

## ***Interactive comment on “Creating a catchment perspective for river restoration” by L. Benda et al.***

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Author responses to Anonymous Referee #1 (referenced by manuscript page and line number. Please refer to Referee's comments, as referenced by manuscript page and line number.

In summary, almost all comments, corrections and suggestions made by the Anonymous Referees have been accepted and incorporated into a revised manuscript. Specific responses are located below. In a few instances, the authors and or one of the editors of the special HESS journal edition on river restoration disagreed with referee suggestions.

General Comment: Change the title, add more detail, too general. The title has been slightly modified: Creating a Catchment Scale Perspective for River Restoration. One

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of the editors to the special volume on river restoration wanted the title maintained as is.

General Comment: Delete Section 3. Section 3.0 was not deleted. An overview of hydro-geomorphic landforms and processes pertinent to river restoration will be of value to practitioners and planners involved with restoration. In addition, one of the editors to the special volume on river restoration indicated that this section should be kept in the paper. However, it has been slightly modified to increase clarity.

Specific Comments: Pg. 2931, line 6. The term 'biological' has been used to replace 'ecological' as suggested by the reviewer.

Pg. 2931, line 10. Reordered sequence of citations as suggested by the reviewer.

Pg. 2932, line 10. The word 'watershed' has been converted to 'catchment' as suggested by the reviewer.

Pg. 2932, line 16. Text has been revised to clarify the issue of elimination of evidence for the natural fluvial landscape and elimination of the landscape itself as suggested by the reviewer.

Pg. 2933, line 5. Reviewer comment accepted, added reference to Neolithic times in the Pas River basin.

Pg. 2933, line 8-13. Paragraph moved to Methods Section as suggested by the reviewer.

Pg. 2933, line 20. The term "landscape hotspot" has been eliminated from the paper.

Pg. 2934, line 12. Reviewer is correct, added text to clarify reference to minimum flow.

Pg.2934, lines 14-19. Revised plant names to singular as suggested by the reviewer.

Pg. 2934, line 17. Spelling of Q.petraea is corrected as indicated by the reviewer.

Pg. 2934, line 22. Used 'heath' instead of 'shrubs' as indicated by the reviewer.

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Pg. 2934, line 23. Corrected, as suggested by the reviewer.

Pg. 2934, line 24. Corrected reference to vegetation, as suggested by the reviewer.

Pg. 2934, line 25. Revised text to clarify the transition from willow to alder in human disturbed areas, as indicated by the reviewer.

Pg. 2934, line 27. Clarified what is meant by a 'controlled river environment'.

Pg. 2935, line 1. Clarified human occupation of the Pas River basin began 40,000 ybp as suggested by the reviewer.

Pg. 2935, line 6. Revised sentence about forest clearing for pastureland as indicated by the reviewer.

Pg. 2935, line 6. Changed 'iron industry' to 'smelting' as suggested by the reviewer.

Pg. 2935, line 8-11. Rephrased the description of human activities in the basin to distinguish between uplands (deforestation) and rivers (bridges, dikes etc.).

Pg. 2935. In addition to descriptions of fishes in the basin, we have added reference to invertebrates as suggested by the reviewer.

Pg. 2935, line 15. Made the correction as indicated by the reviewer: Ebro barbel (*Luciobarbus graellsii*).

Pg. 2935. Missing information indicated by the reviewer has been added: "Human population in the catchment reached 50986 inhabitants in 2010, although half of the population is concentrated in the river mouth. Thus, population density fluctuates from 165 habitants/km<sup>2</sup> in the coast to 10 habitants/km<sup>2</sup> in the upper parts of the catchment. The service sector is the most important economy sector in the low and middle part of the catchment, while the secondary and primary sector have a higher importance in the middle and higher part of the catchment, respectively. However, in the lower part of the catchment there are still more than a third of the bovine cattle in the catchment. This indicates that dairy farming is more intensive in the lower part of the catchment

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while less intensive cattle practices and a mix of cattle (dairy and meat) are found in the upper part of the catchment."

Pg. 2935, line 20 and following. The reviewer suggested eliminating Section 3 of the paper which provides a brief overview of landforms and processes relevant from a river restoration perspective and from our analysis of the catchment. One of the editors of the special volume on river restoration in HESS indicated that we should keep this section in the paper.

Pg. 2935, line 22. "Low terraces" are now defined as suggested by the reviewer.

