# Methods for Development of Planning-Level Estimates of Stormflow at Unmonitored Stream Sites in the Conterminous United States

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*by Gregory E. Granato*

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## Abstract

This report documents methods for development of planning-level estimates of stormflow at unmonitored stream sites in the conterminous United States. Estimates of total stormflow are derived from statistics for pre-storm streamflow, precipitation, and volumetric runoff coefficients. The statistics developed in this analysis are intended for use with the Stochastic Empirical Loading and Dilution Model (SELDM). Streamflow statistics are used to estimate pre-storm flows, precipitation statistics are used to estimate storm-event characteristics, and runoff coefficient statistics are used with precipitation statistics to estimate the volume of runoff from the highway and the upstream basin. The report documents selected methods for data compilation and analysis of statistics for each of these stormflow components. Each section of the report includes a description of data, methods, and software that can be used to estimate the necessary statistics. The selected methods meet data-quality objectives for developing order-of-magnitude planning-level water-quality estimates at unmonitored sites in the conterminous United States. Appendicies to the report document reviews of previous investigations, background information, and describe alternative methods for stormflow analysis. The geographic information system files, computer programs, data files, and regression results developed for this study are included on the CD-ROM accompanying this report.


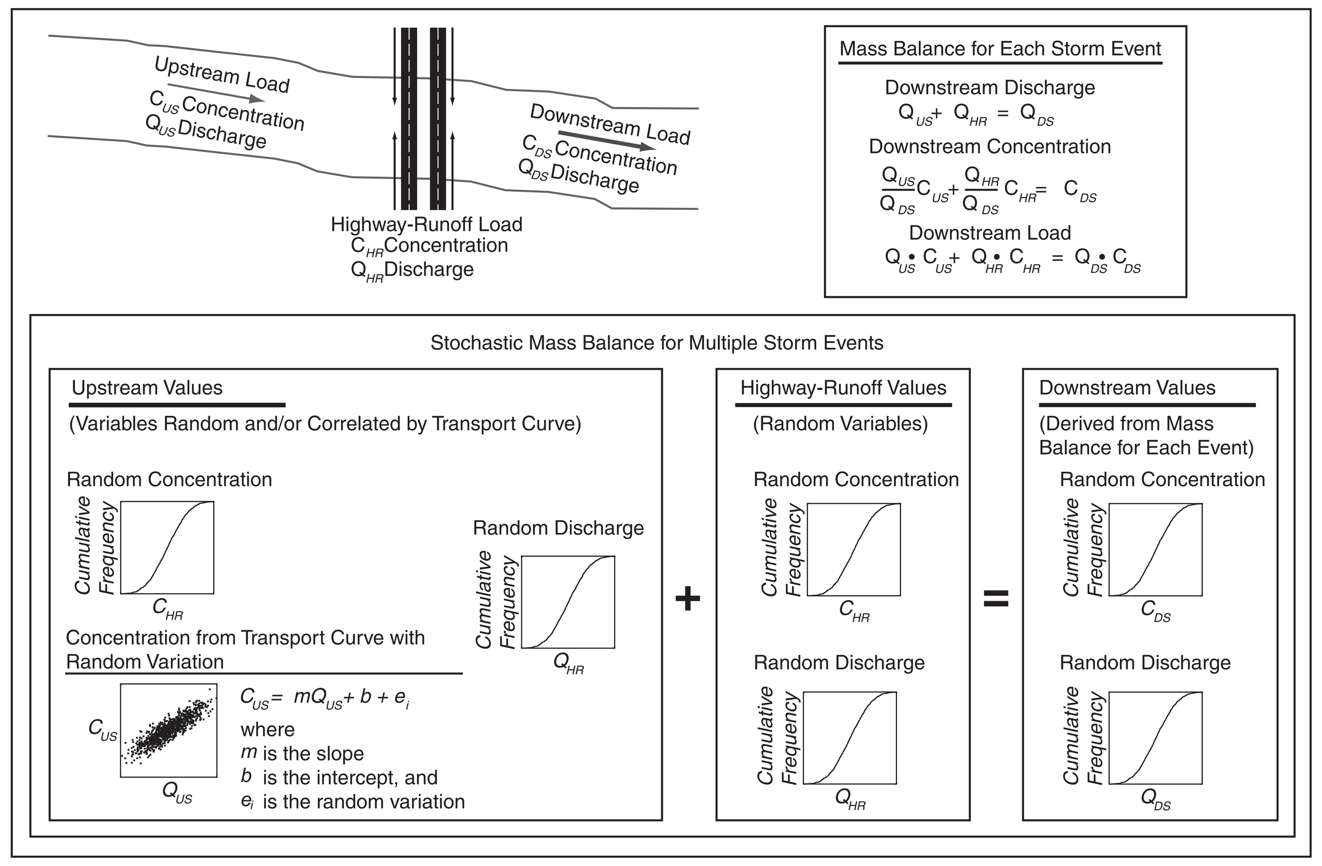


Figure 1. Schematic diagram showing the stochastic mass-balance approach for estimating discharge, concentration, and loads of water-quality constituents upstream of a highway outfall, from the highway, and downstream of a highway-runoff outfall.

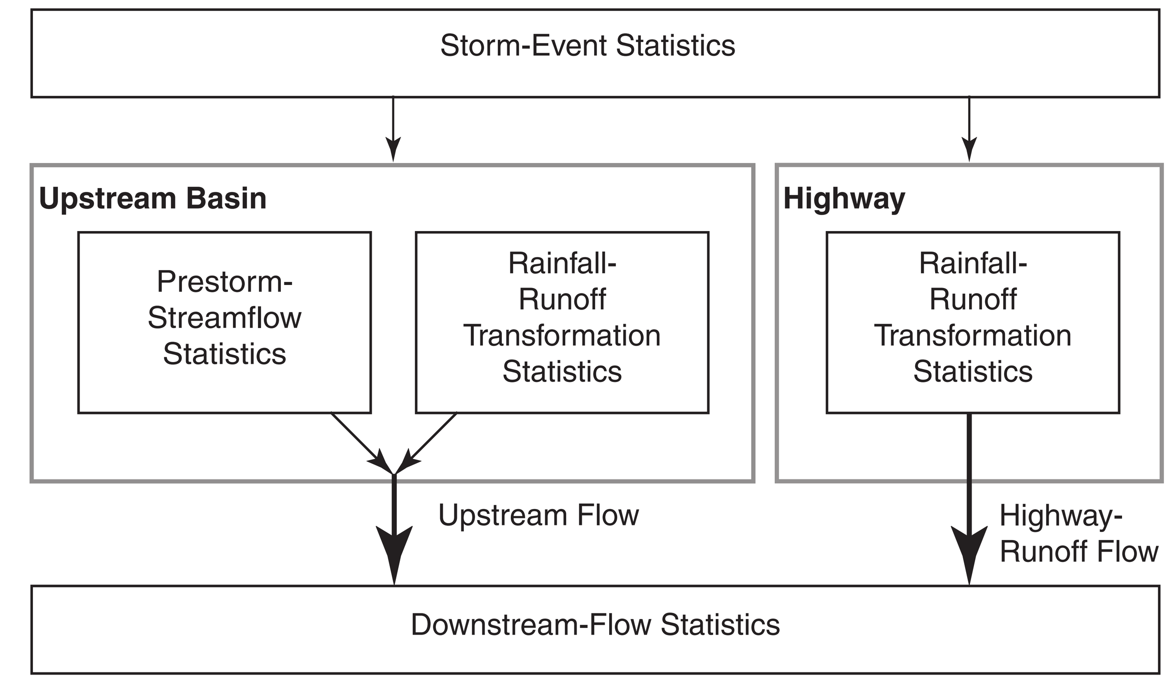


Figure 2. Schematic diagram showing the components of upstream flow and highway runoff that must be estimated for mass-balance analysis of receiving-water quality.

