0.0	14.6	70.9	70.8	0.0	83.9	8.9	7.2
1589500	Sawmill Creek at Glen Burnie, MD	25.4	7.6	36.0	0.0	28.7	66.8	65.3	84.5	4.7	10.1	0.6
1590000	North River near Annapolis, MD	0.3	25.1	54.8	0.0	5.2	70.6	71.7	0.0	57.3	40.3	2.4
1590500	Bacon Ridge Branch at Chesterfield, MD	0.8	24.0	60.1	0.0	4.6	71.0	71.4	0.0	69.4	26.5	4.1
1591000	Patuxent River near Unity, MD	0.2	51.4	39.1	0.1	2.0	65.7	64.5	14.5	64.5	17.2	3.8
1591400	Cattail Creek near Glenwood, MD	0.5	59.3	23.5	0.1	4.3	73.2	73.4	3.2	88.1	4.3	4.4
1591500	Cattail Creek at Roxbury Mills, MD	0.4	58.1	21.9	0.1	5.0	73.6	73.4	2.7	88.5	4.3	4.5

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Years of Record	Area (mi^2)	Perimeter (mi)	Length (mi)	Channel Slope (ft/mi)	Watershed Slope (ft/ft)	Basin Relief (ft)	Lime (%)	High Elev. (%)	Hypso
1591700	Hawlings River near Sandy Spring, MD	21	26.13	34.9	11.2	26.8	0.05664	172.3	0.0	0.0	0.45
1592000	Patuxent River near Burtonsville, MD	32	127.03	91.7	30.8	12.9	0.08905	314.9	0.0	0.0	0.44
1593350	Little Patuxent River tributary at Guilford Downs, MD	10	1.06	6.2	2.2	66.5	0.04518	90.8	0.0	0.0	0.41
1593500	Little Patuxent River at Guilford, MD	67	38.12	48.9	17.3	16.0	0.06252	141.1	0.0	0.0	0.33
1594000	Little Patuxent River at Savage, MD	46	98.41	73.8	25.0	12.6	0.07582	266.5	0.0	0.0	0.48
1594400	Dorsey Run near Jessup, MD	19	11.37	27.5	8.2	35.6	0.05176	140.4	0.0	0.0	0.37
1594440	Patuxent River near Bowie, MD	22	349.50	165.0	55.9	10.1	0.07366	371.6	0.0	0.0	0.41
1594445	Mill Branch near Mitchellville, MD	10	1.28	8.7	2.6	39.2	0.02770	46.0	0.0	0.0	0.41
1594500	Western Branch near Largo, MD	25	29.52	39.3	11.3	9.9	0.04571	103.9	0.0	0.0	0.47
1594526	Western Branch at Upper Marlboro, MD	10	89.25	71.1	20.3	6.2	0.05202	129.0	0.0	0.0	0.45
1594600	Cocktown Creek near Huntington, MD	19	3.90	12.3	3.3	22.4	0.08602	77.3	0.0	0.0	0.53
1594670	Hunting Creek near Huntingtown, MD	10	9.25	18.8	5.7	18.5	0.08937	96.3	0.0	0.0	0.58
1594710	Killpeck Creek at Huntersville, MD	12	3.72	13.1	4.0	39.4	0.06064	98.6	0.0	0.0	0.67
1594800	St. Leonard Creek near St. Leonard, MD	11	7.23	17.1	5.1	22.3	0.09602	101.9	0.0	0.0	0.60
1594930	Laurel Run at Dobbin Road near Wilson, MD	20	8.26	18.1	6.3	87.8	0.15199	255.1	0.0	100.0	0.30
1594936	North Fork Sand Run near Wilson, MD	20	1.92	10.3	3.2	180.8	0.14094	277.4	0.0	100.0	0.38
1594950	McMillan Fork near Fort Pendleton, MD	11	2.33	10.8	3.1	221.5	0.12347	323.3	0.0	100.0	0.44
1596005	Savage River near Frostburg, MD	13	1.43	8.5	3.4	21.8	0.09877	93.3	0.0	100.0	0.35
1596500	Savage River near Barton, MD	51	48.91	54.5	20.9	64.5	0.20820	905.8	0.0	94.6	0.62
1597000	Crabtree Creek near Swanton, MD	33	16.75	29.5	10.7	117.2	0.19438	921.3	0.0	95.5	0.56
1598000	Savage River at Bloomington, MD	24	115.87	99.5	45.9	46.2	0.22653	1363.4	0.0	85.8	0.62
1599000	Georges Creek at Franklin, MD	70	72.99	57.2	19.6	57.3	0.17102	1181.4	0.0	64.7	0.58
1601500	Wills Creek near Cumberland, MD	70	247.57	107.3	46.5	41.3	0.19835	1205.5	0.0	42.4	0.52
1609000	Town Creek near Oldtown, MD	22	149.23	103.2	46.8	12.5	0.17223	730.4	0.0	7.4	0.33
1609500	Sawpit Run near Oldtown, MD	24	5.00	16.2	6.0	53.5	0.16636	235.6	0.0	0.0	0.54
1610150	Bear Creek at Forest Park, MD	18	10.27	22.2	10.0	49.7	0.11542	402.3	0.0	0.0	0.36
1610155	Sideling Hill Creek near Bellegrove, MD	11	102.54	73.3	36.8	20.8	0.14148	632.8	0.0	0.0	0.40
1612500	Little Tonoloway Creek near Hancock, MD	17	17.28	26.3	7.5	82.9	0.14322	397.8	0.0	0.0	0.31
1613150	Ditch Run near Hancock, MD	21	4.60	17.7	6.8	55.0	0.11342	326.2	0.0	0.0	0.67

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	# First Order Streams	Total Stream Length	Area in MD	2-Year Prec. (in x 100)	100-Year Prec. (in x100)	Res70 (%)	Com70 (%)	Ag70 (%)	For70 (%)	St70 (%)	IA70 (%)	Res85 (%)
1591700	Hawlings River near Sandy Spring, MD	11	42.2	1.000	324.6	815.3	6.4	0.5	73.0	19.0	0.1	2.8	9.2
1592000	Patuxent River near Burtonsville, MD	63	234.0	1.000	321.6	808.5	3.8	0.5	70.2	23.7	1.4	1.9	9.7
1593350	Little Patuxent River tributary at Guilford Downs, MD	1	2.2	1.000	323.0	810.0	56.2	17.3	12.3	13.5	0.0	36.2	68.0
1593500	Little Patuxent River at Guilford, MD	25	79.6	1.000	320.1	803.7	29.5	6.5	37.2	17.9	0.3	16.9	38.5
1594000	Little Patuxent River at Savage, MD	56	191.5	1.000	321.9	809.3	14.4	3.9	51.4	25.3	0.1	9.0	23.7
1594400	Dorsey Run near Jessup, MD	3	15.3	1.000	367.7	943.6	10.5	20.6	27.3	33.4	0.0	22.0	9.2
1594440	Patuxent River near Bowie, MD	249	693.8	1.000	333.4	845.3	10.8	6.3	45.5	31.2	2.7	9.6	16.3
1594445	Mill Branch near Mitchellville, MD	1	2.5	1.000	348.4	895.6	7.0	0.1	77.9	3.7	0.0	2.7	9.5
1594500	Western Branch near Largo, MD	7	41.4	1.000	338.0	869.1	26.0	5.8	32.5	31.1	0.0	15.1	22.6
1594526	Western Branch at Upper Marlboro, MD	33	142.7	1.000	318.8	819.5	20.2	6.4	38.9	30.5	0.0	13.5	16.4
1594600	Cocktown Creek near Huntington, MD	2	5.6	0.984	323.3	831.7	56.9	0.0	11.9	31.2	0.0	21.6	26.8
1594670	Hunting Creek near Huntingtown, MD	3	13.9	1.000	364.0	936.0	16.1	1.5	10.6	70.9	0.0	7.4	2.3
1594710	Killpeck Creek at Huntersville, MD	2	5.9	1.000	339.0	872.0	23.6	12.1	10.3	54.1	0.0	19.2	2.0
1594800	St. Leonard Creek near St. Leonard, MD	5	16.0	1.000	364.0	936.0	7.9	0.4	10.2	81.6	0.0	3.3	0.4
1594930	Laurel Run at Dobbin Road near Wilson, MD	2	8.6	0.882	258.0	604.0	0.0	0.0	7.9	85.4	0.0	0.0	0.0
1594936	North Fork Sand Run near Wilson, MD	1	3.0	1.000	258.0	604.0	0.0	0.0	9.4	86.5	0.0	0.0	0.0
1594950	McMillan Fork near Fort Pendleton, MD	2	3.6	1.000	258.0	604.0	0.0	0.0	17.1	82.9	0.0	0.0	0.0
1596005	Savage River near Frostburg, MD	1	2.2	1.000	286.0	668.0	3.2	0.0	11.1	85.8	0.0	1.2	2.2
1596500	Savage River near Barton, MD	17	86.1	1.000	250.3	585.0	0.1	0.1	18.2	81.4	0.1	0.1	0.3
1597000	Crabtree Creek near Swanton, MD	6	26.9	1.000	262.3	614.1	0.3	0.2	11.8	87.8	0.0	0.2	0.7
1598000	Savage River at Bloomington, MD	42	199.1	1.000	256.3	599.6	0.1	0.1	13.1	85.5	0.4	0.1	0.3
1599000	Georges Creek at Franklin, MD	29	118.8	1.000	262.1	612.9	3.9	0.9	9.2	80.3	0.0	2.2	6.7
1601500	Wills Creek near Cumberland, MD	110	417.1	0.220	247.0	576.9	1.7	0.3	15.4	82.2	0.0	1.0	9.7
1609000	Town Creek near Oldtown, MD	89	327.9	0.399	252.0	588.6	0.0	0.2	15.0	84.7	0.0	0.2	0.5
1609500	Sawpit Run near Oldtown, MD	3	12.0	1.000	248.0	579.0	0.0	0.0	10.4	89.6	0.0	0.0	0.0
1610150	Bear Creek at Forest Park, MD	7	22.7	0.298	271.0	632.0	0.0	1.4	46.4	52.2	0.0	1.4	0.0
1610155	Sideling Hill Creek near Bellegrove, MD	55	202.0	0.214	273.8	638.9	0.0	0.4	23.2	76.4	0.0	0.4	0.0
1612500	Little Tonoloway Creek near Hancock, MD	10	34.1	0.609	273.3	637.5	0.0	1.7	18.4	79.3	0.0	1.7	0.0
1613150	Ditch Run near Hancock, MD	3	10.5	0.461	270.4	630.6	0.5	0.1	74.8	24.5	0.0	0.3	0.0

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Com85 (%)	Ag85 (%)	For85 (%)	St85 (%)	IA85 (%)	Res90 (%)	Com90 (%)	Ag90 (%)	For90 (%)	St90 (%)	IA90 (%)	Res97 (%)
1591700	Hawlings River near Sandy Spring, MD	0.8	0.0	27.0	0.1	3.8	15.5	2.0	48.6	25.3	0.1	8.9	19.2
1592000	Patuxent River near Burtonsville, MD	0.5	0.0	32.0	1.8	3.1	14.1	0.6	48.4	30.8	1.8	5.1	17.4
1593350	Little Patuxent River tributary at Guilford Downs, MD	13.2	0.0	5.4	0.0	34.8	69.2	9.4	6.7	5.1	0.0	32.5	64.4
1593500	Little Patuxent River at Guilford, MD	5.6	0.0	20.4	0.5	18.5	41.5	6.3	19.6	18.4	0.6	21.7	47.1
1594000	Little Patuxent River at Savage, MD	3.5	0.0	28.6	0.2	11.0	28.4	3.4	32.0	27.3	0.3	13.3	35.9
1594400	Dorsey Run near Jessup, MD	14.8	0.0	47.6	0.0	16.7	9.5	15.9	12.9	42.8	0.0	19.6	15.7
1594440	Patuxent River near Bowie, MD	2.9	0.0	38.7	1.0	8.6	19.5	3.1	30.7	37.0	1.1	10.7	24.4
1594445	Mill Branch near Mitchellville, MD	1.7	0.0	18.1	0.0	4.5	12.3	2.4	51.2	15.6	0.0	8.0	38.4
1594500	Western Branch near Largo, MD	3.9	0.0	41.6	0.3	11.4	26.0	4.2	23.6	37.6	0.8	13.8	38.7
1594526	Western Branch at Upper Marlboro, MD	3.9	0.0	43.9	0.2	9.5	18.8	4.1	29.0	40.5	0.4	11.8	29.3
1594600	Cocktown Creek near Huntington, MD	2.5	0.0	52.7	0.0	8.7	28.4	2.3	20.9	48.3	0.0	9.0	48.4
1594670	Hunting Creek near Huntingtown, MD	0.5	0.0	76.6	0.0	1.5	4.6	0.6	20.0	73.4	0.0	2.4	13.4
1594710	Killpeck Creek at Huntersville, MD	2.8	0.0	68.6	0.0	4.1	9.2	4.5	21.4	60.4	0.0	7.8	15.5
1594800	St. Leonard Creek near St. Leonard, MD	0.0	0.0	77.8	0.0	0.3	5.7	0.2	16.4	73.1	0.0	1.7	15.2
1594930	Laurel Run at Dobbin Road near Wilson, MD	0.0	0.0	72.6	0.0	1.3	0.0	0.0	7.6	80.8	0.0	1.4	0.7
1594936	North Fork Sand Run near Wilson, MD	0.0	0.0	78.6	0.0	0.9	0.0	0.0	12.9	79.3	0.0	0.9	0.0
1594950	McMillan Fork near Fort Pendleton, MD	0.0	0.0	76.0	0.0	0.6	0.0	0.0	18.9	77.7	0.0	0.4	2.0
1596005	Savage River near Frostburg, MD	0.5	0.0	66.7	15.9	1.0	1.3	0.3	12.5	66.8	16.0	0.8	7.1
1596500	Savage River near Barton, MD	0.3	0.0	76.4	0.6	0.3	0.5	0.2	20.2	76.0	0.7	0.3	1.6
1597000	Crabtree Creek near Swanton, MD	0.4	0.0	77.6	0.0	0.5	0.6	0.3	14.6	82.0	0.0	0.4	2.2
1598000	Savage River at Bloomington, MD	0.2	0.0	79.6	0.8	0.3	0.4	0.2	15.0	79.8	0.8	0.4	1.4
1599000	Georges Creek at Franklin, MD	0.3	0.0	64.4	0.0	3.7	6.0	0.3	11.3	64.0	0.0	3.4	6.7
1601500	Wills Creek near Cumberland, MD	1.4	0.0	69.7	0.1	4.2	10.4	1.5	11.0	69.4	0.1	4.4	12.1
1609000	Town Creek near Oldtown, MD	0.2	0.0	78.0	0.0	0.3	0.5	0.0	20.7	79.4	0.0	0.1	1.8
1609500	Sawpit Run near Oldtown, MD	0.0	0.0	88.9	0.0	0.0	0.0	0.0	10.5	88.6	0.0	0.0	1.2
1610150	Bear Creek at Forest Park, MD	0.0	0.0	77.8	0.0	0.0	0.0	0.0	18.4	67.8	0.0	3.2	0.6
1610155	Sideling Hill Creek near Bellegrove, MD	0.0	0.0	76.6	0.0	0.0	0.0	0.0	22.9	77.4	0.0	0.5	2.8
1612500	Little Tonoloway Creek near Hancock, MD	0.0	0.0	86.2	0.2	0.0	3.7	0.0	16.5	74.8	0.2	1.4	5.9
1613150	Ditch Run near Hancock, MD	0.0	0.0	72.7	0.0	0.0	3.2	0.0	47.4	47.6	0.0	0.8	7.6