Pg. 2936, line 4. The reference to 'valley geometry' as process versus landform has now been clarified.

Pg. 2936, line 7. The reference to 'fluvial environment' as process versus landform has now been clarified.

Pg. 2936, line 13. Revised description of valley transitions from constrained to unconstrained as suggested by the reviewer.

Pg. 2936, line 18. Revised description of valley transitions from constrained to unconstrained as it pertains to sediment deposition as suggested by the reviewer.

Pg. 2939, line 25. Added text to describe what channel attributes are available: "developing a synthetic, attributed (attributes include channel gradient, width, elevation, length)..."

Pg. 2940, line 6., Pg. 2940, line 8. Reference is now given to expanded descriptions of methods below where they are first introduced in the text in the Methods Section.

Pg. 2940, lines 20-24. Source of regressions for channel width and depth now clarified: "Bankfull channel width and depth were estimated using a regional regression of drainage area and mean annual precipitation to field-measured widths and depths over a range of channel sizes encompassing 195 river sites (selected in areas with little to

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no engineered works) in the region of Cantabria: bankfull width =  $1.683 \cdot \text{area}^{0.4365} \cdot \text{precipitation}^{0.4408}$ ; bankfull depth =  $0.63 \cdot \text{area}^{0.1731} \cdot \text{precipitation}^{0.1516}$

Pg. 2941, lines 4-9. New text has been added to explain the issue of resolution in measuring near channel valley surface elevations: "Estimated bankfull depths for the Pas River range from a little over 2 m at the mouth to a little over 1 m at the upstream extent of this analysis. We therefore delineate inundation depths between about 1 and 6 m. Because elevations above the channel are referenced to a nearby location on the channel, the extent of the delineated area is dependent on the degree to which local elevation differences can be resolved with the DEM, rather than on the absolute accuracy of the elevation values. We do not know the accuracy to which the available 5-m DEM in the Pas River can resolve these elevation differences, without field verification our results must be viewed as a testable hypothesis. Although the natural fluvial landscape contains floodplains, wetlands, off-channel water bodies and terraces the fluvial landscape depicted on the map figures correspond to valley floor elevations at one, two and three bankfull depths.

Pg. 2942, line 16. We have now replaced the relative erosion rate of 100 t/km<sup>2</sup>/yr with a rate of 1000 t/km<sup>2</sup>/yr based on the cited literature, as suggested by the reviewer: "Estimated sediment yield rates in northern Spain that includes the Pas River basin range between 500 and 1500 t/km<sup>2</sup>/yr (Cerdá, 2001, Rodríguez-Blanco, in press). Thus, we apply an sediment yield rate of 1000 t/km<sup>2</sup>/yr."

Pg. 2943 and following. Text within the Results Section has been edited in several locations to minimize confusion about river locations.

Pg. 2943, line 12 and Pg. 2943, line 13. The source of data in the regressions for channel width and depth is now contained within the paper: "Bankfull channel width and depth were estimated using a regional regression of drainage area and mean annual precipitation to field-measured widths and depths over a range of channel sizes encompassing 195 river sites (selected in areas with little to no engineered works) in

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the region of Cantabria."

Pg. 2943, line 19. The term in the paper "fluvial landscape" is defined in at least three separate areas within the paper.

Pg. 2944, lines 8-10. The paragraph has been moved to the Discussion as indicated by the reviewer.

Pg. 2946, lines 15-23. New text clarifies the consequences of tributary stream gradients in supply mainstem channels with materials.

Pg. 2948, lines 5-8. Paragraph moved to Discussion as indicated by the reviewer.

Pg. 2949, lines 19-22. Reworded the text as suggested by the reviewer.

Pg. 2948, lines 23-26. Sentences moved to the Discussion as indicated by the reviewer.

Pg. 2949, line 8 and following. The reviewer makes the suggestion of "avoid mentioning figure numbers in the Discussion". We are unclear what this comment refers to. Since the data in the paper as captured by the figures in the paper is what is being discussed in the Discussion section, we refer to the figure numbers as necessary.

Pg. 2951, lines 8-9. Text has been edited and clarified as suggested by the reviewer.

