AVERAGE ANNUAL RAINFALL AND RUNOFF IN GEORGIA, 1941–70

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HYDROLOGIC ATLAS 9

INTRODUCTION

The source of freshwater in Georgia is rainfall.* What happens to the water after it reaches the ground depends upon many factors such as rate of rainfall, topography, soil condition, density and type of vegetation, and temperature. The proportion of rainfall that runs off as surface water varies considerably from one area of the State to another. This may be readily noted by comparing differences in patterns and in average annual volumes displayed on maps showing average annual rainfall and runoff (figs. 1 and 2). This atlas presents average annual rainfall and runoff values for the base period 1941-70; demonstrates areal variations in the relationship of these two climatic factors; explains some of the reasons for the differences in the relationship; and shows the year-to-year variability of average annual values for the base period.

FACTORS AFFECTING RAINFALL–RUNOFF RELATIONSHIPS

Areas having high rainfall tend to be areas of high runoff and conversely areas having low rainfall tend to be areas of low runoff. However, the amount of rainfall is only one of the factors affecting the amount of runoff.

The annual runoff from an area is greatly influenced by the evaporation potential of the atmosphere and the extent to which water remains on or near the land surface to sustain evaporation from land and water surfaces and transpiration by plants. In short, any part of the rainfall that is taken up by evapotranspiration cannot produce runoff from the area.

For water to be evaporated or transpired, it must remain on the land surface or in the soil within reach of plant roots. The extent to which this occurs is determined by the topographic and geologic characteristics of the area. For example, steep land slopes and relatively impermeable soils promote rapid runoff from the area, thereby reducing the opportunity for water to be evaporated or transpired. Flat land and surface depressions promote the ponding of water, which in turn promotes evapotranspiration. Highly permeable soils and substrata promote the rapid infiltration of water, which greatly reduces the opportunity for water to be evaporated, especially if the water table is well below land surface. Poor soils that support only sparse vegetation contribute to low transpiration even if abundant moisture is available in a shallow water table. Any water that enters the subsurface-flow system may eventually emerge in surface streams where it again becomes available for evaporation.

Man's activities can also affect runoff. The diversion of water from one basin to another reduces the runoff from the losing basin and increases the apparent runoff from the gaining basin. The impounding of surface water increases evaporation and irrigation increases evapotranspiration, thereby decreasing runoff. Urbanization also affects runoff. Impervious areas, such as roads, tend to increase overland flow and decrease recharge to the subsurface-flow system of the area. The more rapid removal of a greater part of the available water tends to decrease evapotranspiration and increase runoff from the area.

Significant differences in rainfall-runoff relationships may be demonstrated between physiographic provinces (fig. 5), but these relationships also vary considerably due to local conditions within physiographic provinces. For example, in Taylor and Marion Counties, an area east of Columbus, runoff is as much as 24 inches, about half of the 50 inches of rainfall; whereas in part of Lee County farther south, runoff is only 12 inches, or one-fourth of the 48 inches of rainfall. Both of these areas are in the upper Coastal Plain. In Taylor and Marion Counties, much of the soil is very porous and infiltration rates are high. Vegetation is relatively sparse over large areas and evapotranspiration is low. In Lee County more of the rainfall remains on or near the surface and dense vegetation is common, and this results in high evapotranspiration.

ACCURACY

The maps of rainfall and runoff (figs. 1 and 2) were constructed as accurately as was practicable using data available for the period 1941-70. If data on these maps are used as indications of probable future hydrologic events, they are subject to time-sampling error and to space-sampling error. The magnitude of the time-sampling error depends on how well the hydrologic events during the base period 1941-70 represent hydrologic events during the future. The probable magnitude of these errors for data-collection points may be estimated by standard statistical methods (Hardison, 1969), but this has not been attempted here because the maps show lines of equal value rather than data-collection points. The magnitude of the space sampling error depends on the density and geographical spacing of gage sites and on how well these sites represent conditions in nearby areas.

