An Overview of High- and Low-Flow Statistics and Why Record Length Matters

Streamflow Monitoring Workshop

February 3, 2016

U.S. Department of the Interior
U.S. Geological Survey

"And it never failed that during the dry years the people forgot about the rich years, and during the wet years, they lost all memory of the dry years. It was always that way." –John Steinbeck *East of Eden*

Outline

1) Basics of computing high- and low-flow frequency statistics

2) Importance of Record Length

3) Regionalization and geographical coverage

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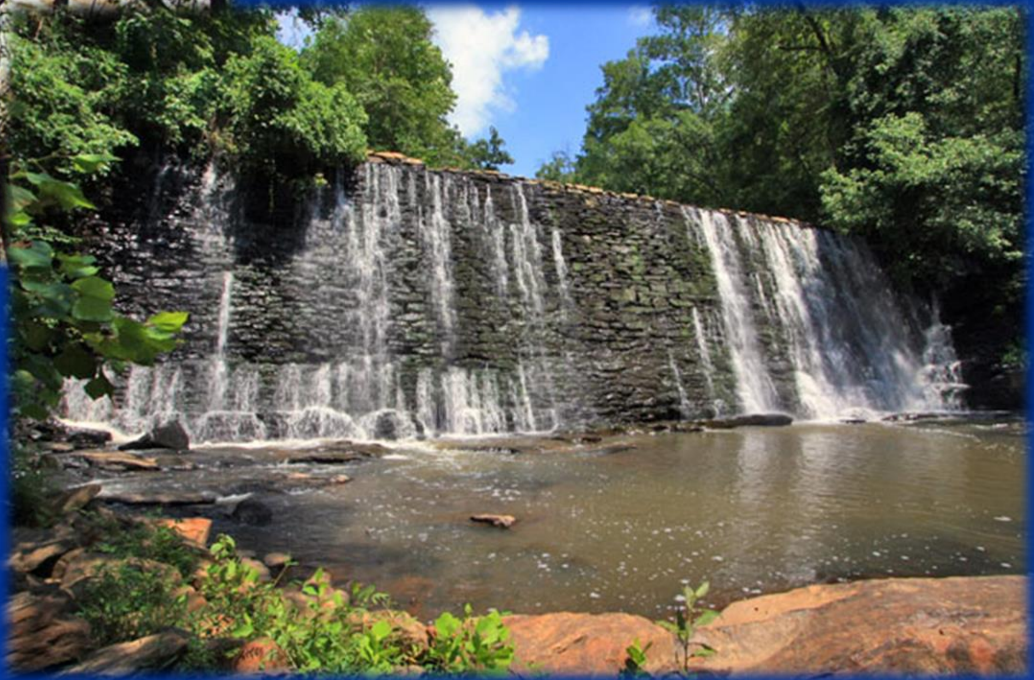
Statistical Basics for High- and Low-Flow Frequency Analyses



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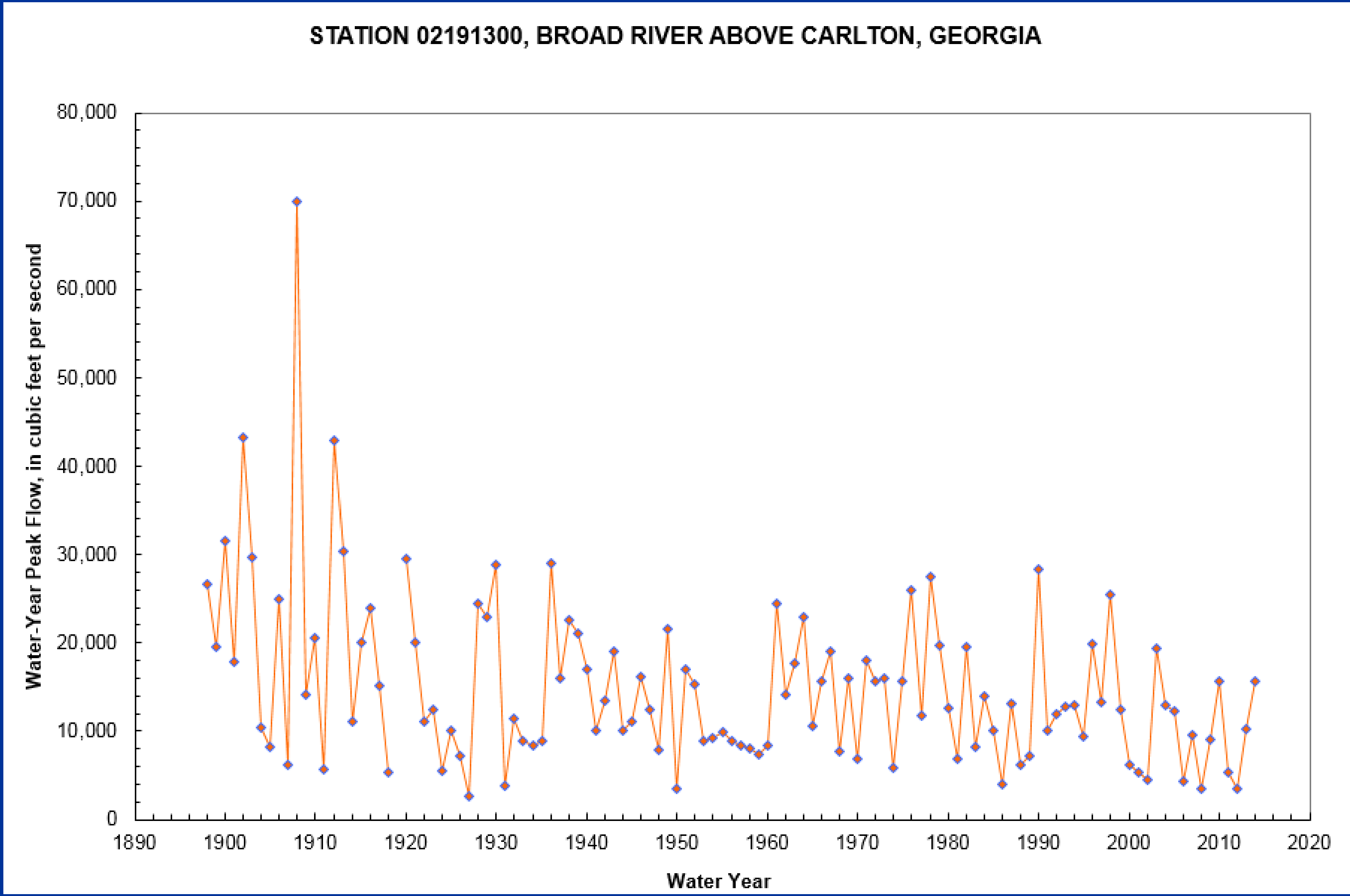
In 1951, Ven Te Chow published a paper titled "A General Formula For Hydrologic Frequency Analysis"



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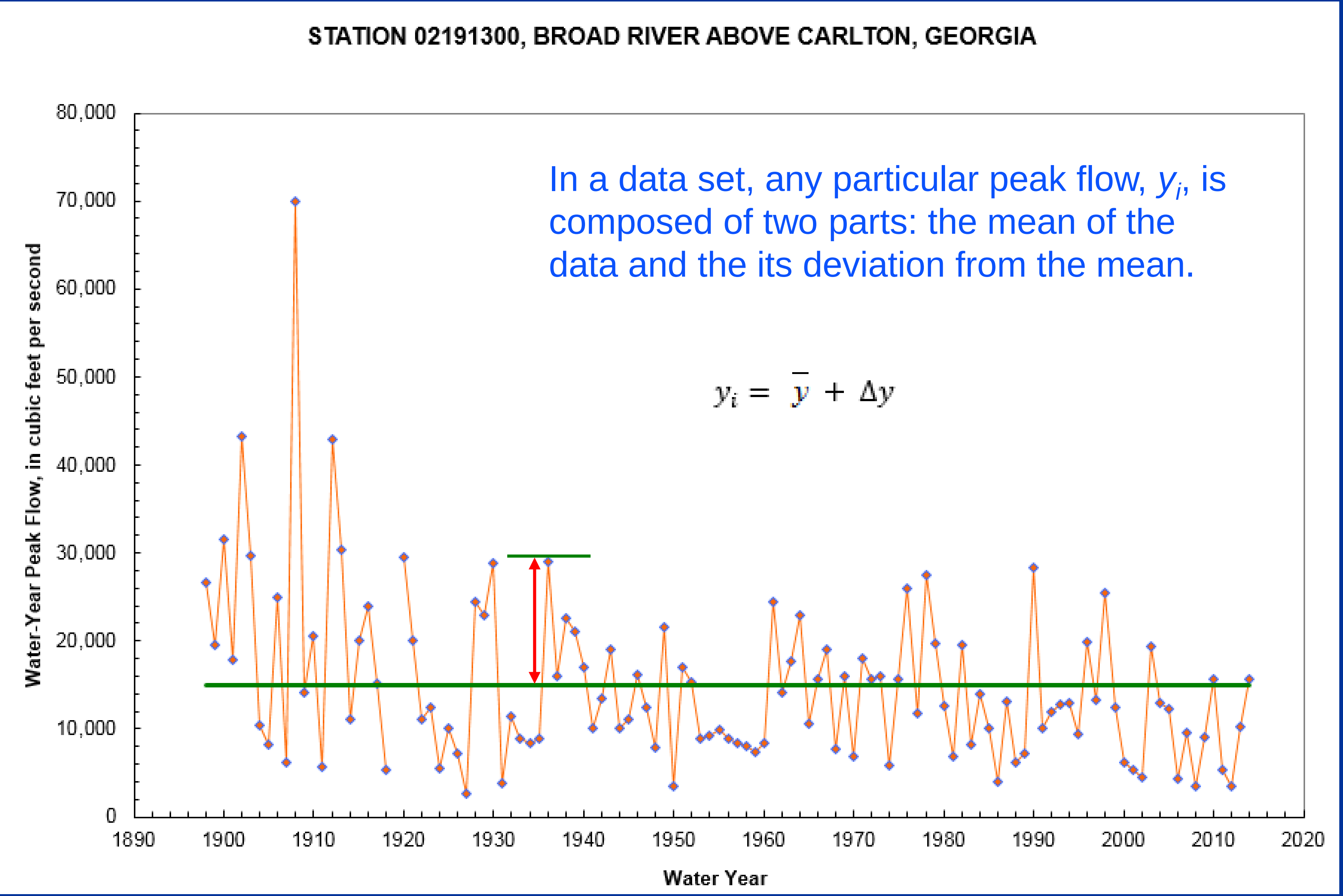

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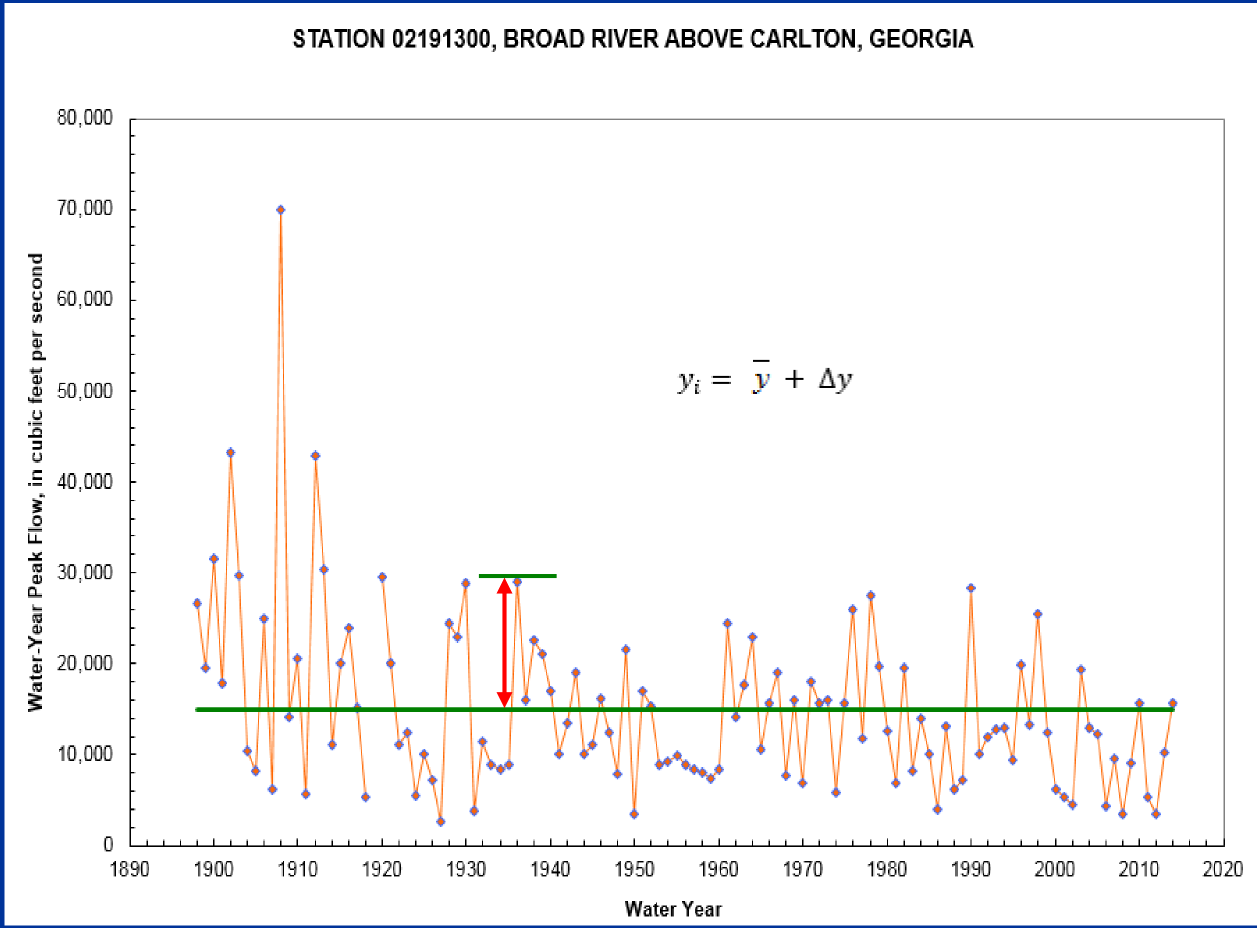

The departure from the mean may be positive or negative, large or small. From a statistical perspective, this quantity possesses two important properties: (1) the tendency to deviate from the mean; and (2) the frequency of occurrence.

