20th August 2025

Dear Editor,

Thank you for your comments and monitoring the publication process of our manuscript.
Please find below (in blue) the updates that we made to the manuscript in response to the reviewer's comments, as well as some minor corrections to errors we found in the previous version of the manuscript.

Comment reviewer #1

Specific Comments

Page 3, Line 101-104: The claim seems to be that fast flow pathways are a key factor because streamflow reacted earlier than groundwater in 'about half of the events'. This raises the question if that is special compared to other catchments, or is this typical? And how does this relate to velocity (fast flow paths) vs celerity (earlier rise)?

We rewrote this part for greater clarity (line 101-109), following the answer below.

A quicker rise in streamflow compared to groundwater levels is indeed observed in many catchments and is not unique to our study area (e.g., Beiter et al., 2020). Generally, this is seen as an indication that other processes than groundwater flow or subsurface flow are responsible for the initial increase in streamflow during an event, such as precipitation falling on the channel or overland flow on near stream areas.

This observation refers to celerity, i.e., the speed at which a change in pressure or water level propagates, rather than velocity, which refers to the movement of water particles or solutes, since we are discussing timing of hydrograph responses (rather than tracer movement).

Page 6, Line 185-187: Do these statistics still hold when taking the duration of rainfall into account? If the return period of 24 mm/h over one hour is 1 to 2 years, the return period of a rainfall of 24 mm/h over 24 hours will be much higher. It would be helpful if you could include this information and discuss the possible implications.

We added additional information and the suggested comparison of the experiment for events with longer duration to the revised manuscript. Additionally, we found a mistake in the return period of the natural rain event with similar rainfall intensity than our experiments, and corrected this in the revised manuscript.

Page 10, Line 259: Please be more specific: how were the samples selected? Were not all samples analysed for all tracers?

Only for the Bromide and Deuterium were the samples analysed in the lab. Uranine concentrations and EC were measured continuously in the field using sensors at 1-minute intervals. Not all collected samples were analysed due to financial and time constraints. During the tracer experiments, we intentionally oversampled the breakthrough curve by collecting samples at one-minute to two-minute intervals for the first hour of sampling after tracer application (see Table 1). We analysed only part of the samples to determine whether a clear tracer breakthrough could be identified. As shown in Figures 6g and S1c-d, the breakthrough curves could be very well determined by these samples already. Analysis of the additional samples collected in between the selected samples would not have provided significant new information on the breakthrough curves.

We account for any discrepancies in the time of the arrival (1 minute max if we did not analyse the absolute first sample with an elevated concentration due to sample selection) in the 2-minute uncertainty used in the velocity calculations. In Table 1, we show more clearly which samples were selected for laboratory analysis. **We added this table to the supplementary material (Table S1).**

Table 1: Overview of the samples of overland flow (OF) and topsoil interflow (TIF) that were analysed for bromide and deuterium for the tracer experiments in the clearing and the grassland. The time of application of deuterium labelled water is indicated with grey shading. The time of application of NaBr is indicated with blue shading.