The rainfall map is based on records for 120 rain gages, located mostly in Georgia and evenly spaced throughout. Neighboring gages were in generally good agreement, an indication that each gage fairly well represents nearby areas. There are, however, some exceptions where the density of gages may be insufficient to show variability in the average rainfall pattern. For example, in mountainous areas abrupt changes in land elevation cause uneven distribution of rainfall (orographic effects). Large metropolitan areas have been observed to experience higher rainfall rates than neighboring areas and to have a "rain shadow" downwind in the direction of the prevailing wind. Land areas very near the coast may expect high rates of rainfall from the "sea breeze effect," a result of warm moist air from the ocean being uplifted as it flows over land heated by solar radiation.

The average runoff map is based on records for 148 stream-gaging stations well spaced throughout the State. Because of the many factors that can affect the amount of runoff from land surfaces, anomalies and variations from generalized patterns are more likely to occur with runoff than with rainfall.

In mountainous areas, sharp differences in rainfall amounts and in surface gradients over short distances produce erratic patterns of runoff that are difficult to delineate. Even if they were accurately known, depiction would be difficult at the scale of the maps used here. The lines of equal value shown in mountainous areas are based on runoff from fairly large areas (30 square miles and greater) and should be regarded as averages for areas that are at least 30 square miles.

In areas where very different geologic conditions occur within short distances, the runoff characteristics may also be very different from adjacent areas. For example, immediately south of the Fall Line there are areas characterized by very porous sand and gravel formations that have high infiltration rates and support little vegetation. Streams in these areas exhibit runoff characteristics quite different from nearby streams north of the Fall Line, in the Piedmont province. The characteristics also are different from streams farther south in the Coastal Plain, where infiltration rates may be high but where more abundant vegetation draws on soil moisture. The lines of equal runoff for many areas across the State just south of the Fall Line should be regarded as approximations. The density of stream-gaging stations there is insufficient to accurately depict the existing complex patterns of runoff characteristics. Runoff patterns are also uncertain in areas of karst topography near the Georgia-Florida State line and in ungaged areas near the coast.

Nevertheless, the lines of equal value on the runoff maps fit the gaging-station data, on which they are based, quite well. As a test, deviations of observed runoff from corresponding runoff shown by the map were determined. The average of the absolute values of these deviations was 1.0 inch and the standard deviation was 1.1 inches. Considering that the minimum runoff for any area of the State is about 10 inches, it seems that the map represents runoff for most areas with an error of less than 10 percent.

* Snowfall is relatively common in Georgia, but almost all precipitation is rainfall; therefore, for the purpose of simplicity, the term rainfall will be used instead of precipitation.

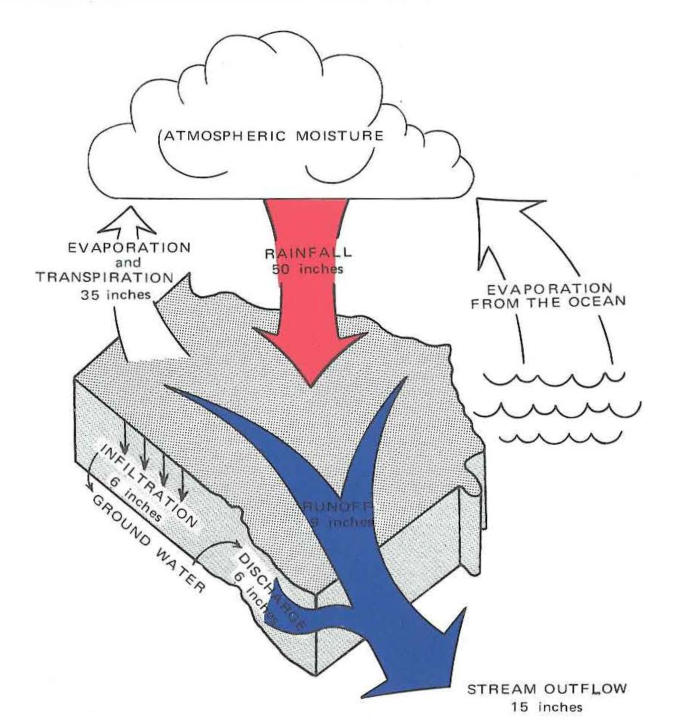

Figure 3.—The annual water cycle in Georgia.