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Com97 (%)	Ag97 (%)	For97 (%)	St97 (%)	IA97 (%)	CN70	CN97	Hyd. A (%)	Hyd. B (%)	Hyd. C (%)	Hyd. D (%)
1591700	Hawlings River near Sandy Spring, MD	1.0	41.2	30.5	0.2	8.3	72.2	71.6	0.0	82.1	5.5	12.4
1592000	Patuxent River near Burtonsville, MD	0.4	43.9	32.2	1.8	5.6	70.4	69.7	4.8	80.9	8.2	6.1
1593350	Little Patuxent River tributary at Guilford Downs, MD	14.3	0.0	15.5	0.0	32.9	76.2	76.0	0.0	87.4	12.6	0.0
1593500	Little Patuxent River at Guilford, MD	8.8	14.0	17.7	0.6	25.2	74.4	74.9	0.0	79.0	12.4	8.6
1594000	Little Patuxent River at Savage, MD	4.6	27.8	23.8	0.3	16.5	72.7	73.2	0.0	84.5	7.5	8.0
1594400	Dorsey Run near Jessup, MD	28.2	7.8	33.8	0.0	29.3	79.4	79.2	8.4	26.0	54.7	10.9
1594440	Patuxent River near Bowie, MD	4.2	27.3	34.8	1.1	12.9	73.3	72.4	5.8	65.8	19.7	8.7
1594445	Mill Branch near Mitchellville, MD	4.8	23.8	29.4	0.0	17.6	79.5	75.6	0.0	39.8	38.1	22.2
1594500	Western Branch near Largo, MD	5.9	19.4	28.1	0.6	19.0	76.4	77.2	1.2	57.8	27.0	14.0
1594526	Western Branch at Upper Marlboro, MD	6.1	23.1	34.7	0.3	17.5	75.6	76.0	5.6	60.8	21.6	11.9
1594600	Cocktown Creek near Huntington, MD	1.9	15.3	34.0	0.0	14.6	70.6	69.9	0.0	63.8	12.0	24.1
1594670	Hunting Creek near Huntingtown, MD	1.3	17.5	65.1	0.0	5.6	63.4	64.8	0.3	68.1	16.4	15.3
1594710	Killpeck Creek at Huntersville, MD	5.7	18.1	55.5	0.0	10.8	71.0	70.1	62.0	12.0	20.6	5.4
1594800	St. Leonard Creek near St. Leonard, MD	0.0	14.5	65.1	0.0	4.5	60.0	62.0	8.3	59.3	20.7	11.7
1594930	Laurel Run at Dobbin Road near Wilson, MD	0.0	7.4	83.4	0.0	1.1	63.0	63.7	0.0	26.6	66.8	6.6
1594936	North Fork Sand Run near Wilson, MD	0.0	14.6	80.9	0.0	0.5	62.6	64.0	0.0	16.3	75.7	8.0
1594950	McMillan Fork near Fort Pendleton, MD	0.5	19.1	74.9	0.0	1.3	62.7	64.4	0.0	34.4	64.2	1.4
1596005	Savage River near Frostburg, MD	1.3	12.3	62.7	14.4	3.7	68.1	74.0	3.7	42.7	26.3	27.2
1596500	Savage River near Barton, MD	0.2	19.7	75.5	0.6	0.6	63.4	64.5	0.4	15.5	80.9	3.2
1597000	Crabtree Creek near Swanton, MD	0.0	13.7	81.7	0.0	0.5	63.2	63.7	0.0	29.8	69.8	0.4
1598000	Savage River at Bloomington, MD	0.1	14.4	79.5	0.8	0.6	59.9	60.7	0.2	21.0	76.8	1.9
1599000	Georges Creek at Franklin, MD	0.4	12.1	64.6	0.0	3.6	63.7	64.7	0.0	15.3	76.2	8.5
1601500	Wills Creek near Cumberland, MD	1.6	10.1	67.6	0.1	5.3	68.9	66.2	3.1	14.6	78.1	4.3
1609000	Town Creek near Oldtown, MD	0.0	20.9	77.1	0.0	0.5	67.9	71.3	9.5	9.4	80.6	0.5
1609500	Sawpit Run near Oldtown, MD	0.0	10.7	86.8	0.0	0.4	71.3	71.6	0.0	11.7	83.6	4.7
1610150	Bear Creek at Forest Park, MD	0.0	17.8	65.9	0.0	3.3	77.2	73.9	0.0	14.6	83.5	1.8
1610155	Sideling Hill Creek near Bellegrove, MD	0.1	21.6	74.4	0.0	1.2	73.8	74.4	0.0	14.6	84.3	1.2
1612500	Little Tonoloway Creek near Hancock, MD	0.0	15.3	72.8	0.1	2.0	72.8	72.2	0.1	7.6	91.8	0.6
1613150	Ditch Run near Hancock, MD	0.0	44.5	42.6	0.0	1.9	78.3	76.2	0.0	1.6	95.7	2.7

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Years of Record	Area (mi^2)	Perimeter (mi)	Length (mi)	Channel Slope (ft/mi)	Watershed Slope (ft/ft)	Basin Relief (ft)	Lime (%)	High Elev. (%)	Hypso
1614500	Conococheague Creek at Fairview, MD	72	500.32	249.7	68.0	9.4	0.11372	498.1	40.3	0.9	0.24
1617800	Marsh Run at Grimes, MD	35	18.91	35.8	10.1	25.9	0.06475	149.3	100.0	0.0	0.49
1619000	Antietam Creek near Waynesboro, PA	19	94.05	68.6	21.7	45.6	0.11056	489.2	49.3	0.3	0.30
1619475	Dog Creek tributary near Locust Grove, MD	11	0.11	2.2	0.8	242.3	0.08050	81.8	97.3	0.0	0.31
1619500	Antietam Creek near Sharpsburg, MD	72	280.97	135.8	57.9	8.8	0.09806	496.6	65.7	0.1	0.27
1637000	Little Catoctin Creek at Harmony, MD	29	8.76	18.9	6.7	186.2	0.15203	490.3	0.0	0.0	0.41
1637500	Catoctin Creek near Middletown, MD	52	67.30	60.0	25.3	45.6	0.13474	665.5	0.0	0.0	0.43
1637600	Hollow Road Creek near Middletown, MD	10	2.32	9.4	3.1	217.8	0.13042	246.4	0.0	0.0	0.26
1639000	Monocacy River at Bridgeport, MD	58	172.50	104.2	32.4	19.7	0.05663	285.8	0.5	0.0	0.18
1639095	Piney Creek tributary at Taneytown, MD	10	0.61	4.5	1.7	74.3	0.03380	63.7	0.0	0.0	0.55
1639500	Big Pipe Creek at Bruceville, MD	52	102.71	77.0	28.8	15.0	0.09137	305.4	0.0	0.0	0.39
1640000	Little Pipe Creek at Bruceville, MD	30	8.11	20.5	4.9	66.7	0.09645	187.4	0.0	0.0	0.47
1640500	Owens Creek at Lantz, MD	53	6.10	17.2	4.5	198.8	0.12628	505.5	0.0	0.0	0.55
1640700	Owens Creek tributary near Rocky Ridge, MD	10	1.12	6.4	2.1	48.5	0.04022	72.4	0.0	0.0	0.60
1640965	Hunting Creek near Foxville, MD	13	2.19	9.2	3.8	250.6	0.14899	492.1	0.0	0.0	0.58
1640970	Hunting Creek tributary near Foxville, MD	10	3.91	11.9	4.1	156.5	0.11883	591.4	0.0	0.0	0.65
1641000	Hunting Creek at Jimtown, MD	42	18.69	30.5	11.3	128.8	0.13256	745.6	9.1	0.0	0.48
1641500	Fishing Creek near Lewistown, MD	37	7.29	15.1	5.3	242.8	0.13680	730.0	0.0	0.0	0.67
1642000	Monocacy River near Frederick, MD	33	665.10	213.2	62.3	6.4	0.08206	428.3	2.6	0.0	0.25
1642400	Dollyhyde Creek at Libertytown, MD	10	2.67	9.3	3.0	49.8	0.07329	101.3	0.0	0.0	0.48
1642500	Lingamore Creek near Frederick, MD	49	82.37	61.7	20.6	24.2	0.09365	295.3	0.0	0.0	0.47
1643000	Monocacy River at Jug Bridge near Frederick, MD	70	820.00	207.3	72.4	5.2	0.08291	520.4	2.9	0.0	0.28
1643500	Bennett Creek at Park Mills, MD	49	63.31	54.0	18.4	29.5	0.10535	304.8	0.0	0.0	0.30
1644420	Bucklodge Branch tributary near Barnesville, MD	10	0.28	2.9	1.0	91.9	0.07449	68.9	0.0	0.0	0.57
1645000	Seneca Creek near Dawsonville, MD	69	102.05	65.1	24.3	14.2	0.07600	256.7	0.0	0.0	0.37
1645200	Watts Branch at Rockville, MD	30	3.70	11.0	3.2	58.8	0.05605	111.8	0.0	0.0	0.49
1646550	Little Falls Branch near Bethesda, MD	40	4.09	12.6	3.6	57.3	0.05174	126.8	0.0	0.0	0.53
1647720	North Branch Rock Creek near Norbeck, MD	11	9.68	19.7	6.4	26.4	0.05331	134.7	0.0	0.0	0.54
1649500	North East Branch Anacostia River at Riverdale, MD	61	73.03	66.6	17.8	27.2	0.07059	211.4	0.0	0.0	0.37

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	# First Order Streams	Total Stream Length	Area in MD	2-Year Prec. (in x 100)	100-Year Prec. (in x100)	Res70 (%)	Com70 (%)	Ag70 (%)	For70 (%)	St70 (%)	IA70 (%)	Res85 (%)
1614500	Conococheague Creek at Fairview, MD	236	856.3	0.005	284.2	664.2	1.7	2.0	59.9	35.8	0.1	2.4	4.6
1617800	Marsh Run at Grimes, MD	5	20.0	1.000	291.3	680.8	4.9	1.6	92.2	1.3	0.0	3.2	8.2
1619000	Antietam Creek near Waynesboro, PA	49	161.1	0.074	342.1	799.8	3.6	1.4	51.8	42.5	0.1	2.6	4.3
1619475	Dog Creek tributary near Locust Grove, MD	1	0.0	1.000	292.0	682.0	0.0	0.0	84.7	15.3	0.0	0.0	0.0
1619500	Antietam Creek near Sharpsburg, MD	119	467.3	0.619	307.1	717.8	3.9	2.5	68.6	24.4	0.1	3.6	7.5
1637000	Little Catoctin Creek at Harmony, MD	6	14.7	1.000	295.4	741.7	0.1	0.6	47.4	51.9	0.0	0.6	3.0
1637500	Catoctin Creek near Middletown, MD	29	117.7	1.000	318.0	760.8	0.6	1.0	60.3	37.9	0.0	1.2	2.6
1637600	Hollow Road Creek near Middletown, MD	2	5.2	1.000	295.0	741.0	2.8	4.9	64.9	27.4	0.0	6.0	6.1
1639000	Monocacy River at Bridgeport, MD	89	344.3	0.068	313.8	738.5	1.5	0.8	77.6	19.7	0.1	1.2	2.3
1639095	Piney Creek tributary at Taneytown, MD	1	1.4	1.000	293.0	734.0	16.4	0.0	83.6	0.0	0.0	6.2	19.1
1639500	Big Pipe Creek at Bruceville, MD	50	179.7	1.000	320.1	802.1	0.6	0.0	85.2	14.2	0.0	0.2	4.8
1640000	Little Pipe Creek at Bruceville, MD	4	13.3	1.000	328.0	822.0	15.5	2.0	68.9	11.4	0.3	7.6	17.8
1640500	Owens Creek at Lantz, MD	2	8.6	1.000	375.4	877.6	0.5	0.0	17.4	82.1	0.0	0.2	1.2
1640700	Owens Creek tributary near Rocky Ridge, MD	1	2.5	1.000	293.0	734.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
1640965	Hunting Creek near Foxville, MD	1	2.9	1.000	376.0	879.0	0.0	0.0	2.9	97.1	0.0	0.0	0.0
1640970	Hunting Creek tributary near Foxville, MD	2	6.4	1.000	376.0	879.0	1.1	0.8	24.4	73.1	0.4	1.1	4.7
1641000	Hunting Creek at Jimtown, MD	10	32.5	1.000	376.0	879.0	4.5	0.5	18.4	75.8	0.4	2.1	5.9
1641500	Fishing Creek near Lewistown, MD	4	12.6	1.000	360.7	852.9	0.0	0.0	0.0	100.0	0.0	0.0	0.0
1642000	Monocacy River near Frederick, MD	312	1220.3	0.659	318.0	772.4	1.3	0.5	72.9	24.4	0.1	0.9	3.9
1642400	Dollyhyde Creek at Libertytown, MD	2	4.7	1.000	309.0	776.0	0.0	0.0	96.9	3.1	0.0	0.0	0.3
1642500	Lingamore Creek near Frederick, MD	52	174.8	1.000	308.0	773.4	0.9	0.1	78.7	17.3	0.4	0.4	4.0
1643000	Monocacy River at Jug Bridge near Frederick, MD	405	1546.9	0.723	315.3	770.5	1.8	0.9	73.4	22.7	0.1	1.4	4.7
1643500	Bennett Creek at Park Mills, MD	46	142.4	1.000	307.0	769.5	2.2	0.8	73.4	23.1	0.0	1.7	6.5
1644420	Bucklodge Branch tributary near Barnesville, MD	1	0.5	1.000	300.0	752.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
1645000	Seneca Creek near Dawsonville, MD	64	223.2	1.000	305.6	766.2	6.5	2.1	65.0	24.3	0.1	4.4	15.1
1645200	Watts Branch at Rockville, MD	3	6.7	1.000	305.0	766.0	31.7	17.5	39.9	9.5	0.0	27.2	25.8
1646550	Little Falls Branch near Bethesda, MD	2	4.9	0.967	342.0	878.0	68.2	24.0	0.0	0.7	0.0	46.3	68.7
1647720	North Branch Rock Creek near Norbeck, MD	5	16.1	1.000	308.0	773.5	16.9	0.2	66.5	13.5	0.0	6.6	32.6
1649500	North East Branch Anacostia River at Riverdale, MD	44	131.4	1.000	332.4	854.8	31.3	19.0	8.8	34.0	0.9	28.6	29.9