## Pre-storm Streamflow

The proportion of zero flows and the mean, standard deviation, and skew of the logarithms of non-zero streamflows are used in SELDM to generate a population of pre-storm flows. These streamflow statistics are estimated by analysis of data from 2,873 U.S. Geological Survey streamflow-gaging stations in the conterminous United States. Streamflow-gaging stations with drainage areas ranging from 10 to 500 square miles and at least 24 years of record during the period 1960-2003 were selected for analysis. Streamflow statistics are regionalized using U.S. Environmental Protection Agency Level III nutrient ecoregions. Initial estimates of pre-storm flow statistics may be made using the drainage-area-ratio method with regional statistics. These estimates may be refined with statistics from nearby, hydrologically similar basins. This report was written to document methods for estimating statistics at ungaged sites, but site specific statistics can be calculated using software developed for use with SELDM. If a long-term record on mean-daily flows is available then the statistics can be calculated with the existing record. If limited data are available (or are collected for analysis) from the site of interest, record extension or augmentation methods may be used to estimate the necessary statistics.

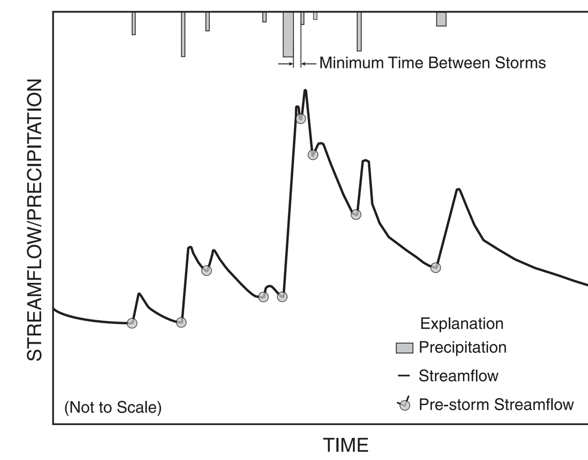


Figure PSF-1. Schematic diagram showing the potential variability in pre-storm flows that may occur if the definition of the minimum time between precipitation events is less than the stormflow recession for a given basin. The minimum time between storms for highway and urban-runoff studies is six hours without measurable precipitation (Driscoll, Palhegyi, and others 1989), whereas the stormflow recession for many basins may be greater than one or more days (Linsley and others, 1975). This approach is consistent with the local-minimum baseflow-separation method (Linsley and others, 1975).