Some of the principal components of the annual water cycle, commonly called the hydrologic cycle, can be measured with the possible exception of transpiration by plants. Rainfall and runoff are the components most practicable to observe systematically.

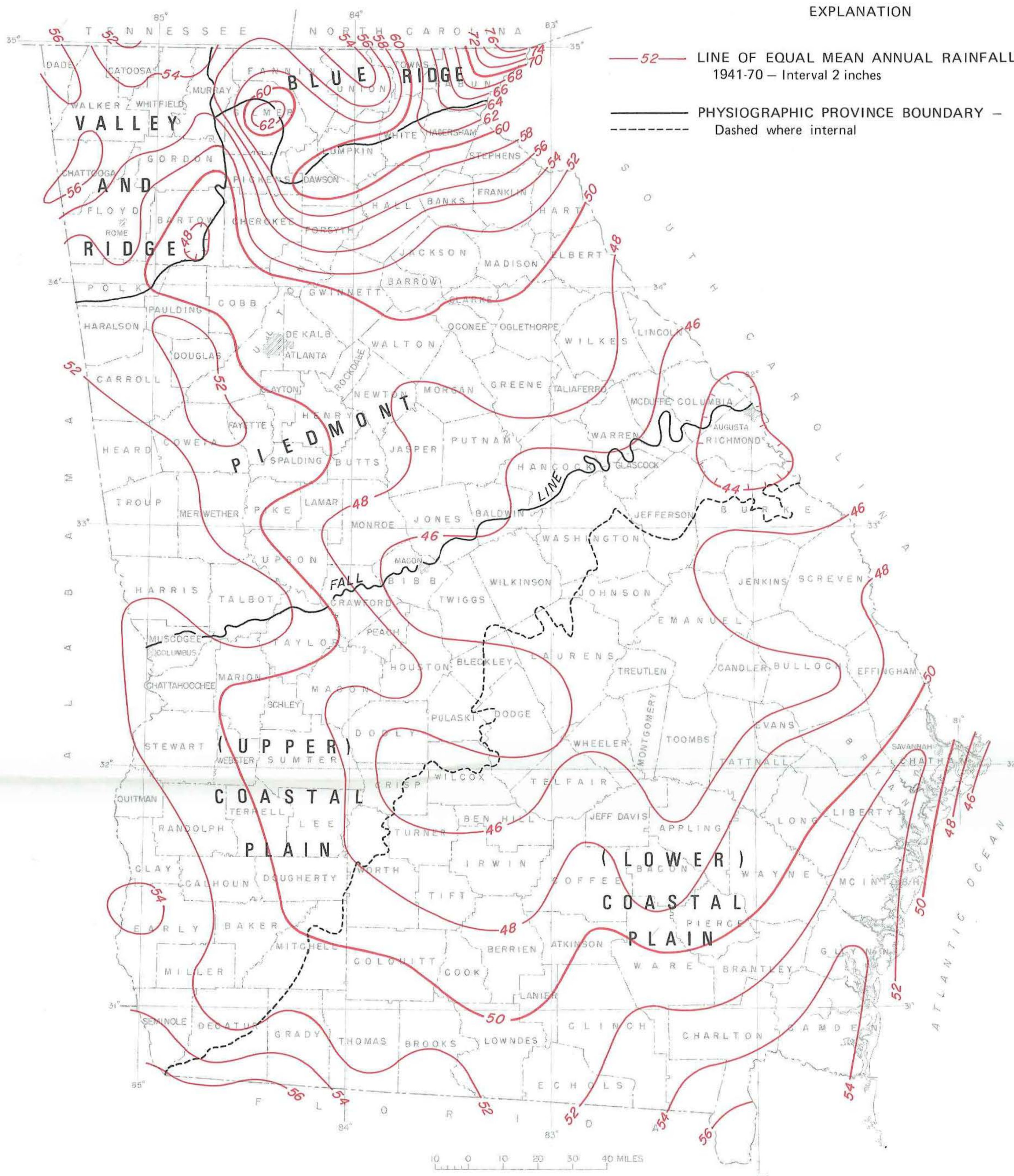

Figure 1.—Average annual rainfall in Georgia, 1941-70, and physiographic provinces.