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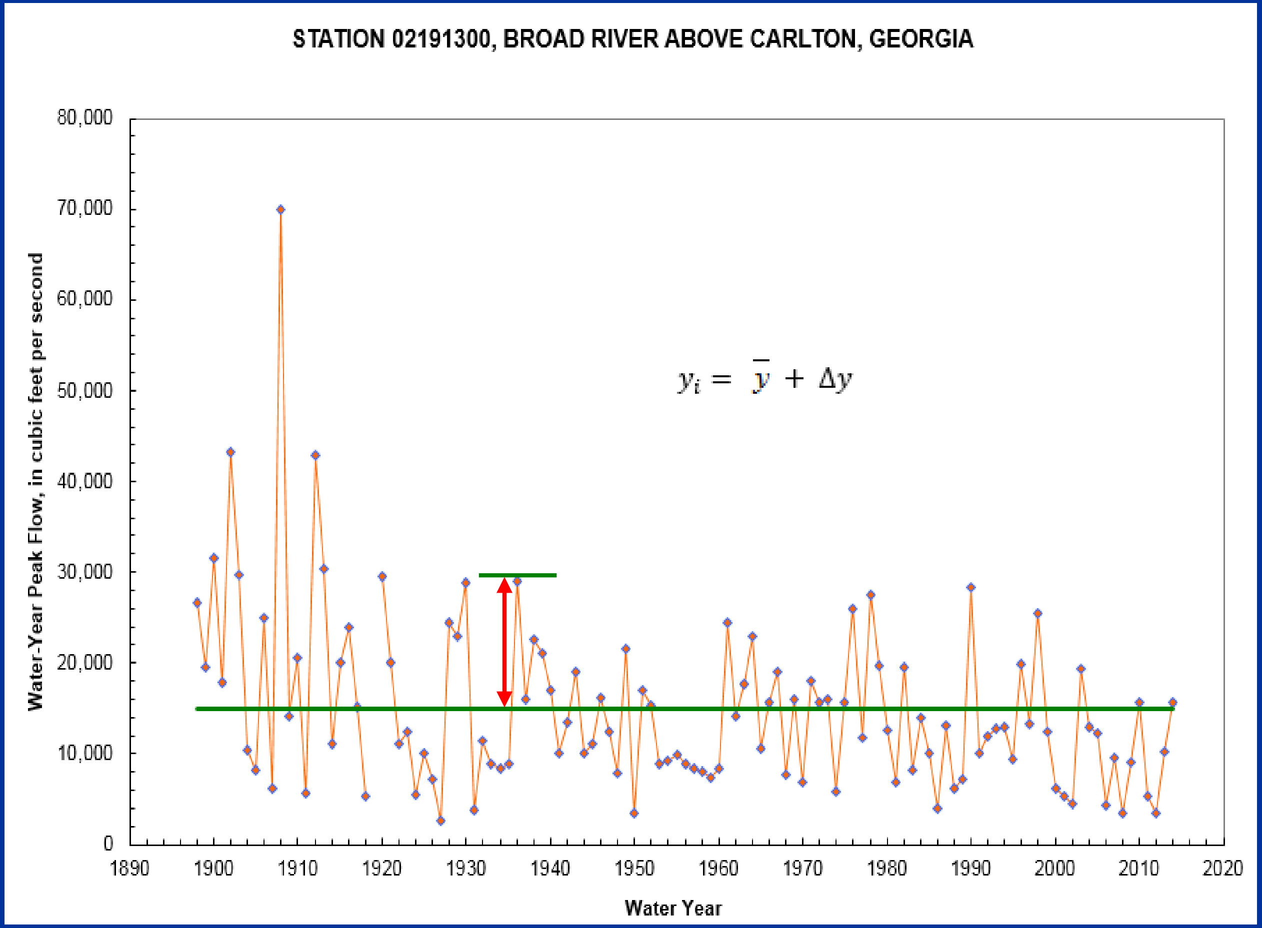

Property 1

If you sum up all the deviations from the mean, by definition, the value would be zero. Thus, an average of the deviations does not provide any useful information.

One way to overcome that problem is to square the deviations and take the average of that value. However, the resulting value is now in different units than the original data.

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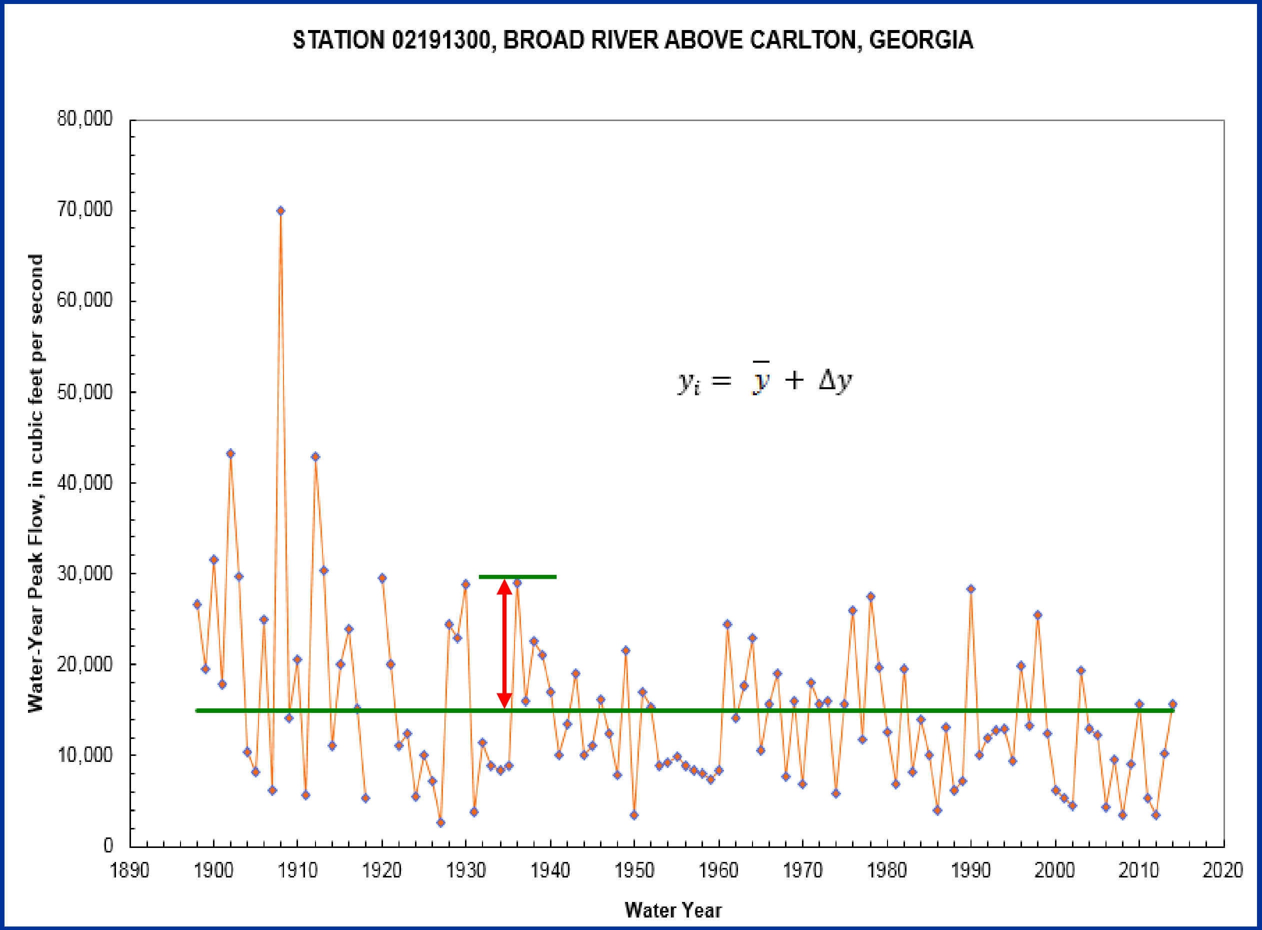

To get back to the original units, we can take the square root of the summed deviations.

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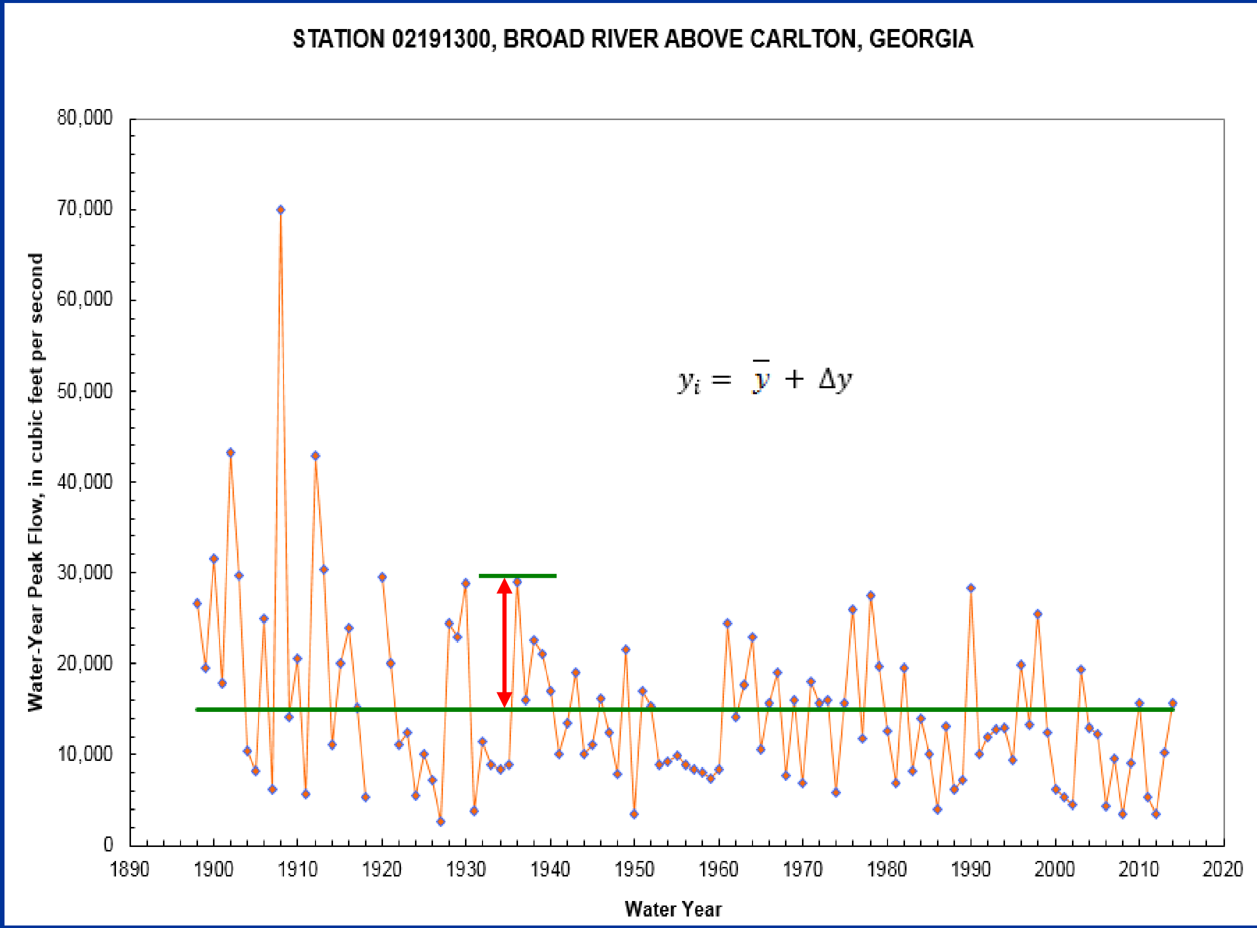

Thus, the tendency to deviate from the mean can be measured by the resulting equation, which is the standard deviation.

$$SD = \sqrt{\frac{\Sigma(y_i - \bar{y})^2}{N - 1}}$$

Consequently, knowing the mean and SD of a data set provides very useful information.