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Com85 (%)	Ag85 (%)	For85 (%)	St85 (%)	IA85 (%)	Res90 (%)	Com90 (%)	Ag90 (%)	For90 (%)	St90 (%)	IA90 (%)	Res97 (%)
1614500	Conococheague Creek at Fairview, MD	0.5	0.0	32.6	0.0	1.6	10.4	5.4	70.4	40.7	0.0	7.1	11.3
1617800	Marsh Run at Grimes, MD	0.7	0.0	8.3	0.0	3.4	11.5	1.1	75.6	8.1	0.2	5.1	13.4
1619000	Antietam Creek near Waynesboro, PA	0.0	0.0	56.9	0.3	3.9	7.5	0.7	46.7	56.1	0.6	5.9	15.2
1619475	Dog Creek tributary near Locust Grove, MD	0.0	0.0	9.7	0.0	0.0	0.0	0.0	76.6	23.4	0.0	0.0	0.0
1619500	Antietam Creek near Sharpsburg, MD	2.6	0.0	24.8	0.1	4.8	8.8	2.7	61.3	24.4	0.1	5.4	14.1
1637000	Little Catoctin Creek at Harmony, MD	0.0	0.0	54.8	0.0	0.8	6.9	0.0	40.3	52.8	0.0	2.5	11.1
1637500	Catoctin Creek near Middletown, MD	0.1	0.0	46.6	0.0	0.8	4.6	0.2	48.9	45.2	0.0	1.5	8.8
1637600	Hollow Road Creek near Middletown, MD	0.0	0.0	37.6	0.0	1.5	5.3	0.6	58.6	35.6	0.0	1.8	11.2
1639000	Monocacy River at Bridgeport, MD	0.1	0.0	13.1	0.0	0.8	3.4	0.0	84.0	14.0	0.0	0.9	3.5
1639095	Piney Creek tributary at Taneytown, MD	3.8	0.0	2.7	0.0	11.4	14.0	5.2	76.8	3.9	0.0	10.9	47.5
1639500	Big Pipe Creek at Bruceville, MD	0.6	0.0	22.0	0.0	1.8	7.0	0.3	69.8	22.0	0.0	2.5	9.7
1640000	Little Pipe Creek at Bruceville, MD	1.2	0.0	19.5	0.1	6.9	23.0	1.9	47.9	18.0	0.1	11.1	31.8
1640500	Owens Creek at Lantz, MD	0.0	0.0	80.8	0.0	0.5	0.6	0.0	21.5	77.4	0.0	0.4	3.5
1640700	Owens Creek tributary near Rocky Ridge, MD	0.0	0.0	4.7	0.0	0.0	0.0	0.0	97.3	2.7	0.0	0.0	0.7
1640965	Hunting Creek near Foxville, MD	0.0	0.0	96.0	0.0	0.0	1.8	0.0	3.7	94.5	0.0	0.8	1.5
1640970	Hunting Creek tributary near Foxville, MD	0.0	0.0	76.7	0.0	1.2	4.2	0.0	18.7	76.8	0.1	1.1	4.6
1641000	Hunting Creek at Jimtown, MD	0.3	0.0	77.3	0.4	1.8	4.9	1.0	14.1	77.6	0.4	2.3	9.6
1641500	Fishing Creek near Lewistown, MD	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	98.8	0.1	0.2	0.8
1642000	Monocacy River near Frederick, MD	0.5	0.0	28.0	0.0	1.7	5.3	0.4	65.3	27.7	0.0	2.2	7.5
1642400	Dollyhyde Creek at Libertytown, MD	0.0	0.0	6.8	0.0	0.1	1.3	0.0	92.7	6.0	0.0	0.5	5.7
1642500	Lingamore Creek near Frederick, MD	0.2	0.0	26.4	0.3	1.3	6.9	0.3	64.9	25.4	0.5	2.6	12.8
1643000	Monocacy River at Jug Bridge near Frederick, MD	1.0	0.0	27.0	0.1	2.4	6.4	0.9	64.2	26.5	0.1	3.1	9.3
1643500	Bennett Creek at Park Mills, MD	0.3	0.0	38.3	0.0	2.0	8.2	0.3	53.9	35.5	0.0	2.6	11.2
1644420	Bucklodge Branch tributary near Barnesville, MD	0.0	0.0	15.2	0.0	0.0	0.0	0.0	82.8	17.2	0.0	0.0	0.0
1645000	Seneca Creek near Dawsonville, MD	2.4	0.0	29.3	0.4	8.3	19.5	3.1	42.0	27.2	1.1	11.6	25.8
1645200	Watts Branch at Rockville, MD	18.3	0.0	13.6	0.0	26.2	23.4	23.2	28.5	11.7	0.0	30.4	27.0
1646550	Little Falls Branch near Bethesda, MD	13.1	0.0	5.2	0.0	32.4	67.6	13.9	0.0	5.0	0.0	33.6	64.4
1647720	North Branch Rock Creek near Norbeck, MD	0.3	0.0	23.2	0.0	9.9	42.7	0.5	24.2	20.4	0.0	14.3	45.5
1649500	North East Branch Anacostia River at Riverdale, MD	6.2	0.0	37.9	0.1	18.9	31.0	6.5	11.3	34.4	0.2	21.4	34.5

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Com97 (%)	Ag97 (%)	For97 (%)	St97 (%)	IA97 (%)	CN70	CN97	Hyd. A (%)	Hyd. B (%)	Hyd. C (%)	Hyd. D (%)
1614500	Conococheague Creek at Fairview, MD	6.6	59.8	34.5	0.0	7.9	74.2	79.6	0.0	29.5	68.9	1.6
1617800	Marsh Run at Grimes, MD	1.2	73.6	7.7	0.2	5.8	76.1	77.4	0.0	96.1	1.6	2.3
1619000	Antietam Creek near Waynesboro, PA	0.3	40.7	46.4	0.1	8.4	70.2	71.3	0.0	82.7	17.3	0.0
1619475	Dog Creek tributary near Locust Grove, MD	0.0	85.4	14.6	0.0	0.0	73.4	77.4	0.0	90.3	9.7	0.0
1619500	Antietam Creek near Sharpsburg, MD	2.7	57.3	22.7	0.1	7.3	73.6	75.3	0.0	89.0	10.1	0.9
1637000	Little Catoctin Creek at Harmony, MD	0.0	38.9	49.9	0.0	2.8	69.5	71.1	0.0	93.7	4.9	1.3
1637500	Catoctin Creek near Middletown, MD	0.3	46.8	42.9	0.0	2.5	71.7	72.2	0.0	90.4	7.9	1.8
1637600	Hollow Road Creek near Middletown, MD	0.9	54.0	34.0	0.0	3.6	73.5	73.3	0.0	91.5	0.6	7.8
1639000	Monocacy River at Bridgeport, MD	0.0	79.5	14.0	0.0	0.9	79.0	81.8	0.0	20.6	77.6	1.7
1639095	Piney Creek tributary at Taneytown, MD	3.5	45.1	3.8	0.0	19.7	80.0	82.8	0.0	15.9	84.1	0.0
1639500	Big Pipe Creek at Bruceville, MD	0.4	66.8	22.0	0.0	3.0	69.2	70.3	50.6	15.0	30.5	3.9
1640000	Little Pipe Creek at Bruceville, MD	1.4	35.2	20.2	0.1	15.4	67.2	68.1	66.2	13.0	20.4	0.4
1640500	Owens Creek at Lantz, MD	0.0	20.2	75.8	0.0	1.1	67.3	68.5	0.0	98.6	0.9	0.5
1640700	Owens Creek tributary near Rocky Ridge, MD	0.0	96.3	3.0	0.0	0.2	80.0	83.6	0.0	7.3	91.9	0.8
1640965	Hunting Creek near Foxville, MD	0.0	3.1	95.4	0.0	0.4	64.3	64.7	0.0	66.8	29.1	4.1
1640970	Hunting Creek tributary near Foxville, MD	0.0	18.1	77.2	0.0	1.2	68.7	68.4	0.0	71.0	20.3	8.7
1641000	Hunting Creek at Jimtown, MD	1.7	13.1	73.5	0.3	4.3	66.0	66.7	0.0	64.7	27.7	7.6
1641500	Fishing Creek near Lewistown, MD	0.0	0.0	98.0	0.1	0.2	57.0	57.1	0.0	71.5	28.5	0.0
1642000	Monocacy River near Frederick, MD	0.5	63.1	27.1	0.0	2.8	71.9	73.4	18.1	33.9	44.7	3.3
1642400	Dollyhyde Creek at Libertytown, MD	0.0	89.6	4.7	0.0	1.4	66.4	72.2	0.0	67.9	31.0	1.1
1642500	Lingamore Creek near Frederick, MD	0.5	61.8	23.4	0.3	3.9	64.3	66.2	6.2	73.7	16.0	4.0
1643000	Monocacy River at Jug Bridge near Frederick, MD	1.2	61.7	25.6	0.1	4.0	70.7	72.1	14.3	44.7	37.8	3.2
1643500	Bennett Creek at Park Mills, MD	0.8	48.1	37.4	0.0	3.9	63.1	61.7	0.0	72.5	22.0	5.5
1644420	Bucklodge Branch tributary near Barnesville, MD	0.0	70.0	30.0	0.0	0.0	67.0	65.5	0.0	36.8	48.1	15.1
1645000	Seneca Creek near Dawsonville, MD	3.9	31.2	31.7	1.1	14.3	69.7	69.9	0.0	79.9	11.0	9.1
1645200	Watts Branch at Rockville, MD	22.8	26.6	8.9	0.0	31.6	76.8	78.0	0.0	81.8	3.1	15.1
1646550	Little Falls Branch near Bethesda, MD	13.5	0.0	1.0	0.0	35.3	78.7	77.2	0.0	97.5	0.9	1.6
1647720	North Branch Rock Creek near Norbeck, MD	0.5	17.8	28.8	0.1	15.9	72.7	70.8	0.0	80.4	3.5	16.1
1649500	North East Branch Anacostia River at Riverdale, MD	8.2	8.9	29.9	0.2	24.8	78.1	77.9	6.1	41.9	38.2	13.8

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Years of Record	Area (mi^2)	Perimeter (mi)	Length (mi)	Channel Slope (ft/mi)	Watershed Slope (ft/ft)	Basin Relief (ft)	Lime (%)	High Elev. (%)	Hypso
1650190	Batchellors Run at Oakdale, MD	10	0.49	4.0	1.4	109.0	0.05617	84.7	0.0	0.0	0.56
1650500	Northwest Branch Anacostia River near Colesville, MD	62	21.21	29.1	9.5	20.4	0.06496	150.2	0.0	0.0	0.48
1651000	Northwest Branch Anacostia River near Hyattsville, MD	61	49.49	58.6	20.5	20.3	0.06941	298.9	0.0	0.0	0.54
1653500	Henson Creek at Oxon Hill, MD	30	17.64	31.1	10.1	24.5	0.06079	168.7	0.0	0.0	0.65
1653600	Piscataway Creek at Piscataway, MD	34	38.60	50.3	15.9	15.8	0.05524	189.0	0.0	0.0	0.69
1658000	Mattawoman Creek near Pomonkey, MD	36	56.80	73.7	20.7	10.4	0.02942	142.2	0.0	0.0	0.71
1660900	Wolf Den Branch near Cedarville, MD	13	1.93	11.7	3.4	17.0	0.01344	45.8	0.0	0.0	0.70
1660920	Zekiah Swamp Run near Newtown, MD	16	80.82	73.6	19.3	10.8	0.03440	137.0	0.0	0.0	0.69
1661000	Chaptico Creek at Chaptico, MD	25	11.16	30.5	8.5	21.1	0.05740	124.6	0.0	0.0	0.73
1661050	St. Clements Creek near Clements, MD	30	18.20	31.2	8.4	13.9	0.04937	103.1	0.0	0.0	0.61
1661430	Glebe Branch at Valley Lee, MD	11	0.10	2.0	0.8	56.7	0.02290	21.3	0.0	0.0	0.34
1661500	St. Marys River at Great Mills, MD	53	25.22	34.8	10.0	13.7	0.02690	93.7	0.0	0.0	0.61
3075450	Little Youghiogheny River tributary at Deer Park, MD	11	0.55	3.9	1.3	106.7	0.06632	76.3	0.0	100.0	0.47
3075500	Youghiogheny River near Oakland, MD	59	133.58	97.6	29.3	7.0	0.11647	239.6	0.0	100.0	0.24
3075600	Toliver Run tributary near Hoyes Run, MD	21	0.52	3.9	1.4	206.3	0.07148	175.8	0.0	100.0	0.65
3076500	Youghiogheny River at Friendsville, MD	76	293.72	140.5	48.8	15.6	0.11548	1149.6	0.0	98.7	0.60
3076600	Bear Creek at Friendsville, MD	35	48.84	49.4	17.1	65.6	0.16886	928.1	0.0	96.3	0.63
3077700	North Branch Casselman River tributary at Foxtown, MD	11	1.07	7.8	2.4	140.0	0.08474	164.2	0.0	100.0	0.47
3078000	Casselman River at Grantsville, MD	52	63.37	61.2	24.5	30.2	0.11771	508.0	0.0	100.0	0.50

