CHARACTERIZATION OF BRANCHED WOODY VEGETATION FOR ESTIMATING FLOW RESISTANCE

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Vegetation is a key factor in the interrelated system of flow, sediment transport, and geomorphology in rivers (Tsujimoto 1999). Numerous studies into vegetal flow are based on laboratory experiments with simple artificial roughness, whereas in reality natural vegetation exhibits a wide variety of forms and flexibility. Though significant advances have been gained, the effects of vegetation on flow are still not fully understood.

This paper investigates the determination of flow resistance caused by branched woody vegetation. Emphasis is placed on assessing the difference between complex natural and simple artificial plants, as it has been reported that simple cylinder-based drag coefficient models are not adequate to cope with branched vegetation (Järvelä 2004). Several cylinder-based studies show that the element pattern significantly affects flow rates. However, more recent experiments with natural vegetation have revealed that different spacing for the same number of plants did not have a significant effect on the friction factor (Fathi-Moghadam and Kouwen 1997, Järvelä 2002).

Based on knowledge gained from flume studies with natural plants, a computational procedure for determining friction factor f or Manning's n for non-submerged leafless woody vegetation is discussed. The procedure uses sound hydraulic principles and measurable parameters of vegetation that are suitable for describing complex woody vegetation. Leafless vegetation is characterized by a bulk drag coefficient C_d and a characteristic plant diameter d_r computed from the projected area.

The projected area can be obtained using theory on mechanical design of trees. The fundamental idea in this theory developed by McMahon (1975) and McMahon and Kronauer (1976) is to apply the Strahler (1952) stream ordering scheme to trees. McMahon and Kronauer (1976) showed that the branching pattern within any tree species is approximately stationary, which means that the structure is self-similar. They presented three equations of branching, diameter, and length ratio that are based on the geomorphic laws of drainage network composition. In the present study, a new application for this knowledge is suggested, namely the determination of the projected area of a branched plant.

The branching, diameter, and length ratios as well as the average diameter of the smallest branches are defined as the plant structure parameters and can be estimated from literature or field measurements. A further three parameters are needed to describe a particular plant individual: the average diameter of the highest order (trunk), the plant height, and the length of the highest order. These three parameters can be easily determined in the field. Accordingly, the total projected area can be computed. To determine the projected area as a function of the plant height $A_p(h)$ it is approximated that the total projected area is linearly distributed over the height. However, if a particular height-area function is known, it can easily be incorporated in the computation. Finally, the friction factor can be computed by equation

$$f = \frac{4d_r h}{a_x a_y} C_d \tag{1}$$

where $d_r = A_p(h)/h$, h = flow depth, and a_x and a_y = the mean longitudinal and lateral distances, respectively, between the plants. Based on the literature review, it is assumed that $C_d = 1.5$ can be used as a base value in Eq. 1, which is analogous to the typically made assumption of $C_d = 1.0$ for cylinders. Even though the friction factor is preferred in this analysis, it can be easily converted to Manning's n by equation $n = (fR^{1/3}/8g)^{1/2}$.

The application of the procedure is limited to non-submerged flow condition, where the projected plant area does not significantly change with velocity. Such conditions are often found on low-gradient floodplains and wetlands. The procedure was evaluated by comparing predicted and measured friction factors for two patterns of leafless willows. The maximum errors were −16% and +18%, respectively (Järvelä 2004). The advantage of the procedure is that it is based on the physical laws and characteristics of vegetation, and it can be easily incorporated into numerical modelling applications.

Keywords: Hydraulics; Flow resistance; Vegetation; Rivers; Floodplains; Wetlands

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