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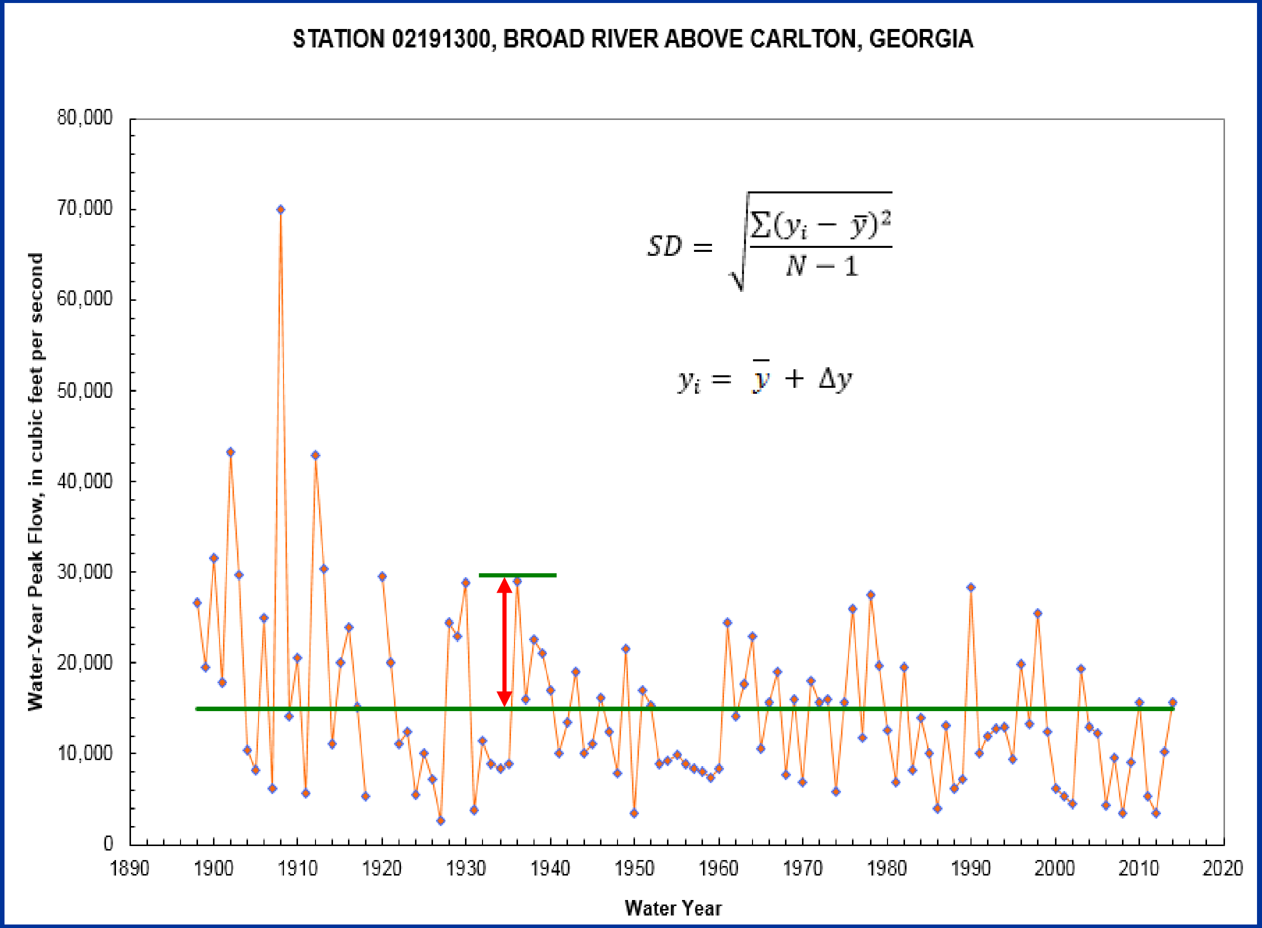

Going back to our earlier slide: Property 2

The departure from the mean may positive or negative, large or small. From a statistical perspective, this quantity possesses two important properties: (1) the tendency to deviate from the mean; and (2) the frequency of occurrence.

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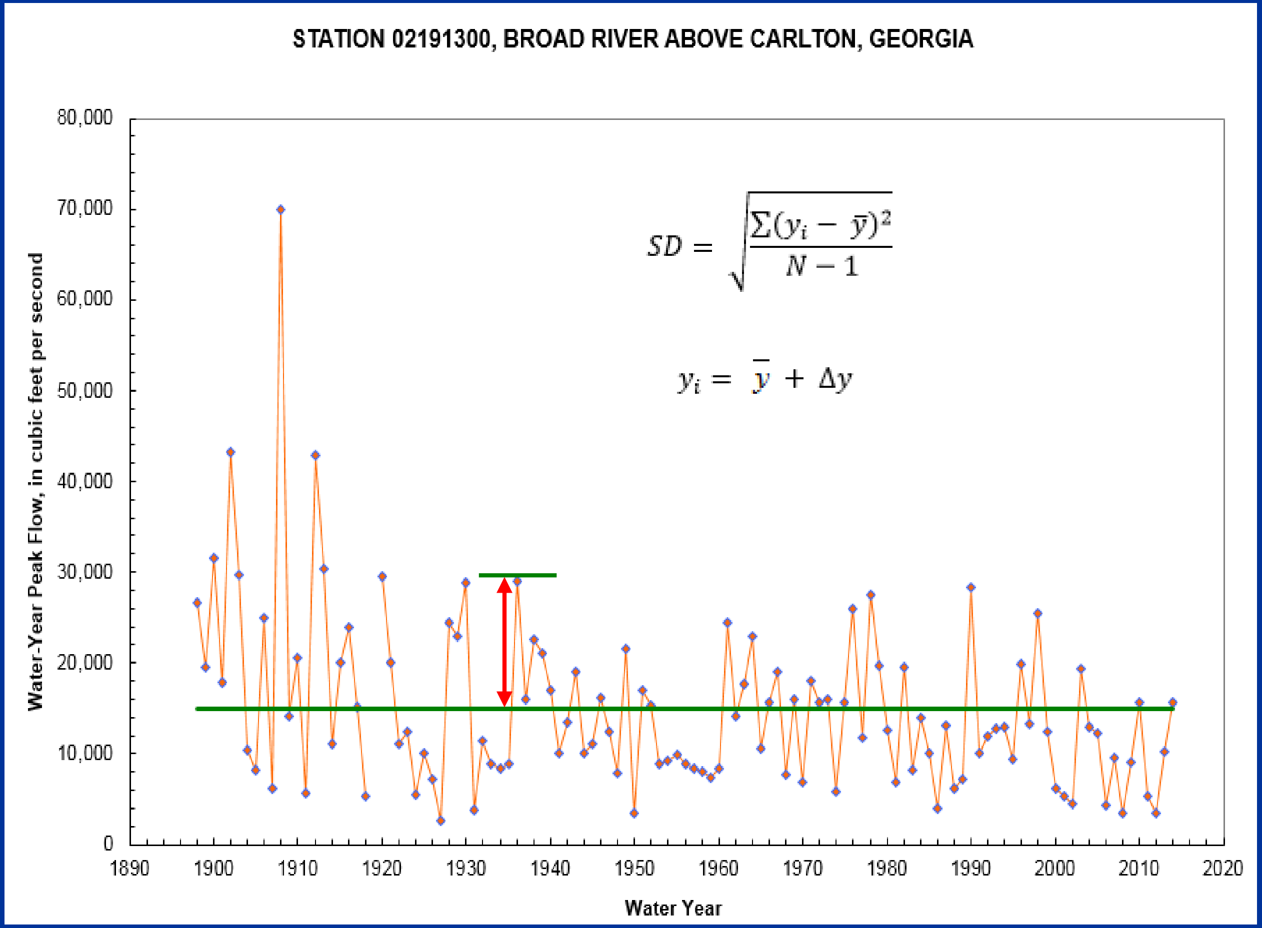

This second property is measured by a term called the frequency factor, K, which depends upon the law of occurrence of a particular hydrologic event under consideration and is a function of the return period and distribution parameters.

This all comes together in the log-Pearson Type III equation.

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Log Pearson Type III Distribution

The log Q corresponding to specific exceedance probabilities, P, are calculated as:

$$\log Q = \overline{X} + KS$$

Where $\overline{X}$ = **mean of logarithms of peaks**

K = frequency factor = f(skew, P)

S = standard deviation of logs of peaks

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T-Year Recurrence Interval

Historically, flood-frequency flows in USGS reports were expressed as *T-year floods* based on the *recurrence interval* of the particular flood quantile.

- **Recurrence interval (or return period) is the average interval of time within which the given flood will be equaled or exceeded once.**
- **The words "recurrence" or "return" do not imply regular predictable occurrence in time.**
- **An example is the 10-year flood. If we had a 100 years of streamflow data, we would expect 10 floods of equal or greater magnitude than the "10-year flood". However, those floods would not occur at regular 10-year intervals.**

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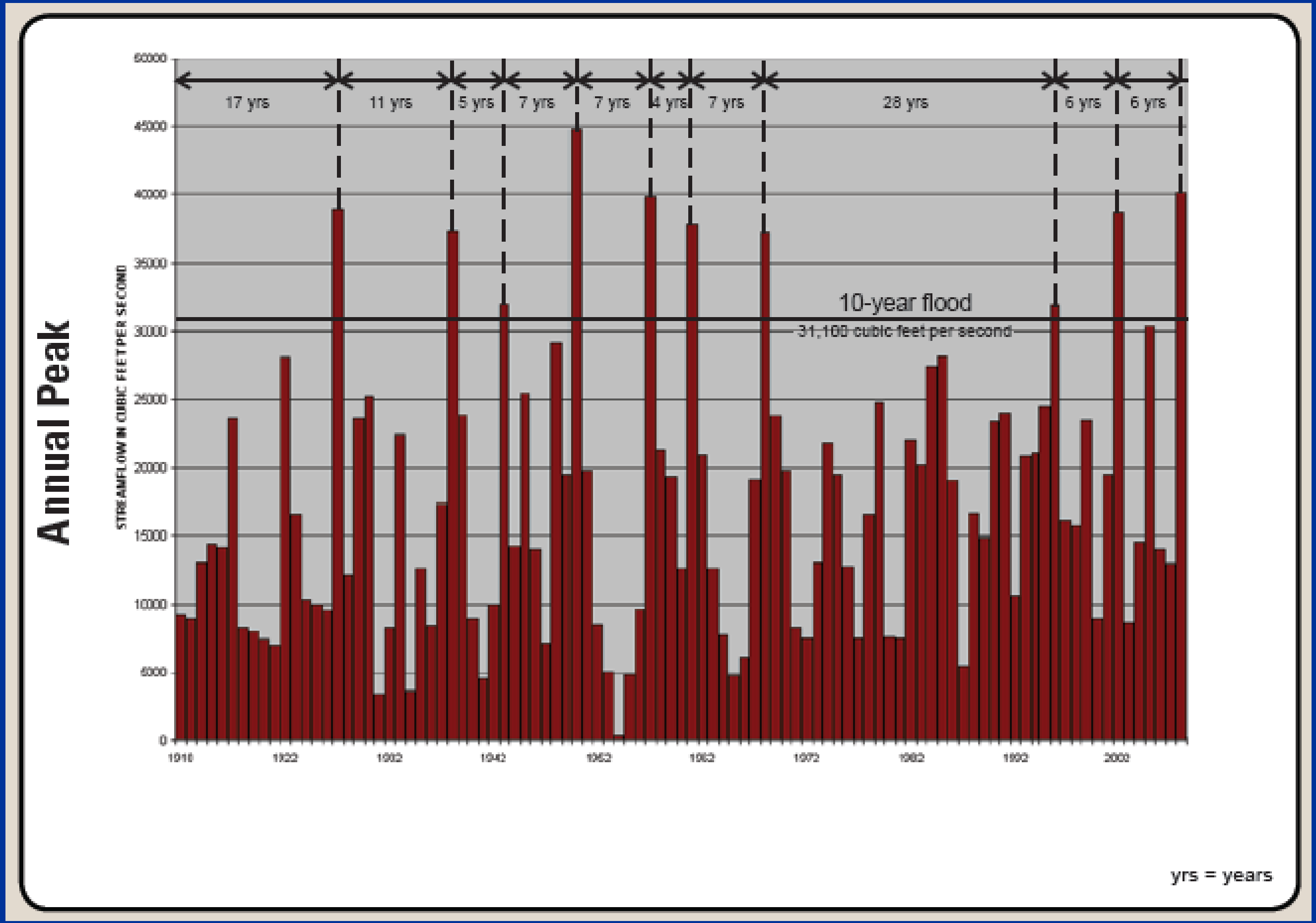
An Example For A 10-year Recurrence



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Annual Exceedance Probability

Return period (or recurrence interval),T = 1 / AEP

*P-percent chance exceedance = AEP * 100*

T-year recurrence interval	Annual exceedance probability	P-percent chance exceedance
2	0.5	50
5	0.2	20
10	0.10	10
25	0.04	4
50	0.02	2
100	0.01	1
200	0.005	0.5
500	0.002	0.2

