ESTIMATION OF BASEFLOW FROM STREAMFLOW DATA IN THE APALACHICOLA-CHATTAHOOCHEE-FLINT AND THE ALABAMA-COOSA-TALLAPOOSA RIVER BASINS

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REFERENCE: *Proceedings of the 1997 Georgia Water Resources Conference,* held March 20-22, 1997, at the University of Georgia, Kathryn J. Hatcher, Editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. As part of an assessment of ground-water resources of the Apalachicola-Chattahoochee-Flint and the Alabama-Coosa-Tallapoosa (ACF-ACT) River basins, the U.S Geological Survey (USGS) used a streamflow-hydrograph separation method to estimate baseflow. An automated procedure, based on the recession-curve-displacement method, was developed to estimate mean-annual baseflow of 67 rivers and streams from the ACF-ACT River basins using streamflow data. The variability in the estimates of unit-area mean-annual baseflow, which ranged from 1 to 30 inches per year, is discussed with respect to characteristics of the drainage areas.

INTRODUCTION

Increasing and competing demands for water in the Apalachicola-Chattahoochee-Flint and the Alabama-Coosa-Tallapoosa River basins have created a need to evaluate regional water resources. The U.S. Army Corps of Engineers and the States of Alabama, Florida, and Georgia requested the U.S. Geological Survey to address the ground-water-supply element of a Comprehensive Study of the ACF-ACT River basins (U.S. Army Corps of Engineers, 1991). This study element addresses ground-water resources in each basin, by estimating the ground-water contribution to major rivers. The USGS analyses of ground-water resources can be used in part to assess resource-allocation alternatives created by existing and proposed uses of the water resources in the river basins.

Purpose and scope

This paper describes the development and use of a streamflow hydrograph-separation procedure by the USGS to estimate the ground-water contribution to rivers and streams (commonly termed baseflow) in the ACF-ACT River basins. Using this procedure, mean-annual baseflow of rivers and streams in the ACF-ACT River basins was estimated and presented in a series of USGS reports describing ground-water resources of ACF-ACT River basins. In this paper, the estimates of baseflow for the ACF-ACT study area are summarized and discussed from a regional perspective.

Description of study area

The ACF-ACT River basins are in the Coastal Plain, Piedmont, Valley and Ridge, Blue Ridge, and Cumberland Plateau physiographic provinces. The study area covers about 42,400 square miles from near the Georgia-Tennessee State line, through much of central and southern Alabama and Georgia and part of the Florida panhandle to the Gulf of Mexico (Figure 1). Based on hydrologic and physiographic boundaries, the two basins were further divided into eight subareas for the ACF-ACT Comprehensive Study (Figure 1) and each subarea was the focus of a separate ground-water-resource evaluation.

Hydrology of study area

The surface- and ground-water systems of the ACF-ACT River basins behave as an integrated, dynamic flow system comprised of an interconnected network of aquifers, streams, reservoirs, control structures, floodplains, and estuaries. The degree of hydrologic interaction between surface water and ground water suggests that the water resources be investigated and managed as a single hydrologic entity to account for climatic and anthropogenic factors that influence flow systems within the basins.

Previous investigations

Rorabaugh (1960; 1964) described a method of streamflow-hydrograph separation to estimate discharge from an aquifer to a stream for each peak in the streamflow record. The method has been successfully used in regional water-resource investigations, including those of Faye and Mayer (1990) and Hoos (1990). Rutledge (1993) employed the method in the development of an automated procedure, whereby a set of computer programs allows digital analysis of long periods of streamflow record. Mayer and Jones (1996) modified one of the computer programs of Rutledge (1993) for application to the ACF-ACT Comprehensive Study. The USGS then used this modified code to estimate baseflow of gaged streams and rivers in the ACF-ACT study area. These results are presented in seven reports of ground-water evaluations of the ACF-ACT subareas (Chapman and Peck [*in press* a,b]; Journey and Atkins [*in press*]; Kidd *et al.* [*in press*]; Mayer [*in press*]; Mooty and Kidd [*in press*]; and Robinson *et al.* [*in press*]).

