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Discussions

Interactive comment on "True colors – changing perceptions of hydrological processes at a hillslope prone to slide" *by* P. Schneider et al.

P. Schneider et al.

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→ We thank the referee for the detailed comments and suggestions. Pleases find our response to the comments below.

Referee #2

This article describes the flow processes on a pre-alpine hillslope in Switzerland, based on a large field rainfall-infiltration experiment. It is an interesting example of a hillslope where hydrological processes were studied in detail. The description of vertical preferential infiltration with limited lateral flow in depth, which result in a pressure increase and are here hypothesized to be the origin of shallow landsliding, clearly changes the perceptions of the authors on the flow processes in this particular hillslope.

1. However I think it is not a really new theory (see for example Krzeminska et al. in HESS where the influence of orientation and connectivity of fissures in a landslide was studied with a modeling exercise), so I think the title should be adapted as it seems to be promising a completely new idea.

→ Reply: We see the point of the referee concerning the title and we will change the title accordingly to "True colors – experimental identification of hydrological processes at a hillslope prone to slide".

2. I do not agree with the conclusion that lateral subsurface flow in the subsoil does not exist.

→ Reply: We state that lateral subsurface flow in deeper soil horizons (Go and Gr) could not be identified during the three experiments (2x sprinkling, 1x brilliant blue), which were conducted at the Rufiberg. However, we consider lateral 'subsurface stormflow' (SSF) in the H horizon (= 'organic layer interflow') as the dominant runoff mechanism for rainfall intensities of up to 20 mm/h at the Rufiberg. As we have found no indication for lateral subsurface flow in the subsoil, we see no need to speculate about runoff formation mechanisms, which could not be identified. In terms of a 'hypothetical' deeper drainage system at the Rufiberg it is important to recognize that the hillslope (i) drains only during or shortly after storms, (ii) that the hillslope is characterized by an absence of continuous surface flows (springs, creeks, etc.) despite its humid climate, and (iii) that the deeper soil layers are permanently saturated (Gr) or near saturation (Go) throughout the year. This supports our findings, that the deeper soil layers are not drained by an efficient preferential flow system.

3. The conclusions about the flow processes sometimes confuse me: it seems to me that the initial soil conditions are very near saturation and during the first stages of sprinkling the soil becomes more or less saturated at the different depths of SMC measurements.

→ Reply: Only the deeper soil horizons Gr and Go are permanently saturated or near saturation, respectively, which indicates the strongly reduced drainage even at steep slopes (we measure persistent GW levels at some GW monitoring wells). In contrast, the H horizon is rather well drained (low compaction, high porosity, high density of macropores and root-channels, steep gradient of up to 35°) and the grass roots may evaporate soil moisture of the H horizon (and the top of the Go horizon) efficiently. Consequently, the antecedent soil moisture conditions in the topsoil are expected to be relatively low compared to the Go and Gr horizons, but may very seasonally (snowmelt in spring vs summer evaporation). This is reflected in the 'total rainfall' threshold values for the onset of runoff at the Rufiberg ranging from 9-21 mm (see table 1).

4. Based on the dye-stained profiles I would think that the difference between initial SMC and saturation are mainly the macropores through which the water infiltrated preferentially into the greater depths, while the surrounding soil matrix was already almost saturated. Therefore I would not expect much interaction from macropores to matrix, as there is not much place in the soil matrix for the water to go, when the matrix is already almost saturated.

→ Reply: We fully agree with this interpretation – in fact, this is strongly supported by the brilliant blue experiment. We will add a sentence to the manuscript to specify that in more detail.

5. The authors say that these preferential flow paths do not drain laterally. It is well known that lateral flow in soils often decreases with depth as is the case here. The drainage of the 0.25-1.0 m layer shows that there must be some lateral rapid drainage of these vertical preferential flow paths: the subsurface flow in this layer reacts quite quickly to the beginning and the end of the rainfall experiment and the measured conductivity of the deeper layers as referred to in the article by Brönnimann et al 2013 (which is probably more representative for the matrix) is far too low to produce such drainage, so it must be connected macropores.