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	# First Order Streams	Total Stream Length	Area in MD	2-Year Prec. (in x 100)	100-Year Prec. (in x100)	Res70 (%)	Com70 (%)	Ag70 (%)	For70 (%)	St70 (%)	IA70 (%)	Res85 (%)
1650190	Batchellors Run at Oakdale, MD	1	1.1	1.000	305.0	766.0	0.0	0.0	88.7	0.0	0.0	0.0	21.6
1650500	Northwest Branch Anacostia River near Colesville, MD	11	37.1	1.000	309.1	777.1	26.3	1.0	44.1	19.4	0.0	10.9	29.8
1651000	Northwest Branch Anacostia River near Hyattsville, MD	16	72.0	0.969	311.7	793.2	54.5	7.5	18.9	13.3	0.0	27.2	51.5
1653500	Henson Creek at Oxon Hill, MD	7	23.3	1.000	325.4	836.2	51.1	24.3	0.5	18.3	0.0	40.9	41.4
1653600	Piscataway Creek at Piscataway, MD	16	57.5	1.000	357.3	917.8	26.1	8.9	21.8	37.8	0.2	17.5	12.8
1658000	Mattawoman Creek near Pomonkey, MD	31	96.1	1.000	302.3	777.3	16.4	1.9	21.7	58.6	0.1	7.8	10.9
1660900	Wolf Den Branch near Cedarville, MD	1	3.6	1.000	287.4	739.1	24.3	0.0	3.3	72.4	0.0	9.2	0.0
1660920	Zekiah Swamp Run near Newtown, MD	43	143.3	1.000	306.0	786.8	16.2	0.9	21.4	53.9	5.0	6.9	8.1
1661000	Chaptico Creek at Chaptico, MD	5	18.0	1.000	339.0	872.0	21.5	0.0	22.8	55.7	0.0	8.2	7.1
1661050	St. Clements Creek near Clements, MD	7	31.2	1.000	320.0	823.0	15.1	0.3	28.6	56.0	0.0	6.0	5.8
1661430	Glebe Branch at Valley Lee, MD	0	0.0	1.000	334.0	858.0	82.6	0.0	17.4	0.0	0.0	31.4	8.4
1661500	St. Marys River at Great Mills, MD	15	48.2	1.000	334.0	858.0	9.3	2.2	12.8	75.5	0.0	5.4	8.1
3075450	Little Youghiogheny River tributary at Deer Park, MD	1	1.2	1.000	246.0	575.0	0.0	0.0	0.0	100.0	0.0	0.0	0.3
3075500	Youghiogheny River near Oakland, MD	69	234.5	0.610	248.5	581.0	2.3	0.6	42.3	53.7	0.5	1.3	3.3
3075600	Toliver Run tributary near Hoyes Run, MD	1	0.0	1.000	245.9	574.7	0.0	0.0	35.9	64.1	0.0	0.0	0.0
3076500	Youghiogheny River at Friendsville, MD	126	466.1	0.770	235.5	550.7	1.6	0.3	30.3	63.4	2.8	0.9	2.8
3076600	Bear Creek at Friendsville, MD	22	81.2	1.000	224.3	524.7	0.4	0.4	37.3	61.9	0.0	0.5	0.5
3077700	North Branch Casselman River tributary at Foxtown, MD	1	2.3	1.000	238.0	557.0	0.0	0.0	0.4	99.6	0.0	0.0	0.0
3078000	Casselman River at Grantsville, MD	17	83.0	0.943	238.4	557.2	0.4	0.1	24.0	73.5	0.9	0.2	0.8

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Com85 (%)	Ag85 (%)	For85 (%)	St85 (%)	IA85 (%)	Res90 (%)	Com90 (%)	Ag90 (%)	For90 (%)	St90 (%)	IA90 (%)	Res97 (%)
1650190	Batchellors Run at Oakdale, MD	0.0	0.0	4.4	0.0	5.4	24.7	0.0	40.0	16.0	0.0	14.6	21.0
1650500	Northwest Branch Anacostia River near Colesville, MD	1.3	0.0	26.3	0.0	11.6	37.6	1.7	17.8	25.5	0.0	16.9	47.1
1651000	Northwest Branch Anacostia River near Hyattsville, MD	3.8	0.0	20.7	0.1	22.3	54.2	4.2	7.9	19.7	0.1	25.1	57.7
1653500	Henson Creek at Oxon Hill, MD	10.0	0.0	34.2	0.0	26.5	40.9	10.3	3.2	31.9	0.0	28.2	47.0
1653600	Piscataway Creek at Piscataway, MD	0.7	0.0	56.0	0.2	7.7	16.3	0.6	19.5	51.8	0.2	9.9	23.2
1658000	Mattawoman Creek near Pomonkey, MD	2.1	0.0	67.1	0.1	5.0	15.4	2.4	17.6	61.6	0.2	7.1	21.2
1660900	Wolf Den Branch near Cedarville, MD	0.0	0.0	81.8	0.0	0.0	10.0	0.0	10.4	74.9	0.0	4.6	12.3
1660920	Zekiah Swamp Run near Newtown, MD	1.4	0.0	62.6	0.2	4.0	11.3	1.5	23.3	58.8	0.3	5.3	12.4
1661000	Chaptico Creek at Chaptico, MD	0.2	0.0	56.3	0.0	1.9	11.8	0.4	37.0	49.6	0.0	3.3	14.9
1661050	St. Clements Creek near Clements, MD	0.1	0.0	58.1	0.0	1.8	7.8	0.0	34.8	55.9	0.0	2.3	11.5
1661430	Glebe Branch at Valley Lee, MD	0.0	0.0	20.2	0.0	2.1	33.4	0.0	24.0	42.5	0.0	8.4	36.9
1661500	St. Marys River at Great Mills, MD	1.4	0.0	72.1	1.4	4.0	10.7	2.3	13.5	68.0	1.4	6.1	15.6
3075450	Little Youghiogheny River tributary at Deer Park, MD	0.0	0.0	95.3	0.0	0.1	2.9	0.0	4.4	90.7	0.0	0.7	7.1
3075500	Youghiogheny River near Oakland, MD	0.6	0.0	44.3	0.4	1.6	5.3	0.9	45.0	44.4	0.5	2.5	8.1
3075600	Toliver Run tributary near Hoyes Run, MD	0.0	0.0	61.2	0.0	0.0	0.0	0.0	44.5	55.5	0.0	0.0	0.0
3076500	Youghiogheny River at Friendsville, MD	0.5	0.0	60.6	3.6	1.3	5.0	0.6	27.7	59.1	3.8	2.1	7.5
3076600	Bear Creek at Friendsville, MD	0.1	0.0	59.9	0.0	0.3	1.8	0.2	37.2	58.3	0.0	0.9	3.2
3077700	North Branch Casselman River tributary at Foxtown, MD	0.0	0.0	95.4	0.0	0.0	0.0	0.0	0.3	92.9	0.0	0.0	1.0
3078000	Casselman River at Grantsville, MD	0.4	0.0	64.9	1.0	0.8	1.1	0.3	26.3	63.6	1.3	0.8	3.3

Appendix A1: Watershed Properties for USGS Stream Gages in Maryland (continued)

Station Number	Station Name	Com97 (%)	Ag97 (%)	For97 (%)	St97 (%)	IA97 (%)	CN70	CN97	Hyd. A (%)	Hyd. B (%)	Hyd. C (%)	Hyd. D (%)
1650190	Batchellors Run at Oakdale, MD	0.0	27.6	37.6	0.8	6.7	74.3	66.9	0.0	90.1	4.7	5.2
1650500	Northwest Branch Anacostia River near Colesville, MD	0.7	9.2	27.2	0.1	20.1	71.9	70.8	0.0	86.5	3.7	9.8
1651000	Northwest Branch Anacostia River near Hyattsville, MD	3.9	4.1	18.6	0.1	27.8	75.1	74.4	0.1	80.6	12.1	7.2
1653500	Henson Creek at Oxon Hill, MD	12.0	2.2	23.4	0.0	34.8	82.1	81.4	6.4	35.1	43.9	14.6
1653600	Piscataway Creek at Piscataway, MD	1.2	17.6	48.3	0.2	11.6	78.1	76.2	6.4	37.8	40.2	15.6
1658000	Mattawoman Creek near Pomonkey, MD	3.8	15.8	55.4	0.1	10.0	74.6	75.2	5.9	10.5	57.2	26.4
1660900	Wolf Den Branch near Cedarville, MD	0.0	9.5	64.2	0.0	6.2	72.7	73.2	4.5	19.6	50.6	25.3
1660920	Zekiah Swamp Run near Newtown, MD	2.4	22.7	56.8	0.2	6.7	76.1	75.4	27.0	17.0	47.4	8.6
1661000	Chaptico Creek at Chaptico, MD	0.9	34.9	47.9	0.0	4.6	75.0	76.7	24.6	10.1	50.2	15.1
1661050	St. Clements Creek near Clements, MD	0.1	31.8	55.0	0.0	3.4	74.7	75.6	12.6	27.1	44.8	15.5
1661430	Glebe Branch at Valley Lee, MD	0.0	25.4	37.6	0.0	9.2	82.8	79.1	0.0	66.9	24.4	8.7
1661500	St. Marys River at Great Mills, MD	4.9	10.9	63.4	1.7	9.4	72.1	74.0	13.0	13.1	54.7	19.2
3075450	Little Youghiogheny River tributary at Deer Park, MD	0.0	2.8	87.7	0.0	1.8	64.0	65.2	0.0	0.0	63.7	36.3
3075500	Youghiogheny River near Oakland, MD	1.4	42.8	43.2	0.4	3.5	68.7	70.9	0.0	21.5	63.5	15.0
3075600	Toliver Run tributary near Hoyes Run, MD	0.0	44.4	55.6	0.0	0.0	68.1	71.6	0.0	79.1	15.5	5.3
3076500	Youghiogheny River at Friendsville, MD	1.1	26.5	57.5	3.7	3.1	67.3	68.6	0.4	35.8	53.3	10.5
3076600	Bear Creek at Friendsville, MD	0.2	31.2	62.9	0.0	1.3	68.8	69.4	0.0	35.3	62.9	1.8
3077700	North Branch Casselman River tributary at Foxtown, MD	0.0	0.3	91.8	0.0	0.2	60.1	60.0	0.0	70.5	19.0	10.5
3078000	Casselman River at Grantsville, MD	0.4	25.2	62.6	1.3	1.4	65.9	66.9	0.4	20.2	66.8	12.6

Appendix A2: Watershed Properties for USGS Stream Gages in Delaware

Station Number	Station Name	Years of Record	Area (mi^2)	Basin Relief (ft)	Hyd. A (%)
1483200	Blackbird Creek at Blackbird, DE	47	4.21	43.5	3.1
1483500	Leipsic River near Cheswold, DE	33	10.3	37.5	3.6
1484000	Murderkill River near Felton, DE	31	11.5	25.9	3.8
1484100	Beaverdam Branch at Houston, DE	42	2.27	14.7	49.4
1484500	Stockley Branch at Stockly, DE	57	4.42	27.6	41.4
1486100	Andrews Branch near Delmar, MD	10	4.31	22.3	10.4
1487000	Nanticoke River near Bridgeville, DE	56	73.3	29.9	18.9
1487900	Meadow Branch near Delmar, DE	9	4.8	5.1	6.3
1488500	Marshyhope Creek near Adamsville, DE	54	48.1	20.7	8.3
1490600	Meredith Branch Near Sandtown, DE	10	9.2	19.9	10.3

Appendix B: Avenue Scripts to determine Watershed Properties for USGS Stream Gages in Maryland

1. **`Master.ave:`** the driver program that controls logic flow and populates the basin properties file.

2. **`DelineateBasin.ave:`** this sub-program delineates the watershed at the location of the USGS streamgage and returns a grid representation of the delineated watershed draining to that gage.

3. **`VectorizeBasin.ave:`** the sub-program converts the grid representation of the watershed to a vector representation (a "shapefile")

4. **`CalcBasinProp.ave:`** this sub-program calculates the "hard" properties of the watershed that do not vary with time such as area, slope, longest flow length, and basin relief.

5. **`VectorizeStream.ave:`** this sub-program produces a vectorized representation of the gaged length of the stream following the UGSS +/- 50% rule.

6. **`CalcLUProp.ave:`** this sub-program determines the land use distribution in the watershed for a given coverage. Output includes percent residential area, percent commercial area, percent agricultural area, percent forested area, percent storage, percent imperviousness, and average curve number. The sub-program is called multiple times with different land use coverages as input (e.g. 1970's, 1990, 1997).

7. **`StatsgoLookup.ave:`** this sub-program determines average curve number within a watershed given the land use used by CalcLUProp.ave an the STATSGO soils database.

