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Estimation of drought and flood recurrence interval from historical discharge data: a case study utilising the power law distribution

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The choice of which statistical distribution to fit to historical discharge data is critical when attempting to predict the most extreme flows. It has been shown that depending upon the distribution selected, the calculated return periods can vary dramatically. Cunnane (1985) discussed the factors affecting the choice of distribution for river flow series data, and was able to show that small differences in the Extreme Value Type 1 (Gumbel), Type 2, and Type 3 can lead to large differences in the predicted return period. Indeed this divergence increases as the return period becomes larger: a finding which has obvious implications for fluvial management.

Despite this, in many studies which fit a frequency-magnitude distribution to fluvial discharge data, the choice of distribution appears driven by regional convention, or even by some other apparently arbitrary factor. Benson (1968) analysed data for ten US stations, and compared the fit using the log-normal, gamma, Gumbel, log-Gumbel, Hazen and log-Pearson type 3 distributions. On the basis of this study alone, the standard approach to flow frequency estimation in the USA became the fitting of a log-Pearson type 3 (LP3) distribution (US Water Resources Council, 1982). While several other countries have adopted a similar approach, usage of the LP3 distribution is not geographically universal. Hydrologists in the United Kingdom conventionally utilise a fitted generalised logistic distribution for flow frequency estimation (Robson and Reed, 1999) while Chinese hydrologists utilise the log-normal distribution (Singh, 2002).

Choice of fitted distribution is obviously crucial, since selecting one distribution rather than another will change the estimated probabilities of future droughts and floods, particularly the largest and rarest events. Malamud et al. (1996) showed that a flood of equivalent size to that experienced on the Mississippi in 1993 has a recurrence interval on the order of 100 years when a power-law distribution is fitted, but a much longer recurrence interval — on the order of 1000 years — using the USA's standard LP3 method. In addition Pandey et al. (1998) found that fitting a power-law distribution, compared with fitting a Generalized Extreme Value distribution, can lead to a large decrease in the predicted return period for a given flood event. Both these findings have obvious implications for river management design.

Power-law distributions have been fitted to fluvial discharge data by many authors (most notably by Malamud et al., 1996 and Pandey et al., 1998), who then use these fitted distributions to estimate flow probabilities. These authors found that the power-law performed as well or better than many of the distributions currently used around the world, despite utilising fewer parameters. The power-law has not, however, been officially adopted by any country for fitting to fluvial discharge data.

This paper demonstrates a statistically robust method, based on Maximum Likelihood Estimation, for fitting a power-law distribution to mean daily streamflows. The fitted distribution is then used to calculate return periods, which are compared to the return periods obtained by other, more commonly used, distributions. The implications for river management, extremes of flow in particular, are then explored.