The State received an average of 50 inches of rainfall per year, which varied locally from less than 44 inches to more than 76 inches, and also varied greatly from year to year.

The map was prepared from data furnished by the National Weather Service and was reviewed by that agency. Rainfall data are collected at specific points, well distributed throughout the State, and provide point samples of the amount of rainfall that occurred. From these samples, data interpolations and extrapolations were made and approximate lines of equal value were drawn. This process is similar to the method of compiling topographic maps using areally distributed points of known land elevation. The map of average annual rainfall shown here is a reasonable representation of average annual rainfall for the State during the indicated time period, but caution should be used in interpolating between lines of equal value on the map, particularly in mountainous areas.

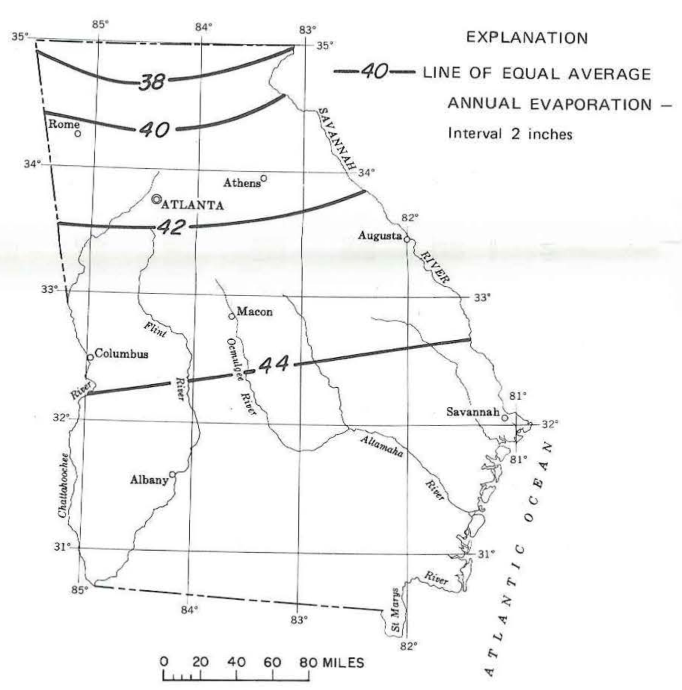

Figure 4.—Average annual lake evaporation for 1946-55 (from Kohler and others, 1959).

The evaporation potential of the atmosphere is greater in southern than in northern Georgia. Thus, on the basis of evaporation potential of the atmosphere, the annual runoff should be greater in the north than in the south if all other factors are constant.

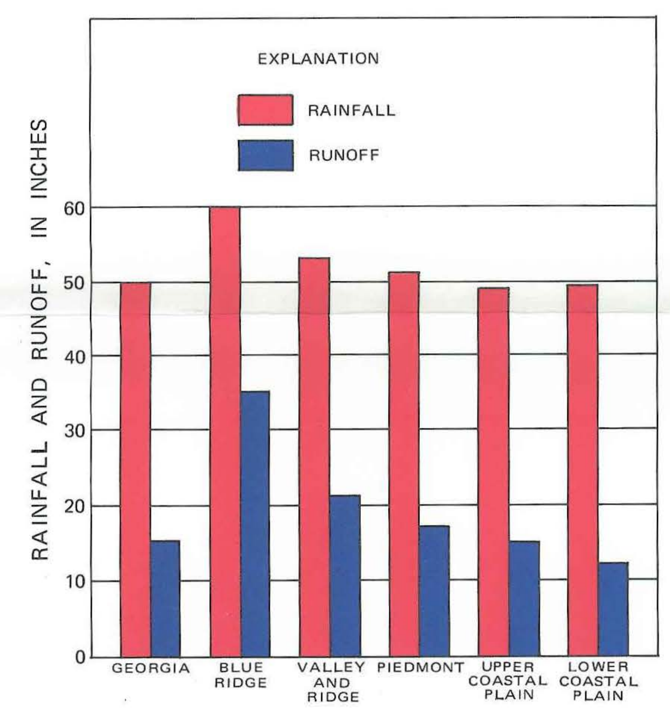

Figure 5.—Average annual rainfall and runoff in the State and by physiographic provinces, 1941-70.