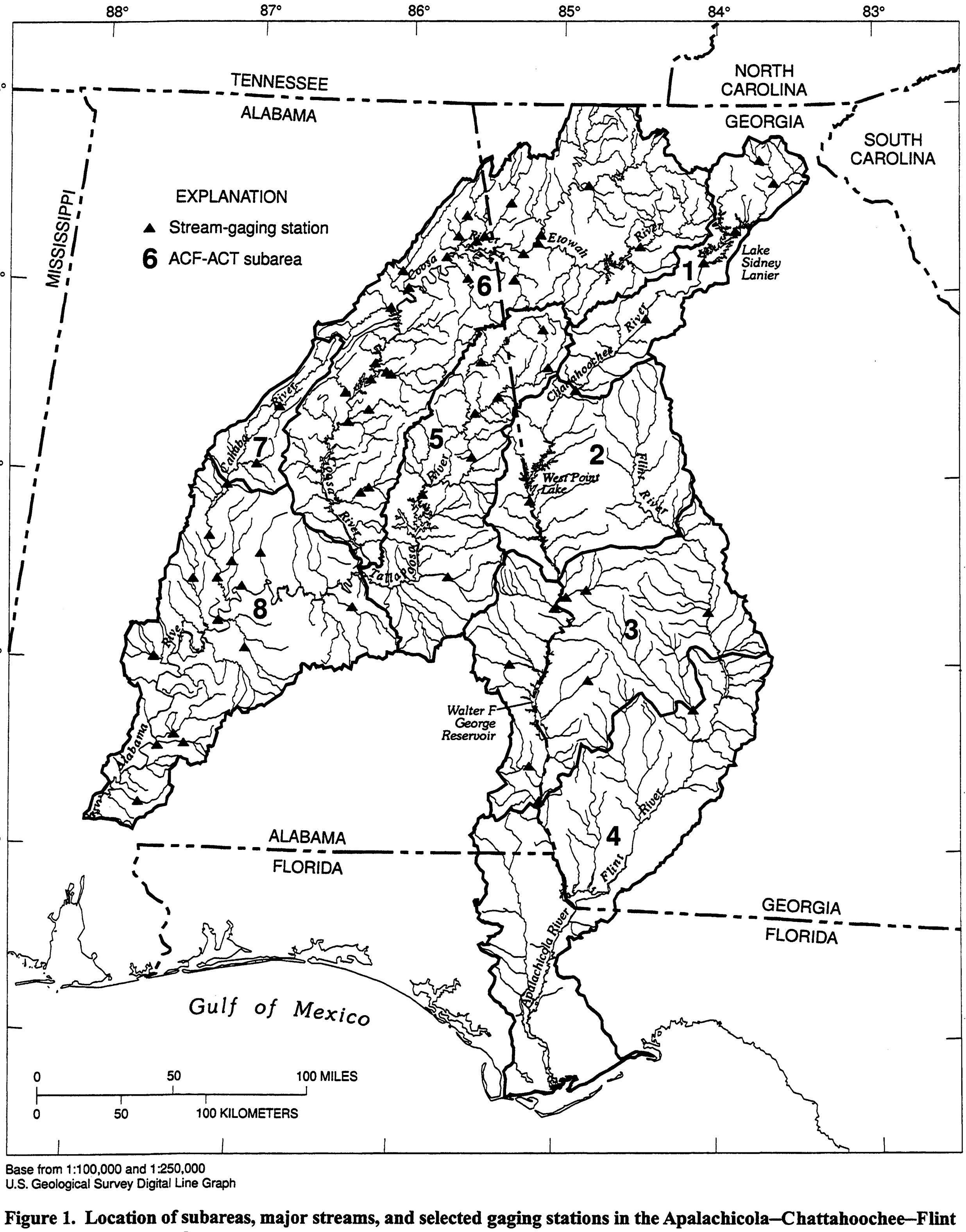

Figure 1. Location of subareas, major streams, and selected gaging stations in the Apalachicola–Chattahoochee–Flint (ACF) and Alabama–Coosa–Tallapoosa (ACT) River basins.

STREAMFLOW-HYDROGRAPH SEPARATION

A streamflow hydrograph represents the volumetric rate of streamflow, usually plotted on a logarithmic scale, over time at a specific stream location (gaging station). The objective of separating a hydrograph usually is to estimate the quantity of water discharged from an aquifer or aquifer system to a stream (commonly termed baseflow). Various graphical methods have been used to determine the location of the line on a streamflow hydrograph that separates the upper part—which is attributable to the volume of overland runoff; from the lower part—which represents the volume of baseflow. If there is little or no ground-water withdrawal in the drainage area and conditions are at steady-state, baseflow of a stream can be considered equivalent to the volumetric rate of ground-water recharge over the drainage area.

The recession-curve-displacement method was developed by Rorabaugh (1960; 1964), and is based on the assumption that a master recession curve, defined by a constant recession index, represents the recession of streamflow during times when all streamflow is from ground-water discharge. After a rainfall event and the subsequent peak in the streamflow hydrograph, a period of overland runoff to the stream occurs. A recession curve is fitted to the streamflow hydrograph after runoff associated with the peak has ceased. At this time, called critical time, it can be shown that the change in discharge between a previous recession curve and the newly fitted recession curve is related to the baseflow rate during the period between this critical time and the critical time for the subsequent peak. By summing the baseflow determined in this manner for all streamflow peaks within a specified time period, mean baseflow over the period can be estimated.