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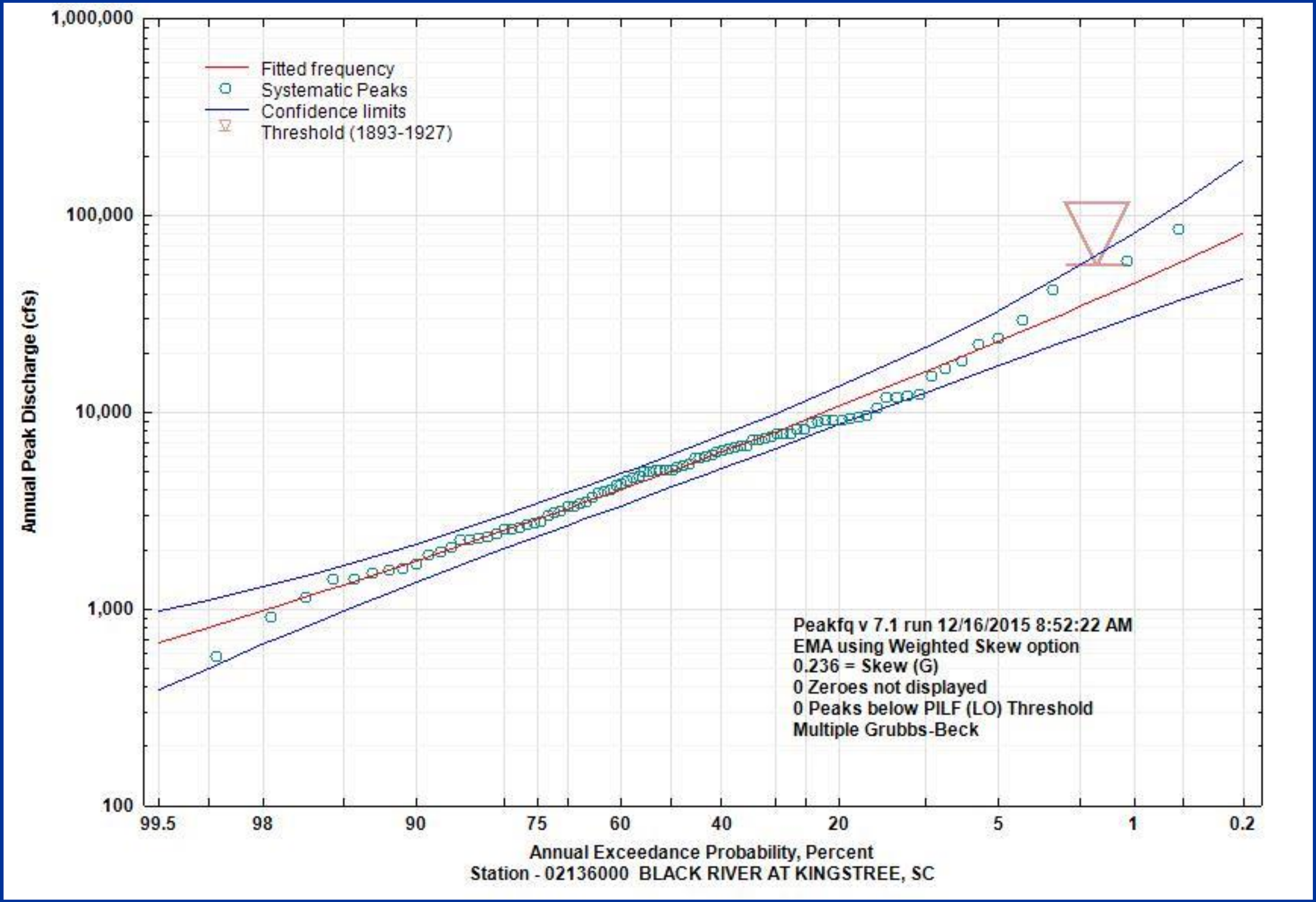
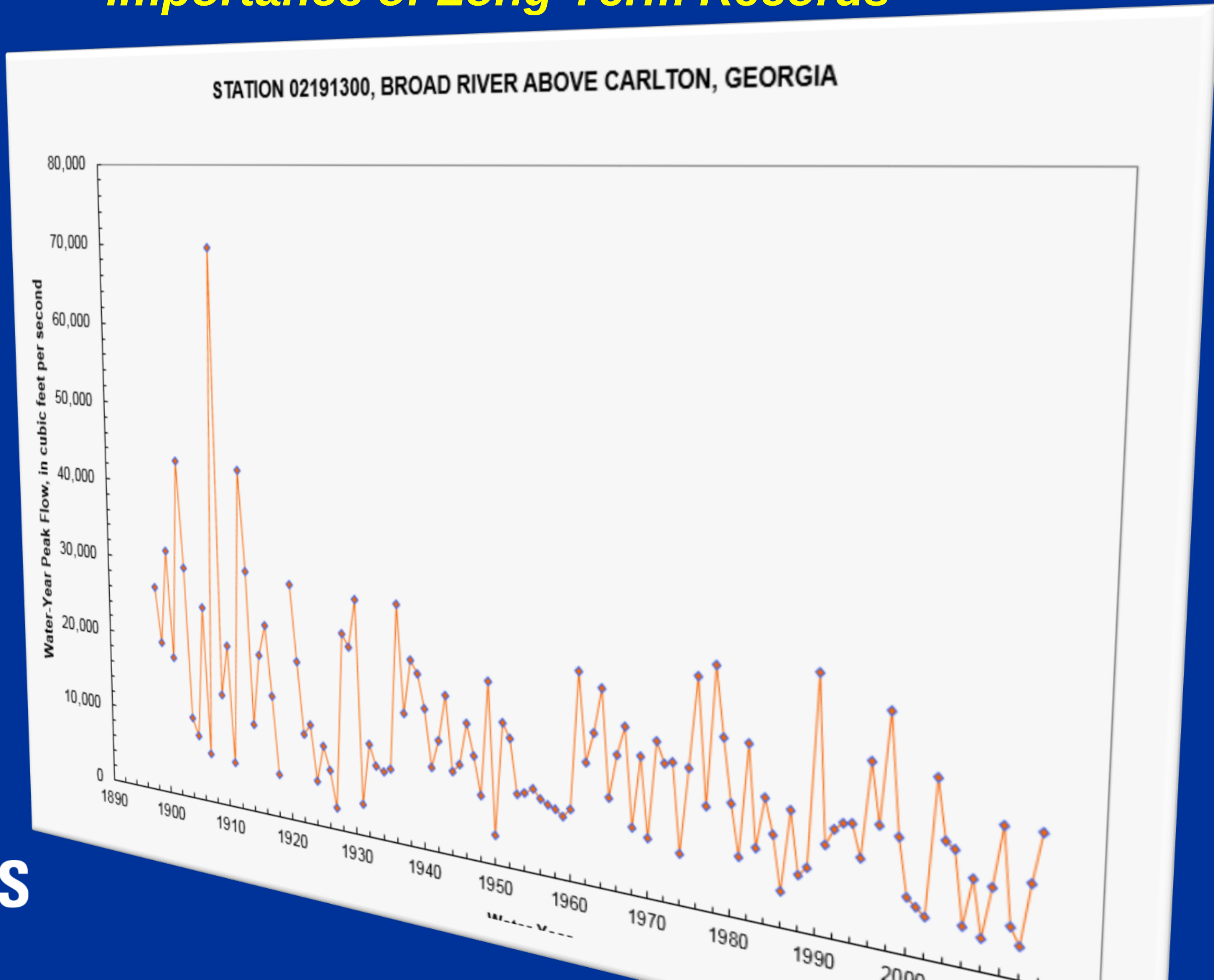
Example of an LPIII Analysis



Importance of Long-Term Records



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Populations versus Samples

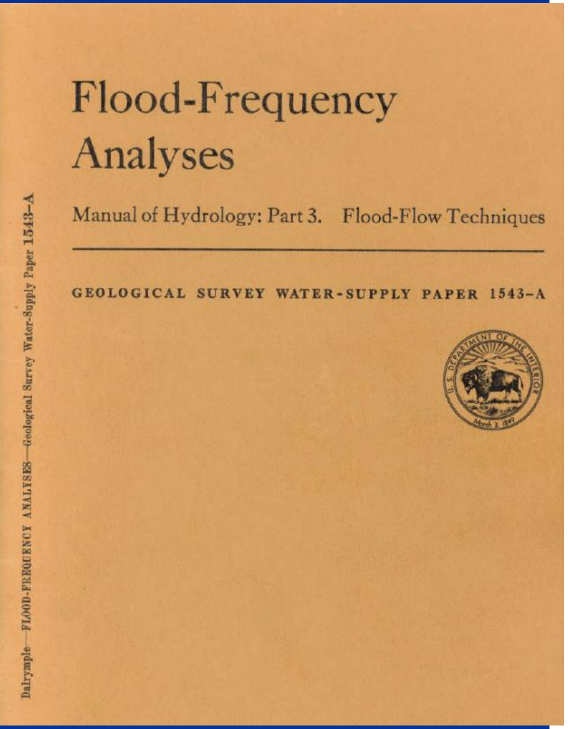
- There is a **"population"** of potential events (in our case, annual peak flows).

- All that is available to us are **samples** from the population (periods of record). We infer magnitudes and frequencies of events from the sample.

- An assumption is made that the samples are **"representative"**.

- Different samples will yield different estimates.

Populations versus Samples



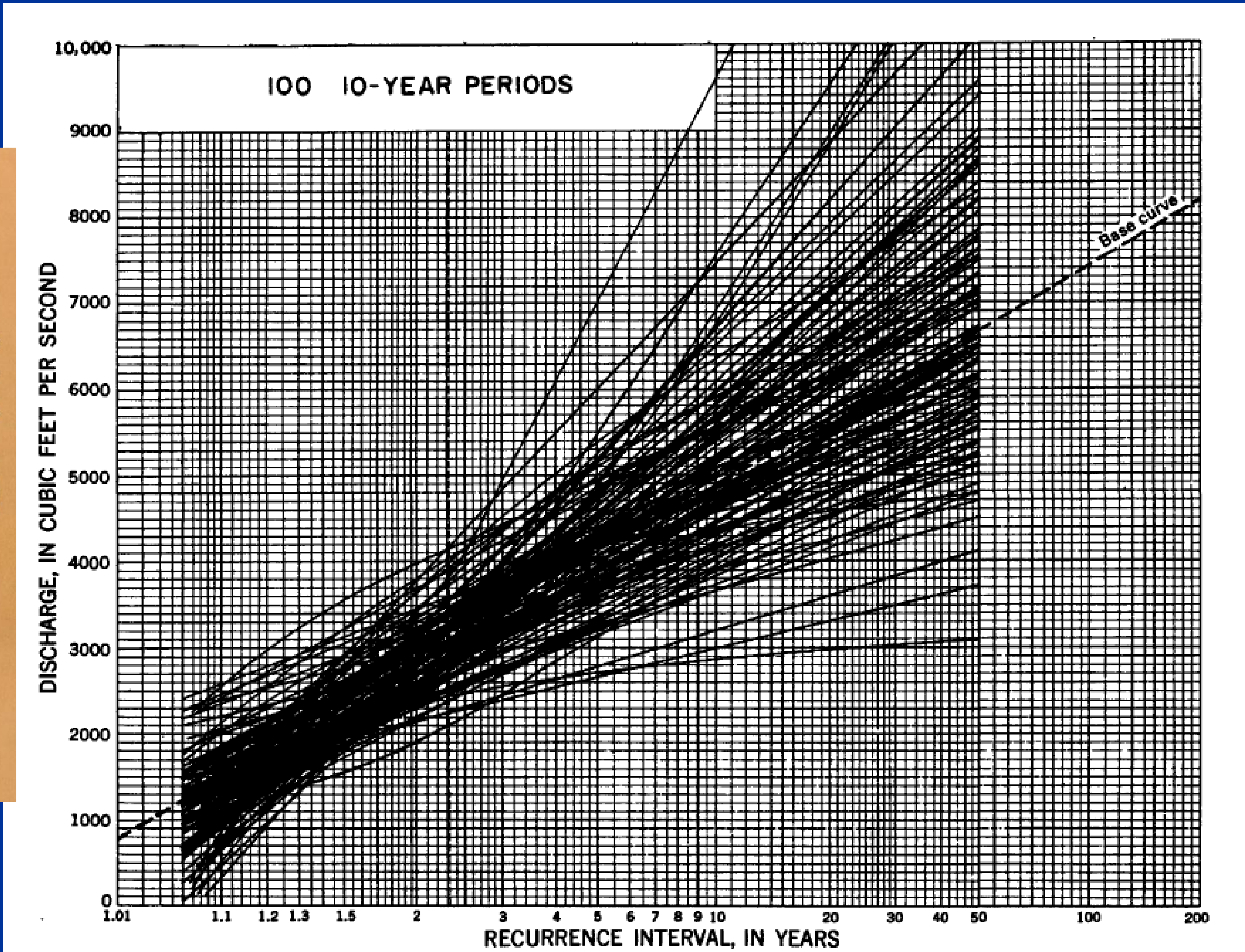


FIGURE 20.—Frequency curves for 10-year periods.

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Populations versus Samples

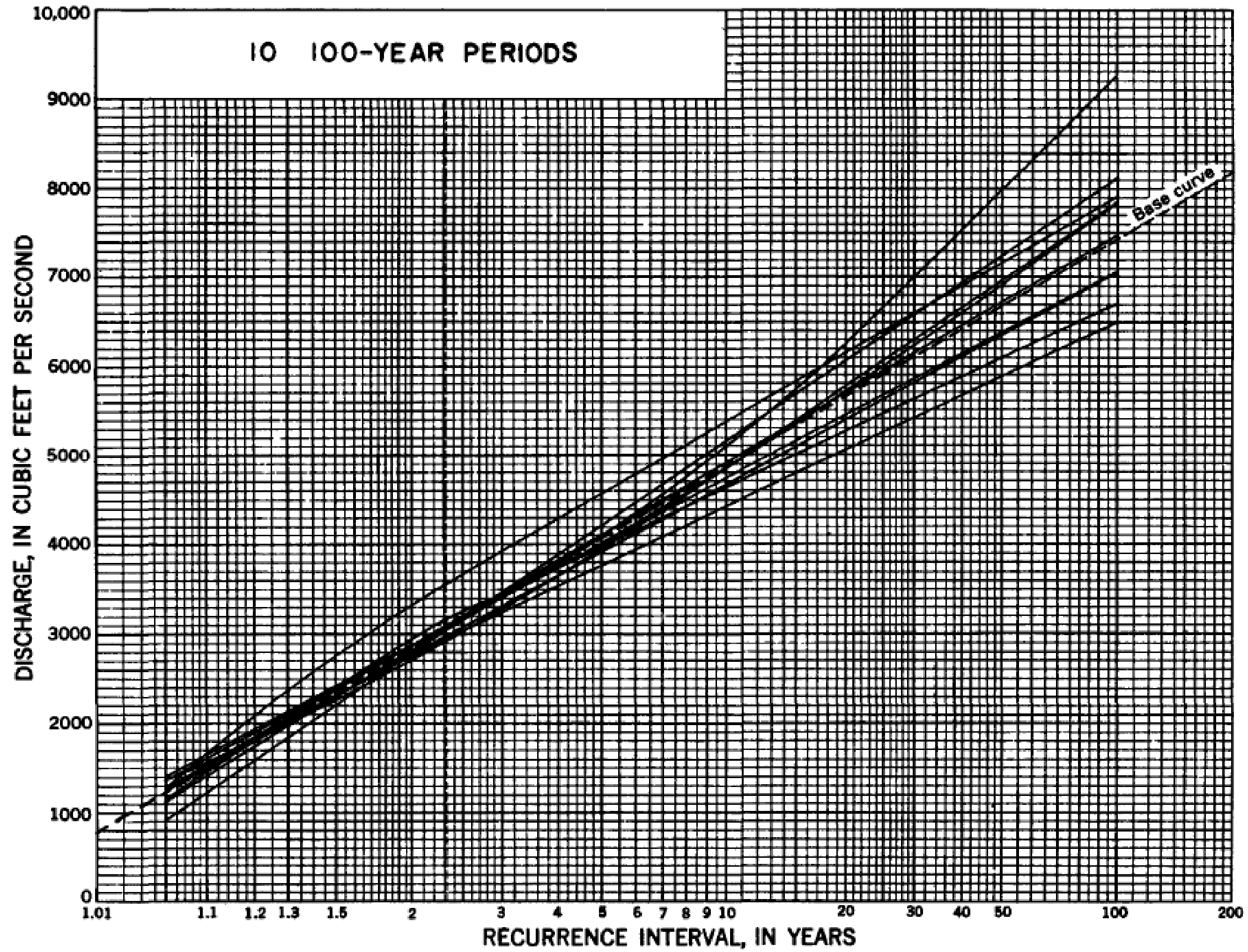

FIGURE 23.—Frequency curves for 100-year periods.