Clearing			**Grassland**		
Date and time	Overland flow	Topsoil interflow	Date and time	Overland flow	Topsoil interflow
2023-08-09 9:47		x	2023-11-08 14:04	x	x
2023-08-09 9:58	x		2023-11-08 14:20	x	x
2023-08-09 10:05		x	2023-11-08 14:21	x	
2023-08-09 10:12	x		2023-11-08 14:22	x	x
2023-08-09 12:02	x	x	2023-11-08 14:23	x	
2023-08-09 12:07	x	x	2023-11-08 14:24	x	x
2023-08-09 12:08			2023-11-08 14:25	x	
2023-08-09 12:10	x	x	2023-11-08 14:26	x	x
2023-08-09 12:11	x		2023-11-08 14:27	x	
2023-08-09 12:12	x	x	2023-11-08 14:28	x	x
2023-08-09 12:13	x		2023-11-08 14:29	x	
2023-08-09 12:14	x	x	2023-11-08 14:30	x	x
2023-08-09 12:15	x		2023-11-08 14:32	x	x
2023-08-09 12:16	x	x	2023-11-08 14:34	x	x
2023-08-09 12:17	x		2023-11-08 14:36	x	x
2023-08-09 12:18	x	x	2023-11-08 14:37		
2023-08-09 12:19	x		2023-11-08 14:38	x	x
2023-08-09 12:20	x	x	2023-11-08 14:40	x	x
2023-08-09 12:22	x	x	2023-11-08 14:42	x	x
2023-08-09 12:24	x	x	2023-11-08 14:44	x	x
2023-08-09 12:26	x	x	2023-11-08 14:46	x	x
2023-08-09 12:28	x	x	2023-11-08 14:48		x
2023-08-09 12:30	x	x	2023-11-08 14:50	x	x
2023-08-09 12:32	x	x	2023-11-08 14:54	x	x
2023-08-09 12:34	x	x	2023-11-08 14:58	x	x
2023-08-09 12:36	x	x	2023-11-08 15:02	x	
2023-08-09 12:38		x	2023-11-08 15:06	x	x
2023-08-09 12:40	x	x	2023-11-08 15:10	x	x
2023-08-09 12:44	x	x	2023-11-08 15:14	x	x
2023-08-09 12:48	x	x	2023-11-08 15:18	x	x
2023-08-09 12:52	x	x	2023-11-08 15:20	x	
2023-08-09 12:56	x	x	2023-11-08 15:22		x
2023-08-09 13:00	x	x	2023-11-08 15:26		x
2023-08-09 13:04		x	2023-11-08 15:30	x	x
2023-08-09 13:08		x	2023-11-08 15:35		x

2023-08-09 13:10	x		2023-11-08 15:40	x	x
2023-08-09 13:12		x	2023-11-08 15:45		x
2023-08-09 13:16		x	2023-11-08 15:50	x	x
2023-08-09 13:20	x	x	2023-11-08 16:00	x	x
2023-08-09 13:25		x	2023-11-08 16:10	x	x
2023-08-09 13:30	x	x	2023-11-08 16:20	x	x
2023-08-09 13:35		x	2023-11-08 16:30	x	x
2023-08-09 13:40	x	x			
2023-08-09 13:50	x	x			
2023-08-09 14:00	x	x			
2023-08-09 14:10		x			
2023-08-09 14:15	x				
2023-08-09 14:20		x			
2023-08-09 14:30	x	x			
2023-08-09 14:40		x			
2023-08-09 14:45	x				
2023-08-09 14:50		x			
2023-08-09 15:00	x	x			
2023-08-09 15:10		x			
2023-08-09 15:20		x			
2023-08-09 15:30	x	x			
2023-08-09 15:40		x			
2023-08-09 15:45		x			
2023-08-09 16:00	x	x			
2023-08-09 16:15		x			
2023-08-09 16:30	x	x			
2023-08-09 16:45		x			
2023-08-09 17:00	x	x			
2023-08-09 17:25		x			
2023-08-09 17:35	x				
2023-08-09 17:55		x			
2023-08-09 18:05	x				
2023-08-09 18:15		x			
2023-08-09 18:48		x			
2023-08-09 19:00	x				
2023-08-09 21:00	x				
2023-08-09 23:00	x				
2023-08-10 1:00	x				
2023-08-10 3:00	x				
2023-08-10 5:00	x				
2023-08-10 7:00	x				

2023-08-10 9:00	x				
2023-08-10 10:50	x	x			
2023-08-10 11:50		x			
2023-08-10 13:17		x			

Page 12, Line 341: where did the remaining third of the water go?

In the revised manuscript, we added an explanation of where the remaining third of the water likely went (line 355) following the answer below.

The runoff ratio was 20% for OF and 46% for TIF, indicating that we collected 66% of the water applied to the plot at the trench during the experiments. The remaining one third of the water might have either percolated in deeper soil layers or flowed laterally out of the plot as they were not bound (e.g. via the "blue dye" channel in clearing leaving the plot on the right-side Fig.8.a).

Page 15, Line 398: NaBr was applied to shallow piezometers. Did you observe any overflowing of these boreholes?

No update was made in the manuscript as we did not observe any overflow from the tubes.

Page 17, Table 5: Why are the velocity estimates from the Deuterium results not included here?

We did not update the manuscript regarding this comment due to the following answer below.

