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Discussions

Interactive comment on "Hydrogeology of an alpine rockfall aquifer system and its role in flood attenuation and maintaining baseflow" *by* U. Lauber et al.

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Reply to comments of A.J. Long on the manuscript "Hydrogeology of an alpine rockfall aquifer system and its role in flood attenuation and maintaining baseflow" by U. Lauber et al.

Summary: This work is important because high-alpine areas are difficult to access, and therefore, any data or findings in such a study should be published. Also, high-alpine hydrological settings are particularly sensitive to climate change because of decreases in snowpack that feeds headwater streams. See my main comments below and minor

comments added as sticky notes in the supplement.

Reply: We thank A.J. Long for acknowledging the importance of this work and for his very useful and constructive comments that will contribute to further improve the manuscript. Most of the referees' remarks will be taken into account and we will perform the following changes:

General comments:

1) A more extensive literature review is needed to describe similar previous work in alpine catchments, especially those in similar environments, to show what is unique about this study and what new insights have been gained. The only such comparison described is a study of discharge ratios by one of the authors of this paper (Schmidt and Morche, 2006). It's important to communicate how this paper will advance hydrologic science in some way. The Introduction states that high-alpine catchment research remains incomplete because of poor accessibility; however, this statement is not well supported. But if this statement is true, then it won't be difficult to describe what is new in this paper.

Reply: The reviewer's remarks are reasonable. However, there is indeed not much literature available. Nevertheless, we will expand the literature review results of the study will be compared with previous work, as far as it is possible. The importance of this work, which highlights new aspects of drainage properties of a high-alpine catchment, will be presented in more detail.

2) Does the karst aquifer play an important role? The importance of the karst aquifer and associated conduit network is not discussed until page 6821. Two sentences allude to this but don't go into any detail (6821 lines 17-18, 25-26). It's not clear if this discussion applies only to the karst aquifer that feeds the karst spring GS-RU, or if it also might apply to the karst that underlies the alluvial/rockfall aquifers, which might be hydraulically connected. If this aquifer seems to have a well-developed conduit network, then this should be discussed earlier in the paper.

Reply: Most of the system input comes from a major karst spring upstream from the alluvial/rockfall aquifers, but otherwise, there seems to be little direct interaction between these aquifers and the underlying and surrounding limestone. Therefore, the main focus of our paper is on the alluvial/rockfall aquifers. However, to address this fair review comment, we will better explain the role (or non-role) of the karst aquifer at several places in our paper.

3) Tracer test – It wasn't totally clear that breakthrough curves for SP-R2 and SP-R3 might be mostly surface-water flow before 75 h until I read it a few times. Along with a little more explanation in the text, it would be helpful show on fig 7 which parts of the curves represent all groundwater flow and which parts represent mostly surface-water flow. Also, the secondary peaks representing subsurface flow are small, and each spring has only one sample to identify the peak. So, is the peak magnitude larger than measurement error? My guess is that the peaks are real because there seems to be very little noise in the overall breakthrough curves. Also, the peak in the downstream site is lagged behind the upstream site, which might tell us about groundwater velocity between the two springs.

Reply: The reviewer is right. We will give more explanation in the text to clarify which part of the breakthrough curves is related to surface flow. The measurement error of the spectro-fluorimeter is < 0.1 μg/L and thus smaller than the magnitude of the peak. The increase of the concentration is from 0.6 μg/L to 1.5 μg/L. Furthermore, the peak was detected at the two sampling points and the time lag of the peak downstream is reasonable. We therefore conclude that the observed peaks are real.

4) A plot or table of recession coefficients for the 15 events for GS-RU and GS-RD (6821 lines 21-23) would be useful and would help support the discussion that follows. Box plots might effectively show the difference between the two sites. Also, with 15 values it might be helpful to report the mean, median, and standard deviation of recession coefficients, or just show the data spread with box plots. Some discussion of the differences between the karst and alluvial/rockfall aquifers is presented, but this

could be expanded a little. A more thorough comparison of metrics for GS-RU (karst) and GSRD (alluvial/rockfall) would quantify differences in karst versus alluvial/rockfall aquifers. This comparison could be used to better show that the alluvial/rockfall system is a much better flood buffer that the karst. Also, are there other karst alpine catchments that don't have this buffer and are more susceptible to flooding? This is one idea to help you describe the importance of this study area in the broader context, if possible.

