Prepared in cooperation with the South Carolina Department of Transportation

Methods for Estimating Magnitude and Frequency of Floods in Rural Basins in the Southeastern United States: South Carolina

Introduction

For more than 50 years, the U.S. Geological Survey (USGS) has been developing regional regression equations that can be used to estimate flood magnitude and frequency at ungaged sites. Flood magnitude relates to the volume of flow that occurs over some period of time and usually is presented in cubic feet per second. Flood frequency relates to the probability of occurrence of a flood; that is, on average, what is the likelihood that a flood with a specified magnitude will occur in any given year (1 percent chance, 10 percent chance, 50 percent chance, and so on). Such flood estimates are needed for the efficient design of bridges, highway embankments, levees, and other structures near streams. In addition, these estimates are needed for the effective planning and management of land and water resources, to protect lives and property in flood-prone areas, and to determine flood-insurance rates.

Issue

Historically, flood-frequency studies have been done on a statewide basis using hydrologic regions that represent areas of relatively homogeneous flood characteristics determined for the particular State of interest. Flood-frequency estimates made at gaged sites and regional flood-frequency equations developed from the gaged-site estimates contain varying degrees of uncertainty based on numerous factors, such as length of record, number of stations available for regionalization, range of basin characteristics, and so on. To provide simple methods of estimating flood-peak flows, the USGS has developed and published regression equations for every State, the Commonwealth of Puerto Rico, and a number of metropolitan areas in the United States. These investigations typically are not coordinated between neighboring States and are, therefore, based on various periods of record and sometimes result in hydrologic regions that are not contiguous at the State boundaries. Thus, if flood-frequency estimates are needed for a basin that crosses State boundaries, engineers and water-resource managers may have to work with several equations based on an assortment of basin characteristics with results that have varying degrees of uncertainty.

To address this issue in the Southeast, the USGS Water Science Centers in South Carolina, Georgia, and North Carolina, worked cooperatively with the South Carolina Department of Transportation, the Georgia Department of Transportation, the North Carolina Department of Transportation, and the North Carolina Floodplain Mapping Program, to develop flood-frequency techniques that are applicable across State boundaries in these three States.

Regression Analysis

Flood-frequency estimates for 828 gaged stations in South Carolina, Georgia, North Carolina, and surrounding States were computed following methods described in Bulletin 17B of the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data (1982). Based on assessments of geographical patterns in the residuals of the regression estimates, five hydrologic regions were established using U.S. Environmental Protection Agency ecoregions (2007) (fig. 1): Ridge and Valley–Piedmont (Region 1), Blue Ridge (Region 2), Sand Hills (Region 3), Coastal Plain (Region 4), and Southwest Georgia

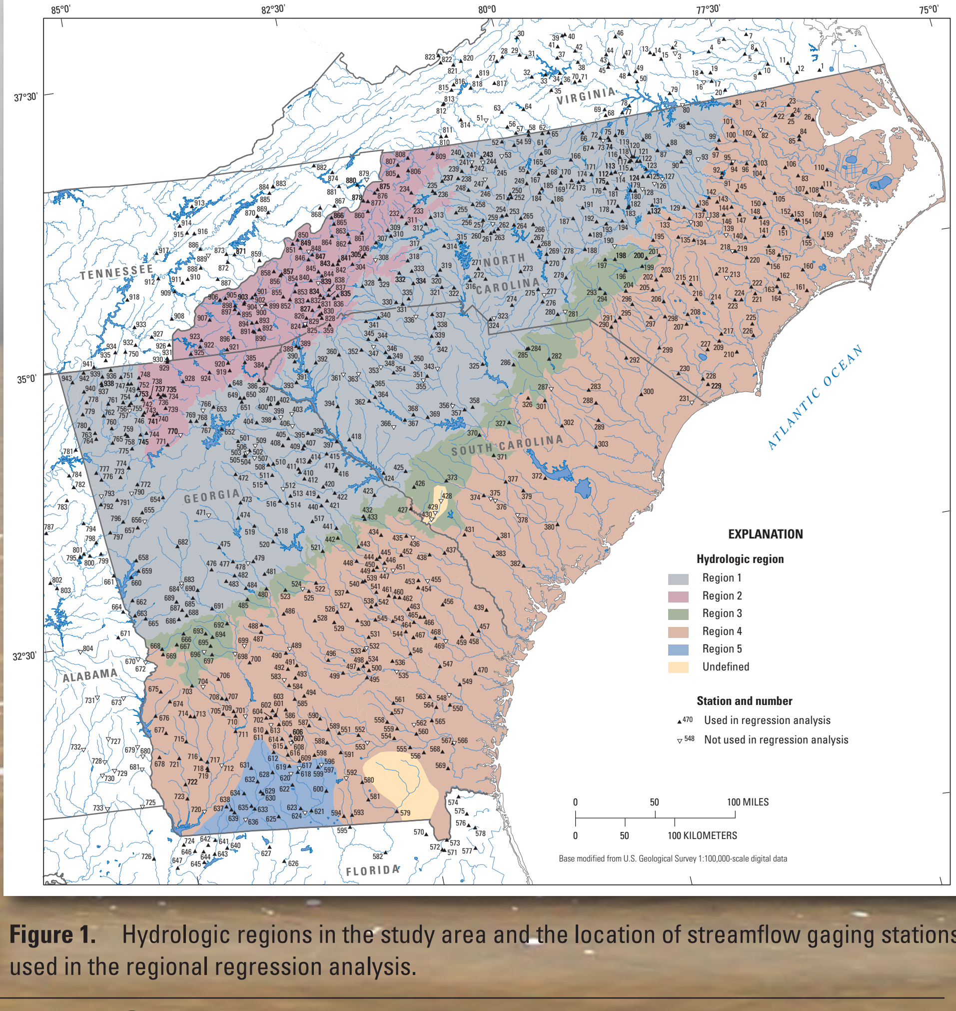

Figure 1. Hydrologic regions in the study area and the location of streamflow gaging stations used in the regional regression analysis.