We did not include Deuterium in the velocity estimates as we applied the Deuterium-labelled water diffusely via the sprinklers. The application distance to the trench ranged from a few centimeters to several meters, which makes it difficult to define a single representative travel distance to calculate the particle velocity. Although we observed Deuterium breakthrough at the trenches, the uncertainty in the travel distance makes the derived velocity estimate not directly comparable to the tracers applied in a line at a defined distance from the trench. For this reason, we chose not to include Deuterium in Table 5.

However, based on the observed first arrival times of deuterium at the trench and estimated travel distances between 0.5-10 m in the clearing and 0.5-7.5 m in the grassland, we can estimate a possible maximum velocity range of 8-150 m h^{-1} for OF and 3-50 m h^{-1} for TIF in the clearing and 10-150 m h^{-1} for OF and 4-56 m h^{-1} for TIF in the grassland.

Page 18, Line 445-454: Could you elaborate more on this topic? What does the incomplete recovery mean for your conclusions? Are the differences in tracer transport and recovery only because of the nature of the different flow paths, or are properties of the compounds also an explanation that needs to be considered. e. g, different adsorption characteristics?

We added information to the revised manuscript (line 628-637) following the answer below.

The tracers used in this study (NaBr, NaCl, Uranine, and Deuterium) are all commonly used in hydrological tracer experiments because they are generally considered to be conservative and exhibit minimal adsorption under typical soil conditions. In particular, the anions Br^- and Cl^-, as well as Deuterium, are well known for their low reactivity and high mobility in soils (e.g., Anderson et al., 2009; Feyen et al., 1999; Scaini et al., 2017; Tsuboyama et al., 1994; van Verseveld et al., 2017). While we cannot entirely rule out small differences in transport behavior among the tracers, we do not expect these to significantly influence the recovery for our experiments. The main reasons for incomplete recovery are: 1) a portion of the tracer likely remained in the soil, 2) lateral losses (as indicated by blue dye flow paths in Figure 8), 3) percolation into deeper flow paths that we could not capture in our collection systems, and 4) measurement uncertainties (e.g., in the flow rates).

Page 19, Table 6: Unfortunately, it is not fully clear what is shown here exactly. Is the recovery expressed cumulatively? Is it the percentage of the total applied mass, or only for the first tracer lines in the first columns? Please add explanation to the table caption. Maybe consider moving the last two sentences from the caption to the discussion.

We revised the caption of Table 6 and referred to the possible loss of tracer via the outflow in the revised manuscript in line 635.

Page 22, Line 564: Would this not require a similar velocity of transport at both sites to be a fair comparison?

We clarified this point in the revised manuscript (line 583-587) following the response below.

Our statement refers to the total mass of tracer recovered in TIF over the first 100 minutes of the experiments. This comparison focuses on the overall tracer recovery integrated over the 100-minute period. Of course, very different velocities would lead to very different tracer recoveries over a certain period but in this case the focus is on recovery and therefore the comparison is still valid. In fact, the point we aimed to emphasize here is that, despite lower TIF flow rates in the grassland (and higher contributions from overland flow), the amount of tracer reaching the TIF outlet was still similar to that in the clearing. This suggests that there is concentrated tracer transport through the subsurface occurring at the grassland plot.

Page 23, Line 594 - 601: how about ambient temperature? Water viscosity changes a lot with temperature, and that influences the flow velocity.

We acknowledged in the revised manuscript that the viscosity was different and contributed to the difference in the velocity (line 625 –629). We also added Figure S2 to the supplementary material.

Page 25, Line 604-635: This part of the discussion could be more elaborate. The OF velocity will be determined by slope and surface characteristics (roughness, infiltrability), which in turn will be determined by the types and states of vegetation and soil. Also, the temperature (viscosity of the water) and other experimental conditions like length of the flow paths also play a role. It is thus not only 'vegetated' vs 'bare' soil. Comparing mean (see below) velocities without normalizing for these factors is not really conclusive.

In the revised manuscript, we reformulated that part and added more information on the processes and how it could influence the velocity (line 642 – 678).

How were the velocities averaged? Arithmetic or harmonic mean? This also applies to the other average velocities reported here. Example: When the time that overland flow needs to travel a distance of 2 m would be 1 minute and 2 minutes, the average velocity would be 1.3333 m per minute (harmonic mean).