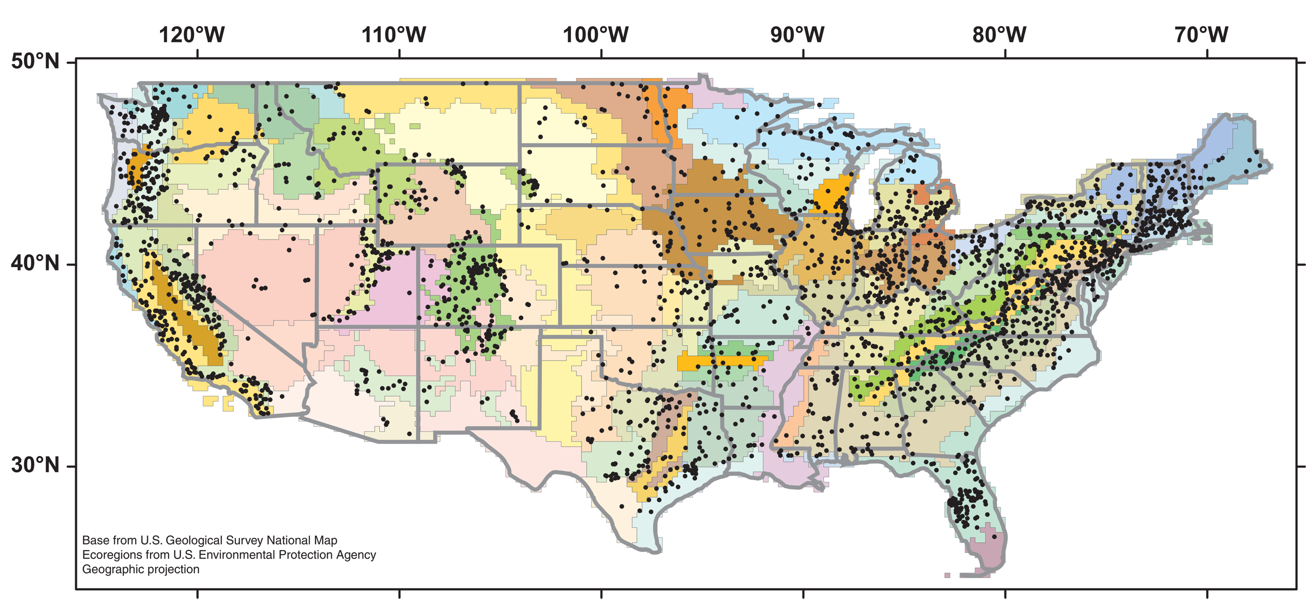


Figure PSF-2. Spatial distribution of 2,783 selected U.S. Geological Survey streamflow-gaging stations (black dots) with among U.S. Environmental Protection Agency (2004) Level III ecoregions (colored polygons) that have been discretized to a 15-minute grid in the conterminous United States. The selected U.S. Geological Survey streamflow-gaging stations have drainage areas between 10 and 500 square miles, with at least 24 years of streamflow data collected during the 1960-2003 period, and are not listed as being at, near, or immediately below a dam. Ecoregions are identified on the plate useco.pdf on the CD-ROM accompanying this report.

