IMPORTANCE OF RECORD LENGTH WITH RESPECT TO ESTIMATING THE 1-PERCENT CHANCE FLOOD

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Abstract. U.S. Geological Survey (USGS) streamflow gages have been established in every State in the Nation, Puerto Rico, and the Trust Territory of the Pacific Islands. From these streamflow records, estimates of the magnitude and frequency of floods are often developed and used to design transportation and water-conveyance structures to protect lives and property, and to determine flood-insurance rates.

Probably the most recognizable flood statistic computed from USGS streamgaging records is the 1-percent (%) chance flood; better known has the 100-year flood. By definition, this is a flood that has a 1% chance of occurring in any given year. The 1% chance flood is a statistical estimate that can be significantly influenced by length of record and extreme flood events captured in that record. Consequently, it is typically recommended that flood statistics be updated on some regular interval such as every 10 years. This paper examines the influence of record length on the 1% chance flood for the Broad River in Georgia and the substantial difference that can occur in the estimate based on record length and the hydrologic conditions under which that record was collected.

INTRODUCTION

Reliable estimates of the magnitude and frequency of floods are required for the design of transportation and water-conveyance structures such as roads, bridges, culverts, dams, and levees. Federal, State, regional, and local officials also need these estimates for the effective planning and management of land use and water resources, to protect lives and property in flood-prone areas, and to determine flood-insurance rates. The U.S. Geological Survey (USGS) established the first streamgaging station in 1889 on the Rio Grande River near Embudo, New Mexico. Since that time, thousands of USGS streamflow gages have been established in every State in the Nation, Puerto Rico, and the Trust Territory of the Pacific Islands. Using those records, the magnitude and frequency of floods can be determined for a river at the location of a streamgage (at-site analysis) and also be used in regional studies to develop regression equations that can be used to estimate flood magnitude and frequency at ungaged locations (Feaster and others, 2009).

Flood-frequency estimates made at gaged locations contain varying degrees of uncertainty due to the number of annual peak flows being analyzed and how representative that statistical sample is of the total population. The effects of sample size for statistical predictions can be intuitable. When more annual peak flows are available, more confidence can be assumed in the flood-frequency estimate. Engineers and water-resources managers are often interested in the 1-percent chance exceedence flood (1% chance flood) also known as the 100-year flood (Holmes and Dinicola, 2010). But most data sets of annual maximum floods at a gaged site are much less than 100 years in length. Consequently, when the annual peak flows are fit to a particular distribution for statistical predictions, the 1% chance flood is estimated from an extrapolation beyond the measured data. The significant influence that length of record has on reducing the standard error or uncertainty in the regional equations can be seen in the following graph (fig. 1) by Benson and Carter (1973). The increase in length of record also reduces the uncertainty in the at-site estimate. This paper focuses on the at-site analysis and examines the influence of record length on the 1% chance flood and the substantial difference that can occur in the estimate based on record length and the hydrologic conditions under which that record was collected.
In the 1960s, it was recognized that for both engineering and economic reasons, there was a need to establish uniform and accurate techniques for developing at-site flood frequency estimates (Thomas, 1985; Griffis and Stedinger, 2007). As a result, a Federal interagency work group was created that provided the current set of uniform flood-frequency techniques recommended for use by Federal agencies and documented in Bulletin 17B (B17B) (Interagency Advisory Committee on Water Data, 1982). Most flood-frequency analyses are done using maximum annual peak flows. Incorporated into B17B are a number of methods that allow for the adjustment of flood-frequency estimates based on such things as low and high statistical outliers and historical information. In essence, these adjustments help put extreme annual peak flow values into a more reasonable context with respect to length of record. Often an annual peak flow may be flagged as an outlier due to the relatively short length of systematic record in which that data point was measured. As additional data are collected and the length of record increases, the extreme annual peak flows are placed into a more accurate historical and statistical frame of reference and therefore, the accuracy of the flood-frequency estimates would be expected to increase.

To show how the length of record and hydrologic conditions under which that record was collected can influence the 1% chance flood estimate, an analysis was done using peak-flow data from USGS station 02191300, Broad River near Carlton, Georgia. This station was chosen because the streamflow is from a rural, unregulated basin with measured peak flows going back to 1898. The running flood-frequency analysis was done beginning with the first 10 years of record, which is the minimum length of record suggested for such an analysis in B17B. The analysis was repeated by adding the next annual peak flow through 2009 (fig. 2). The USGS program PeakFQ (Flynn and others, 2006) was used for the analysis using the station skew and no historical adjustments. Beginning with the first 10 years of record (1898-1907), the 1% chance flood was 61,000 cubic feet per second (ft³/s). In 1908, a large peak occurred and the 1% chance flood increased to 99,600 ft³/s. With the benefit of having collected data at this station for the last 111 years, it is known that the 1908 peak has been the largest peak to occur at this station. From the high point in 1908, the 1% chance flood, on average, continued to decrease in what appears to be an asymptotical approach to a stable 1% chance flood estimate with the value for 2009 being 49,100 ft³/s, which is less than 50% of the 1908 estimate.

As a measure of uncertainty, PeakFQ provides the lower and upper 95th percentile flows for the flood frequency estimates. The confidence intervals are influenced both by period of record and the magnitude of the flood events captured in that record. Figure 3 shows those values plotted with the 1% chance flood for water years 1907-1910 and then 10 year intervals afterwards through water year 2009. The water year is the annual period from October 1 through September 30 and is designated by the year in which the period ends. With the peak of record that occurred in 1908, the 1% chance flood estimate based on 11 years of record was 99,600 ft³/s with lower and upper 95th percent confidence intervals of 59,000 and 274,000 ft³/s, respectively, indicating a large uncertainty in the 1% chance flood estimate. With additional years of record, the uncertainty continued to decrease until in 2009 with 111 years of record, the 1% chance flood estimate was 49,100 ft³/s with lower and upper confidence intervals of 41,800 and 59,700 ft³/s, respectively, indicating a substantially higher level of confidence in the 1% chance flood estimate.

**SUMMARY**

In water-resource assessments, tools are available to augment our understanding of the hydrological processes being studied but these techniques do not replace the hydrologic value of long-term observed data. Although B17B provides methods for adjusting flood-frequency estimates based on historical information, often such information is not readily available and therefore, scientists and engineers are not always able to place extreme events into a proper historical context. As figure
2 indicates, if only a short period of the record at station 02191300 were available, the estimated 1% chance flood for that site could be drastically different from what would occur over a much longer period of time. Thus, it is imperative that annual peak flow data be collected (and be collected for periods much longer than sometimes commonly thought necessary) in order to provide better information that can be used to make decisions and develop policies with respect to infrastructure design and management near the Nation's rivers and streams.

REFERENCES


Figure 2. Sensitivity of the at-site 1-percent chance flood with record length at station 02191300, Broad River above Carlton, Georgia.
Figure 3. The 1-percent chance flood estimates along with the lower and upper 95\textsuperscript{th} percent confidence intervals at station 02191300, Broad River above Carlton, Georgia.