Coherent structures and sediment entrainment mechanisms at river confluences

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River confluences are fundamental components of river networks that play an important role in regulating the movement of sediment through these networks. The convergence of flow induced by the configuration, or planform, of the two conjoining channels results in highly three-dimensional patterns of fluid motion and the production of large-scale coherent structures. The paper investigates the role played by these coherent structures and, in particular, by the quasi-2D eddies generated within the mixing interface and by the streamwise oriented vortical (SOV) cells forming in the vicinity of the mixing interface in sediment entrainment and the formation of the confluence scour hole. Analysis is performed based on Large Eddy Simulations conducted for a small river confluence with a concordant bed and with a high angle between the two incoming streams for different flow conditions (e.g., different momentum ratios). To extend the parameter range, additional simulations are performed for confluences with different planform geometries. Analysis of the vortical structure of the instantaneous and mean flow and of the corresponding bed friction velocity distributions allow clarifying the critical role played by large scale turbulence associated with the mixing interface eddies and the SOV cells, as well as by coherent structures generated by large-scale bank irregularities or high channel curvature on sediment entrainment mechanisms within the confluence hydrodynamic zone of the confluence. In particular, numerical results show that strongly coherent SOV cells are one of the main mechanisms for the growth of the confluence scour hole. The reason why SOV cells have a large capacity to entrain sediment is because their cores are subject to large-scale bimodal oscillations toward and away of the mixing interface, which greatly enhances the erosion capacity of these structures.