We decided to keep the arithmetic mean in the updated manuscript as we provide the data for the calculation of the harmonic mean.

How would the measured flow velocities compare with theoretical estimates, e.g., Gauckler-Manning-Strickler formula? Would you get realistic roughness values when inverting the formula?

No change was done in the manuscript as it was not possible to get realistic values from the Manning-Strickler formula (see answer reviewer I).

Page 26, Line 685: The data should be uploaded before publication. In fact, it would be helpful if they could be included in the review. Otherwise, chances are too high that this will never happen.

We have created the data to the WSL repository envidat.ch and provided a link to the dataset, that will be available soon (within a week), in the revised manuscript (line 738).

Minor Comments / Clarifications

Page 3, Line 103: What does 'close' mean, in m?

In the revised manuscript, we added that groundwater table depths in the catchment vary between 1.5 m and the soil surface (line 99).

Page 5, Line 125-127: Please be a bit clearer: 10 cm organic rich AND another horizon rich in organic with 30 cm thickness, or up to 30 cm depth? Would that be A and B horizon, or litter layer and A horizon, or something else?

We added a clear description of the horizon to the revised manuscript (line 130 – 138).

Page 5, Line 128: Figure S1 is not about roots

We made sure that every reference to a figure or a table in the text is correct.

Page 8, Table 3: Tracer volumes are given for Uranine and Deuterium - what were the masses? Please specify to align with the table header

In the revised manuscript, we changed the table header and provided clearer information regarding the amounts of applied tracers and solution volumes.

Page 18, Figure 7: Is this the from the Deuterium experiment? Please add more info to the caption.

We clarified this in the revised manuscript.

Page 20, Fig 8: These are great images. Perhaps make them a bit larger (page width)?

Thank you, we enlarged Figure 8 to the full-page size in the revised manuscript.

Page 22, Line 543: Does this refer to Deuterium labeled water? Please clarify.

We clarified this in the revised manuscript in line 560-562.

Page 22, Line 562: That could possibly be exfiltration from biomat flow, right?

We added information about the processes and highlighted that we collected both OF and biomat flow in the revised manuscript (line 580-585).

Page 22, Line 564 – Page 23, Line 566: This requires a little more explanation. Would that mean that concentrations were much higher with the lower flow rates?

We clarified this in the revised manuscript in line 583-587.

Page 24, Line 609: What does this flow rate should tell the reader? Isn't the surface area/wetted perimeter equally important?

We realize that this additional information is not important for the point that we want to make and instead of giving more information, we rewrote and shortened this sentence to avoid confusion (line 645).

Page 25, Line 642: Please clarify why the saturated and steady-state conditions would make comparisons difficult?

We rewrote the sentence and added arguments for greater clarity (line 684-687) following the answer below.

In the other studies, the authors need to account for vertical flow through the unsaturated zone and especially the change in storage in the soil during soil wetting. In contrast, our study was conducted during near-saturated, steady-state conditions where storage changes were minimal.

Page 25, Line 673: info that these are 'trenched' maybe more important than the width

We changed this sentence in the revised manuscript and mentioned trench in addition to the 8 m wide plots. We kept the 8 m wide here to indicate that the plots were relatively large.

Page 26, Line 680: maybe include a comment on the difference in OF and TIF velocities - both are fast, but also OF still is significantly faster

We rewrote sentences in the conclusion and added this information to the revised manuscript.

Technical Corrections

We corrected the following mistakes pointed out by reviewer #1 in the updated manuscript

Page 6, Line 160: “(see Gauthier et al. (2025))“ - Consider avoiding the double parentheses - check style guide

Page 10, Line 283: “h” - variables are set in italic, please check style guide – also variables elsewhere

Page 10, Line 270: “containing the 3 mg L-1 brilliant blue dye” – check wording/sentence structure

Page 10, Line 272: “tree” - typo

Page 10, Line 279: “was able to see” - check wording/sentence structure

Page 18, Line 450: “large” - Please check

Page 25, Line 651: Check sentence structure

Comment reviewer # 2

Specific Comments:

It seems that the mean intensity for experiments in clearing and grassland is quite different (Table 2). I would guess that might also impact the partitioning between OF and TIF, where high intensity for grassland will result in a higher OF. So, I am not sure which plays a bigger role, intensity or soil macropores.