The relationship between rainfall and runoff is complex and has many anomalies and local variations. With the exception of the mountainous area in the northeast, average annual rainfall in Georgia is fairly uniformly distributed; that is, it varies no more than 10 percent from the average of 50 inches. On the other hand, average annual runoff, again excepting the mountainous northeast, varies about 50 percent from the average of 15 inches. The general effect of geology and physiography is illustrated by rainfall-runoff relationships for major physiographic provinces. In the Blue Ridge province, an area of crystalline rocks and steep land slopes, runoff is 58 percent of the 59.8 inches of rainfall. In the Piedmont province, an area of crystalline rocks that has flatter slopes than the Blue Ridge province, runoff is 33 percent of 50.5 inches of rainfall. In the Valley and Ridge province, an area of sedimentary rocks and varied land slopes, runoff is 39 percent of 53.3 inches of rainfall. In the Coastal Plain, an area of sedimentary rocks, generally porous soils, and relatively flat land slopes, runoff is 26 percent of 49.1 inches of rainfall. The Coastal Plain is subdivided into "upper" and "lower" zones (figs. 1 and 2) as has been done in previous studies (Carter and Putnam, 1977), and runoff is 31 percent of 49.0 inches of rainfall in the upper zone and 24 percent of 49.1 inches of rainfall in the lower zone.

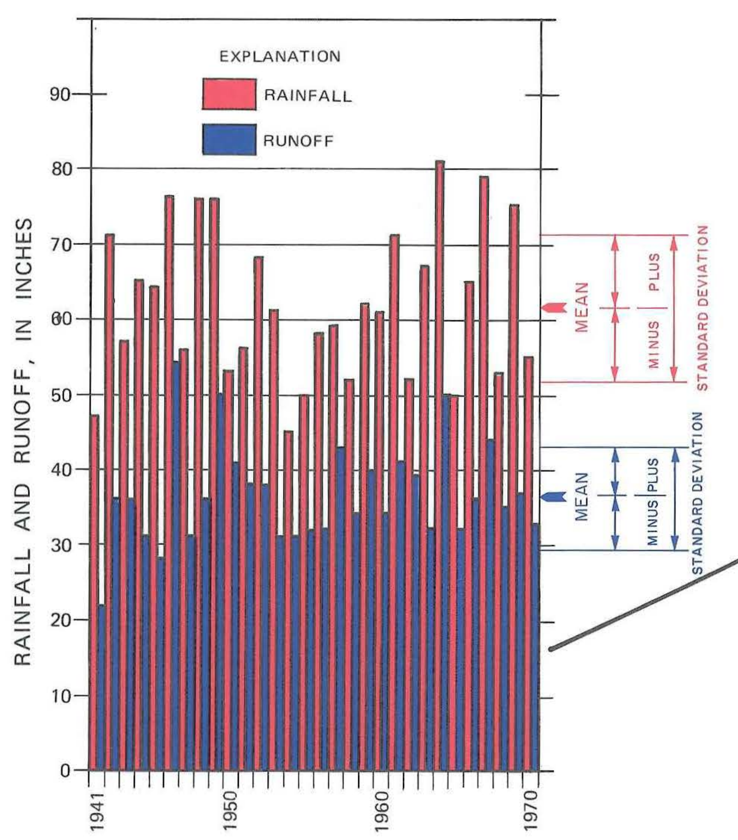

Figure 6A.—Average annual runoff at Toccoa River near Dial and average annual rainfall nearby, 1941-70.

