Fluvial geomorphic considerations of annual maximum series versus partial duration series for flood frequency analyses

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Extended Abstract

Flood frequency analyses are a cornerstone of planning studies and engineering design in river environments. Typically, infrequent floods are of interest where public health, safety, and welfare are paramount, such as when planning development near flood hazard areas or when designing bridges, levees, and dams. However, frequent floods can be of greater interest where fluvial geomorphic work is a key consideration, such as analyses of long-term sediment transport in alluvial channels. While infrequent floods can exert considerable fluvial geomorphic work on alluvial channels, over the long term, the concept of a dominant discharge (Inglis 1941), commonly calculated as an effective discharge (Wolman and Miller 1960; Andrews 1980), shows the influence of frequency driving the fluvial geomorphic importance of frequent floods.

A flood frequency analysis (FFA) is a statistical process that uses a sample of peak flood flows to estimate the population of flood flows and thus the relationship between peak flows and probability of occurrence. A Poisson distribution is an appropriate statistical model for the occurrence of various magnitude peak flood flows, assuming, in part, the floods occur independently. An annual maximum series (AMS) of peak flood flows includes only the greatest peak flow in a year; a peaks-over-threshold (POT) sample is a type of partial duration series (PDS) that includes peak flows exceeding a threshold flow. The AMS is based on an "assumption of convenience" that floods in adjacent years are independent; according to Lang et al. (1999) a POT series implies dual-domain-modeling because it requires analysis of both the magnitude of flow and the time of occurrence. An objection to using AMS is that it accounts for only the largest flood in each year regardless of whether any other floods in this year exceed the largest floods of other years (Stedinger et al. 1993). The POT series provides additional flexibility in the sampling of floods relative to an AMS, so the POT series can provide a more complete description of the flood regime; however, this flexibility requires selection of both a threshold flow and an independence criterion that satisfy the Poisson distribution requirements (Lang et al. 1999). The POT approach suffers from a lack of general guidelines for its application; consequently, as compared to the AMS approach, the POT approach remains relatively unpopular and under used in FFAs (Lang et al. 1999).

FFAs following industry standard guidelines in Bulletin 17B (IACWD 1982) or 17C (England et al. 2018) are appropriate for annual exceedance probabilities (AEPs) of 0.10 or less (i.e., peak flows with an average annual exceedance of 10 years or longer), which are usually based on an AMS from gaging station records, such as for hydrologic regimes dominated by annual snowmelt runoff. However, for floods with AEPs greater than 0.10 (i.e., average annual exceedances less than 10 years), a POT series may be more appropriate, such as for systems with hydrologic regimes dominated by multiple runoff producing rainfall storms each year. Challenges arise implementing a FFA using a POT series because Bulletins 17B and 17C do not recommend specific guidelines for such an analysis.

In the pioneering work of Langbein (1949) on comparing annual floods and partial duration floods, he identified that *for an equivalent sample of floods*, the recurrence intervals in the PDS are smaller than in the AMS, but that the difference becomes inconsequential for floods rarer than about the 5-year recurrence interval (Figure 1). However, Langbein (1949) noted the distinction in occurrence of these floods: (1) in the AMS, the recurrence interval is the average time over which a specific flood will recur as an annual maximum; (2) in the PDS, the recurrence interval is the average time between specific floods regardless of their relationship to the year or any other period of time. This distinction remains even though for rare floods the two methods produce recurrence intervals that approach numerical equality.

