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The impact of hydrograph variability and frequency on the morphodynamics of gravel-bed rivers

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Hydromodification is the alteration of natural watershed hydrologic processes, which is known to change the way that water naturally enters watercourses. In the case of urbanization, this change has manifested through individual hydrograph characteristics (resulting in a decrease in duration and in the time-to-peak), as well as through the increase of the frequency of morphologically significant flood events. These hydrologic changes have been documented to impact the morphology of gravel-bed rivers, often resulting in channel degradation. However, the actual extent that urbanization changes bedload transport characteristics, which is known to be the most important driver of channel morphology, are not yet known.
A laboratory experiment was undertaken in a 0.5m gravel-bed flume with sediment feed using a single poorly sorted bimodal sediment mixture in order to evaluate the impacts of changing hydrograph characteristics and frequencies on bedload transport and bed morphology. The hydrograph characteristics and frequencies were derived from long term stream-gauge records of urbanizing gravel-bed watercourses. These records are long enough to therefore be representative of the actual relative changes of the hydrologic regime; from an unaltered to a highly hydromodified system. A series of four hydrologic scenarios were established, representing 10 years of morphologically significant discharge events for four different stages of urban land-use, and corresponding hydrologic regimes. Each scenario begins with the same initial conditions and is allowed to evolve naturally with each successive hydrograph. For each scenario, the hydrograph duration and unsteadiness were varied, while peak discharge remained constant for all scenarios. In addition, the number of hydrographs ranged from nine to 33 for the unaltered to the most hydromodified scenarios, respectively.
Discharge was measured constantly with a v-notch weir, and varied with a calibrated valve relationship. Bedload transport was measured by a bedload trap located at the channel outlet. Changes in morphology were assessed by a combination of high-resolution topography scans using a mini echo-sounder, in-situ surface grain-size samples and bed photographs. Changes in water surface profile were measured using a combination of ultrasonic sensors and rulers against the clear channel walls.
The results are analyzed by means of phase plots to infer differences in the expected hysteresis between rising and falling limbs of each hydrograph, caused by unsteadiness and shifts in frequency. The difference in cumulative transport between scenarios is also assessed. The surface texture and topography differences are assessed by changes in surface texture and in topography based on generated DEMs from the bed scans. The results of these experiments assist in further evaluating how gravel-bed rivers evolve with changing hydrologic regimes, which can be useful for evaluating changes to habitat, flooding or property loss corresponding to erosion. Additionally, the insights into the relative changes in sediment transport dynamics can be used to assist in stream rehabilitation projects with altered or nonstationary hydrologic regimes.