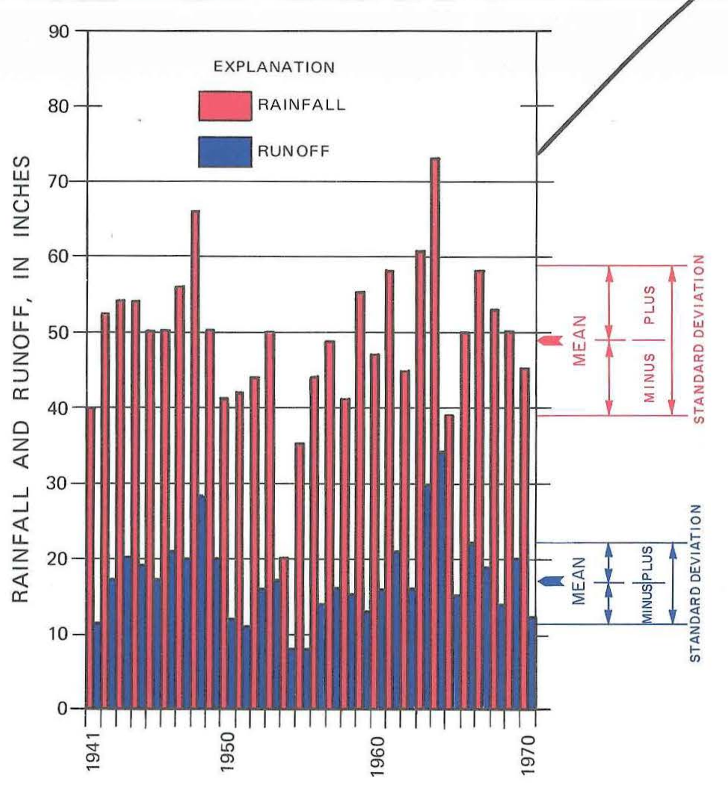

Figure 6B.—Average annual runoff at Apalachee River near Buckhead and average annual rainfall nearby, 1941-70.

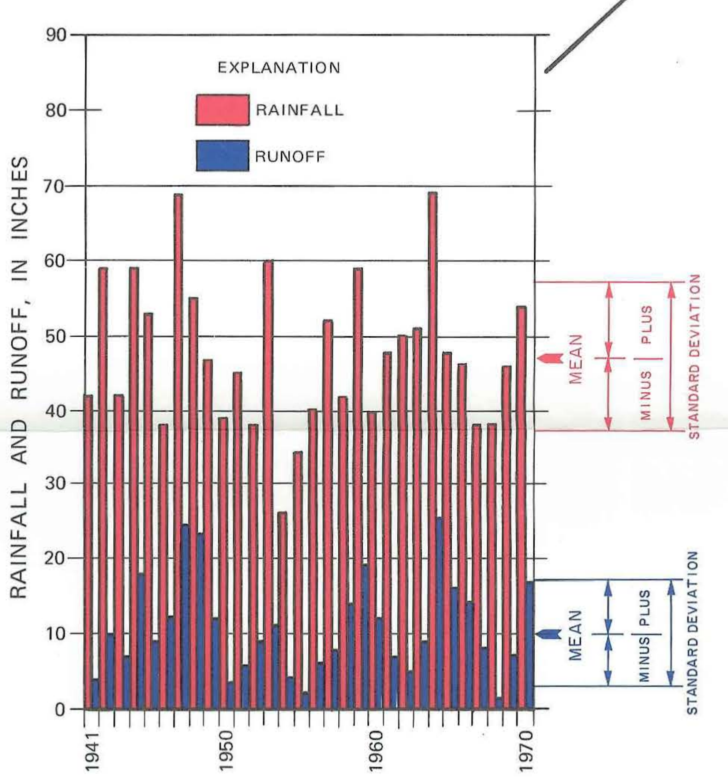

Figure 6C.—Average annual runoff at Alapaha River near Alapaha and average annual rainfall nearby, 1941-70.

Rainfall and runoff vary with time as well as with location. The annual runoff can vary several fold between extremely wet and dry years, especially in areas such as the Coastal Plain where the average runoff is a fairly small percentage of the average rainfall.

These graphs of average annual rainfall and runoff are for sample streams and for nearby rain gages in the Blue Ridge province (fig. 6A), in the Piedmont province (fig. 6B), and in the Coastal Plain (fig. 6C). They do not exhibit trends or recognizable cyclic patterns. They do show examples of "persistence", the tendency of wet or dry years to cluster. This effect has been noted by many investigators (Dawdy and Matalas, 1964).