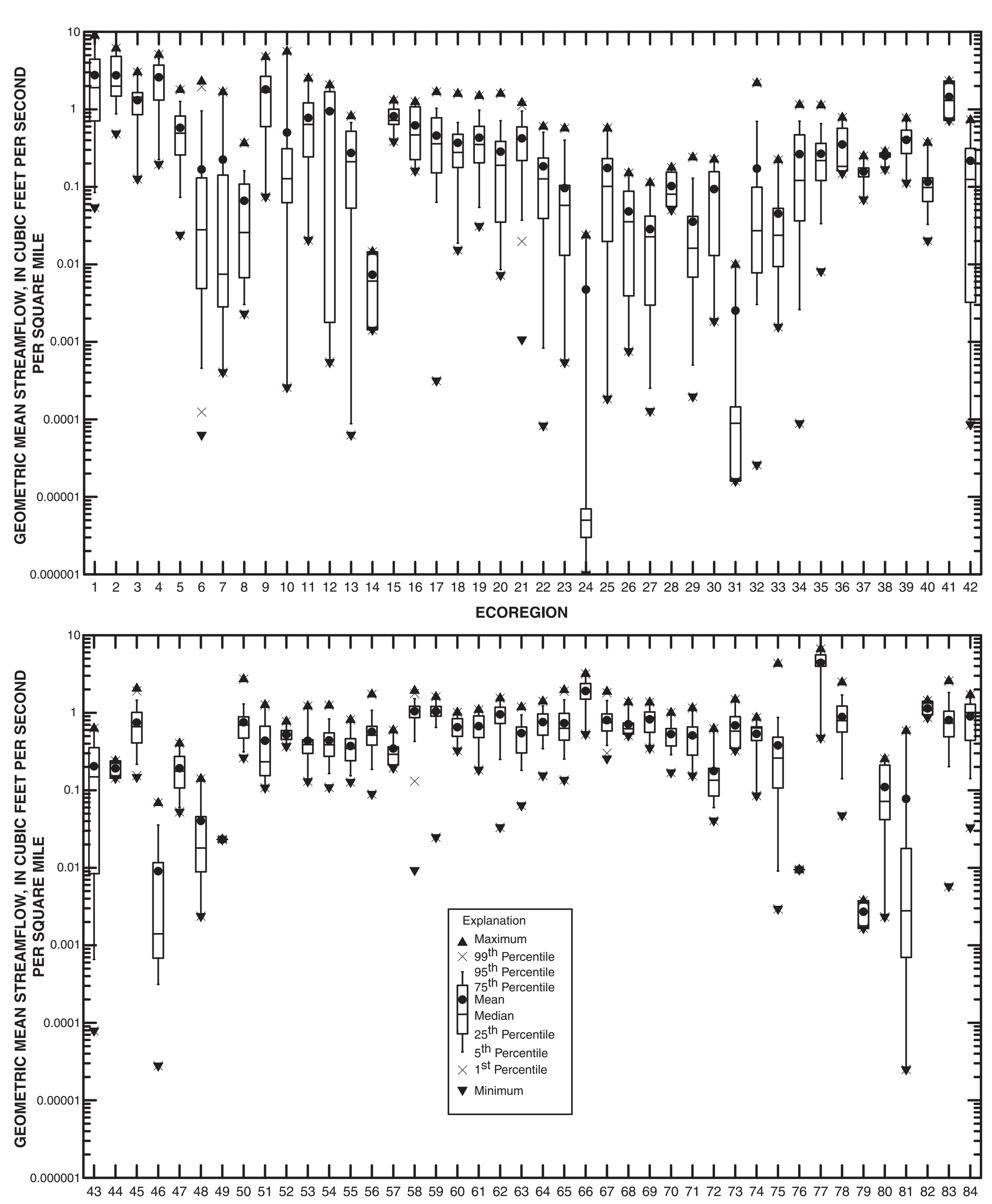


Figure PSF-3. Population of geometric-mean streamflow values for different streamflow-gaging stations within each ecoregion in the conterminous United States, normalized by drainage area.

## Synoptic Precipitation-Event Statistics

The lower bound and the average of the precipitation volume, duration, and time between storm midpoints are used in SELDM to generate a population of storm events. Storm-event precipitation statistics are estimated by analysis of data from 2,610 National Oceanic and Atmospheric Administration hourly-precipitation data stations in the conterminous United States. Precipitation-monitoring stations with at least 25 years of data during the 1965-2006 period were selected for analysis. Storm-event statistics are regionalized using U.S. Environmental Protection Agency rain zones and Level III nutrient ecoregions. Initial estimates of storm-event statistics may be made using regional statistics. These estimates may be refined with statistics from nearby, hourly-precipitation data stations.

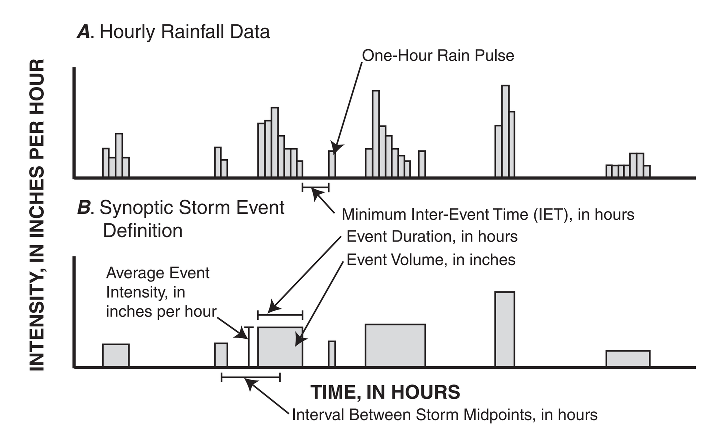


Figure SEP-1. Schematic diagram showing the characterization of a synoptic storm event (Modified from Driscoll, Palhegyi and others 1989).