Master.ave

```
theView = av.finddoc("View1")
t = theView.findtheme("gagexysmall.shp")
flowdir = theview.findtheme("flow direction")
areagrid = theview.findtheme("flow acc.").getgrid
dirgrid = flowdir.getgrid
demgrid = theview.findtheme("original dem").getgrid
filledgrid = theview.findtheme("filled dem").getgrid
luold = theview.findtheme("kens70").getgrid
lunew = theview.findtheme("kens97").getgrid
soilstheme = theview.findtheme("statsgo_all.shp")
limegrid = theview.findtheme("limestone").getgrid

anFTab = t.GetFTab
shedprops =
ftab.makenew("d:\peak_flow_estimation\shedprops.shp".AsFileName,
polygon)
shedpropstable = table.make(shedprops)
shapefield = shedprops.findfield("shape")
shedpropstable.SetName("Gaged Watershed Properties")
gagefield = Field.Make ("gageno", #FIELD_FLOAT, 12, 0)
areafield = Field.Make ("area", #FIELD_FLOAT, 10, 1)
lengthfield = Field.Make ("length",#FIELD_FLOAT, 10, 1)
slopefield = Field.Make("slope", #FIELD_FLOAT, 10, 1)
relieffield = Field.Make("relief", #FIELD_FLOAT, 10, 1)
limefield = Field.Make("Lime", #FIELD_FLOAT, 10, 1)
res97field = Field.Make("res97", #FIELD_FLOAT, 10, 1)
com97field = Field.Make("com97", #FIELD_FLOAT, 10, 1)
ag97field = Field.Make("ag97", #FIELD_FLOAT, 10, 1)
for97field = Field.Make("for97", #FIELD_FLOAT, 10, 1)
st97field = Field.Make("st97", #FIELD_FLOAT, 10, 1)
ia97field = Field.Make("ia97", #FIELD_FLOAT, 10, 1)
cn97field = Field.Make("cn97", #FIELD_FLOAT, 10, 1)
res70field = Field.Make("res70", #FIELD_FLOAT, 10, 1)
com70field = Field.Make("com70", #FIELD_FLOAT, 10, 1)
ag70field = Field.Make("ag70", #FIELD_FLOAT, 10, 1)
for70field = Field.Make("for70", #FIELD_FLOAT, 10, 1)
st70field = Field.Make("st70", #FIELD_FLOAT, 10, 1)
ia70field = Field.Make("ia70", #FIELD_FLOAT, 10, 1)
cn70field = Field.Make("cn70", #FIELD_FLOAT, 10, 1)

streamprops =
ftab.makenew("d:\peak_flow_estimation\gagedstreams.shp".AsFileName,
polygon)
streampropstable = table.make(streamprops)
streamshapefield = streamprops.findfield("shape")
streamgagefield = Field.Make ("gageno", #FIELD_FLOAT, 12, 0)
streampropstable.SetName("Gaged Stream Segments")

shedpropslist =
{gagefield,areafield,lengthfield,slopefield,relieffield,limefield,

res97field,com97field,ag97field,for97field,st97field,ia97field,cn97field
,

res70field,com70field,ag70field,for70field,st70field,ia70field,cn70field
}
shedprops.AddFields(shedpropslist)

streamprops.AddFields({streamgagefield})

nshed = anFtab.GetNumRecords
```

```
shapename = anftab.FindField("Shape")
exgagefield = anftab.FindField("Usgs")
for each i in 1..nshed
   shedrec = shedprops.AddRecord
   streamrec = streamprops.AddRecord
   thepoint = anftab.ReturnValue(shapename, i - 1)
   gagename = anftab.ReturnValue(exgagefield, i - 1)
   theshed =
av.Run("delineatebasin",{thepoint,flowdir,theview,areagrid})
   vecshed = av.Run("vectorizebasin",{theshed,theview})
   shedprops.SetValue(shapefield, shedrec, vecshed)
   hardprops =
av.Run("CalcBasinProp",{thepoint,areagrid,theshed,dirgrid,demgrid,thevie
w,limegrid})
   vecstream =
av.Run("vectorizestream",{areagrid,flowdir,filledgrid,theshed,thepoint,h
ardprops.get(4),theview})
   streamprops.SetValue(streamshapefield, streamrec, vecstream)
   streamprops.SetValue(streamgagefield, streamrec, gagename)
   shedprops.SetValue(gagefield, shedrec, gagename)
   shedprops.SetValue(areafield, shedrec, hardprops.get(0))
   shedprops.SetValue(lengthfield, shedrec, hardprops.get(1))
   shedprops.SetValue(slopefield, shedrec, hardprops.get(2))
   shedprops.SetValue(relieffield, shedrec, hardprops.get(3))
   shedprops.SetValue(limefield, shedrec, hardprops.get(5))
   luprops1 = av.Run("CalcLUProp",{lunew, theshed, "MOP",
hardprops.get(4), vecshed})
   shedprops.SetValue(st97field, shedrec, luprops1.get(0))
   shedprops.SetValue(for97field, shedrec, luprops1.get(1))
   shedprops.SetValue(res97field, shedrec, luprops1.get(2))
   shedprops.SetValue(com97field, shedrec, luprops1.get(3))
   shedprops.SetValue(ag97field, shedrec, luprops1.get(4))
   shedprops.SetValue(ia97field, shedrec, luprops1.get(5))
   shedprops.SetValue(cn97field, shedrec, luprops1.get(6))
   luprops2 = av.Run("CalcLUProp",{luold, theshed, "USGS",
hardprops.get(4), vecshed})
   shedprops.SetValue(st70field, shedrec, luprops2.get(0))
   shedprops.SetValue(for70field, shedrec, luprops2.get(1))
   shedprops.SetValue(res70field, shedrec, luprops2.get(2))
   shedprops.SetValue(com70field, shedrec, luprops2.get(3))
   shedprops.SetValue(ag70field, shedrec, luprops2.get(4))
   shedprops.SetValue(ia70field, shedrec, luprops2.get(5))
   shedprops.SetValue(cn70field, shedrec, luprops2.get(6))
end
shedprops.seteditable(FALSE)
streamprops.seteditable(FALSE)
```

DelineateBasin.ave

```
theflowdirgtheme = self.get(1)
theview = self.get(2)
theflowacc = self.get(3)
theFlowDirGTheme.SetActive(TRUE)
theFlowDirGtheme.UpdateLegend
theFlowDir = theFlowDirGTheme.GetGrid

p = self.get(0)
xoutlet = p.GetX
youtlet = p.GetY
mPoint = MultiPoint.Make({p})
theSrcGrid = theflowdir.ExtractByPoints(mPoint, Prj.MakeNull, FALSE)

' get flow dir and acc from extension preferences

if (theFlowDirGTheme = NIL) then
  MsgBox.Error("Cannot find flow direction theme in view!","Watershed
Tool")
  return NIL
end

' calc watershed
snapdistance = (theflowacc.getcellsize) * (2^(0.5))

theWater = theFlowDir.Watershed(theSrcGrid)'.SnapPourPoint(theflowacc,
snapdistance))

' rename data set
aFN = av.GetProject.GetWorkDir.MakeTmp("watt", "")
theWater.Rename(aFN)
thewater = thewater/thewater

' check if output is ok
if (theWater.HasError) then return NIL end
return thewater
```

VectorizeBasin.ave

```
theView = self.get(1)
theGrid = self.get(0)
aFileName = "d:\peak_flow_estimation\tempshed.shp".AsFileName
aPrj = theView.GetProjection
theResult = theGrid.AsPolygonFTab(aFileName,false,aPrj)
theFtheme = ftheme.make(theresult)
shapefield = theResult.findfield("shape")
poly1 = theresult.returnvalue(shapefield, 0)
numrecs = theresult.getnumrecords
if (numrecs > 1) then
   for each i in 2..numrecs
      poly2 = theresult.returnvalue(shapefield, i - 1)
      poly1 = poly1.returnmerged(poly2)
   end
end
return {poly1, theFtheme}
```

CalcBasinProp.ave

```
outletpoint = self.get(0)
AreaGrid = self.get(1)
maskGrid = self.get(2)
DirGrid = self.get(3)
demgrid = self.get(4)
theview = self.get(5)
limegrid = self.get(6)

'basinarea = AreaGrid.CellValue(outletpoint,Prj.MakeNull)
limegrid = limegrid * maskgrid
basintab = maskgrid.getVTab
ctfield = basintab.findfield("Count")
basinarea = basintab.returnvalue(ctfield, 0)

'upgrid = dirGrid.FlowLength(NIL, TRUE)
'downgrid = dirGrid.FlowLength(NIL, FALSE)
upgrid = (theview.findtheme("upgrid").getgrid) * maskgrid
downgrid = (theview.findtheme("downgrid").getgrid) * maskgrid
'a=gtheme.make(upgrid)
'a.setname("upgrid")
'theview.addtheme(a)
'a=gtheme.make(downgrid)
'a.setname("downgrid")
'theview.addtheme(a)

sumgrid = upgrid + downgrid
maxlength = upgrid.GetStatistics.Get(1)
tolerance = 0.1 * dirGrid.GetCellSize
long_path = (1.AsGrid - (sumgrid > (maxlength -
tolerance).AsGrid)).SetNull(1.AsGrid)
path1085 = ((long_path * upgrid) < (0.9.AsGrid * maxlength)) and
((long_path * upgrid) > (0.15.AsGrid * maxlength))
path1085 = (1.AsGrid - path1085).SetNull(1.AsGrid)

maxlength = Units.Convert(maxlength, theView.GetUnits,
#UNITS_LINEAR_MILES)
a=path1085*demgrid
'b=gtheme.make(a)
'b.setname("path1085")
'theview.addtheme(b)
elevstat = (path1085 * demgrid).GetStatistics
min_elev = elevstat.Get(0)
max_elev = elevstat.Get(1)
theslope = (max_elev - min_elev) / (maxlength * 0.75)
'msgbox.info(min_elev.asstring, "minelevation")
'msgbox.info(max_elev.asstring, "maxelevation")
'msgbox.info(maxlength.asstring,"maxlength")

cellsize = AreaGrid.GetCellSize
unitsElt = theView.GetUnits
if (unitsElt = #Units_Linear_Unknown) then
   MsgBox.Warning("Reported basin area is incorrect!" + NL + "You will
need to Re-Run Basin Statistics before calculating discharges","View
units have NOT been specified.")
end
areami2 =
Units.ConvertArea(basinarea,unitsElt,#Units_Linear_Miles)*(cellsize ^ 2)
'basinrelief = BRGrid.CellValue(outletpoint,Prj.MakeNull)
outletelev = demgrid.CellValue(outletpoint,Prj.MakeNull)
'outletelev = (demgrid * maskgrid).getstatistics.get(0)
basinrelief = ((demgrid * maskgrid).getstatistics.get(2)) - outletelev
```

```
LI = 0
   LIcalc = MaskGrid * (limegrid = 0)
   LITab = LIcalc.GetVTab
   if (LITab <> NIL) then
     LIVal = LITab.FindField("Value")
     LICnt = LITab.FindField("Count")
      numrecords = LITab.GetNumRecords
      for each i in 1..numrecords
         tempval = LITab.ReturnValue(LIVal, i - 1)
         if (tempval = 1) then
            LI = LITab.ReturnValue(LICnt, i - 1)
         end
      end
   end
LI = LI / basinarea * 100.0
highelev = (demgrid >= 2000.AsGrid) * maskgrid
temptab = highelev.getVTab
tempcnt = temptab.findfield("Count")
tempval = temptab.findfield("Value")
nrec = temptab.getnumrecords
highbasinarea = 0
for each i in 1..nrec
   theval = temptab.returnvalue(tempval, i - 1)
   if (theval = 1) then
      highbasinarea = temptab.returnvalue(tempcnt, i - 1)
   end
end
highbasinarea = highbasinarea / basinarea * 100.0
proplist = {areami2, maxlength, theslope, basinrelief, basinarea, LI,
highbasinarea}
return proplist
```

VectorizeStream.ave

```
'This program uses the input table from Make ST Input Table to find
'streams that are within the 50% area rule

areagrid = self.get(0)
dirgrid = self.get(1).getgrid
elevgrid = self.get(2)
maskgrid = self.get(3)
thepoint = self.get(4)
theview = self.get(5)

basintab = maskgrid.getVTab
ctfield = basintab.findfield("Count")
basinarea = basintab.returnvalue(ctfield, 0)

  theLine = ElevGrid.ReturnCostPath(DirGrid,thePoint)
  theMP = theLine.AsMultiPoint
  theMPList = theMP.AsList
  numpoints = theMPList.Count

  UpStreamGrid = (AreaGrid > (0.5 * BasinArea)) * MaskGrid
  UpStreamGrid = UpStreamGrid.IsNull.Con(0.AsGrid,UpStreamGrid)

  fname = Filename.Make("d:\peak_flow_estimation\rivertmp.dbf")
  attVTab = VTab.MakeNew(fname,dBase)
  attVTab.SetEditable(True)
  xfield = Field.Make("X Coord", #Field_Double, 10, 10)
  yfield = Field.Make("Y Coord", #Field_Double, 10, 10)
  valfield = Field.Make("ID Value", #Field_Byte, 2, 0)
  attVTab.AddFields({xfield, yfield, valfield})

  for each i in 0..(numpoints - 1)
   p = theMPlist.Get(i)
   rec = attVTab.AddRecord
   attVTab.SetValue (xfield, rec, p.GetX)
   attVTab.SetValue (yfield, rec, p.GetY)
   attVTab.SetValue (valfield, rec, i)
  end

  aPrj = theView.GetProjection
  theCellSize = AreaGrid.GetCellSize
  theExtent = AreaGrid.GetExtent
  theXYName = XYName.Make(attVTab, attVTab.FindField("X Coord"),
attVTab.FindField("Y Coord"))
  XYtab = FTab.Make(theXYName)
  IDField = XYTab.FindField("IDField")
  DownGrid = Grid.MakeFromFTab(XYTab, aPrj, IDField, {theCellSize,
theExtent})
  DownGrid = ((DownGrid / DownGrid) * AreaGrid) < (1.5 * BasinArea)
  DownGrid = DownGrid.IsNull.Con(0.AsGrid,DownGrid)
  Sgrid = UpStreamGrid + DownGrid
  Sgrid = Sgrid / Sgrid

aFileName = "d:\peak_flow_estimation\tempstream.shp".AsFileName
aPrj = theView.GetProjection
theResult = sgrid.AsPolygonFTab(aFileName,false,aPrj)
shapefield = theResult.findfield("shape")
poly1 = theresult.returnvalue(shapefield, 0)
numrecs = theresult.getnumrecords
if (numrecs > 1) then
   for each i in 2..numrecs
```

```
      poly2 = theresult.returnvalue(shapefield, i - 1)
      poly1 = poly1.returnmerged(poly2)
   end
end
return poly1
```