Rutledge (1993) developed a set of computer programs designed to automate the various steps of the recession-curve-displacement method of Rorabaugh (1960; 1964) for easy application to the large volume of streamflow record available in the United States. Based on input supplied by the user, the average baseflow over any period of continuous record can be estimated. To accommodate the needs of the ACF-ACT Comprehensive Study, Mayer and Jones (1996) modified one of the programs of Rutledge (1993) to determine baseflow for individual water years and provide graphical output of the separated hydrographs for ease of evaluation (Figure 2). The modified program also allows for the use of a variable adjustment factor to provide a better graphical fit of the recession curve to the measured data (see Mayer and Jones (1996) for a discussion on the computation and use of the adjustment factor). Mayer and Jones (1996) compared baseflow estimates based on various values of the adjustment factor to manually derived estimates of baseflow reported by Faye and Mayer (1990) and Hoos (1990). Statistical analyses of these comparisons offer user guidance on the use of the adjustment factor.

BASEFLOW ESTIMATES IN THE ACF-ACT RIVER BASINS

The ground-water resources of the eight subareas of the ACF and ACT River basins were evaluated and described by the USGS. Using the computer program of Mayer and Jones (1996), the USGS determined mean-annual baseflow of 67 rivers and streams in seven of the eight ACF-ACT subareas. The results of these analyses were used in the computation of a hydrologic budget for the two river basins, which can be used by water managers of the U.S. Army Corps of Engineers and the three States to help develop water-resource management policy.

Stream-discharge data from continuous-record gaging stations in the ACF-ACT study area were selected for baseflow analysis, based on periods of record of unregulated flow. For each gaging station, the area of the drainage basin and the recession index were determined graphically. Three water years representative of periods of low, average, and high stream discharge were selected for each gaging station and were used to estimate annual baseflow. Mean-annual baseflow was then estimated to be the average of annual baseflow computed for each of the three representative water years. For a more detailed description of these procedures, refer to the ACF-ACT subarea reports (see "Previous Investigations" and "Literature Cited" for references).

Various streams in the ACF-ACT study area were examined, ranging from first to fourth order. The drainage areas contributing to streamflow at the 67 gaging stations ranged from 20.2 to 21,967 square miles; and for the water years considered, the mean-annual stream discharge ranged from 22.8 to 43,360 cubic feet per second. Assuming steady-state conditions and minimal ground-water withdrawal within the drainage areas during the water years analyzed, baseflow is considered equivalent to ground-water recharge, and can be expressed in inches per year over the drainage areas contributing to streamflow at a gaging station. For the drainage areas of the 67 gaging stations in the ACF-ACT study area, estimates of unit-area mean-annual baseflow ranged from 1.2 to 29.7 inches per year (in/yr). Most of the estimates (47) were in the range of 8.3 to 14.8 in/yr.

Attempts to correlate baseflow estimates over the study area to physiographic and other features of the drainage areas were inconclusive, partly due to their relatively poor distribution and wide variability. Also, it was difficult, if not impossible, to correlate estimates from small and large drainage areas. Many of the smaller drainage areas are wholly within larger drainage areas, and a baseflow estimate for one of these smaller drainage areas is an integral component of the baseflow estimate for the larger drainage area encompassing it.

There are many possible explanations for the wide variability of the estimates of average baseflow. The procedure used to estimate baseflow for the ACF-ACT study consisted of several subjective steps, including, among others—the choice of gaging stations with respect to stream type or order; the graphical determination of the recession indices; and the choice of water years representing low, average, and high stream discharge. Also, considering the study area spans parts of five major physiographic provinces and numerous soil and rock types, the hydrogeologic framework is too complex to be correlated to the relatively small number of poorly distributed data points. Further study is needed to determine the source(s) and nature of the variability in estimates of baseflow.

SUMMARY

Results of the ground-water-supply element of the ACF-ACT Comprehensive Study provides water managers of the U.S. Army Corps of Engineers and the States of Alabama, Florida, and Georgia baseflow estimates derived from the separation of hydrographs of available streamflow data. The hydrograph- separation procedure developed by the USGS automated the recession-curve-displacement method based on the needs of the ACF-ACT Comprehensive Study, and allowed the estimation of mean-annual baseflow for a large number of stream-gaging stations on rivers and streams in the ACF-ACT study area. The baseflow estimates varied considerably over the study area, and attempts to correlate these estimates to physiographic or other features were inconclusive, probably because of one or more of the following reasons—insufficient data distribution; variability in the size of drainage areas; necessarily subjective application of the hydrograph-separation procedure; or the complexity of the hydrogeologic system.

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