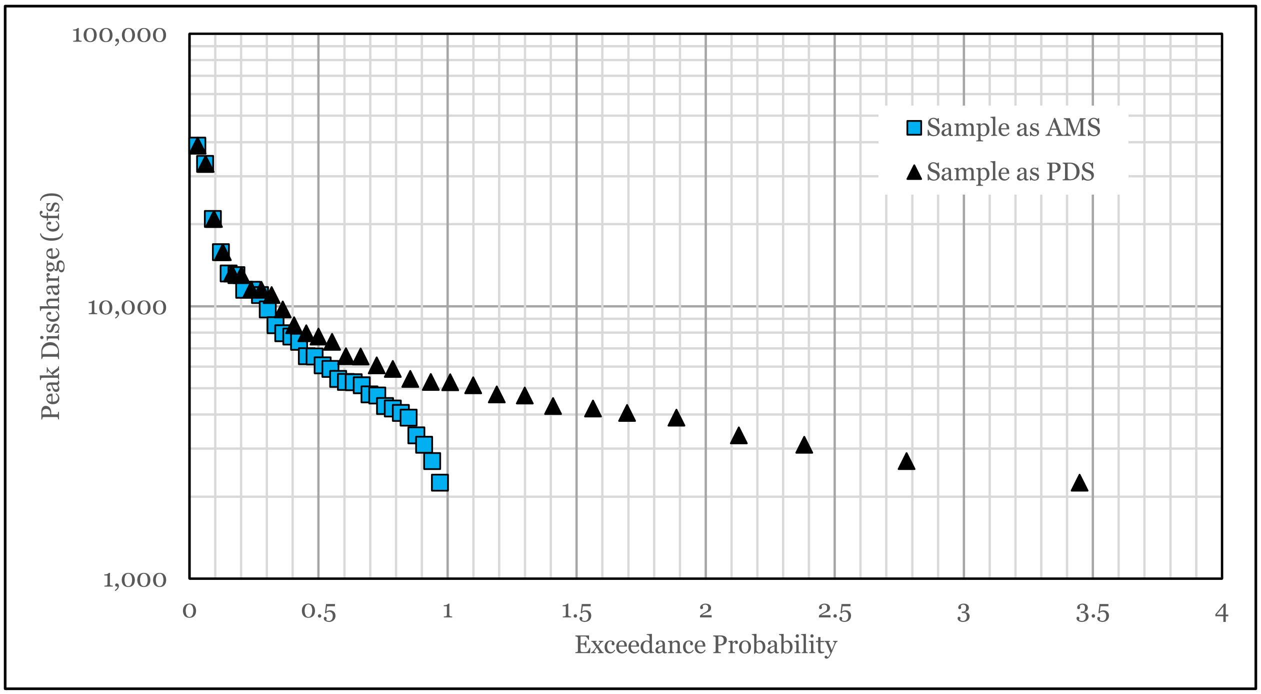

Figure 1. Flood sample as AMS versus PDS

If, however, a threshold discharge for a POT series is selected to identify the same number (N) of floods as in an AMS, such that the sample of floods is not equivalent, the recurrence interval of a flood decreases for floods more frequent than about the 5-year recurrence interval (Figure 2).

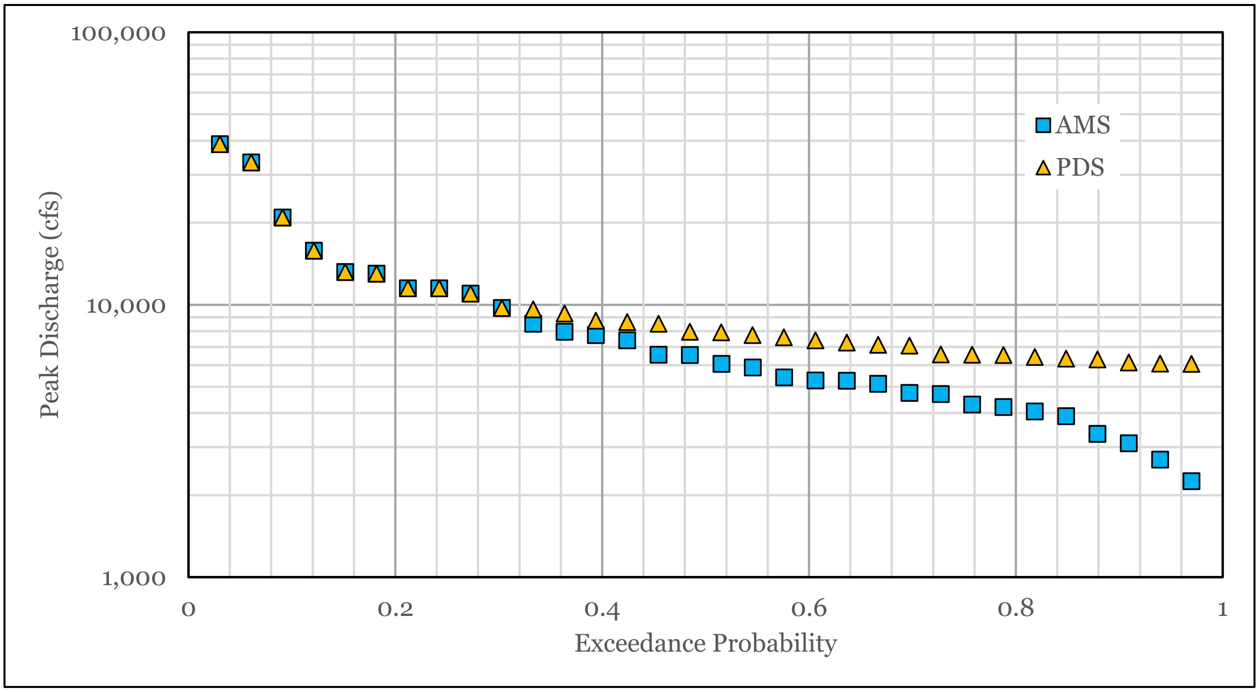

Figure 2. Comparison of AMS and PDS for a PDS sample preserving the N floods in the AMS

If a threshold discharge is selected based on an influential fluvial geomorphic process, such as bed surface mobilization and notable transport, the recurrence interval of all floods can increase (Figure 3). To meet the assumption of flood independence, McCuen et al. (1993) note the threshold is usually set for PDSs in the U.S. so the flood count is no more than two or three per year.