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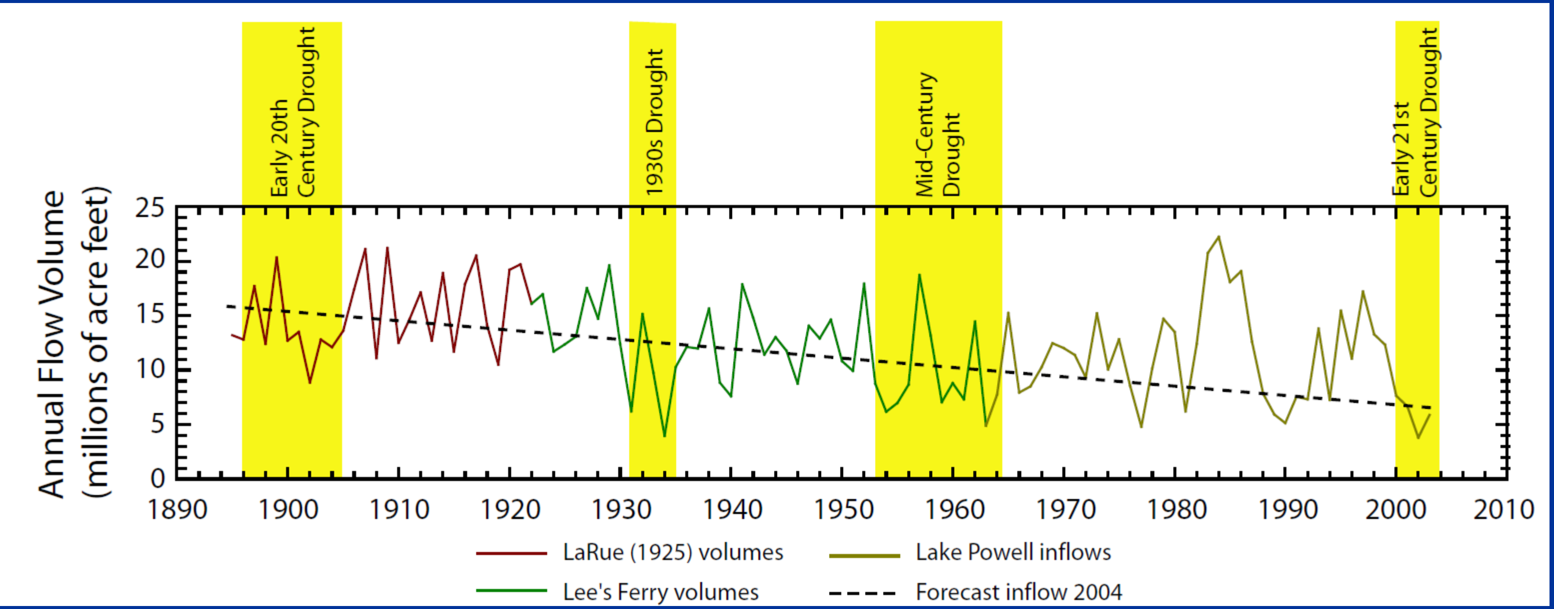
Importance of Long-Term Records

Longer records tend to capture a broader range of hydrologic conditions and will better represent the "population" value.



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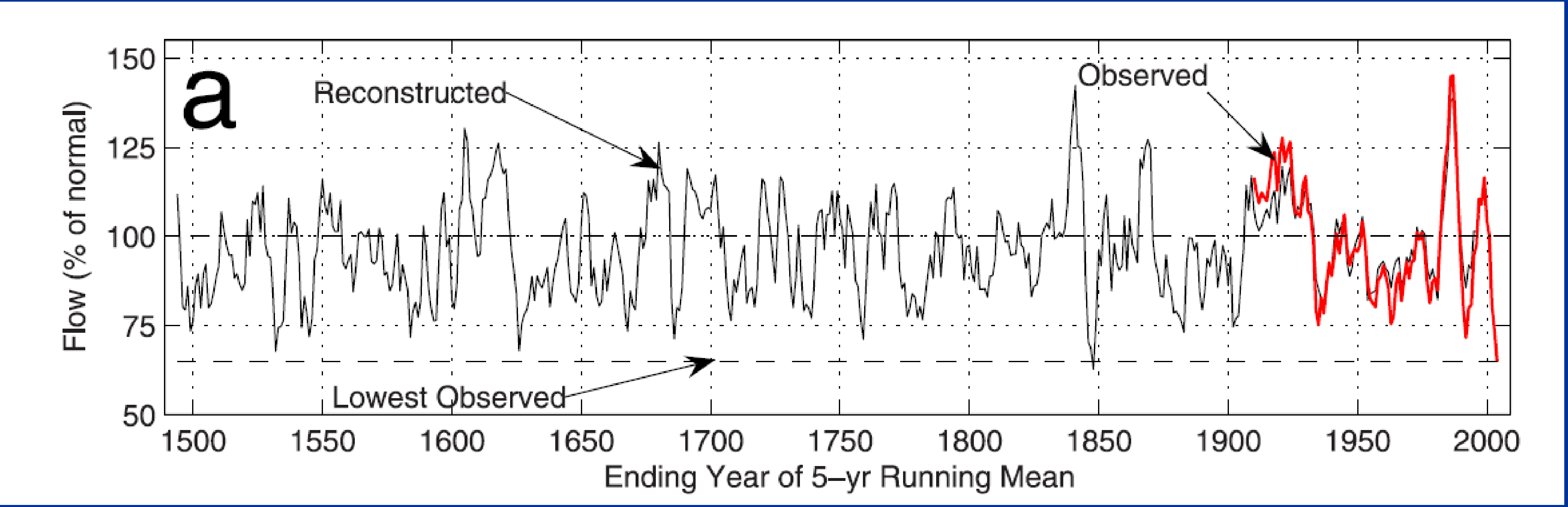
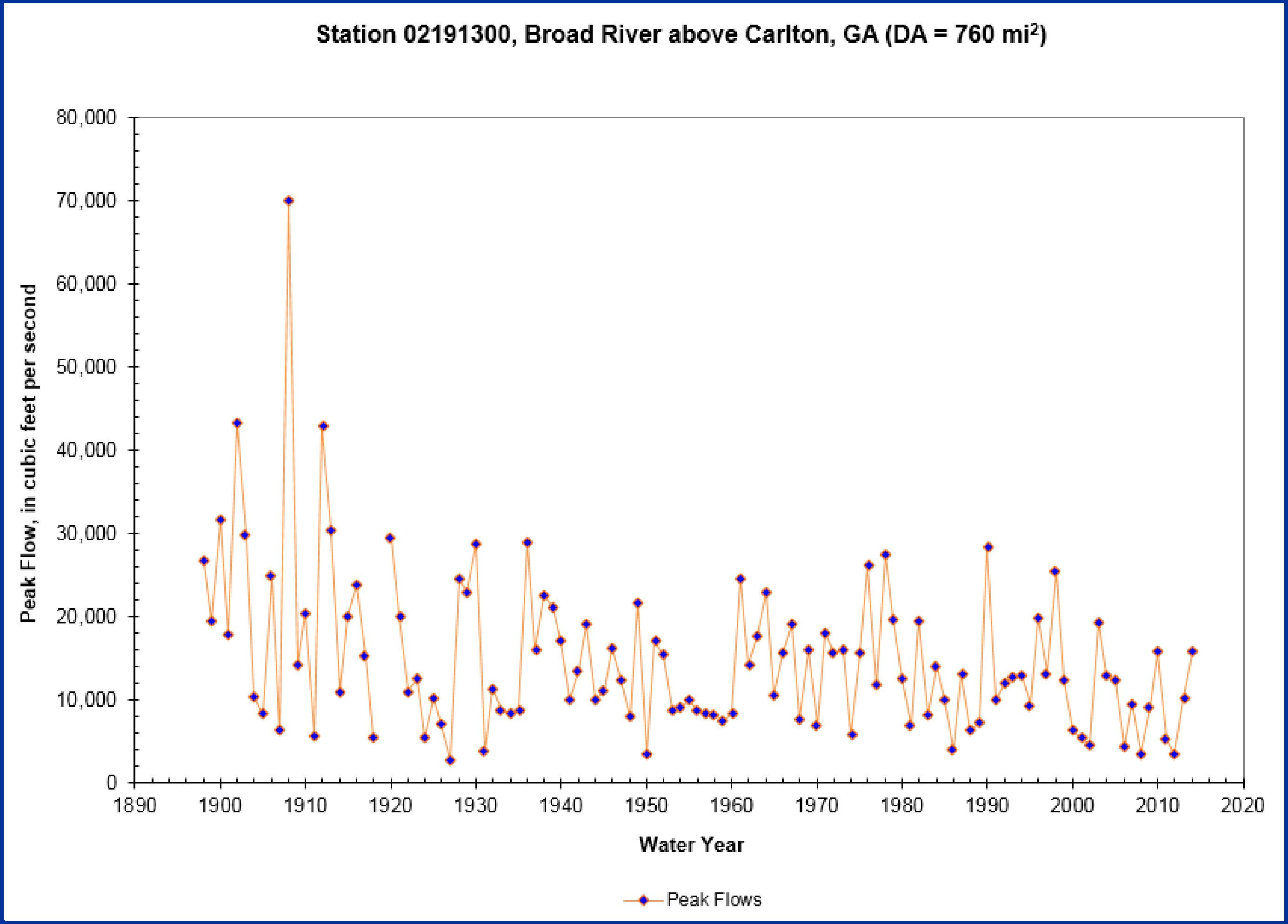
Unfortunately, the period from about 1905-1922, which time and additional research as shown was an unusually wet period, was used to estimate water production allocation under the Colorado River Compact.

Importance of Long-Term Records



This reconstructed (tree rings) record going back to the 1400s shows how truly unfortunate it was for the Colorado River Compact water allocations were based on river flow data from the short period of record in the earlier 1900s.

Lets Look At An Example of How The 1% Chance Flood Changes Over Time Based on Record Length and Hydrologic Conditions



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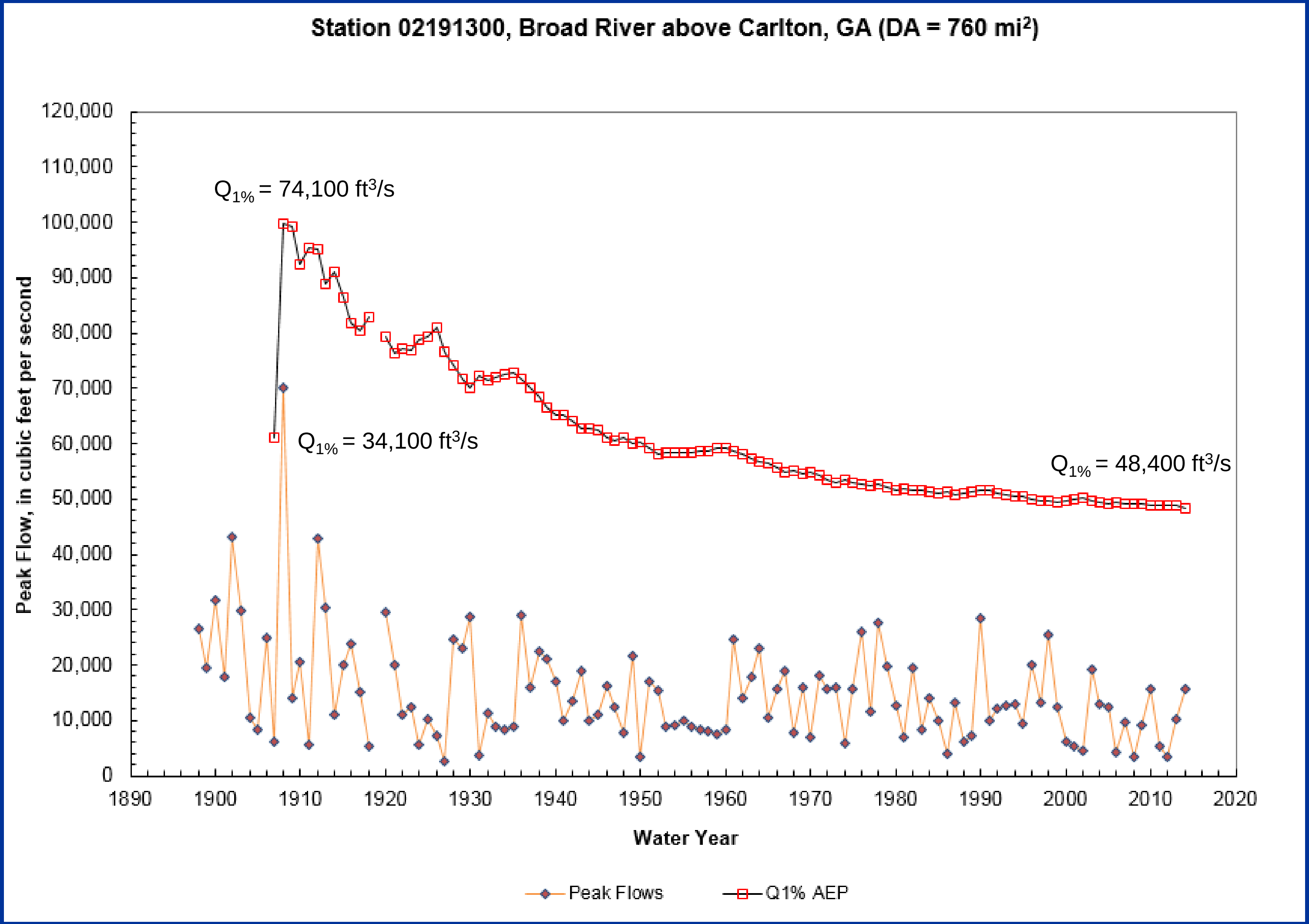
How the 1% AEP Changes With Additional Record



