Closure of “Trapping Large Wood Debris in Rivers: Experimental Study of Novel Debris Retention System”

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The discussers have raised three questions, all fundamentally related to the application of the proposed debris retention system in practice. In the closure of the discussion to this paper, the authors have responded to these questions by structuring their thoughts into the same three categories as opted by the discussers, namely: field application, sustainability, and driftwood in natural systems.

Field application

The discussers query the performance of the retention system in the field where debris is composed of a range of material (e.g., plastics, plant material) beyond the logs tested in the flume. This aspect was considered in the design of the flume experiments, which were presented in Panici and Kripakaran (2021). The underlining principle of the large wood debris (LWD) trapping system described in this paper is to retain only large wood while allowing all small elements to pass through. Diehl (1997) and Panici and de Almeida (2018) reported that LWD jams are typically initiated by large elements that subsequently trap other smaller debris,

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eventually forming a LWD jam. For the system presented in Panici and Kripakaran (2021), the spacing of the mesh can be adjusted to allow small floating objects (e.g., plastic) to pass through while trapping LWD, e.g., by setting the mesh opening size according to the design diameter of expected LWD in the river; this may require further investigations (either experimental or at full-scale). As the LWD accumulation develops at the retention system, it is however bound to increasingly trap smaller floating objects, although sediment transport may not be affected until the accumulation extends closer to the bed.

The authors recommend adopting the highest tested angle α (= 45°) and a width S spanning half-channel on either side – corresponding to a structure of type C in Panici and Kripakaran (2021), to simultaneously minimise afflux (i.e., increase of upstream water level) and maximise efficiency. Experimental tests also showed that afflux will depend on the volume of LWD trapped by the system and the Froude number (Fr). Therefore, its estimation can be carried out according to the following steps:

1. Determine the design LWD volume expected during an event (e.g., a flood).
2. Estimate the volume of trapped LWD based on the efficiency of the chosen retention system and the design LWD volume.
3. Estimate the accumulation factor A_F defined in Panici and Kripakaran (2021).
4. Assess the backwater increase by using equation (6) in Panici and Kripakaran (2021).

The model of the retention system used in the experiments blocked less than 10% of the flow cross-section. This is not expected to increase in full-scale applications. However, if a feasible structural design of the system necessitates increasing the blocked area, the afflux may also increase. On the other hand, the afflux increase due to LWD blockages will be minimal since the flow cross-section area blocked by LWD is significantly larger than that blocked by the structural frame of the retention system, and the accumulated LWD also offsets the area of the frame that it covers.

While the authors did not measure the vertical depth of LWD blockage in Panici and Kripakaran (2021), this was observed to never reach the flume bed. Although average flow depths of lowland rivers can be shallower than those simulated in Panici and Kripakaran (2021), the system design would still work for flood conditions, when flow is likely to be subcritical and having high depth. This is also the condition when the majority of LWD is transported (Diehl, 1997). The height of the trapping system can be chosen to trap LWD elements up to a chosen flood peak level (e.g., 100 years return period), including additional out-of-water height to accommodate floating LWD at the water surface.

Sustainability

The design of the LWD trapping system, specifically the spacing between the two racks, can be adjusted to allow recreational use of the river. However certain risks can be prevalent such as canoeists getting trapped at the structure, canoeists and swimmers getting injured by LWD or structural elements, walkers attempting to climb the structure or the accumulated LWD and falling into the river. Since these risks are very similar to those identified for weirs and in the UK (Rickard et al., 2003), risk mitigation measures could be similar. For example, warning signs (highly visible and clearly outlining the danger) would advise canoers of the forthcoming hazards. These signs will need to follow the local navigation authority guidance. Fencing will also be an effective means of preventing walkers to get near the structure on the riverbanks.

Routine maintenance and LWD removal will ensure that no invisible submerged spurs (e.g., from trapped LWD) can cause harm to recreational users.

Typical locations for the trapping system installation are in the upstream reach of affected structures, in between the bridge and any potential source of LWD recruitment (e.g., forested areas). Since the system has been tested for *Fr* in the range 0.143-0.426, full-scale applications should be employed under similar conditions to ensure model-prototype similarity. The values of *Fr* used in the experimental work are typical of lowland rivers, and so results may not be directly applicable for mountainous catchments or very fast-flowing streams.

The removal of collected LWD and other debris will need to be included in a routine trapping system maintenance and management plan. For medium-sized rivers (e.g., the majority of lowland European streams), access and operations may be executed from the banks where access to workforce and machineries is possible. This solution would be substantially less disruptive and expensive than removal of LWD in emergency situations and at bridge piers where access could only occur from the bridge itself. However, for large rivers this solution may not be as cost-effective. Sediment transport was not tested in the study, but it is expected that disruption would be minimal, since no blockage from the system is expected at riverbed level. Also, accumulated LWD during a flood would alter sediment transport, but this can be restored to normal conditions (after LWD removal) by the river natural processes.

LWD release in post-flood event is possible as long as it can provide a positive impact in the downstream reach. LWD elements are known to be transported in well-defined areas of the river channel (Panici, 2021), so careful release of LWD can be used to create engineered LWD for stabilizing river channels, restore natural river processes and mitigate flood peaks (Gurnell et al., 2019). It is also well-known that LWD will provide positive impact for aquatic habitat (Abbe and Montgomery, 1996, Lagasse et al., 2010) and it is common practice to reintroduce LWD for these purposes (Thomas and Nisbet, 2007). The only caveat to LWD release downstream of affected structures, is that this must not endanger downstream hydraulic structures; therefore, when other bridges or infrastructures are located shortly downstream of a river section protected by the LWD trapping system, reintroduction of LWD should not be encouraged.

Driftwood in Natural Systems

LWD has been shown to increase dramatically the risk of scour at bridge piers (Panici et al., 2020), with the maximum scour depth potentially increasing by a factor of two (Ebrahimi et al., 2020). LWD also poses other risks to bridges and other structures including damage from collisions and increased flood risk from accumulations, threatening human lives, and causing substantial direct and indirect costs (Lassettre and Kondolf, 2012). Lastly, an unprotected structure when clogged with LWD will potentially trap as many LWD elements as the trapping system analysed in this study, thus constituting a blockage to downstream LWD conveyance (and still being a hazard for the integrity of the structure).

The trapping systems are likely to be considered when the risks from LWD to bridges and its consequences outweigh significantly the benefits from allowing LWD transport through the bridges. This is in agreement with the framework suggested by Wohl et al. (2016), which recommends that mitigation measures be based on a balance of hazards and benefits.

Furthermore, while the proposed system limits the LWD input in the river reach between the retaining system and the hydraulic structure, continuity in wood transport can still be ensured by removing and releasing the collected LWD immediately after the protected structure. This may be a more reliable option than measures that encourage flow of LWD past structures (e.g., bridges), which have shown limited efficiency (e.g., Schalko et al., 2019) and consequently may also fail to protect structures from LWD-related actions.

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