Pg. 2952, lines 9-18. We agree with the reviewer on this comment. The Methods section now contains a list of relevant parameters that would make a stream segment quality to become a restoration candidate, and these parameters are again mentioned in the Discussion section: "Our analysis is used to identify a provisional set of candidate channel-valley segments that would have the greatest potential for improving aquatic and riparian habitats through restoration. Candidate segments will have some combination of the following characteristics: wide floodplains (as depicted by valley floor elevations equivalent to one, two and three bankfull depths); significant tributary confluences; high spatial density of confluences; transitions in valley floor width (con-

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strained to unconstrained and vice versa); proximity to sources of sediment and organic material; and closely aligned, parallel running tributary-mainstem channels.”

Pg. 2955. The last section of the Discussion now contains additional text based on the recommendations of the reviewer: “Whether the candidate fluvial landscapes described above present restoration opportunities will require a clear planning process that links on the ground projects with desired ecological outcomes as well as field evaluation of relevant geomorphic and ecological criteria (Mika et al., 2010). In addition, analysis of restoration opportunities must consider socio-economic constraints, a topic beyond the scope of this paper. At a minimum, restoration activities would be constrained by land use and ownership, such as urban versus agricultural areas. A catchment scale context for restoration planning could enhance existing restoration programs in the Pas River catchment (Pas Water Authority). Restoration efforts aimed at reconnecting channels with their larger fluvial landscape should also contain a monitoring component (Pasquale et al. 2011).”

Pg. 2956. Rewrote the Conclusions Section based on the recommendation of the reviewer: “In this paper we present a new and innovative approach for creating a catchment scale perspective for river restoration planning. We combined new computer tools (NetMap, [www.netmaptools.org](http://www.netmaptools.org), Benda et al. 2007, 2009) with high resolution digital elevation data to evaluate the meso-scale structure of fluvial landscapes in the Pas River catchment in northern Spain. Our analysis focused on four hydro-geomorphic landform attributes including 1) valley geometry, 2) river network structure, tributary confluences and material flux, 3) hillslope-fan/terrace forcing and 4) longitudinal profile controls on fluvial morphology. Valley floor surfaces were mapped according to elevation above the channel and proximity to key hydro-geomorphic landforms. The predicted natural fluvial landscape (containing channels, floodplains, off channel water bodies, wetlands and terraces) is spatially patchy and organized by catchment topography, river network structure and fan and terrace landforms. The present day fluvial landscape is constrained by numerous engineered structures (dikes, dams, levees,

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roads). Comparing the existing fluvial landscape with the predicted fluvial landscape indicates that about 15% of the natural fluvial landscape remains in the Pas River catchment. Our analysis was used to identify provisional candidate sites for restoration that would contain some combination of wide floodplains, significant tributary confluences, high density of confluences, valley transitions, proximity to sources of sediment and organic material, and closely aligned, parallel running tributary-mainstem channels. Our illustrative set of candidate restoration sites are grouped into four landform domains: 1) narrow valley-string of pearls, 2) broad valleys-complex floodplains, 3) confluence related areas and valley transitions, and 4) lower riverine-estuarine environments. Because of the remote sensed aspect of this illustrative study, field validation is required to check computer based predictions of the natural fluvial landscape as well as the potential for future restoration activities. Our analysis stems from a collaboration between the University of Cantabria, Sandander Spain (MARCE project and Earth Systems Institute ([web link](#))). NetMap is being applied to the northern one third of Spain and thus similar catchment scale perspectives for river restoration planning could be developed in other areas.”

Pg. 2956. References. We have added several of the citations suggested by the reviewer at appropriate locations in the paper.

Pg. 2962. The definition of “active channel” in Table 1 caption, as questioned by the reviewer, is contained within the manuscript, and it includes the low flow channel as well as any gravel bars or lightly vegetated floodplain surfaces. The percent reduction in surface area contained in Table 1 has now been removed to avoid confusion.

Pg. 2964. Reviewer recommends deleting Figure 2 because it is redundant with Figure 4. We agree and have deleted the figure.

Pg. 2965. Corrected figure caption as indicated by the reviewer.

Pg. 2968. The reviewer writes “why do the authors depict more channels in the general map than in the detailed portion” please make both maps identical. We believe the

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reviewer is referring to Figure 6, and if so, the more detailed portion that contains fewer channels is simply to illustrate the point being made about some steep tributary channels being associated with wider fluvial landscapes in the mainstem channel.

Pg. 2972 and 2973. The reviewer writes “Figures 10 and 11 are the direct result of the present work, they should be described in the Results section, not left for the discussion.” We disagree. The Discussion is where the results of our work are interpreted in the context of restoration planning, and hence Figures 10 and 11 describe candidate sites for river restoration.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 2929, 2011.