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Flow patterns, turbulence and hydraulic resistance in freshwater macrophyte stands

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Many unshaded lowland rivers are showing abundant aquatic vegetation growth in spring and summer. The presence of these aquatic plants (macrophytes) will affect river hydraulics as well as biochemical and ecological processes. In terms of hydraulics, the plants are acting as an obstruction to flow, increasing the hydraulic resistance of the river and reducing average flow velocities. Next to these large-scale effects, more complicated flow patterns are developed at the scale of individual macrophyte stands. In the present study flow velocity profiles, turbulence and roughness characteristics were determined for three morphologically different freshwater macrophyte species. In a race-track flume, monospecies macrophyte stands were exposed to three enforced flume velocities (0.05 m s^{-1}, 0.1 m s^{-1} and 0.3 m s^{-1}).

The results clearly demonstrate that plant morphology is a major factor determining the preferential flow paths in, over and around macrophyte stands. The observed interaction between flow and plant growth highlights some important similarities and dissimilarities between submerged, floating and emergent macrophytes. Also, the hydraulic resistance of a vegetated channel was found to vary among species and flow conditions. For flexible species, like *C. platycarpa* and *P. natans*, reconfiguration of the plants clearly affects the hydraulic resistance of the macrophyte stand. This

stresses that one should be extremely careful in extrapolating empirical relations. Furthermore, the research shows that the hydraulic characteristics of aquatic plants are influencing the dispersion of solutes and colloidal particles, as well as sedimentation and erosion processes. And in turn, these processes are determining surface water quality, river morphology and habitat development for invertebrates or fishes. Therefore, a sound understanding and quantification of the interaction between flow and macrophytes is important for sustainable river management in terms of water quantity, water quality, geomorphology and ecology.