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Hydrology and Earth System Sciences
Discussions

Interactive comment on "A conceptual model of check dam hydraulics for gully control" *by* C. Castillo et al.

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We would like to thank Referee 1 for the helpful comments. We have tried to address these questions in the following answers.

Comment 1: The manuscript is clearly written, straightforward and the story is easy to follow. The paper is technically sound and the methods are well described. This paper is an important contribution to our understanding of the effects of check dams on hydrological processes occurring in the gullies. It is one of the more comprehensive attempts to quantify energy dissipation in a gully-check dam system. The authors present the location of hydrologic jump as one of the key factor in determining dam spacing. This location is subject to change depending on discharge, potential silting of

inter-dam spaces and changes in roughness. Hence the planner must take most conservative approach ensuring hydraulic jump occurs at the toe of the dam regardless. Further, a straightforward rule for check dam spacing in the field is then proposed to be "head-to-toe rule". Did we come full circle? Wasn't it one of the most common criteria found in the literature all along with some variations (Heede, 1978) referred to in the Introduction?

Author's answer: It may seem paradoxical that after the hydraulic analysis carried out in this work the authors propose a design criterion coincidental with the simplest rule given in the literature for check dam spacing. Firstly, it's worth noting that the head-to-toe rule, yet the simplest, it is not the most frequent recommendation in technical books. The head-to-toe rule was probably the most common criteria in the past, for instance, when an extensive programme of public works was carried in the US during the'30s in the 20th century, judging by the examples provided by Heede (1960) where he argued that this rule might lead to overdesign. Instead, in many of the most recent and well-known manuals or technical papers on soil conservation (Morgan, Coppin and Richards, Heede) this requirement is made less stringent by applying coefficients to increase the spacing up to 50%.

This might be a tempting alternative in the design stage since it leads to a substantial reduction in construction expenses if designers are unaware of the potential hydraulic implications of that decision. Our findings highlight that c close to 1 (the equivalent to the classical head-to-toe criterion) is required for an effective control of the hydraulic jump. Therefore, flexibility in the application of the criterion is not recommended unless further evidence is provided to support this decision. Secondly, to our knowledge, there are no previous studies attempting to explain the rationale behind the supposed efficiency of the head-to-toe criterion. In our work we attempt to contribute to the understanding of the basic hydraulics underlying the patterns of energy dissipation in this situation not only for academics but also for stakeholders with technical background involved in gully control and restoration. For both audiences, not only the design criterion

is important, but also the reasons why it is so significant.

Comment 2: In the Discussion the authors suggest that fine gully sediments in agricultural setting might lead to almost horizontal slopes with shear stresses below the critical value. Based on the literature and experience I have never found this (horizontal depositional areas) to be the case regardless of the settings. Could this conclusion be the result of the simplifying assumptions made in the paper? Namely, the channels are straight and rectangular. Does the complexity of the natural channel accounts for the difference between this hypothesis and empirical observations?

Author's answer: In the discussion section we commented on the application of the ultimate slope criterion in check dam spacing for fine textured sediments in agricultural areas. In this case and for that method, the calculated critical shear stress might be so low that could lead to negligible ultimate slopes closer to the horizontal. Therefore, the authors were referring to a particular method for design, rather than to the situations that might be found in actual gullies. So, we do not predict horizontal ultimate slopes in real situations, but recommend assuming horizontal slopes in check dam design for stability purposes in the long-term.

We agree with the reviewer that many experiences show us that non-horizontal sediment wedges occur in restored gullies. Striking facts have also been reported, such as partial burying of upstream dams, as mentioned in the discussion. Our approach was not focused on the stability of the sediment wedge when uniform flow is assumed, but on the main dissipation processes occurring in a varied flow within the restored gully in terms of check dam design. In many occasions check dam damage or collapse have taken place in settings where an apparent ultimate slope was previously established (e.g. Iroume and Gayoso, 1991). Cycles of degradation and aggradation might take place along the sediment wedge throughout the life of the structure (e.g. Castillo et al., 2007) and if degradation is dominant at a certain point, fatal failures may occur. Hydraulic jump is a major dissipative process and, consequently, its location and characteristics should be taken into account and, if possible, controlled. Moreover, when

the hydraulic jump is forced to occur at the toe of the check dam, the flow remains subcritical along the channel, minimizing the risk of erosion at the sediment wedge. We recognize the limitations of this work since only straight rectangular channels were considered. As stated in the manuscript, further studies based on more realistic situations are required. Nevertheless, we believe that our approach is a significant step in that direction, since it allows a clearer and comprehensive understanding of the basic processes involved in check dam hydraulics.

Following the reviewer's suggestions, we will include a clarification of these aspects in the introduction and discussion sections of the revised manuscript.

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