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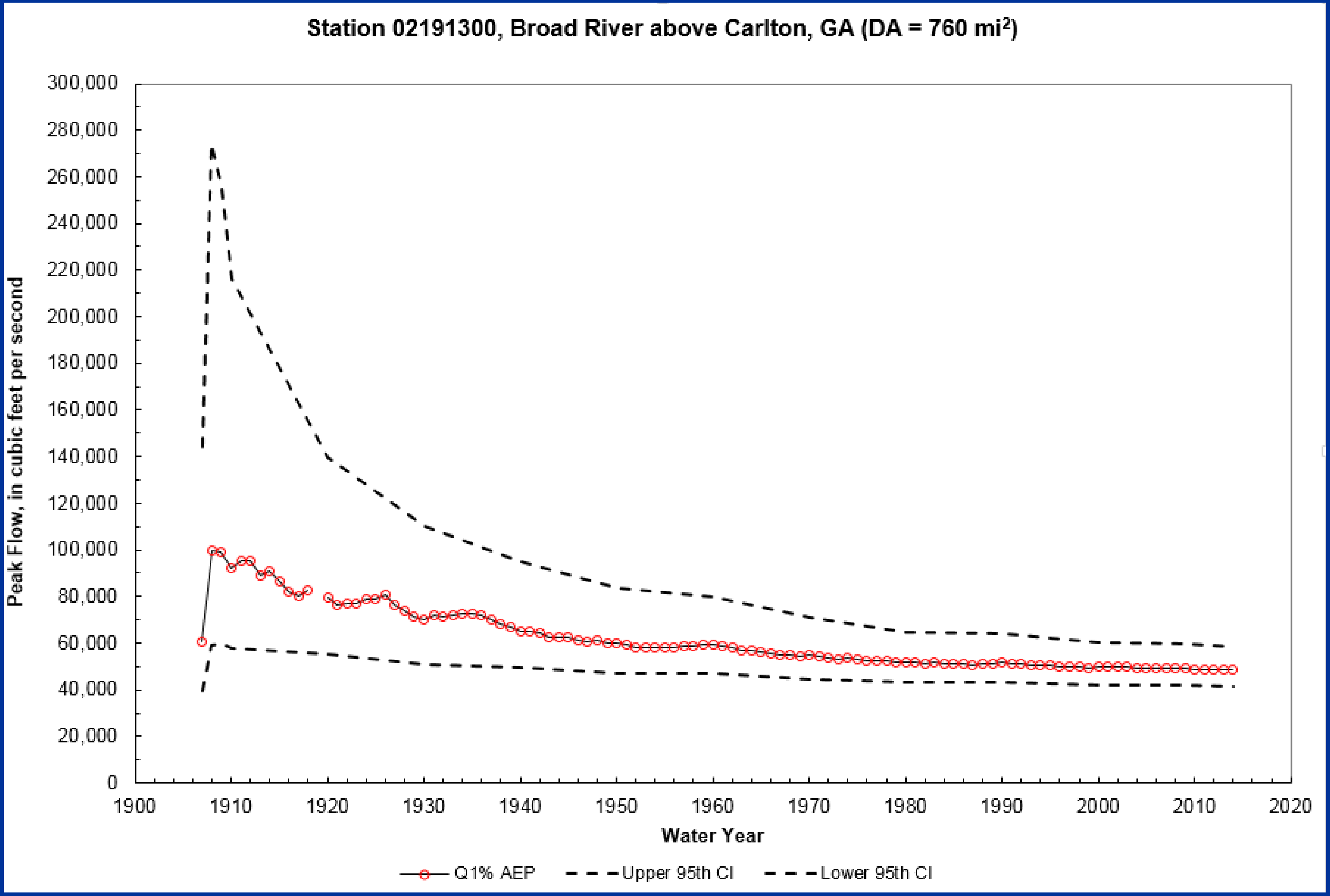
It's Important to be Aware of the Uncertainty



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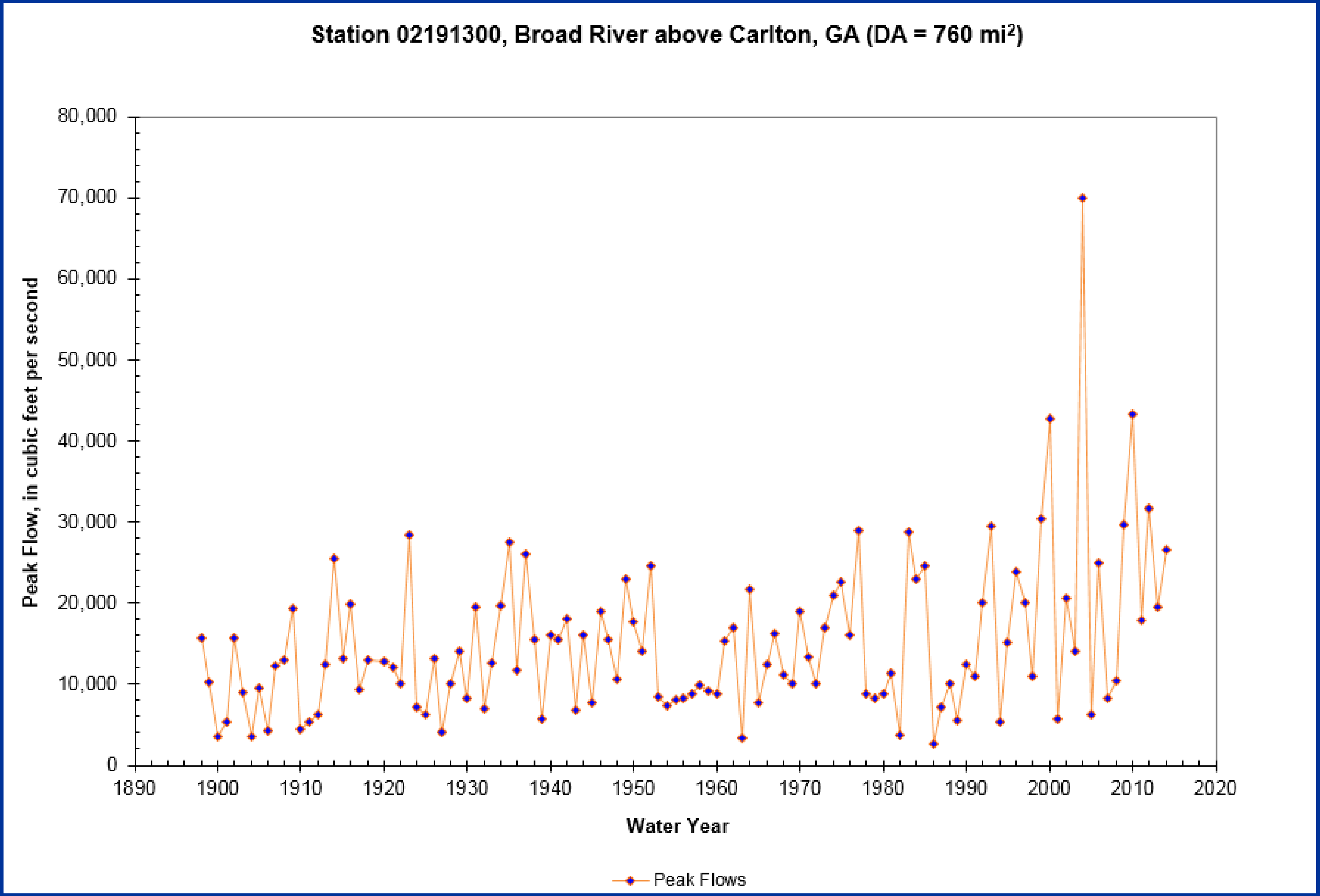
What If The Record Had Been Collected In Reverse Order?



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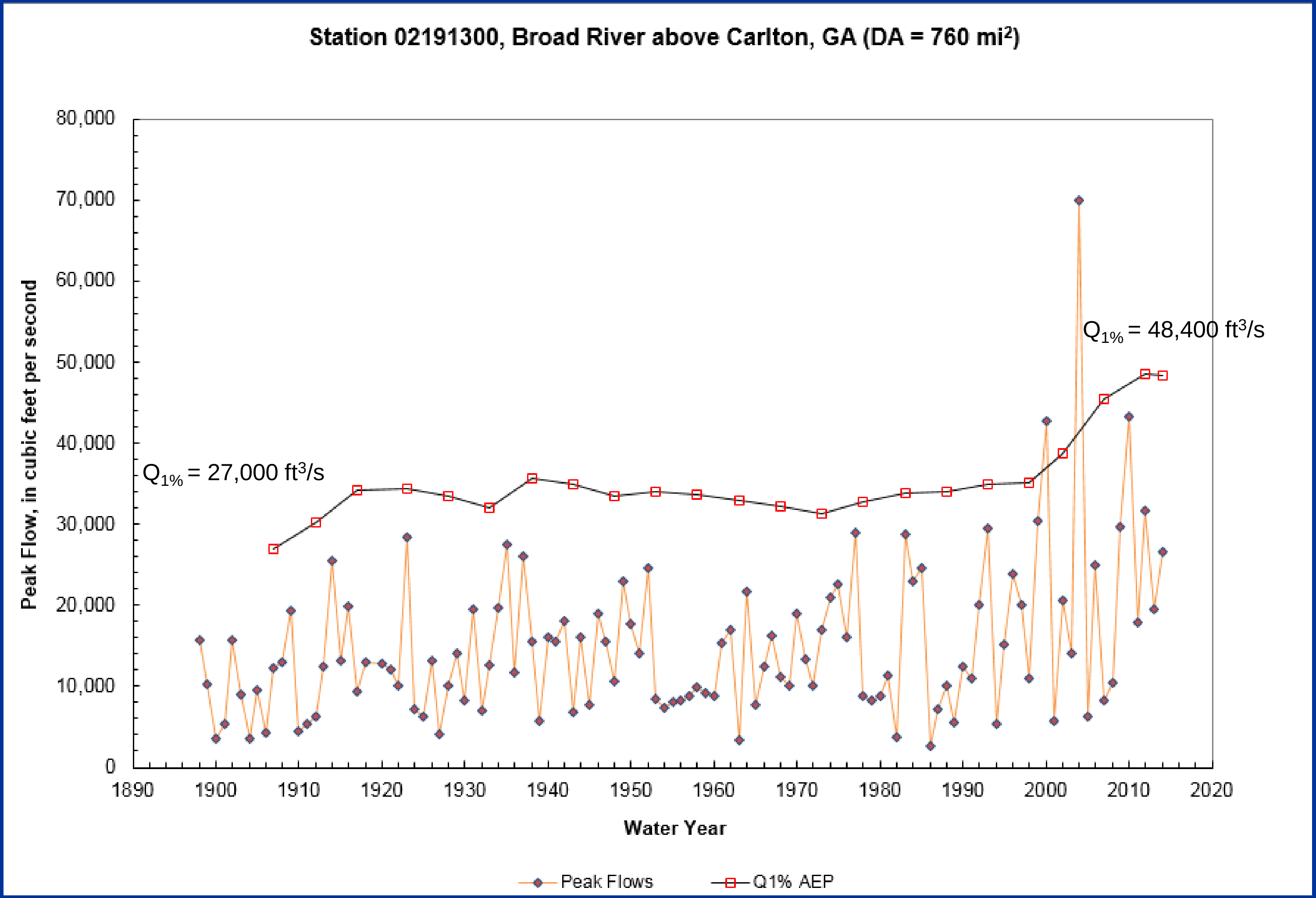
What If The Record Had Been Collected In Reverse Order?

Period of record (and hydrologic conditions captured in that record) is a big deal.