CalcLUProp.ave

```
lugrid = self.get(0)
maskgrid = self.get(1)
lookuptable = self.get(2)
basinarea = self.get(3)
shedpoly = self.get(4)
'cngrid = av.run("statsgolookup",{lugrid, lookuptable, shedpoly})
cngrid = self.get(5)
lumask = lugrid * maskgrid
'need to put in curve number work

theview = av.finddoc("view1")
cnavg = (cngrid * maskgrid).getstatistics.get(2)

LUTab = lumask.GetVTab
LUVal = LUTab.findfield("Value")
LUCnt = LUTab.findfield("Count")
if (lookuptable = "MOP") then
   stlist = {50, 60}
   fclist = {40, 41, 42, 43, 192}
   reslist = {11, 12, 13}
   comlist = {14, 15}
   aglist = {21, 22, 23, 24, 25, 191, 241, 242}
   d = dictionary.Make(15)
   implist = {11, 12, 13, 14, 15, 16, 17, 18, 72, 73, 80, 191, 192, 241,
242}
   impval = {0.25, 0.30, 0.65, 0.82, 0.70, 0.50, 0.11, 0.11, 1.0, 0.5,
1.0, 0.15, 0.15, 0.1, 0.1}
   for each i in 1..implist.Count
      d.Add(implist.Get(i - 1), impval.Get(i - 1))
   end
else
   stlist = {51, 52, 53, 54, 61, 62}
   fclist = {41, 42, 43}
   reslist = {11, 16}
   comlist = {12, 13, 14, 15}
   aglist = {21, 22, 23, 24}
   d = dictionary.Make(8)
   implist = {11, 12, 13, 14, 15, 16, 71, 74}
   impval = {0.38, 0.85, 0.72, 1.0, 0.85, 0.38, 1.0, 1.0}
   for each i in 1..implist.Count
      d.Add(implist.Get(i - 1), impval.Get(i - 1))
   end
end
st = 0
fc = 0
res = 0
com = 0
ag = 0
IA = 0
for each i in 1..LUTab.GetNumRecords
   theval = LUTab.ReturnValue(LUVal, i - 1)
   thecnt = LUTab.ReturnValue(LUCnt, i - 1)
   if (reslist.FindByValue(theval) <> -1) then
      res = res + thecnt
   elseif (aglist.FindByValue(theval) <> -1) then
      ag = ag + thecnt
   elseif (fclist.FindByValue(theval) <> -1) then
      fc = fc + thecnt
   elseif (comlist.FindByValue(theval) <> -1) then
      com = com + thecnt
   elseif (stlist.FindByValue(theval) <> -1) then
```

```
      st = st + thecnt
   end
   if (d.Get(theval) <> NIL) then
      IA = IA + (thecnt * (d.Get(theval)))
   end
end

st = st / basinarea * 100
fc = fc / basinarea * 100
res = res / basinarea * 100
com = com / basinarea * 100
ag = ag / basinarea * 100
ia = ia / basinarea * 100

answerlist = {st, fc, res, com, ag, ia, cnavg}
return answerlist
```

StatsgoLookup.ave

```
lugrid = self.Get(0)
lutype = self.Get(1)

Grid.SetAnalysisCellSize (#GRID_ENVTYPE_VALUE, 100)
gridrect = lugrid.GetExtent
Grid.SetAnalysisExtent (#GRID_ENVTYPE_VALUE, gridrect)
if (luType.Contains("USGS")) then
    lookUpTable = av.GetProject.FindDoc("usgslookupfair.txt")
    if (lookUpTable <> NIL) then
       lookUpVTab = lookUpTable.GetVTab
    else
       lookUpFN =
FileName.Make("$UMDGIS\mdinterface\usgslookupfair.txt")
       lookUpVtab = VTab.Make(lookUpFN, FALSE, FALSE)
    end
else
    lookUpTable = av.GetProject.FindDoc("andlookupfair.txt")
    if (lookUpTable <> NIL) then
       lookUpVTab = lookUpTable.GetVTab
    else
       lookUpFN = FileName.Make("$UMDGIS\mdinterface\andlookupfair.txt")
       lookUpVtab = VTab.Make(lookUpFN, FALSE, FALSE)
    end
end

theview = av.finddoc("view1")
soiltheme = theview.findtheme("statsgo_all.shp")
if (soiltheme = nil) then
   msgbox.info("soiltheme is nil","")
end
muidjvtab = soiltheme.getftab

lusftab = lugrid.getvtab
lusfields = lusftab.getfields
chk=false

if (chk=false) then
  fromfield=lookupvtab.findField("lucode")
  if (fromfield=nil) then
    msgbox.info("Could not find field named lucode in lookup table.
This field must exist.","")
    exit
  end
  tofield=lusFtab.FindField("Value")
  if (tofield=nil) then
    msgbox.info("Could not find field named Value in landuse attribute
table.  This field must exist.","")
    exit
  end

  lusFtab.join(tofield, lookupvtab, fromfield)
end

'---------- Join the soil group percentage table to the soil polygon
table
soilFtab=soilTheme.getFtab
soilfields = soilftab.getfields
thebitmapS=soilFtab.Getselection
thebitmapS.clearAll
thebitmapL=lusFtab.Getselection
thebitmapL.clearAll
```

```
selpoly=gridrect.AsPolygon
soiltheme.selectbypolygon(selpoly, #VTAB_SELTYPE_NEW)

pct_a=soilFtab.FindField("pct_A")
if (pct_a=nil) then
  msgbox.info("Can't find field pct_A in soils coverage.","")
  exit
end
pct_b=soilFtab.FindField("pct_B")
if (pct_b=nil) then
  msgbox.info("Can't find field pct_B in soils coverage.","")
  exit
end
pct_c=soilFtab.FindField("pct_C")
if (pct_c=nil) then
  msgbox.info("Can't find field pct_C in soils coverage.","")
  exit
end
pct_d=soilFtab.FindField("pct_D")
if (pct_d=nil) then
  msgbox.info("Can't find field pct_D in soils coverage.","")
  exit
end
pct_water=soilFtab.FindField("pct_Water")
if (pct_water=nil) then
  msgbox.info("Can't find field pct_Water in soils coverage.","")
  exit
end
'find fields from land use coverage
**********************************************
hyd_a=lusFtab.FindField("hyd_a")
if (hyd_a=nil) then
  msgbox.info("Can't find field hyd_a in soils coverage.","")
  exit
end
hyd_b=lusFtab.FindField("hyd_b")
if (hyd_b=nil) then
  msgbox.info("Can't find field hyd_b in soils coverage.","")
  exit
end
hyd_c=lusFtab.FindField("hyd_c")
if (hyd_c=nil) then
  msgbox.info("Can't find field hyd_c in soils coverage.","")
  exit
end
hyd_d=lusFtab.FindField("hyd_d")
if (hyd_d=nil) then
  msgbox.info("Can't find field hyd_d in soils coverage.")
  exit
end
starttime=date.now
idsval = soilFtab.FindField("Ids")
nrec = soilFtab.GetNumRecords
soilFtab.SetEditable(TRUE)
for each i in 1..nrec
   ids = soilFtab.ReturnValue(idsval, i - 1)
   if (ids = "W") then
      soilFtab.SetValue(pct_water, i - 1, 100)
   end
end
soilFtab.SetEditable(FALSE)
' get four grids from soil coverage
************************************************
```

```
av.showmsg("Creating percentage grids from soils coverage. . .")
soilG_a=Grid.MakeFromFTab(soilFtab,Prj.MakeNull,pct_a,nil)
soilG_b=Grid.MakeFromFTab(soilFtab,Prj.MakeNull,pct_b,nil)
soilG_c=Grid.MakeFromFTab(soilFtab,Prj.MakeNull,pct_c,nil)
soilG_d=Grid.MakeFromFTab(soilFtab,Prj.MakeNull,pct_d,nil)
water_grid=Grid.MakeFromFtab(soilFtab,prj.makenull,pct_water,nil)
'get four grids from land use coverage
*********************************************
lusG_a = lugrid.lookup("Hyd_a")
lusG_b = lugrid.lookup("Hyd_b")
lusG_c = lugrid.lookup("Hyd_c")
lusG_d = lugrid.lookup("Hyd_d")

RCNg=(((soilG_a * lusG_a) + (soilG_b * lusG_b) + (soilG_c * lusG_c) +
(soilG_d * lusG_d) + (water_grid *
100))/(soilG_a+soilG_b+soilG_c+soilG_d+water_grid)).Int
RCNg = water_grid.con(water_grid, rcng)
lusFtab.UnJoinAll
return RCNg
```

Appendix C1: Flood Frequency Results for USGS Stream Gages in Maryland (all flows are in ft^3/s)

Station Number	Station Name	Years of Record	1.25	1.50	1.75	2	5	10	25	50	100	200	500
1485000	Pocomoke River near Willards, MD	50	517	608	663	703	1,027	1,291	1,687	2,032	2,425	2,873	3,564
1485500	Nassawango Creek near Snow Hill, MD	49	331	437	501	548	927	1,230	1,676	2,053	2,470	2,932	3,619
1486000	Manokin Branch near Princess Anne, MD	46	80	108	125	137	237	317	436	537	648	771	954
1489000	Faulkner Branch near Federalsburg, MD	42	106	172	212	241	558	873	1,417	1,945	2,592	3,379	4,672
1490000	Chicamacomico River near Salem, MD	29	144	184	208	225	365	476	640	779	934	1,107	1,366
1490800	Oldtown Branch at Goldsboro, MD	10	112	150	173	190	344	481	704	911	1,157	1,449	1,921
1491000	Choptank River near Greensboro, MD	52	1,017	1,388	1,613	1,776	3,188	4,376	6,188	7,776	9,581	11,630	14,760
1491050	Spring Branch near Greensboro, MD	10	42	53	59	64	108	149	219	286	370	475	652
1492000	Beaverdam Branch at Matthews, MD	32	151	210	245	271	538	803	1,271	1,743	2,345	3,110	4,438
1492050	Gravel Run at Beulah, MD	10	64	87	101	111	215	317	497	679	910	1,205	1,718
1492500	Sallie Harris Creek near Carmicheal, MD	30	109	162	195	218	472	729	1,188	1,651	2,242	2,989	4,279
1492550	Mill Creek near Skipton, MD	11	69	100	118	132	287	455	778	1,128	1,600	2,235	3,414
1493500	Morgan Creek near Kennedyville, MD	49	199	287	340	378	828	1,325	2,296	3,364	4,832	6,834	10,620
1494000	Southeast Creek at Church Hill, DE	14	294	405	472	521	1,008	1,477	2,283	3,075	4,063	5,291	7,375
1495000	Big Elk Creek at Elk Mills, MD	68	1,761	2,306	2,638	2,877	4,929	6,659	9,316	11,670	14,370	17,470	22,280
1495500	Little Elk Creek at Childs, MD	10	1,241	1,469	1,609	1,709	2,543	3,233	4,287	5,219	6,291	7,527	9,457
1496000	Northeast River at Leslie, MD	37	1,006	1,260	1,415	1,527	2,523	3,400	4,808	6,111	7,663	9,514	12,510
1496200	Principio Creek near Principio Furnace, MD	27	567	813	964	1,072	2,175	3,239	5,066	6,847	9,054	11,770	16,340
1577940	Broad Creek tributary at Whiteford, MD	15	91	121	140	153	297	443	711	989	1,354	1,832	2,692
1578500	Octoraro Creek near Rising Sun, MD	19	2,500	3,423	3,986	4,391	8,508	12,530	19,540	26,510	35,310	46,380	65,420
1580000	Deer Creek at Rocks, MD	73	2,417	3,011	3,372	3,633	5,693	7,325	9,710	11,740	13,990	16,490	20,240
1580200	Deer Creek at Kalmia, MD	11	2,885	3,680	4,165	4,514	7,577	10,230	14,410	18,210	22,670	27,920	36,260
1581500	Bynum Run at Bel Air, MD	25	589	822	964	1,066	2,026	2,891	4,290	5,582	7,114	8,925	11,820
1581700	Winter Run near Benson, MD	32	1,414	2,002	2,360	2,618	4,897	6,819	9,737	12,280	15,140	18,350	23,210
1582000	Little Falls at Blue Mount, MD	56	1,500	1,883	2,117	2,285	3,643	4,736	6,356	7,750	9,313	11,070	13,730
1582510	Piney Creek near Hereford, MD	14	132	208	254	288	686	1,120	1,939	2,808	3,958	5,466	8,174
1583000	Slade Run near Glyndon, MD	34	100	126	143	154	251	330	449	553	670	803	1,006
1583100	Piney Run at Dover, MD	10	394	558	658	729	1,455	2,153	3,348	4,513	5,957	7,740	10,730
1583495	Western Run tributary at Western Run, MD	10	51	78	95	107	243	385	644	911	1,255	1,696	2,466
1583500	Western Run at Western Run, MD	55	1,231	1,691	1,972	2,174	4,324	6,510	10,470	14,550	19,870	26,740	38,980

Appendix C1: Flood Frequency Results for USGS Stream Gages in Maryland (all flows are in ft^3/s) **(continued)**

