Which Discharge Rate Controls the Long-Term Geomorphic Evolution of a Watershed?

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Abstract. Over long periods, watersheds respond to fluvial processes driven by a wide range of discharges. Low discharges have little ability to modify the land surface, but this contribution is magnified because such flow rates are common. High discharges have a much greater ability to modify the land surface but rarely occur. The importance of a given discharge to the erosion of a basin can be calculated by multiplying the discharge's frequency of occurrence and the erosion rate produced by the discharge. The discharge that contributes the most geomorphic work is called the geomorphic effective event (GEE). In this study, we investigate the behavior of the GEE through analytical and numerical approaches. A generic stream power model with a threshold is used to describe either the detachment or transport of sediment by flowing water. The exponential and log-normal distributions are used to describe the variability of discharges. The results suggest that the return period of the GEE depends primarily on the threshold value when the exponent on discharge is less than two. Otherwise, it depends primarily on the exponent. The GEE usually cannot be substituted for the probability density function of discharge because it produces a different long-term erosion rate. Furthermore, the return period of the GEE can vary spatially in a basin. For example, the return period can be different between locations where the fluvial process is dominant and sub-dominant if the threshold is non-zero. For a detachment-limited model, the return period of the GEE is different upstream and downstream of knickpoints, and for a transport-limited model, the return period is different along channel profiles even at steady state. Spatial variation in streamflow generation also produces spatial variations in the return period of the GEE.