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

Summary: The paper presents a very interesting and well described example for the hydrogeological characterization of an alpine rockfall aquifer. Some minor remarks are made that might contribute to better highlight the relevance of the assessed data.

Reply: We thank Michael Sinreich for his supportive comment and his remarks that will contribute to further improve the manuscript. We will gladly take his comments into

consideration. Here are our answers to his specific comments:

Tracer test conditions and results could be described in more detail, in particular those aspects from which major conclusions are inferred. Since sampling density during peak time is low, tracer recovery calculation strongly depends from only one or few sampling points. This uncertainty should be considered when using high recovery rate as reference for storage capacity. Has any tracer remobilization been observed during floods within the 3-week sampling period that would confirm the storage hypothesis?

Reply: Indeed, sampling density and SP-1 and SP-2 during main tracer breakthrough is low, which of course can have an influence on the recovery. However, the main breakthrough at SP-3 is well documented with samples and the total recovery of 60 % the tracer was calculated from this sampling station. So, in our opinion, the total recovery of tracer is well supported. However, a microbial decay or decay under sunlight at surface flow path might influence the recovery as well. We will include those aspects into the discussion of the recovery and the storage capacity, respectively.

While the main peaks of SP-R2 and SP-R3 are due to surface flow (which indeed doesn't become very clear from the text), the identified second peaks are associated with subsurface flow arrival. As they are represented by only one single measurement each, particular caution should be exercised for interpretation. Not only the measurement error of the apparatus determines the reliability of this data but rather possible variations in the background value. Fluorescence intensity at the Naphthionate's wavelength can easily be influenced by fluctuations in organic matter content and turbidity, respectively, if transitory conditions are met. It appears from Fig. 9 that there might be some small rainfall events having occurred following injection. How can be excluded that such hydraulic variations are responsible for a temporary increase of natural background, or tracer remobilisation within the rockfall aquifer, respectively. Has the evolution of background values been tested prior to the injection or over other flood events?

Reply: The reviewer′s remarks are reasonable. However, there is clear evidence that

the second peak of tracer is not influenced by fluctuations of organic matter and turbidity. The background values are as low as the values from the other samples and the fluorescence maximum is distinct (Please note the attached figure with the raw analysis data). Besides this, we will include a discussion about possible remobilization. Minor fluctuations in the tracer concentrations have been observed during the measurement period. However, we exclude a major remobilization of tracer, which would induce the strong concentration increase, because discharge at the two gauging stations had decreased gradually several days before and after that sample.

Have karst springs in the lower part of the valley, if any, been observed for tracer arrival in order to check potential drainage from the rockfall aquifer to the underlying karst aquifer?

Reply: There are few springs in the lower part of the valley, which have a low discharge of few L/s and emanate from quaternary sediments at the margins of the river bed. Those springs have been sampled, but no tracer had been found.

I did not manage to deduce from the manuscript if there occurred quasi steady-state conditions at which a water balance of the rockfall aquifer system could be established, including potential water loss to the karst aquifer.

Reply: A water balance of the rockfall aquifer system has been conducted in July 2011. It was found that discharge downstream the alluvial/rockfall aquifer (GS-RD) is higher than the amount of water infiltrating into the sediments (discharge from the karst spring GS-RU). Thus, water stored in the alluvial/rockfall system was probably released. A discharge from the karst aquifer into the alluvial/rockfall deposits is also possible. As the rapid glacial deepening of the valley inhibited the karstification of the limestone below the valley floor, there is no loss of water into the karst aquifer.

Is the time delay of floods purely an advective phenomenon or might some kind of Piston effect within the heterogeneous rockfall aquifer play a role?

Reply: Indeed, we did not mention this process, but Piston flow effects in the alluvial/rockfall deposits are likely to occur. We will take this process into consideration and add a note in the revised manuscript.

Do recession coefficients downstream the rockfall represent solely the emptying of the according reservoir, or to which extent could these values be influenced by the continuous input from the Partnach spring and thus by the characteristics of the karst aquifer.

Reply: The reviewers′ remarks are reasonable. The output signal is also influenced by the input signal from the karst aquifer. We will better explain the role (or non-role) of the karst aquifer at several places in our paper.

The reviewers have already mentioned the missing comparison with other studies within a same context. There are indeed only few studies available regarding this topic. For instance, we used a similar approach for characterizing the hydrogeological conditions of an alpine rockfall aquifer in the same region (Sinreich et al., 2002), obtaining information on flow velocity within the rockfall mass, recession coefficients of the draining spring, time delay of flood events, input-output discharge relationship as well as interaction with the underlying karst aquifer. It would be particularly interesting to compare the finding of both studies and to discuss similarities and differences in their results. Links to related studies would furthermore help to highlight the unique features of the present one.

Reply: We thank the reviewer for this helpful reference, which we will include in our discussion and compare the results with our findings.

Reference: Sinreich et al. (2002) Hydrogeologie einer alpinen Bergsturzmasse (Schwarzwassertal, Vorarlberg) [Hydrogeology of an alpine rockfall mass]. Beitr. z. Hydrogeologie, 53, 5-20.

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

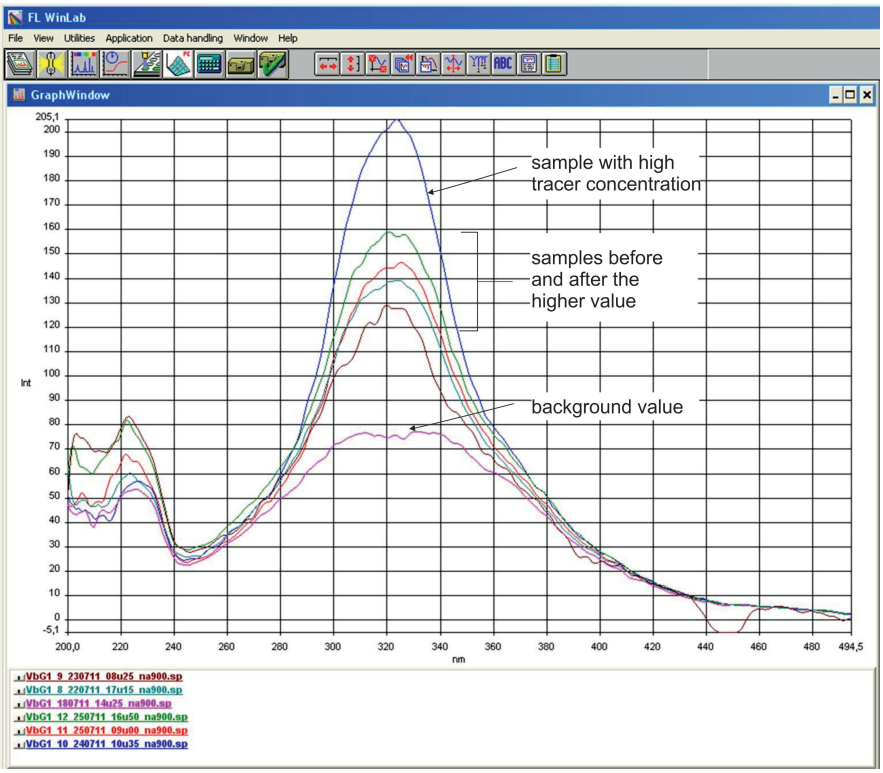
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Fig. 1.