The mean and standard deviation (the range of deviations from the mean which includes approximately two-thirds of the occurrences) of each set of data are indicated on each graph. The standard deviations of the annual rainfall data, in inches, at the three sites are about the same. The mean of the annual rainfall in the mountainous Blue Ridge province is higher than at the other two sites which have about the same mean. The standard deviations of the annual runoff data, in inches, at the three stream sites are also about the same. However, the mean of the annual runoff is high in the Blue Ridge province, somewhat lower in the Piedmont province, and even lower in the Coastal Plain.

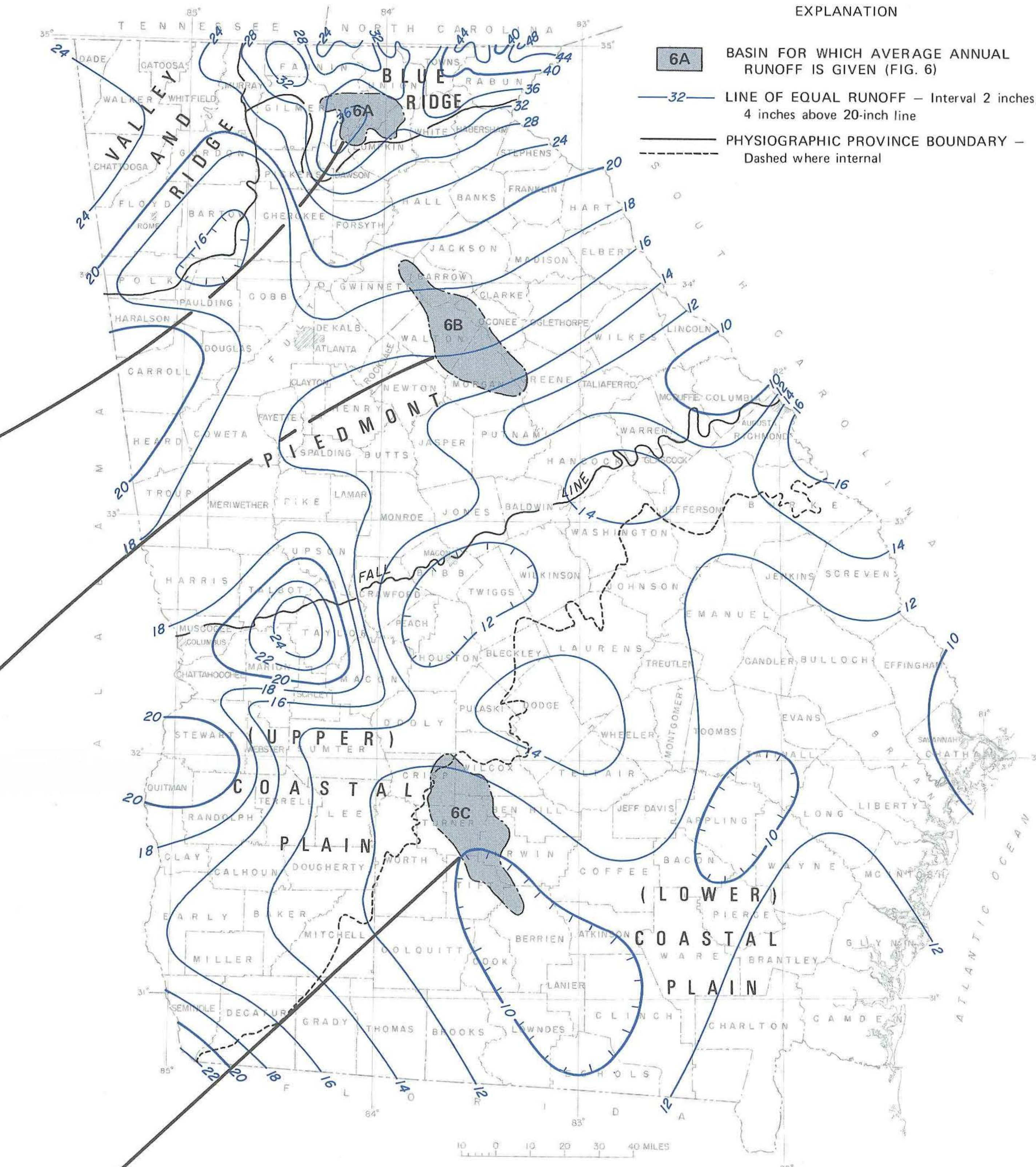

Figure 2.—Average annual runoff in Georgia, 1941-70, and physiographic provinces.