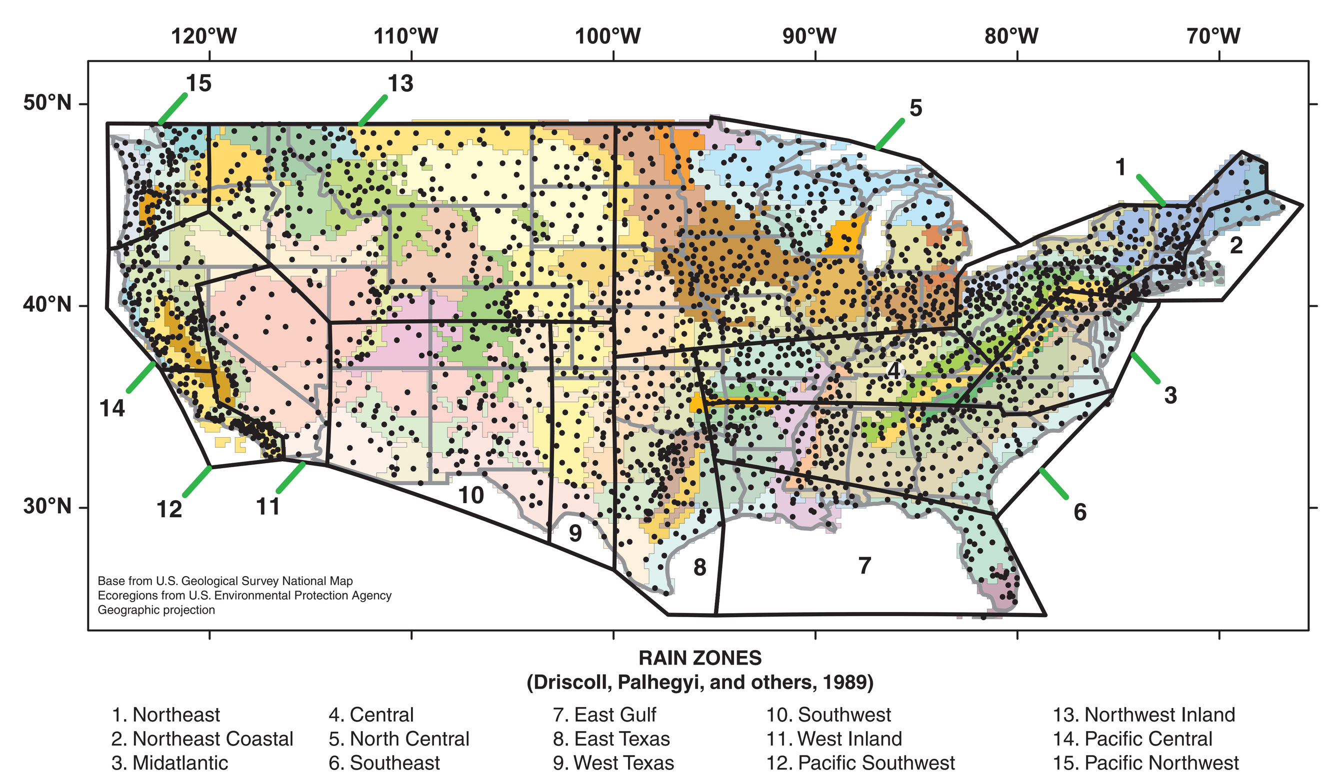


Figure SEP-2. Spatial distribution of 2,610 hourly-precipitation data stations (black dots) among the the U.S. Environmental Protection Agency rain zones (Driscoll, Palhegyi, and others, 1989) and the U.S. Environmental Protection Agency (2004) Level III ecoregions (colored polygons) that have been discretized to a 15-minute grid in the conterminous United States. Ecoregions are identified on the plate useco.pdf on the CD-ROM accompanying this report.

