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Variables Controlling Cyclic Steps Formation and Evolution in the Loess Plateau, China

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Cyclic steps are long-wave bedforms that only migrate upstream and are sustained by internal hydraulic jumps. This type of bedform is ubiquitous in the Loess Plateau, China. We collect field data from two small basins in this region. The Wangmaogou basin is controlled by checkdams, while the Qiaogou basin has no downstream hydraulic control; however, both basins have channels with cyclic steps. In some areas of the Wangmaogou basin, check dams fail and a breaching flow creates a knickpoint incision. This knickpoint propogates upstream as a single cyclic step. However, in the Qiaogou basin, the main channel and adjacent tributary gullies include long trains of cyclic steps. In these channels, step height and slope generally increases upstream, as the main bed slope increases. Cyclic steps manifest in different ways in this domain and directly affect channel morphology and sediment production from the Loess Plateau uplands. The motivation of our study is to clarify the dominant factors of step formation and evolution.

We use a 1D morphodynamic model to study the formation and evolution of cyclic steps to answer these questions. Various scenarios with different initial conditions are considered to analyze the effect of dimensionless parameters, such as the initial bed slope and the resistance coefficient, on step formation and morphology. Our results show steps can only form under supercritical inflow conditions with at least an infinitesimal perturbation in the bed. Grain size and resistance coefficient are two key factors that control steps formation and evolution. The finer the sediment grain size, the slower the bed evolves, and the longer it takes to reach equilibrium. With a lower initial bed slope and a smaller bed resistance coefficient, we can obtain higher steps with a faster migrating rate. We also found that under certain circumstances, a single step can evolve into a series of steps. We analyze these examples to understand the dominant controls on step formation. We also estimate the future evolution of the channels in the Loess Plateau Uplands and postulate the changes to sediment production in the region.