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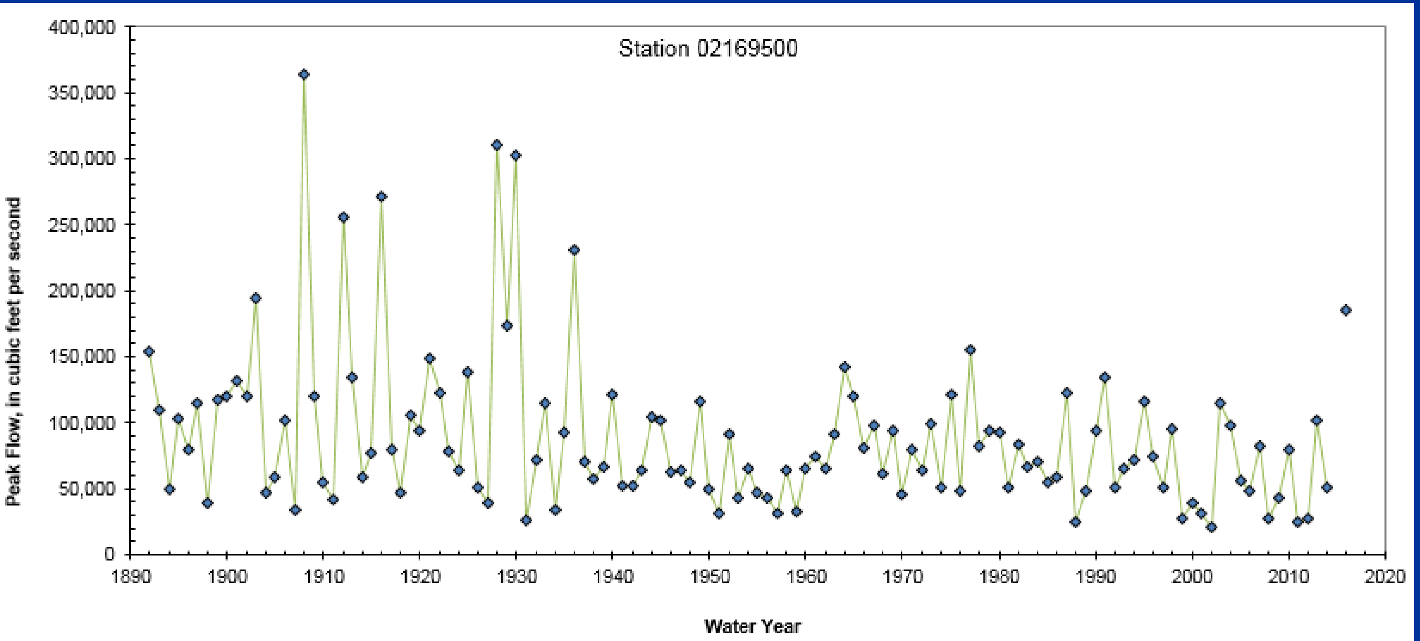
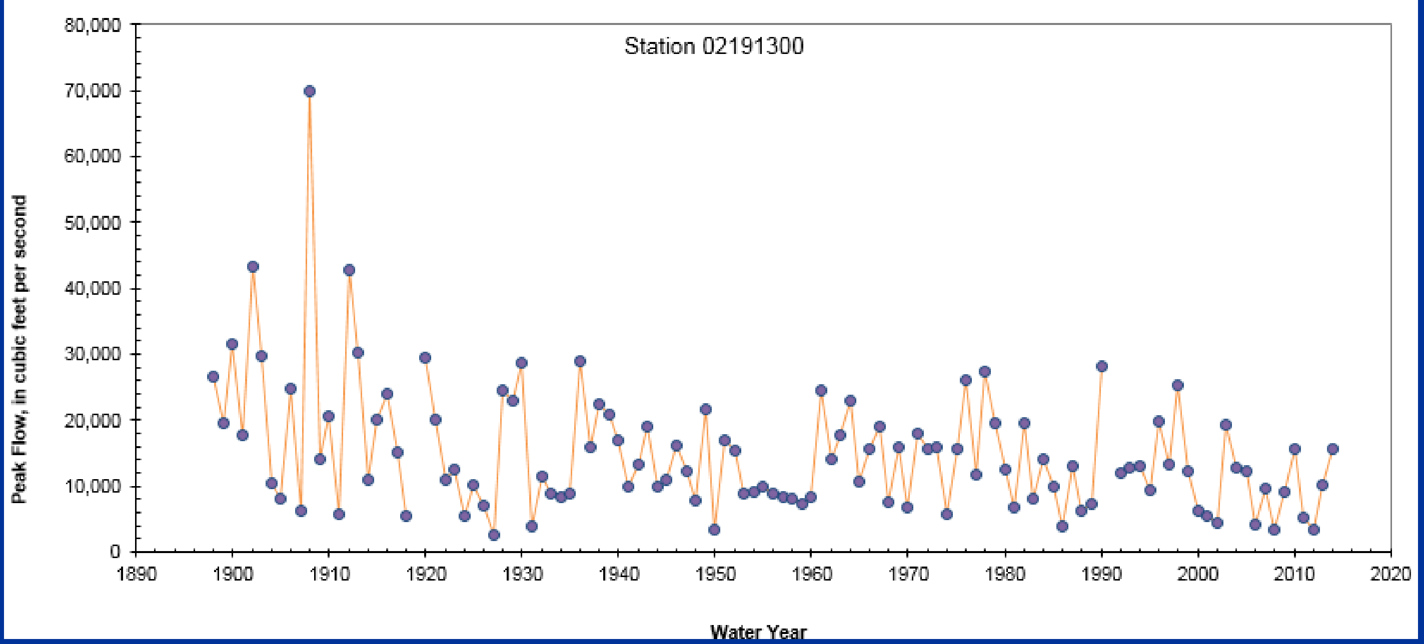


Drainage Area

02169500 = 7,850

02191300 = 760



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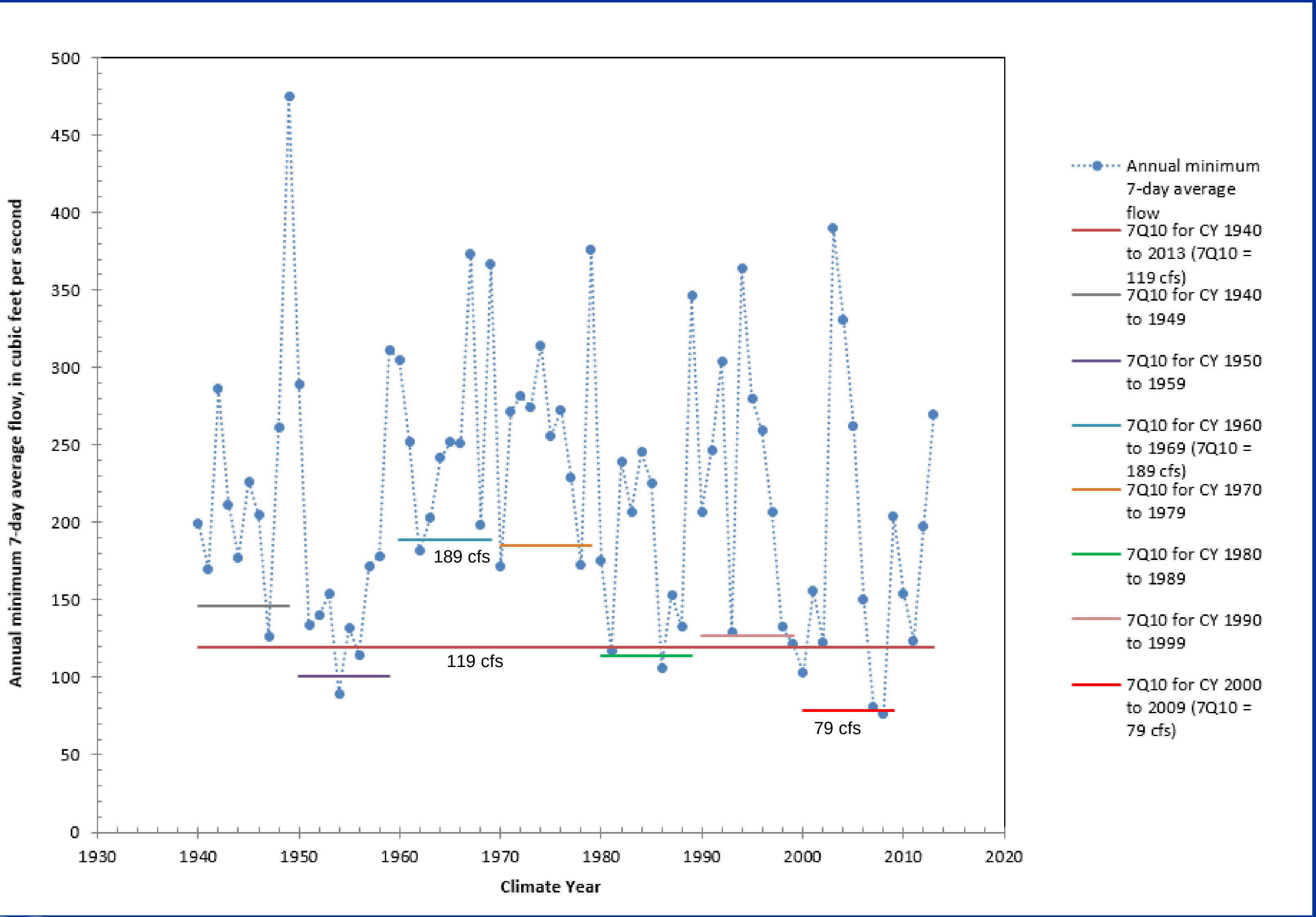
A Low-Flow Example: 7Q10



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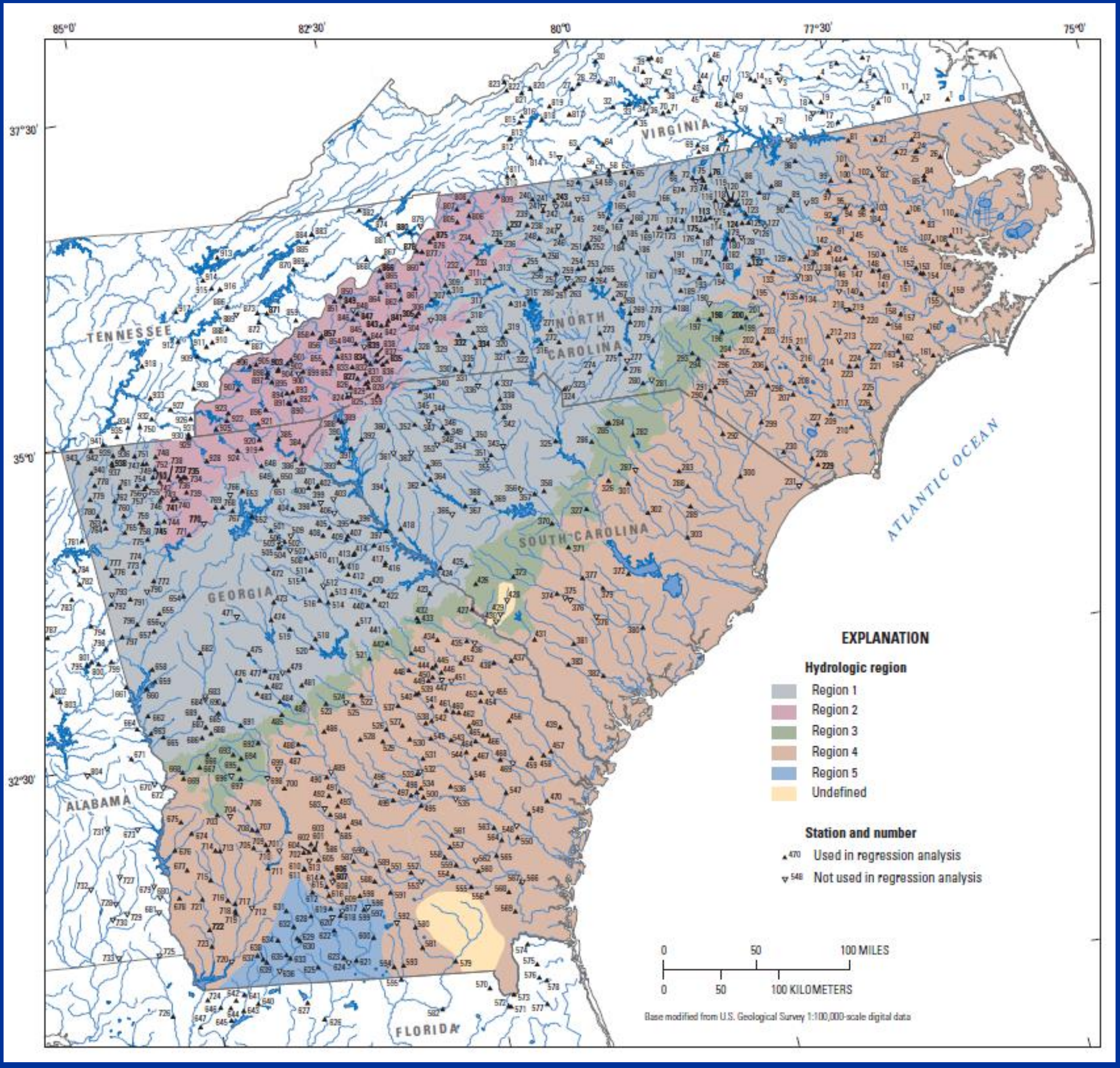
Basics of Regionalization



Murphy’s Law for Hydrology

If a region has a100 gaged streams and one ungaged stream, the most pressing need for immediate streamflow information will be for the stream with no gage…

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Regionalization Analysis

Purpose:

- **Provide estimates of flow characteristics at ungaged sites using information from other gages in the area.**
- **Provide a second estimate of a flow characteristic at gaged sites to develop a weighted estimate (especially if only short records are available at the gage).**

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Rural Flood Frequency: Through Water Year 1999

