Västilä, Kaisa; Järvelä, Juha

Floodplain vegetation controls on cohesive sediment transport: two-stage channel approach for improving water quality

Published: 01/01/2016

Please cite the original version:
Floodplain vegetation controls on cohesive sediment transport: two-stage channel approach for improving water quality

Kaisa Västilä* and Juha Järvelä

I. Two-stage channel approach

Vegetated two-stage (compound) channels (Fig. 1 b-c) have been proposed as an environmentally preferable alternative to simple trapezoidal channels (Fig. 1a) for drainage and flood management in catchments smaller than ~100 km² (e.g., USDA 2007). The two-stage profile provides flood conveyance and ecological benefits, including nutrient retention at specific conditions (e.g., Mahl et al. 2015).

Considering the transport of cohesive sediment and sediment-bound substances, two-stage channels may be aimed at either achieving a state of dynamic equilibrium or at improving water quality through floodplain deposition (e.g. Västilä et al. 2015b). However, there is little knowledge on the potential of two-stage channels for long-term net retention of suspended sediment (SS) and nutrients.

We examine (1) how the properties of floodplain plant stands control the net erosion and deposition of SS under real field conditions and (2) the potential of the two-stage approach for water quality improvements. A 3-year investigation was conducted in the cohesive Ritobäcken Brook (Finland) with a two-stage profile constructed in 2010 (Fig. 2). The data included SS loads at 5-min intervals upstream and downstream of a 190 m long study reach as well as annual cross-sectional development in 200 points in five differently vegetated (grassy, willows, bare) sub-reaches (Västilä et al. 2015b).

Figure 1. a) Trapezoidal cross-section, b) two-stage channel with floodplain on one side, c) two-stage channel with floodplain on both sides.

Figure 2. The two-stage (compound) study reach.

Figure 3. Definition of vegetative blockage factor.

II. Floodplain vegetation controls on cohesive sediment transport

The significance of different factors for explaining annual net retention of SS on the floodplain was examined using multiple regression analysis (Table 1). Based on previous observations, the selected factors included the cross-sectional vegetative blockage factor $B_V$ (Fig. 3), distance from the sediment supply point, and the flow velocity within floodplain vegetation ($u_V$). $u_V$ was modeled with the two-layer approach of Luhar & Nepf (2013) for foliated woody vegetation.

The regression model estimated satisfactorily the cross-sectional mean deposition ($r^2=0.71$, Fig. 4). Although the coefficients of the model are site-specific, the three explanatory factors are expected to govern deposition in other relatively straight vegetated compound channels as well. At the study site, erosion was found to be prevented by grassy vegetation with a height of ~10 cm.

Table 1. Regression model for net deposition on the floodplain: explanatory factors ($p<0.01$ for each), their effect on net deposition, and ways to improve retention.

<table>
<thead>
<tr>
<th>Explanatory factor</th>
<th>Effect on net deposition</th>
<th>Retention improved through</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetative blockage factor</td>
<td>+</td>
<td>Higher vegetation</td>
</tr>
<tr>
<td>Distance from sediment supply point</td>
<td>–</td>
<td>Partial mowing to improve SS supply to floodplain</td>
</tr>
<tr>
<td>Flow velocity within vegetation</td>
<td>–</td>
<td>Denser plant stands</td>
</tr>
</tbody>
</table>

Figure 4. Net deposition as measured and predicted by the regression model.

III. Implications for water quality

The regression model estimated satisfactorily the cross-sectional mean deposition ($r^2=0.71$, Fig. 4). Although the coefficients of the model are site-specific, the three explanatory factors are expected to govern deposition in other relatively straight vegetated compound channels as well. At the study site, erosion was found to be prevented by grassy vegetation with a height of ~10 cm.

Table 1 indicates how the two-stage approach allows managing the transport of fine particulate matter through suitable maintenance of floodplain vegetation. According to the two-year mass balance, 5.5% of the total SS load was deposited on the 190 m long floodplain, thus improving water quality. Suspended sediment concentration was very strongly correlated with total phosphorus concentration (Västilä et al. 2015a), and thus there was likely annual net retention of phosphorus as well. Fig. 5 summarizes the key observations of the two-stage design regarding water quality.

Figure 5. Central considerations related to the potential of two-stage channels for improving water quality.

IV. Future work

Further investigations at two-stage field sites and in laboratory flumes are planned to improve understanding of the hydrodynamic transfer processes occurring at the interfaces between flexible floodplain vegetation and open water. This knowledge contributes to the design and maintenance of two-stage channels by revealing how the retention and release of nutrients and harmful substances can be controlled with the help of natural vegetation.

References:

*Contacts:
- kaisa.vastila@aalto.fi
- Post-doctoral Researcher

Acknowledgements: Financial support was received from the Academy of Finland and Maa- ja vesiteknikainstituutti. Help from the laboratory personnel at Aalto Water Engineering is acknowledged.