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Morphodynamic stability and characteristic length scales of bifurcations and confluences loops

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The morphodynamics of multi-thread fluvial environments like braided and anastomosing rivers is fundamentally driven by the continuous concatenation of channel bifurcations and confluences, which govern the distribution of flow and sediment among the different branches that are reconnecting further downstream. Almost all studies performed to date consider the two processes separately, although they frequently appear as closely interconnected. In this work, we tackle the problem of analyzing the coupled morphodynamics of such bifurcation-confluence systems by studying the equilibrium and stability conditions of a channel loop, where flow splits into two secondary anabranches that rejoin after a prescribed distance. Through the formulation of a novel theoretical model for erodible bed confluences based on the momentum balance on two distinct control volumes, we show that the dominating anabranch (i.e. that carrying more water and sediment) is subject to an increase of the water surface elevation that is proportional to the square of the Froude number. This increase in water surface elevation tends to reduce the slope of the dominating branch, which produces a negative feedback that tends to stabilize the bifurcation-confluence system. A linear analysis of the coupled model reveals that the stabilizing effect of the confluence depends on the ratio between the length of the connecting channels and the average water depth, independently of the channel slope and Froude number. Furthermore, the effect of the confluence is potentially able to stabilize the channel loop in conditions where the classic stabilizing mechanism at the bifurcation (i.e. the topographical effect related to the gravitational pull on the sediment transport) is very weak, as expected when most of the sediment is transported in suspension. The identification of a characteristic length scale that produces a coupling between the confluences and bifurcations opens intriguing possibilities for interpreting the self-adjustment of the planform scale of natural multi-thread rivers.