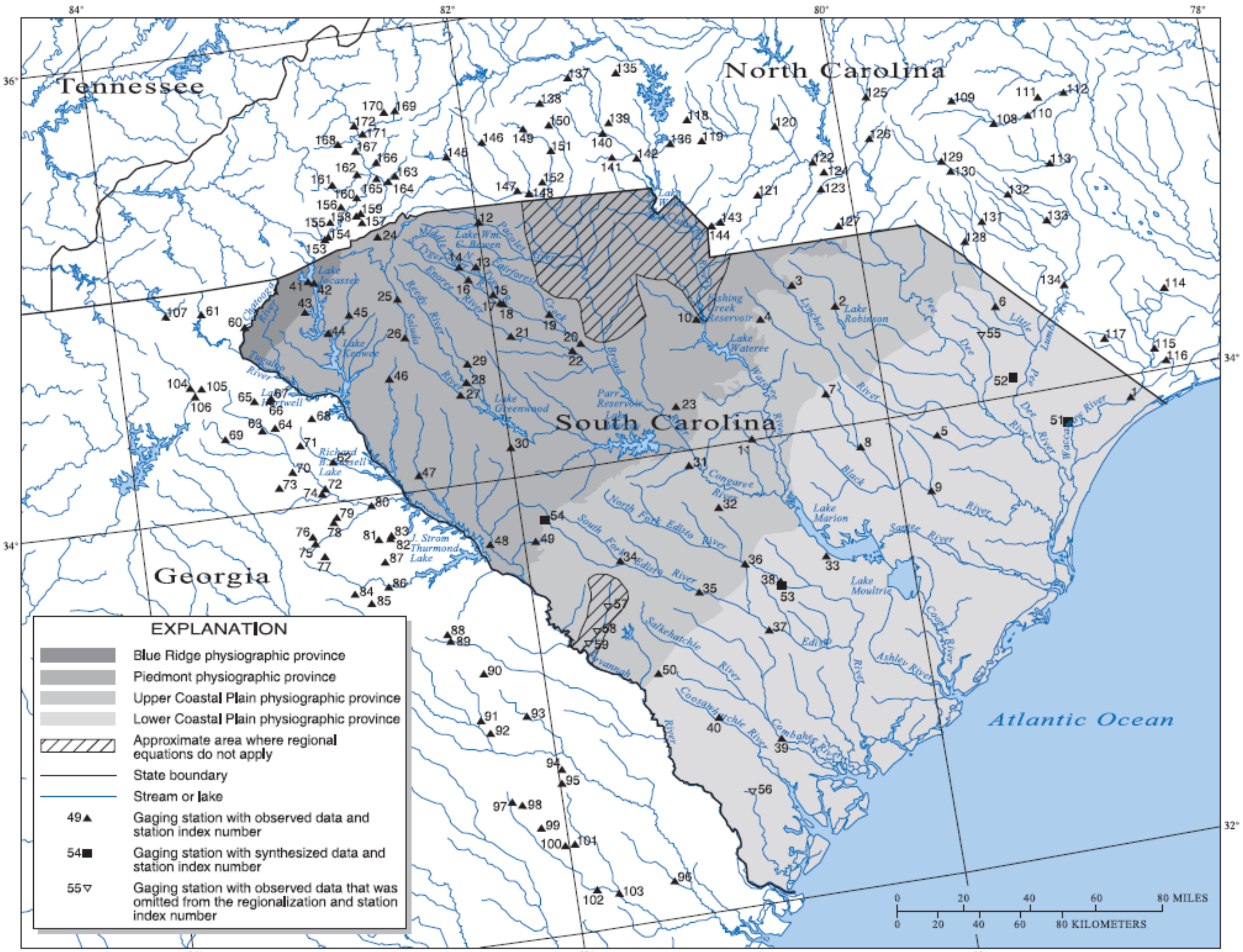


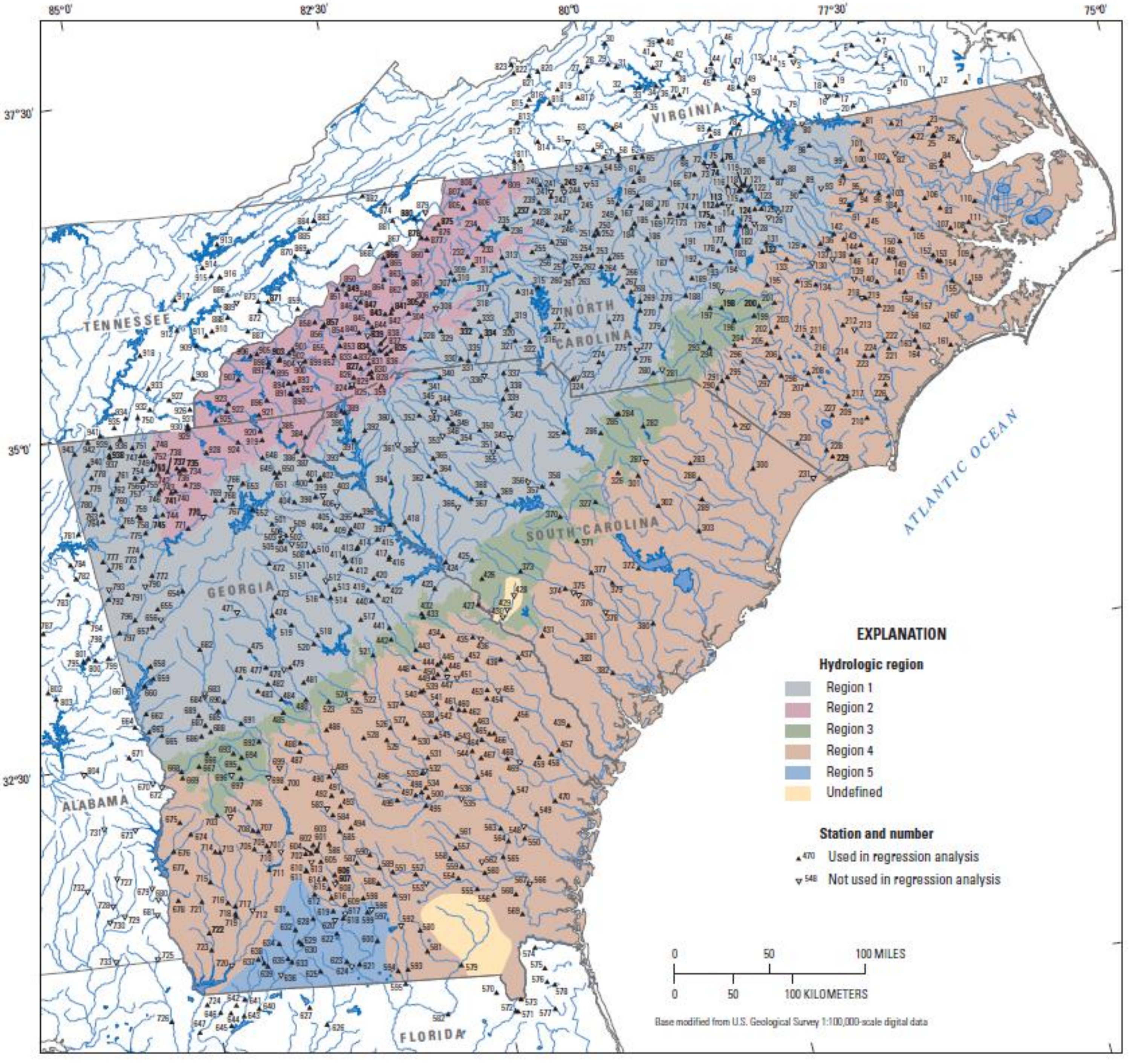
Figure 1. Physiographic provinces and locations of streamflow gaging stations on rural streams in South Carolina and parts of North Carolina and Georgia.

USGS SIR 2009-5156: Peakflows through water year 2006

GA = 310

NC = 303

SC = 64

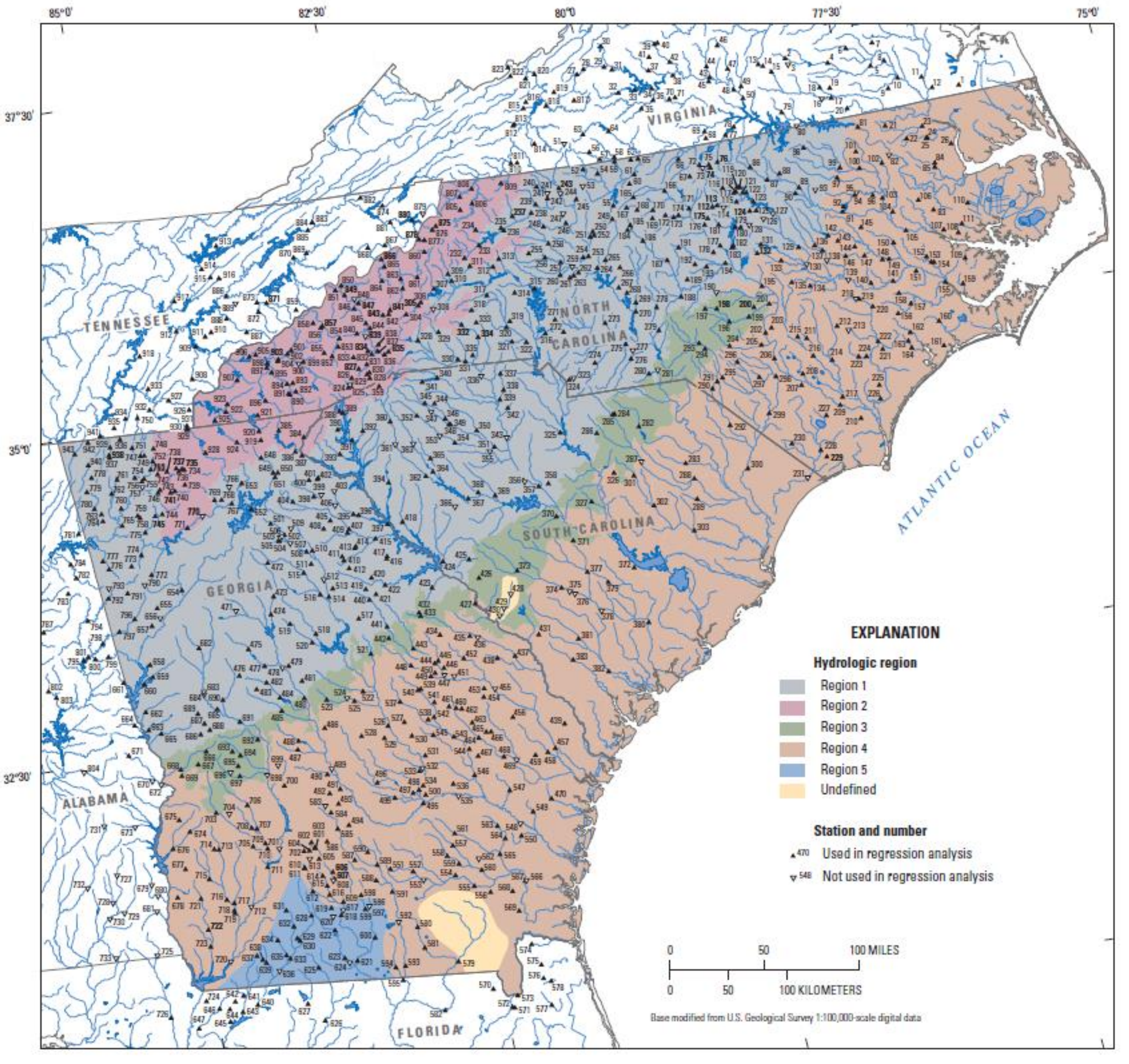


Total area divided by number of gages: (mi²/gage)

GA = 192

NC = 178

SC = 500



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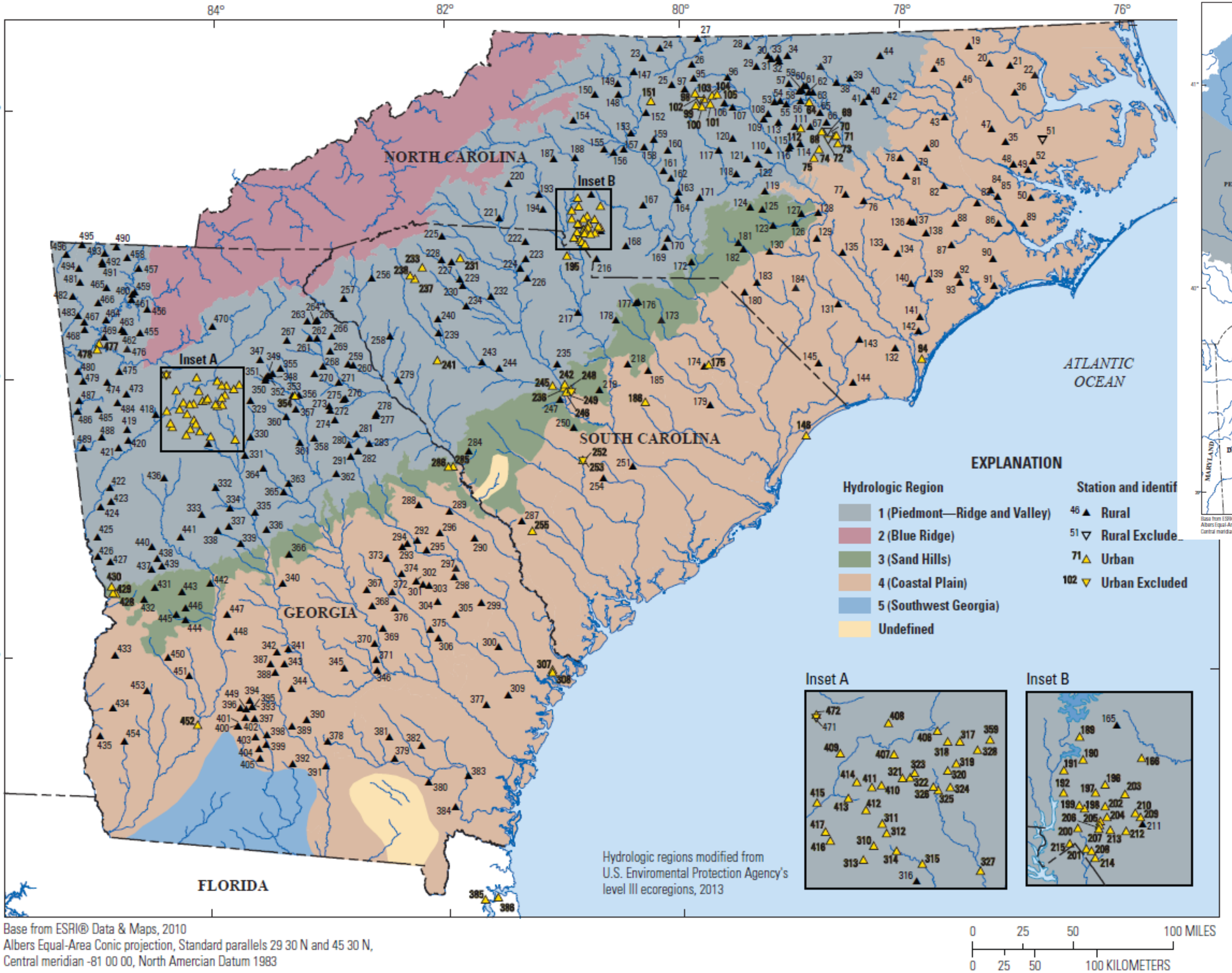

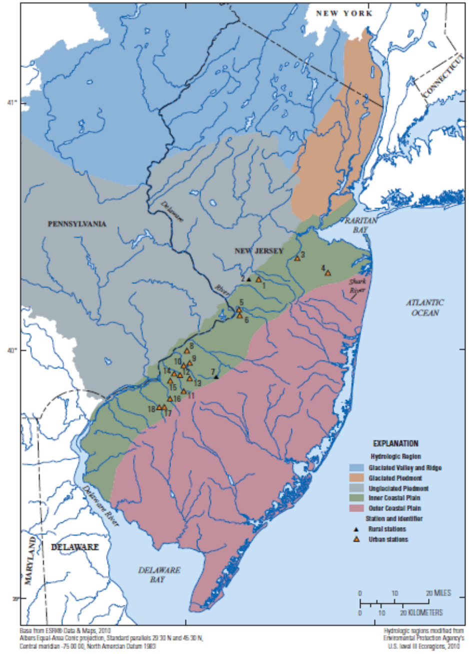

Urban and small, rural flood frequency

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