Station Number	Station Name	Years of Record	1.25	1.50	1.75	2	5	10	25	50	100	200	500
1583600	Beaverdam Run at Cockeysville, MD	16	717	886	990	1,064	1,674	2,173	2,926	3,584	4,332	5,184	6,495
1584050	Long Green Creek at Glen Arm, MD	24	370	536	637	710	1,482	2,253	3,618	4,987	6,723	8,914	12,680
1584500	Little Gunpowder Falls at Laurel Brook, MD	59	1,708	2,272	2,616	2,864	5,020	6,852	9,682	12,200	15,090	18,420	23,580
1585100	White Marsh Run at White Marsh, MD	28	759	1,027	1,190	1,307	2,346	3,242	4,638	5,889	7,337	9,010	11,620
1585200	West Branch Herring Run at Idlewylde, MD	31	357	478	551	604	1,061	1,446	2,036	2,556	3,151	3,829	4,872
1585300	Stemmers Run at Rossville, MD	29	788	1,011	1,146	1,244	2,066	2,749	3,788	4,702	5,744	6,936	8,772
1585400	Brien Run at Stemmers Run, MD	29	188	255	297	327	648	979	1,589	1,589	3,066	4,167	6,155
1585500	Cranberry Branch near Westminster, MD	51	114	178	217	245	576	934	1,610	2,325	3,271	4,512	6,742
1586000	North Branch Patapsco River at Cedarhurst, MD	54	1,522	1,920	2,163	2,338	4,078	5,762	8,700	11,630	15,370	20,110	28,370
1586210	Beaver Run near Finksburg, MD	17	434	575	661	723	1,278	1,762	2,529	3,226	4,045	5,004	6,525
1586610	Morgan Run near Louisville, MD	17	686	950	1,111	1,227	2,317	3,302	4,904	6,391	8,163	10,270	13,650
1587000	North Branch Patapsco River near Marriottsville, MD	26	2,268	2,932	3,337	3,628	6,333	8,787	12,820	16,630	21,240	26,820	36,010
1587050	Hay Meadow Branch tributary at Poplar Springs, MD	11	68	96	112	124	253	386	628	880	1,209	1,637	2,402
1587500	South Branch Patapsco River at Henryton, MD	31	1,505	2,007	2,314	2,534	4,860	7,220	11,500	15,930	21,710	29,240	42,720
1588000	Piney Run near Sykesville, MD	43	332	496	596	668	1,516	2,443	4,225	6,151	8,752	12,240	18,660
1588500	Patapsco River at Woodstock, MD	10	9,761	11,718	12,911	13,770	20,140	24,930	31,660	37,170	43,130	49,590	59,010
1589000	Patapsco River at Hollofield, MD	23	4,866	6,828	8,025	8,886	18,360	28,260	46,630	65,930	91,450	125,000	185,700
1589100	East Branch Herbert Run at Arbutus, MD	34	436	537	599	643	1,037	1,382	1,933	2,441	3,045	3,765	4,929
1589200	Gwynns Falls near Owings Mills, MD	17	141	221	270	305	799	1,429	2,830	4,559	7,171	11,080	19,270
1589240	Gwynns Falls at McDonough, MD	12	579	892	1,083	1,220	3,046	5,277	10,030	15,670	23,930	35,900	60,090
1589300	Gwynns Falls at Villa Nova, MD	36	903	1,239	1,444	1,592	3,186	4,834	7,866	11,030	15,210	20,680	30,540
1589330	Dead Run at Franklintown, MD	29	935	1,195	1,353	1,467	2,560	3,581	5,307	6,981	9,055	11,620	15,960
1589440	Jones Fall at Sorrento, MD	34	525	748	885	983	2,188	3,578	6,407	9,646	14,250	20,770	33,590
1589500	Sawmill Creek at Glen Burnie, MD	30	42	55	63	69	116	155	213	264	321	385	483
1590000	North River near Annapolis, MD	42	82	110	127	139	278	429	720	1,039	1,477	2,076	3,213
1590500	Bacon Ridge Branch at Chesterfield, MD	35	112	156	183	202	397	586	912	1,233	1,635	2,136	2,986
1591000	Patuxent River near Unity, MD	55	771	1,133	1,353	1,512	3,393	5,478	9,548	14,010	20,130	28,450	44,080
1591400	Cattail Creek near Glenwood, MD	21	1,446	1,806	2,026	2,184	3,370	4,265	5,521	6,548	7,652	8,844	10,570
1591500	Cattail Creek at Roxbury Mills, MD	12	479	661	772	852	1,743	2,688	4,472	6,379	8,941	12,360	18,670

Appendix C1: Flood Frequency Results for USGS Stream Gages in Maryland (all flows are in ft^3/s) **(continued)**

Station Number	Station Name	Years of Record	1.25	1.50	1.75	2	5	10	25	50	100	200	500
1591700	Hawlings River near Sandy Spring, MD	21	766	1,056	1,232	1,359	2,598	3,758	5,708	7,577	9,865	12,660	17,290
1592000	Patuxent River near Burtonsville, MD	32	1,767	2,148	2,381	2,548	3,937	5,089	6,846	8,398	10,180	12,230	15,430
1593350	Little Patuxent River tributary at Guilford Downs, MD	10	87	126	149	166	346	526	845	1,167	1,575	2,092	2,985
1593500	Little Patuxent River at Guilford, MD	67	874	1,144	1,308	1,426	2,580	3,673	5,541	7,367	9,645	12,480	17,300
1594000	Little Patuxent River at Savage, MD	46	2,007	2,600	2,961	3,221	5,705	8,016	11,900	15,650	20,270	25,950	35,490
1594400	Dorsey Run near Jessup, MD	19	324	386	424	451	683	876	1,176	1,443	1,753	2,114	2,681
1594440	Patuxent River near Bowie, MD	22	3,081	3,903	4,404	4,765	7,493	9,559	12,460	14,820	17,370	20,110	24,060
1594445	Mill Branch near Mitchellville, MD	10	93	123	141	154	278	391	580	759	977	1,243	1,682
1594500	Western Branch near Largo, MD	25	638	762	837	892	1,272	1,545	1,912	2,202	2,506	2,827	3,280
1594526	Western Branch at Upper Marlboro, MD	10	998	1,392	1,633	1,806	3,681	5,614	5,614	12,840	17,670	23,960	35,230
1594600	Cocktown Creek near Huntington, MD	19	71	105	126	142	327	537	958	1,429	2,085	2,993	4,730
1594670	Hunting Creek near Huntingtown, MD	10	156	208	239	262	452	609	846	1,053	1,286	1,549	1,950
1594710	Killpeck Creek at Huntersville, MD	12	123	140	151	158	209	244	290	326	363	402	457
1594800	St. Leonard Creek near St. Leonard, MD	11	87	102	111	118	170	212	272	323	381	445	542
1594930	Laurel Run at Dobbin Road near Wilson, MD	20	245	299	332	356	545	696	918	1,109	1,323	1,563	1,926
1594936	North Fork Sand Run near Wilson, MD	20	63	89	105	116	247	387	652	936	1,318	1,830	2,772
1594950	McMillan Fork near Fort Pendleton, MD	11	61	78	88	96	168	235	348	456	590	754	1,030
1596005	Savage River near Frostburg, MD	13				51	85	112	154	189	229	274	343
1596500	Savage River near Barton, MD	51	970	1,196	1,334	1,433	2,310	3,075	4,293	5,414	6,743	8,322	10,870
1597000	Crabtree Creek near Swanton, MD	33	305	391	443	481	840	1,176	1,740	2,286	2,960	3,793	5,196
1598000	Savage River at Bloomington, MD	24	2,185	2,790	3,159	3,425	5,859	8,046	11,610	14,960	18,990	23,840	31,790
1599000	Georges Creek at Franklin, MD	70	1,210	1,507	1,689	1,819	2,926	3,859	5,301	6,589	8,080	9,809	12,520
1601500	Wills Creek near Cumberland, MD	70	3,939	4,969	5,598	6,050	10,370	14,410	21,230	27,850	36,060	46,230	63,460
1609000	Town Creek near Oldtown, MD	22	2,410	3,095	3,512	3,813	6,536	8,956	12,860	16,500	20,840	26,020	34,430
1609500	Sawpit Run near Oldtown, MD	24	187	223	246	262	393	502	666	810	974	1,163	1,456
1610150	Bear Creek at Forest Park, MD	18	218	294	339	372	664	915	1,306	1,656	2,062	2,531	3,264
1610155	Sideling Hill Creek near Bellegrove, MD	11	2,192	3,018	3,522	3,885	7,289	10,360	15,360	20,000	25,540	32,120	42,720
1612500	Little Tonoloway Creek near Hancock, MD	17	315	412	471	514	893	1,222	1,741	2,212	2,763	3,409	4,432
1613150	Ditch Run near Hancock, MD	21	154	194	218	236	382	501	681	838	1,016	1,219	1,530

Appendix C1: Flood Frequency Results for USGS Stream Gages in Maryland (all flows are in ft^3/s) (continued)

Station Number	Station Name	Years of Record	1.25	1.50	1.75	2	5	10	25	50	100	200	500
1614500	Conococheague Creek at Fairview, MD	72	5,394	6,456	7,104	7,570	11,330	14,370	18,900	22,830	27,290	32,330	40,070
1617800	Marsh Run at Grimes, MD	35	58	79	91	101	188	270	405	533	689	878	1,189
1619000	Antietam Creek near Waynesboro, PA	19	886	1,163	1,332	1,454	2,586	3,610	5,290	6,868	8,773	11,070	14,820
1619475	Dog Creek tributary near Locust Grove, MD	11	11	16	19	21	44	68	112	158	218	296	436
1619500	Antietam Creek near Sharpsburg, MD	72	1,581	2,078	2,382	2,600	4,521	6,177	8,770	11,110	13,830	17,010	22,000
1637000	Little Catoctin Creek at Harmony, MD	29	263	400	484	544	1,245	2,000	3,425	4,935	6,941	9,580	14,350
1637500	Catoctin Creek near Middletown, MD	52	1,438	1,911	2,199	2,406	4,320	6,038	8,827	11,420	14,530	18,240	24,250
1637600	Hollow Road Creek near Middletown, MD	10	143	187	214	233	411	571	832	1,075	1,367	1,717	2,288
1639000	Monocacy River at Bridgeport, MD	58	6,341	7,394	8,036	8,498	11,930	14,520	18,170	21,190	24,460	28,040	33,290
1639095	Piney Creek tributary at Taneytown, MD	10	76	100	115	125	218	297	422	535	666	819	1,060
1639500	Big Pipe Creek at Bruceville, MD	52	2,202	2,755	3,092	3,335	5,685	7,903	11,690	15,400	20,040	25,840	35,760
1640000	Little Pipe Creek at Bruceville, MD	30	221	314	371	412	848	1,289	2,081	2,888	3,927	5,257	7,588
1640500	Owens Creek at Lantz, MD	53	179	275	334	376	874	1,418	2,457	3,571	5,063	7,043	10,650
1640700	Owens Creek tributary near Rocky Ridge, MD	10	107	134	151	163	266	353	486	606	744	904	1,155
1640965	Hunting Creek near Foxville, MD	13	59	86	102	114	249	394	668	960	1,350	1,867	2,813
1640970	Hunting Creek tributary near Foxville, MD	10	146	231	283	321	791	1,329	2,400	3,589	5,227	7,462	11,660
1641000	Hunting Creek at Jimtown, MD	42	510	672	771	842	1,411	1,858	2,504	3,044	3,634	4,279	5,227
1641500	Fishing Creek near Lewistown, MD	37	68	100	120	134	308	505	899	1,341	1,959	2,814	4,457
1642000	Monocacy River near Frederick, MD	33	13,010	14,919	16,082	16,920	22,640	26,690	32,090	36,330	40,770	45,430	52,000
1642400	Dollyhyde Creek at Libertytown, MD	10	232	331	392	435	887	1,331	2,107	2,876	3,843	5,053	7,117
1642500	Lingamore Creek near Frederick, MD	49	1,601	2,023	2,280	2,465	4,134	5,611	7,994	10,210	12,850	16,010	21,140
1643000	Monocacy River at Jug Bridge near Frederick, MD	70	12,750	15,503	17,181	18,390	27,580	34,630	44,700	53,060	62,200	72,220	86,980
1643500	Bennett Creek at Park Mills, MD	49	1,468	1,935	2,219	2,424	4,606	6,842	10,940	15,220	20,870	28,280	41,720
1644420	Bucklodge Branch tributary near Barnesville, MD	10	53	74	87	96	188	276	427	575	757	983	1,362
1645000	Seneca Creek near Dawsonville, MD	69	1,704	2,301	2,665	2,927	5,795	8,798	14,410	20,350	28,280	38,830	58,170
1645200	Watts Branch at Rockville, MD	30	341	476	558	618	1,206	1,765	2,714	3,632	4,764	6,152	8,471
1646550	Little Falls Branch near Bethesda, MD	40	464	661	781	868	1,592	2,170	3,003	3,692	4,437	5,240	6,398
1647720	North Branch Rock Creek near Norbeck, MD	11	452	670	803	899	2,107	3,522	6,435	9,794	14,590	21,390	34,800
1649500	North East Branch Anacostia River at Riverdale, MD	61	2,138	2,783	3,176	3,459	5,699	7,453	9,976	12,080	14,380	16,900	20,590