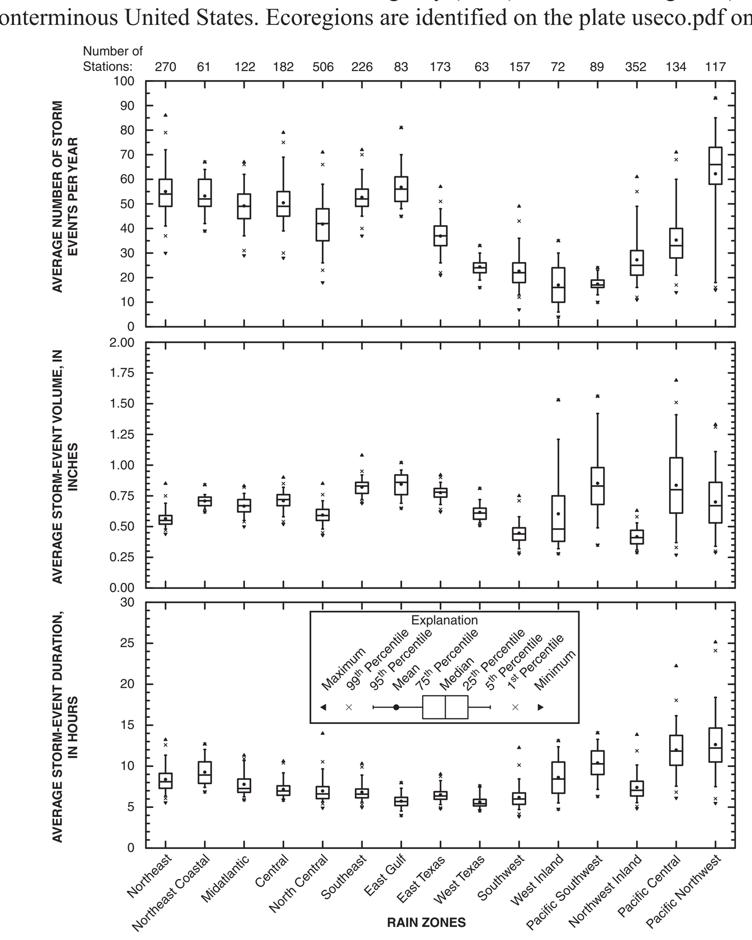


Figure SEP-3. Boxplots showing variations among statistics from precipitation monitoring stations in each rain zone in the conterminous United States for the average number of storms per year, the average storm-event volume, and the average storm-event durations during 1965-2006.

## Volumetric Runoff Coefficients

The mean, standard deviation and skew of volumetric runoff coefficients are used with storm-event statistics in SELDM to generate a population of runoff volumes. Volumetric runoff-coefficient statistics are estimated using data from 6,142 storm events at 306 study sites. Study sites include residential, commercial, industrial, institutional, agricultural, urban open space, and natural land uses. Sites are located in many areas within the conterminous United States. Runoff-coefficient statistics are not regionalized, but are organized by total impervious area. Regression equations were developed to estimate the average, standard deviation and skew of runoff coefficients from the estimated total impervious area.

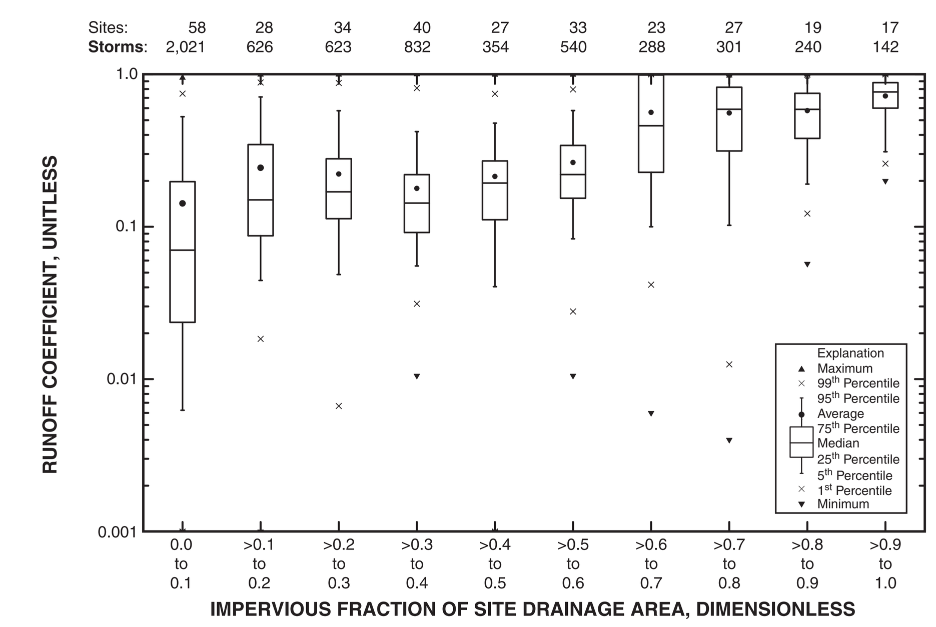


Figure VRC1. Boxplot of volumetric runoff coefficients that are less than or equal to one for individual storm events from the 306 different sites used in this study that are grouped by impervious-fraction intervals.