The average annual runoff for the State was about 15 inches, which varied locally from less than 10 inches to more than 48 inches, and varied greatly from year to year.

Surface-water runoff values are not point-sample data. Although the data are observed at points (stream-gaging stations), the computed runoff at each gage represents an integrated result from the entire contributing area, expressed in terms of depth of water as though it were uniformly distributed over that area. This presents a problem in logic when it is desired to construct a map such as is shown here with lines of equal value representing areal distribution of runoff. The task is not analagous to construction of a topographic map. For example, between two points of unequal elevation on a land surface all intermediate elevations must occur, but between two points of unequal runoff, it is unlikely that all intermediate values of runoff occur. Surface conditions can change abruptly from nearly impervious (high runoff) to very pervious (low runoff). In arid regions many areas experience zero or near zero flow during long periods even with normal rainfall.

However, maps of average runoff can be constructed for many areas and such maps depict useful and reasonably accurate representations of local and regional variations in runoff. This map was prepared by plotting runoff data near the centroid of the drainage basin contributing to the runoff, and by treating these plotted data as point samples for drawing lines through points of approximate equal value. For long, large streams the increment in runoff between two gages was used, where practicable, to represent the runoff from the intervening area between the gages. Runoff from coastal areas, which is generally not measured because of tidal effect on the streams, was estimated on the basis of gaged runoff from nearby inland areas.

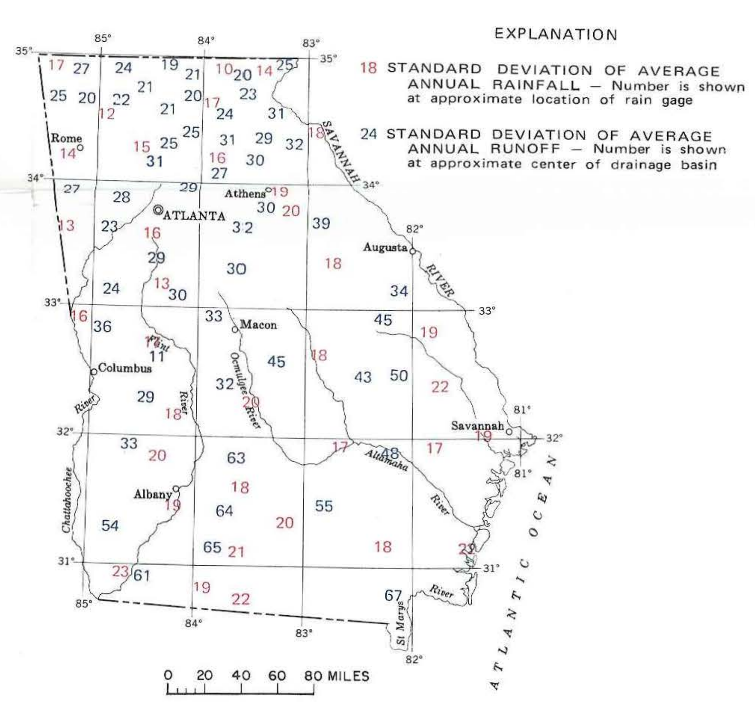

Figure 7.—Standard deviation, in percent, of average annual runoff during 1941-70 at selected stream-gaging stations, and standard deviation of average annual rainfall during 1941-70 at selected rain gages.

Year-to-year variability of average annual streamflow, expressed as the standard deviation of the mean in percent, ranges from low (19-24 percent) in the north, to medium (24-36 percent) in midstate, and to high (48-67 percent) in the south. Variability of average annual rainfall is somewhat less than that for runoff, being lowest (12-17 percent) in the north, and slightly higher (17-23 percent) elsewhere.

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Cartography by Willis G. Hester and Mary C. Turlington

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