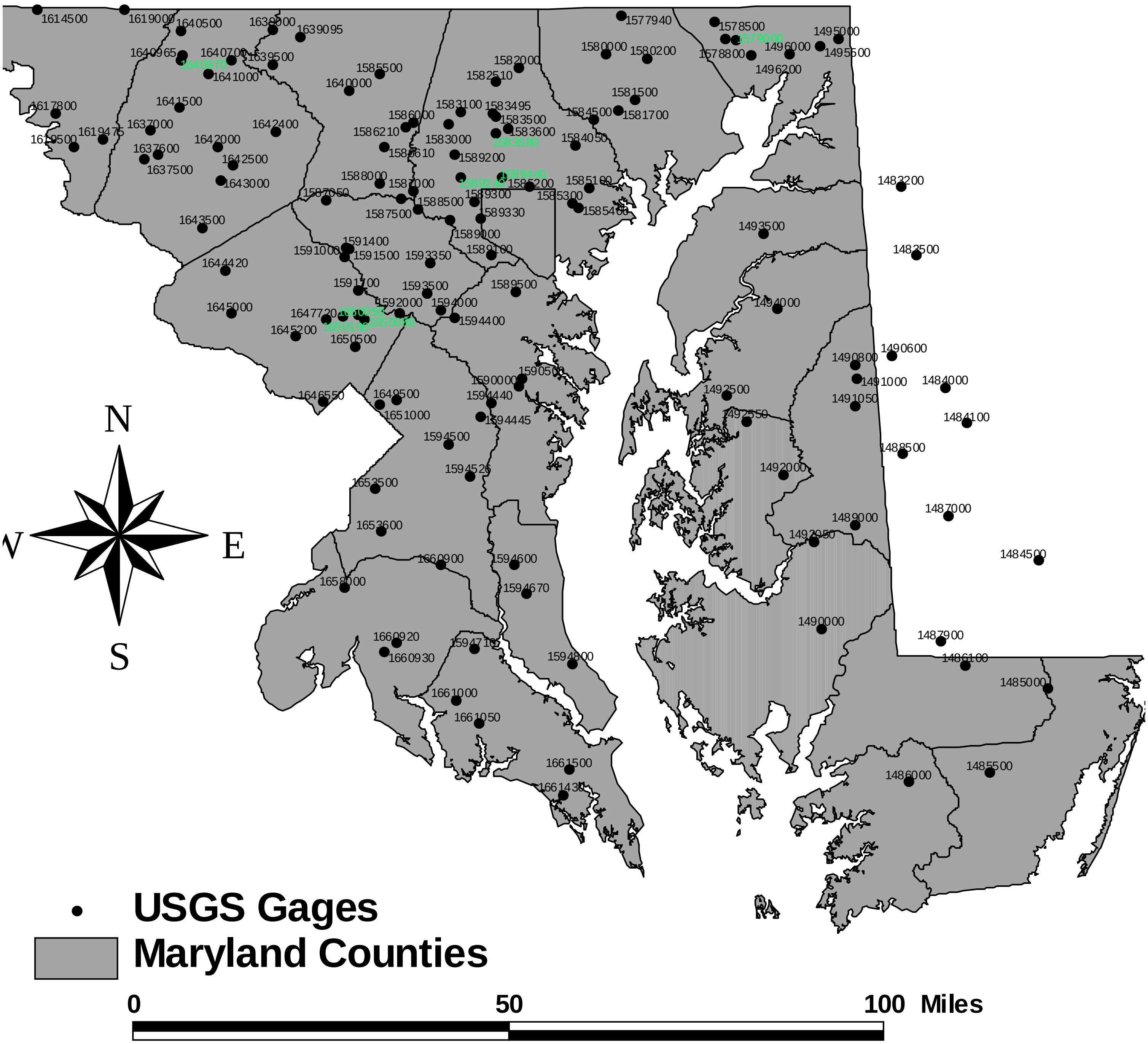
Appendix C1: Flood Frequency Results for USGS Stream Gages in Maryland (all flows are in ft^3/s) **(continued)**

Station Number	Station Name	Years of Record	1.25	1.50	1.75	2	5	10	25	50	100	200	500
1650190	Batchellors Run at Oakdale, MD	10	94	135	160	179	378	585	966	1,362	1,882	2,559	3,770
1650500	Northwest Branch Anacostia River near Colesville, MD	62	790	1,016	1,155	1,254	2,257	3,236	4,958	6,688	8,900	11,720	16,650
1651000	Northwest Branch Anacostia River near Hyattsville, MD	61	1,928	2,439	2,750	2,974	5,055	6,948	10,070	13,040	16,650	21,040	28,330
1653500	Henson Creek at Oxon Hill, MD	30	753	970	1,102	1,197	1,994	2,654	3,653	4,528	5,523	6,655	8,392
1653600	Piscataway Creek at Piscataway, MD	34	594	800	926	1,016	1,998	3,020	4,916	6,917	9,576	13,090	19,520
1658000	Mattawoman Creek near Pomonkey, MD	36	593	918	1,116	1,258	2,903	4,656	7,914	11,320	15,780	21,560	31,840
1660900	Wolf Den Branch near Cedarville, MD	13	72	102	119	132	271	414	677	951	1,310	1,779	2,619
1660920	Zekiah Swamp Run near Newtown, MD	16	949	1,158	1,285	1,377	2,147	2,790	3,780	4,660	5,677	6,853	8,694
1661000	Chaptico Creek at Chaptico, MD	25	195	272	319	352	750	1,195	2,079	3,070	4,455	6,380	10,100
1661050	St. Clements Creek near Clements, MD	30	330	538	664	755	1,926	3,288	6,025	9,087	13,330	19,140	30,120
1661430	Glebe Branch at Valley Lee, MD	11	16	20	23	26	46	64	94	122	157	198	266
1661500	St. Marys River at Great Mills, MD	53	477	696	830	926	2,017	3,174	5,342	7,634	10,670	14,680	21,920
3075450	Little Youghiogheny River tributary at Deer Park, MD	11	15	19	22	23	35	45	57	68	79	90	107
3075500	Youghiogheny River near Oakland, MD	59	2,769	3,405	3,792	4,071	6,285	8,047	10,640	12,860	15,330	18,110	22,290
3075600	Toliver Run tributary near Hoyes Run, MD	21	18	23	26	29	51	72	107	140	182	233	319
3076500	Youghiogheny River at Friendsville, MD	76	4,547	5,405	5,928	6,304	8,813	10,540	12,780	14,490	16,250	18,050	20,530
3076600	Bear Creek at Friendsville, MD	35	961	1,191	1,331	1,432	2,184	2,749	3,539	4,184	4,876	5,623	6,703
3077700	North Branch Casselman River tributary at Foxtown, MD	11	32	38	41	43	60	73	89	103	117	131	153
3078000	Casselman River at Grantsville, MD	52	1,382	1,653	1,818	1,937	2,916	3,722	4,944	6,019	7,251	8,664	10,860

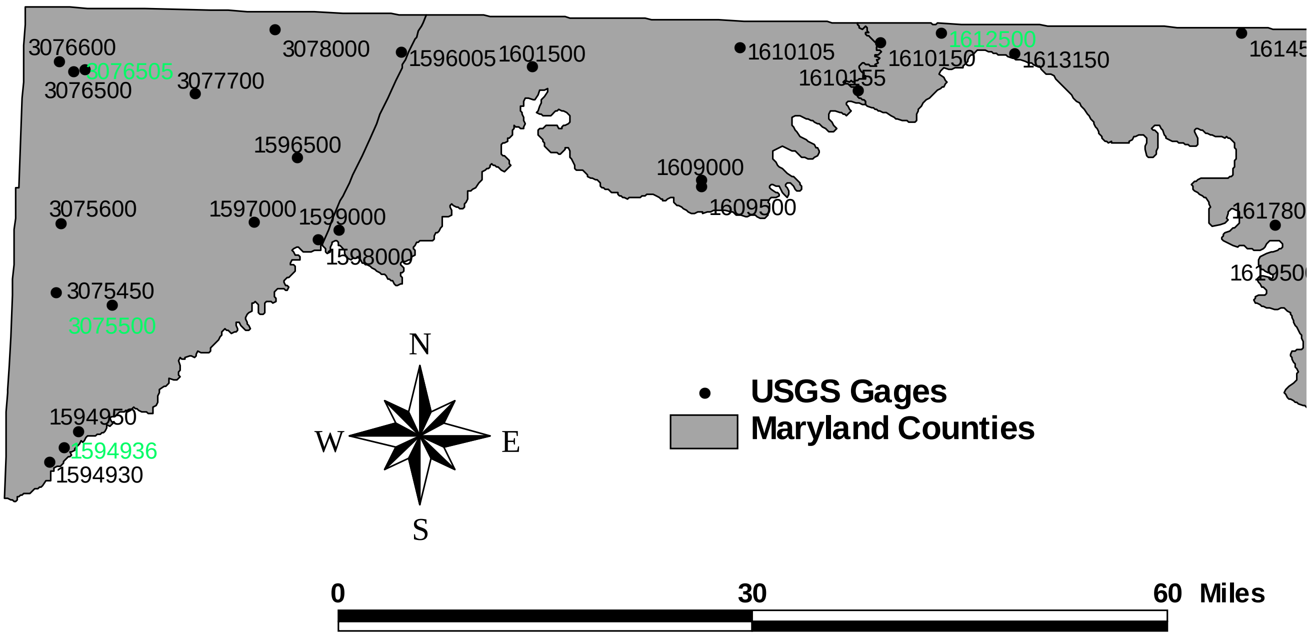
Appendix C2: Flood Frequency Results for USGS Stream Gages in Delaware (all flows are in ft^3/s)

Station Number	Station Name	Years of Record	1.25	1.50	1.75	2	5	10	25	50	100	200	500
1483200	Blackbird Creek at Blackbird, DE	47	89	110	130	147	256	351	501	636	795	980	1,270
1483500	Leipsic River near Cheswold, DE	33	125	155	185	211	408	612	988	1,380	1,900	2,590	3,840
1484000	Murderkill River near Felton, DE	31	191	240	280	313	542	738	1,050	1,320	1,650	2,020	2,610
1484100	Beaverdam Branch at Houston, DE	42	35	41	46	51	78	101	136	167	203	244	309
1484500	Stockley Branch at Stockly, DE	57	44	53	60	65	104	137	189	235	288	350	448
1486100	Andrews Branch near Delmar, MD	10	55	75	83	90	143	191	272	347	439	560	741
1487000	Nanticoke River near Bridgeville, DE	56	361	442	524	605	1,070	1,480	2,130	2,720	3,410	4,220	5,500
1487900	Meadow Branch near Delmar, DE	9	67	70	74	77	108	142	204	272	370	498	739
1488500	Marshyhope Creek near Adamsville, DE	54	521	697	874	1,050	1,940	2,580	3,410	4,040	4,660	5,280	6,080
1490600	Meredith Branch Near Sandtown, DE	10	134	164	188	208	356	491	715	931	1,190	1,508	2,037

Appendix D: Location map for USGS gages used in this report



Appendix D: Location map for USGS gages used in this report (continued)



Appendix E: Comparison of Results with USGS Report Standard Error

The USGS reports standard error of its regression equations in a different manner than that reported elsewhere in this document (See Tables 12-16). Standard error is first calculated by the USGS in the logarithmic space using the equation:

$$S_{e,USGS} = \left[\frac{1}{n-p-1} \sum_{i=1}^{n} \left\{ \log(y_i) - \log(\hat{y}_i) \right\}^2 \right]^{0.5} \qquad \text{(E-1)}$$

The USGS then assumes that residuals are log-normally distributed. Given this assumption, it is possible to express the standard error as a fraction of the mean discharge using the equation,

$$S_{e,frac} = \sqrt{10^{2.3026 \cdot S_{e,USGS}^2} - 1} \qquad \text{(E-2)}$$

Tables E1-E5 report this quantity as a function of region, method, and return period. These values are directly comparable to those reported in other documents produced by the USGS.

Table E1. Standard Error as a fraction of the mean discharge using USGS reporting methods in the Appalachian Region.

Appalachian Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.403	0.432	0.469	0.535	0.600	0.671	--	--
Dillow	---	---	---	0.201	0.243	0.296	0.376	0.442	0.510	--	0.687
Fixed Region	0.224	0.205	0.199	0.208	0.216	0.243	0.291	0.331	0.374	0.419	0.480
L-Moments	0.211	0.198	0.195	0.191	0.228	0.276	0.343	0.395	0.448	0.502	0.576
ROI	---	---	---	0.434	0.493	0.545	0.624	0.690	0.756	0.829	0.929

Table E2. Standard Error as a fraction of the mean discharge using USGS reporting methods in the Blue Ridge Region.

Blue Ridge Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.957	0.923	0.926	0.956	0.992	1.039	--	--
Dillow	---	---	---	0.613	0.617	0.631	0.661	0.694	0.737	--	0.864
Fixed Region	0.756	0.680	0.655	0.644	0.553	0.526	0.521	0.537	0.565	0.604	0.668
L-Moments	0.607	0.560	0.568	0.583	0.533	0.520	0.529	0.554	0.590	0.637	0.713
ROI	---	---	---	0.875	0.902	0.941	1.009	1.068	1.144	1.226	1.352

Table E3. Standard Error as a fraction of the mean discharge using USGS reporting methods in the Piedmont Region (rural and urban).

Piedmont Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.465	0.496	0.536	0.601	0.658	0.722	--	--
Dillow	---	---	---	0.376	0.359	0.377	0.431	0.492	0.567	--	0.769
Fixed Region	0.411	0.363	0.347	0.338	0.280	0.265	0.272	0.291	0.321	0.358	0.413
L-Moments	0.460	0.436	0.416	0.402	0.379	0.390	0.427	0.464	0.507	0.556	0.627
ROI	---	---	---	0.445	0.405	0.397	0.408	0.430	0.452	0.486	0.538

Table E4. Standard Error as a fraction of the mean discharge using USGS reporting methods in the Western Coastal Plain Region.

Western Coastal Plain Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	1.125	1.030	1.000	0.995	1.002	1.079	--	--
Dillow	---	---	---	0.640	0.702	0.765	0.873	0.921	1.039	--	1.290
Fixed Region	0.393	0.372	0.369	0.368	0.396	0.448	0.541	0.610	0.716	0.819	0.917
L-Moments	1.224	1.212	1.188	1.152	1.137	1.141	1.109	1.149	1.214	1.256	1.334
ROI	---	---	---	0.682	0.753	0.815	0.925	1.002	1.094	1.201	1.362

Table E5. Standard Error as a fraction of the mean discharge using USGS reporting methods in the Eastern Coastal Plain Region.

Eastern Coastal Plain Region	Return Period										
Method	1.25	1.50	1.75	2	5	10	25	50	100	200	500
Carpenter	---	---	---	0.585	0.604	0.616	0.645	0.678	0.722	--	--
Dillow	---	---	---	0.773	0.788	0.796	0.792	0.840	0.855	--	0.897
Fixed Region	0.342	0.337	0.342	0.349	0.369	0.382	0.400	0.418	0.440	0.466	0.508
L-Moments	0.520	0.492	0.491	0.495	0.489	0.516	0.580	0.642	0.713	0.791	0.904
ROI	---	---	---	0.416	0.413	0.409	0.405	0.401	0.416	0.432	0.463