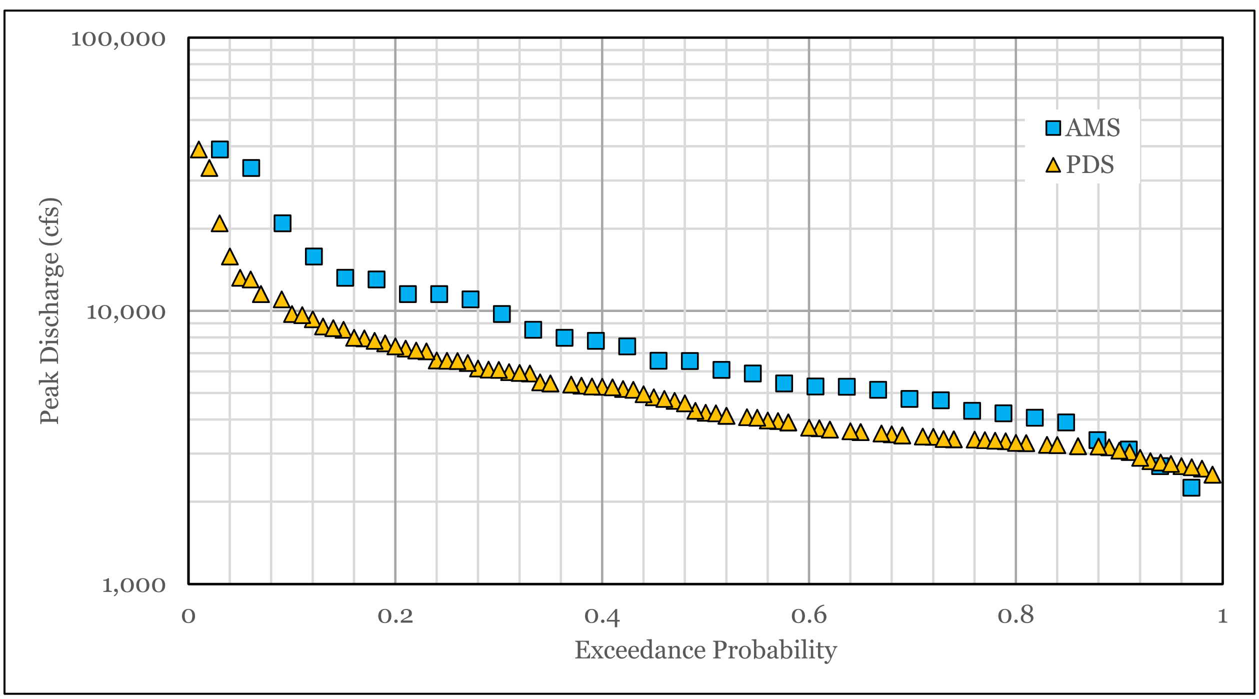

Figure 3. Comparison of AMS and PDS for a PDS sample using meaningful fluvial geomorphic threshold

This presentation summarizes fluvial geomorphic considerations for developing flood hydrology based on frequency analyses using AMS versus PDS. The presentation provides examples of analyses and calculations, as well as the implications associated with each method, to remind practitioners of the importance of these considerations, especially as they pertain to channel stability and restoration, sediment transport and geomorphic change, sedimentation, and designs for frequent floods.

A key consideration addressed is how sediment transport processes can inform specification of a threshold flow meaningful to fluvial geomorphic processes, and in turn, how an appropriate FFA can better inform the estimation of sediment yields. An example FFA using gaging records demonstrates application of this consideration and shows how the AMS and POT series of sampled floods influence the statistical relationships between peak flow and probability of occurrence. The implication of this influence is shown through calculations of mean annual sediment yield using the approach of Stow and Chang (1987) to integrate the sediment yield frequency curve.

The independence criterion was not a focus of consideration in these examples; instead, the independence criteria from Beard's (1974) study were applied. Beard defined flood independence as (1) floods being separated by as many days as five plus the natural logarithm of the square miles of drainage area, and (2) having intermediate flows between peaks that drop below 75 percent of the lower of the two separate peak flows. Lang et al. (1999) noted the selection of independence criteria is complex and can be quite subjective, so consideration of independence criteria was beyond the scope of these analyses.

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