No change was made to the manuscript according to the answer below.

Thank you for this pertinent comment. Indeed, a higher rainfall intensity can generate more OF, and this is probably part of the reason why we have such a difference. However, we have also monitored this location during natural rainfall events and have observed a similar distribution of OF and TIF, see table below. Thus, we do not think that the differences between the plots is mainly due to the differences in the rainfall intensity

Table 1: Runoff ratio of overland flow and topsoil interflow at the clearing and grassland locations under different natural rainfall events.

			Clearing		Grassland	
Date of rain event	Rain depth (mm)	Mean Intensity (mm/h)	OF runoff ratio (-)	TIF runoff ratio (-)	OF runoff ratio (-)	TIF runoff ratio (-)
2022-09-14	19.6	2.5	0.02	0.13	0.23	0.01
2022-09-16	50.6	2.0	0.45	0.57	0.81	0.00
2022-09-26	18.1	1.6	0.16	0.28	0.30	0.01
2022-10-01	33.6	2.0	0.29	0.40	0.54	0.01
2022-10-02	24.9	2.2	0.21	0.13	0.75	0.01
2022-10-08	6.3	0.9	-	-	0.17	0.00

Although we observe some variability in the runoff ratios from event to event, which are probably due to differences in antecedent moisture conditions, rain depth, intensity, the general trend supports our observation that most of the rain (simulated or not) turned into OF and not TIF.

Does that matter if two sprinklers contribute more total deuterium mass at the overlapped area (in the middle of Figure 3a)?

We modified the sprinkler area in Figure 3 in the revised manuscript as the overlapped area was small, see answer below.

We thank the reviewer for this comment. While Figure 3a may have given the impression of a substantial overlap, the actual area where the sprinklers intersected was small. Additionally, the sprinklers apply less water near the edges of the application area, which means that the overlapping zone likely received only slightly more water and tracer. In theory, the local additional application of deuterium and water could generate a local pulse of water or could cause ponding on the surface. However, we did not observe this, and all water infiltrated quickly into the soil. The extra pulse of water and deuterium may also lead to some more preferential flow which would lead to a faster breakthrough than for the other areas. However, we a) would expect this to average out when looking at the full application area and b) did not use the deuterium breakthrough curve to calculate the velocity due to the uncertainty in calculating the minimum distance to the trench.

How do you determine the first increase in the flow rate in Figure 5? I think there are flow rate up and down before and after the points you labelled. Why are the locations you labelled the response to the water pulse? Thank you.

Thank you for these comments. We explained more carefully how we selected the first responses of the water pulses in the revised manuscript.

It took me a long time to really understand what Figure 6 represents: I guess you can unify with NaCl/Uranine/Bromide using red lines, and only with deuterium with grey shading in Figure 6.

For greater consistency with Figure 4, we changed the grey lines to red lines and only used the grey shading to indicate the period of the deuterium application.

For Table 3, you can list the duration of each tracer experiment and their start time if possible.

No change was made to the manuscript according to the below answer.

The tracer applications were 'instantaneous' (i.e., within a minute (see Line 218), except for the deuterium applications, which took 30 minutes in the clearing and 17 minutes in the grassland **(see Lines 238-240)**. The actual application times are indicated with red lines and gray shading in figures 4 and 6. The duration of the experiments is given in Table 2. The actual start time of the tracer applications during the day seems fairly irrelevant and we thus prefer to not include this information in Table 3 to avoid that it looks very cluttered. The actual times are however, indicated in the datasets.

Also, if possible, add a table for sample collections and collection intervals.

We added a table with the details about the samples which were analysed for bromide and deuterium to the supplementary material (Table S1).

Updates from personal mistakes

We have updated some figures, tables, and typographical errors that we found in the text to improve the clarity and the correctness of the manuscript.
We have corrected the return period of the natural events with similar rainfall intensity to the experiment, after noticing an error thanks to the comment of reviewer #1. We also corrected the percentage of the deuterium-enriched water that we used for the tracer experiments.
These revisions result in minor changes and do not affect the significance or interpretation of the results.