(Region 5). South Carolina is wholly encompassed in Regions 1–4.

Historically, USGS reports expressed the T-year floods based on the recurrence interval for the specified flood (for example, the “100-year flood”). However, this terminology is undergoing a shift away from the T-year recurrence and instead using the more technically appropriate “percent chance exceedance probability.” The percent chance exceedance probability conveys the probability, or odds, that a flood of a given magnitude will be equaled or exceeded in any given year. For example, a 1-percent chance exceedance flood (formerly known as the “100-year flood”) corresponds to the flood that has a probability of 0.01 (or 1 percent) of being equaled or exceeded in any given year. The P-percent chance exceedance is computed as the inverse of the recurrence interval (T) multiplied by 100.

This study resulted in a set of predictive equations that can be used to estimate the 50-, 20-, 10-, 4-, 2-, 1-, 0.5-, and 0.2-percent chance exceedance flows (formerly the 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence interval flows, respectively), for rural, ungaged sites in South Carolina, Georgia, and North Carolina. The predictive equations are all functions of drainage area and the percentage of the drainage basin within each of the defined hydrologic regions. For brevity, only the equation for the 1-percent chance exceedance flow is shown as an example at the bottom of the page.

Traditionally, flood-frequency equations only apply to a single hydrologic region. Thus, in a State like South Carolina that has four hydrologic regions, there would be four sets of regression equations (one for each region). As a result, stations that have significant drainage from more than one region are not included in the regression analysis. The use of the basin percentages allows for the inclusion of such stations and, in this particular study, resulted in an additional 83 stations used in the analysis. The use of basin percentages in the regression coefficients allows for a smooth transition of flood estimates for drainage basins that do not lie wholly within one hydrologic region. For example, the slopes for the Blue Ridge and Sand Hills hydrologic regions’ (Regions 2 and 3, respectively) regression lines are visibly different from the slopes for the regression lines for the three remaining hydrologic regions (fig. 2*A*). As a result, the final equations include a “slope adjustment factor” for hydrologic regions 2 and 3. The transition from a site located wholly in hydrologic region 1, represented by the “base” slope (for example, 0.594 for the 1-percent chance exceedance flow), to a site located wholly in hydrologic region 2 is depicted in figure 2*B*. Note that the slope of the regression line becomes visibly steeper as a basin goes from 100 percent in the Ridge and Valley–Piedmont region (Region 1) to a basin that is 100 percent in the Blue Ridge region (Region 2).

The average standard error of prediction for these equations ranged from 34.0 to 47.7 percent. The standard error of prediction is a measure of the accuracy of the regression equations when predicting floods for watersheds not used in the regression analysis. About two-thirds of the regression estimates for ungaged sites will have errors less than the standard error of prediction for the regression equations.

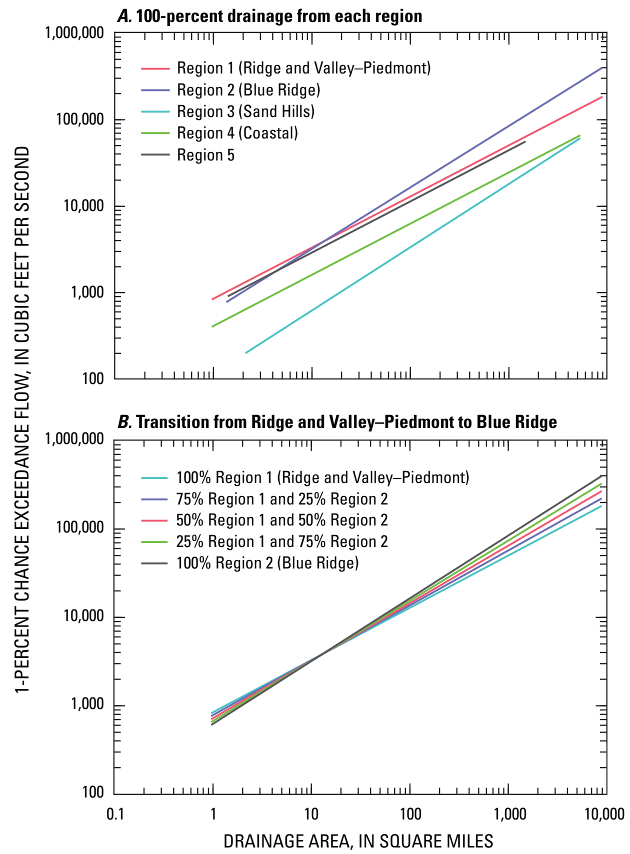

Figure 2. Rural flood-frequency relations *(A)* by region for basins located wholly within one hydrologic region and *(B)* for a basin transition from the Piedmont to the Blue Ridge hydrologic region.

References

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Full report available online at:
http://pubs.usgs.gov/sir/2009/5156/

Sample equation:

$$Q_{1\%} = 10^{[0.0289(PCT_1)+0.0276(PCT_2)+0.0202(PCT_3)+0.0258(PCT_4)+0.0286(PCT_5)]} DA^{[0.594+0.00119(PCT_2)+0.00139(PCT_3)]}$$

where $Q_{1\%}$ is the 1-percent chance exceedance flow, in cubic feet per second; PCT_1, PCT_2, PCT_3, PCT_4, and PCT_5 are the basin percentages in hydrologic regions 1, 2, 3, 4, and 5; and DA is the drainage area, in square miles.