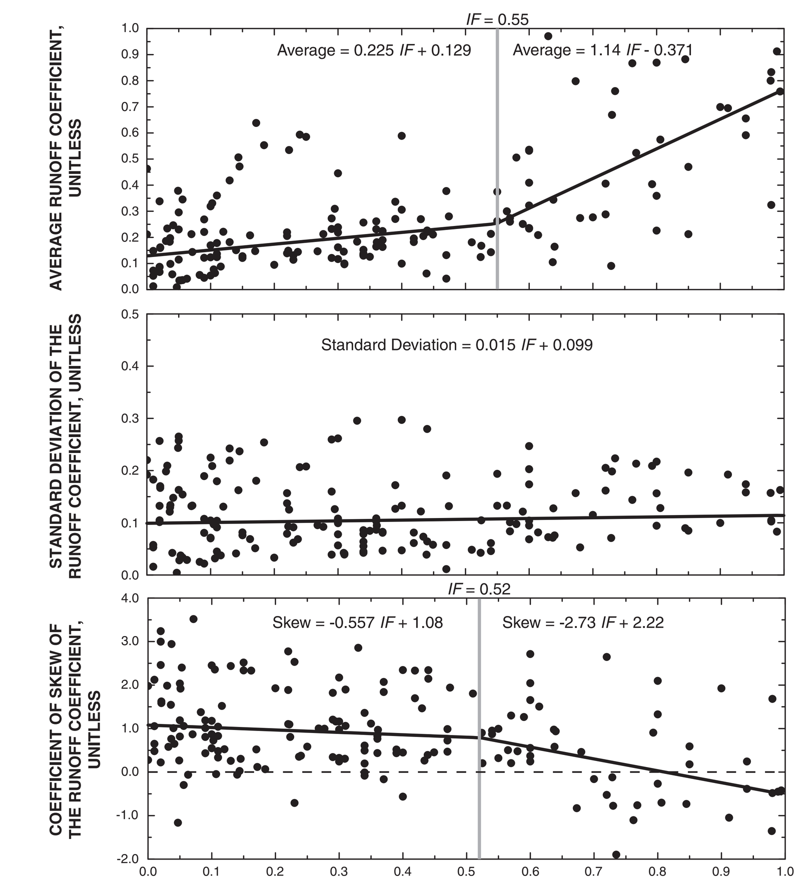


Figure RVC-2. Graphs showing the average, standard-deviation, and skew of runoff coeficients for 167 sites in the database that have nine or more storm events. Nonparametric regression lines (Granato, 2006) indicate the relation between each statistic and the (TIA) impervious fraction. Two-line regression models were developed for the average and skew values to better characterize the relation between these statistics and the (TIA) impervious fraction.

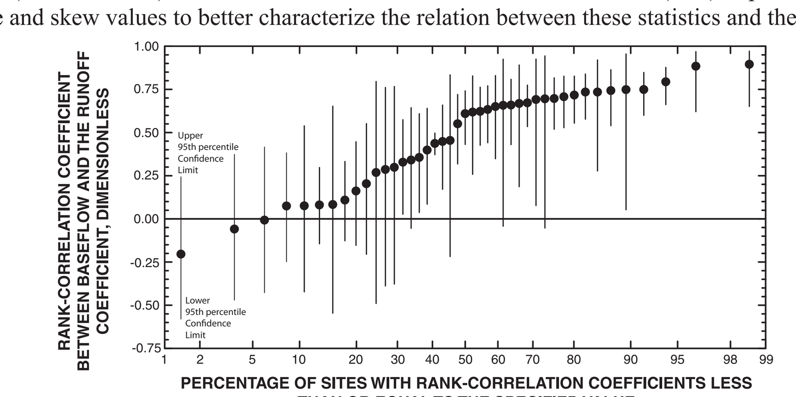


Figure RVC-3. Probability plot showing the nonparametric rank correlation coefficients (Spearman's Rho) between pre-storm flow and the runoff coefficient for the associated storm event. Each point represents data from sites with seven or more paired baseflow and runoff meaurements. Strong positive correlations indicate that the magnitude of prestorm baseflows may be a good predictor for the runoff coefficient, with higher flows indicating wetter antecedent conditions.

## References


Driscoll, E.D., Palhegyi, G.E., Strecker, E.W., and Shelley, P.E., 1989, Analysis of storm event characteristics for selected rainfall gages throughout the United States: U.S. Environmental Protection Agency, OCLC 30534890, 43 p.

Granato, G.E., 2006, Kendall-Theil Robust Line (KTRLine—version 1.0)—A Visual Basic program for calculating and graphing robust nonparametric estimates of linear-regression coefficients between two continuous variables: Techniques and Methods of the U.S. Geological Survey, book 4, chap. A7, 31 p. http://ma.water.usgs.gov/FHWA/SELDM.htm

Linsley, R.K., Jr., Kohler, M.A., and Paulhus, J.L.H., 1975, Hydrology for Engineers 2nd Ed.: New York, McGraw-Hill Book Company, 482 p.

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