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Flow, form, and function: Distinguishing eco-hydraulic controls with relevance beyond the stream reach using synthetic channel morphologies

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Rivers are highly complex, dynamic systems that support numerous ecosystem functions including transporting sediment, modulating biogeochemical processes, and regulating habitat availability for native species. The extent and timing of these functions is largely controlled by the interplay of hydrologic dynamics (i.e. flow) and the shape and structure of the river channel (i.e. form). In spite of this, the majority of river restoration studies are limited to the influence of flow on ecosystem function without regard for the role of channel form in modulating eco-hydraulic response. The few studies that have effectively examined the flow-form interface highlight the scientific and management value of such analyses, but are highly resource intensive. This study represents a first attempt to apply synthetic channel design to the evaluation of river flow-form-function linkages, with the aim of improving basic understanding of how the interplay between flow and form affects ecosystem functions across a range of regionally-significant flows and forms with minimal resource requirements. Archetypal Mediterranean-montane channel types were used to guide the design of 3D synthetic morphologies. These morphologies were then used to quantify 2D eco-hydraulic response to different channel configurations under select hydrologic scenarios (distinguished by alteration and water year type). The eco-hydraulic performance of alternative flow-form settings, based on spatiotemporal patterns of depth and velocity, was evaluated with respect to a suite of river ecosystem functions related to geomorphic diversity, aquatic habitat, and riparian habitat. The methods described herein provide a potential design and inventory tool for quantifying river ecosystem functions and management trade-offs of alternative flow-form combinations with minimal resource and data requirements. While addressing specific scientific questions of interest for Mediterranean-montane rivers, the general framework outlined here could be readily extended to different regions and ecosystem functions to support large-scale river management efforts worldwide.