Reply: We thank the reviewer for the helpful suggestions. We will provide a graph with box plots that illustrate the differences between the two sites. This will help to better present the different discharge characteristics of the two aquifers. Furthermore, we will add a paragraph in the results section, where we discuss the observed differences between the karst and the alluvial/rockfall system.

5) There are a lot of discharge metrics listed in the supplement. Are there any scatter plots of these data to help illustrate what is being described in the "Discharge characteristics" section? When you try plotting data in as many ways as you can think of, you often see interesting data relations that weren't previously apparent. Some of these plots might be useful for the paper (or the supplementary information) and might strengthen your conclusions.

Reply: We will implement the reviewer′s remarks and provide two graphs in the manuscript and further graphs in the supplementary material to better illustrate data relations. We will refer to the different data relations in new paragraphs in the results section and in the conclusions.

6) In the Conclusions, I would like to see a better discussion of the how the main findings of the research come together to tell us something new about a high-alpine valley system. For example, I don't see anything about how the tracer data fit with the flow data and what conclusions can be drawn from the combined results.

Reply: According to the reviewer′s comment we will improve the conclusions. Results of the tracer tests and comparative results between the karst and the alluvial/rockfall aquifer will be added in the last paragraphs.

7) Word use – The word “dampening” describes making something wet. You probably want to use the word “damping” or “damped,” which describe a decrease in amplitude of a wave or oscillation.

Reply: Revisions will be made.

8) Fig 6 – The two alluvial plains and the two rockfall deposits are sitting on top of something that looks similar but is not labeled. What is this material overlying the karst aquifer? What are the dashed lines?

Reply: Indeed, a legend for this figure is missing and will be added in the revised manuscript.

Specific comments:

p. 6811 L. 24: Is this a fluorescent dye?

Reply: Information will be added.

p. 6812 L. 16 and 27: Please explain a little more.

Reply: A citation for the method and a short explanation will be added.

p. 6813 L. 12: What is this?

Reply: Information will be added.

p. 6813, L25-26: Are you reporting r and SE from Morche, or did you determine these yourself? Or did you get the equation from Morche?

Reply: Revisions will be made.

p. 6815, L13-14: Are you fitting alpha separately for the three different sections of the falling limb? Explain. It looks like alpha is fit to 2 sections (stormflow and baseflow) as described above and in Fig.10.

Reply: Yes, stormflow and baseflow recessions are fitted separately. We will add this information in the manuscript.

p. 6816, L 7-8: I don′t understand how this could increase the total discharge. To increase the discharge, you would need to add additional water to the system.

Reply: There is groundwater exfiltration into the river. More information will be added.

p. 6818, L. 6-8: What are the error bars on the concentrations? Is the rise real or measurement error?

Reply: Please note our comment above.

p. 6819, L.1 4: Explain intermediate storage. Apparently water is stored past your measurement period?

Reply: The tracer test indicate that some tracer is stored in the alluvial/rockfall system. Based on the recovery of 59% up to 40% of the tracer are withhold in the system and probably released in the following months, especially during periods of low-flow.

p. 6820, L. 25: Explain “impulse-response analysis”. Is this by curve fitting?

Reply: Revisions will be made.

p. 6820, L. 26: Average of the three responses?

Reply: Revisions will be made.

p. 6821, L. 13-15: Are there other examples that could be used for comparison?

Reply: More literature will be cited.

p. 6821, L 17: Everything has focused on the alluvial/rockfall deposits. So how does the karst affect things?

Reply: The reviewer’s remarks are reasonable. We will add more information in the revised manuscript to describe the importance of the karst aquifer in this aquifer system.

p. 6821, L. 26: This is the first mention of how the karst network is involved.

Reply: Please see our comments above. Revisions will be made and more information on the karst network will be added in the manuscript.

p. 6022. L. 11: What does it mean that storage processes are highest at low water levels?

Reply: Yes, this is our interpretation of the results. Infiltration into the alluvial/rockfall deposits is highest at low water levels (see Fig. 6). With increasing infiltration, more water is withhold in the aquifer system.

p. 6822, L. 21: Why moderate flood recession when flood buffering is low. I would think it would be rapid recession; i.e., flashy flood wave.

Reply: The reviewer is right. This fact needs more explanation. In comparison with other flood recession coefficients, the flood recession downstream from the alluvial/rockfall deposits can be described as moderate.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 6805, 2014.