Bankfull characteristics of alluvial rivers

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Researchers and engineers often characterize alluvial rivers in terms of their bankfull discharge and bankfull geometry (e.g. bankfull depth, bankfull width, and channel slope). The bankfull condition is defined geometrically in terms of water surface elevation at which the flow is just about to overflow onto the floodplain. Empirical studies have found that the bankfull discharge of alluvial rivers roughly corresponds to a flood discharge with a 2-year recurrence interval. Bankfull discharge has also been related to the flow duration curve; in one study it was found to correspond roughly to the flow with an exceedance fraction of 0.006. Despite the clear evidence of a strong relation between bankfull characteristics of alluvial rivers and local hydrology, the physics behind this relation remains poorly understood. In this study, we present a framework for quantifying the formative processes leading to the establishment of bankfull geometry, in order to gain physical insight into the relation between bankfull characteristics and local hydrology. We hypothesize that a river evolves its geometry toward an equilibrium state in which the sediment deposited onto the floodplain through overbank deposition is, in the mean, in overall balance with sediment eroded from the floodplain through lateral channel migration. Together with the equation of momentum balance and a bed material load transport equation, we construct a numerical model, which predicts bankfull discharge and bankfull geometry for a given flow duration curve and upstream sediment supply, as well as other key input parameters such as characteristic slump block lifetime, which controls lateral channel migration rate. In addition, the model also describes the evolution process of bankfull characteristics. We make use of the model to predict the change in bankfull characteristics in response to variety of perturbations, such as change in sediment supply, change in bank vegetation type, and change in flow duration curve. We apply our model to the Minnesota River, MN, USA.