

Deposition of sediment from suspension in emergent vegetation

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Abstract

Emergent instream vegetation influences the transport and deposition of suspended sediment in rivers, and hence their morphology and nutrient dynamics. An experimental laboratory study has shown how emergent vegetation stems promote sediment deposition. The suspended transport and the extent of longitudinal deposits from suspension within emergent stems is enhanced by increased flow depth and reduced by increased sediment grain size and stem density. The shear zone between longitudinal vegetation strips and adjacent unvegetated channel flow induces diffusion of sediment into the vegetated zone. The transverse extent of the resulting deposit is enhanced by increased flow depth and stem density, and reduced by increased sediment grain size. Values of sediment diffusivity for the two experimental situations were inferred by application of two-dimensional formulations of the diffusion-convection equation. These applications indicate that vertical diffusivity is considerably reduced and transverse diffusivity in the shear zone considerably increased by the stems.

Keywords: sediment deposition; suspended sediment; emergent vegetation; sediment diffusivity

Notation

- a projected plant area per unit volume
- a height above bed for reference concentration
- C suspended sediment concentration
- C_a reference level suspended sediment concentration
- C_d drag coefficient of stems
- d stem diameter
- D flow depth
- p probability of deposition
- s stem spacing
- u velocity in subscripted direction
- U mean flow velocity
- u_* shear velocity
- w settling velocity
- x longitudinal direction
- y vertical direction
- z transverse direction
- α scale factor in transverse diffusivity relationship
- β scale factor in transverse diffusivity relationship
- β proportionality between sediment diffusivity and eddy viscosity
- ε diffusivity in subscripted direction
- κ Von Karman constant
- ν eddy viscosity

Introduction

Vegetation is an integral feature of many rivers and has a strong influence on their physical and ecological functioning through its interaction with local hydraulics and sediment dynamics (James et al., 2001). The occurrence of instream vegetation is associated with the distribution of deposited sediment, which

is itself influenced by the vegetation through its effect on the local hydraulics and hence the movement, storage and stabilisation of sediment. The growth of vegetation is also determined by nutrient supply, which is associated at least in part with fine sediment. Effective environmental management of rivers therefore requires understanding of, and the ability to predict, the influence of vegetation on local hydraulics and sediment behaviour. In particular, quantitative descriptions are required of the ingress, movement and deposition of suspended sediment in vegetation stands.

The distribution of sediment concentration (C) in suspended transport may be described by the diffusion-convection equation (e.g. Graf, 1971):

$$\frac{\partial C}{\partial t} = -u_i \frac{\partial C}{\partial x_i} + \frac{\partial}{\partial x_i} \left(\varepsilon_i \frac{\partial C}{\partial x_i} \right) \quad (1)$$

where:

- t is time
- u_i are velocity components in directions x_i
- ε_i are the sediment diffusivities in the corresponding directions.

The rate of deposition at any location on the bed can be described by imposing the boundary condition (James, 1985):

$$\varepsilon_y \frac{\partial C}{\partial y} + (1-p)wC = 0 \quad (2)$$

where:

- y is the vertical direction
- w is the particle settling velocity (assumed to represent $-u_y$)
- p is the probability that a particle reaching the bed will be permanently deposited.

Solution of Eqs. (1) and (2) to predict sediment concentration and deposition distribution patterns requires knowledge of u_i and ε_i values. The most common application is for determination of longitudinal suspended sediment transport rates in unvegetated

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