→ Reply: Our brilliant blue experiment illustrates that the lateral drainage is domi-

nated by 'organic layer interflow', a form of (preferential) 'subsurface stormflow' (SSF) located in the H horizon. The flowpaths into the deeper soil drainages at 0.25 m and 1 m depth were clearly labeled by brilliant blue staining in the organic layer, which then vertically percolated towards the drainages along the old/refilled trench-walls (these artificial preferential pathways were created when the drainage pipes where installed and a 10 m long, 1.2 m deep trench had to be excavated). However, we could not identify a single lateral stained structure over the entire 10 m length/width of the drainage pipes, which connected to the drainages in the subsoil.

6. As this is probably outflow of only the connected system of macropores and the matrix holds the water quite strongly, then it is interesting to think about this system a bit more: these deeper macroporous structures generally ensure that even though the matrix conductivities are extremely low, enough water can infiltrate into the soil and gets distributed throughout the soil profile and then when the soil gets almost saturated these connected pores under normal rainfall conditions can drain laterally fast enough to ensure that the pore pressure does not rise too high as it is the macropore system over the first meter of soil depth which drains. Only in the occasion where the initial soil moisture content is already very high and the rainfall intensity and duration is really extreme, then the capacity of these macropores for infiltration and lateral drainage may not be enough and pressure may build up.

→ Reply: We did not find evidence for lateral drainage of the deeper soil horizons (although we were explicitly looking for such a deeper preferential flow system), as illustrated with our brilliant blue experiment, which aimed to label the transition from vertical percolation into lateral drainage (subsurface flow). Furthermore, the Gr horizon would quickly loose it's greyish color when efficiently drained (and thus macropores would be temporary aerated), as the reaction of Fe^{2+} to Fe^{3+} is rather quick, but the reverse reaction takes rather long – which is a clear indication of persistent saturation (personal communication with Hannes Flühler, former chair of soil physics at ETH Zürich).

7. P8234 lines7-14: these questions are quite sudden to me, I would expect a sum up like this after a more elaborate introduction to the problem. The mention of preferential flow in the first question for example, which is not at all mentioned in the above paragraph. Maybe you should move this kind of summary of most important questions to a later place in your introduction.

→ Reply: We will move these questions from P8235 lines (6)7-14 towards the end of the introduction and place it directly before the last paragraph of the introduction (P8236, 25ff "We conducted sprinkling experiments. . .").

8. P8234 lines 21-22: in the unsaturated zone a soil macropore network, which indeed is not soil piping, may also cause preferential flow at hillslope scales as shown in: van Schaik NLMB, Schnabel S, Jetten VG. 2008. The influence of preferential flow on hillslope hydrology in a semi-arid watershed (in the Spanish Dehesas). Hydrological Processes 22 (18): 3844-3855.

→ PS: To clarify, we assume that Referee #2 refers to P 8235, Line (20)21ff: "Accordingly, SSF can develop along (1) soil pipes in the unsaturated zone. . ." → Reply: The Rufiberg climate is not semi-arid but humid. Thus we believe that runoff formation in semi-arid climates - especially for clay rich soils, which typically involves frequent clay shrinking and swelling in semi-arid climates, thus creating preferential flow structures - is not per se comparable to the Rufiberg. Based on our brilliant blue experiments, we could clearly identify vertical macropores (e.g. earthworm burrows, tree-root channels soil cracks perpendicular to the slope) mostly in the Go horizon and strongly reduced in the Gr horizon, but we did not found any evidence for soil pipes or laterally connected preferential flow structures such as a soil macropore network in the deeper soil horizons. This does not mean that a soil macropore network is absent at Go horizons in Gleysols in general. However, our findings are based on our observations at the Rufiberg during three experiments. We did not find any indication for such a deeper (lateral) preferential drainage system in the Go or Gr horizon at the Rufiberg, although we were explicitly looking for such a system with the brilliant blue experiment. Finally,

we could clearly identify an efficient preferential flow system in the organic top-layer with the brilliant blue experiment, which can nicely explain our data observed in both sprinkling experiments. Thus our interpretation is cross-validated with different types of data to reduce speculation. Moreover, the observations are consistent with the observations and results derived by Brönnimann et al. (2013) at the same site.

9. P8234 lines 25-27: isn't this the same as point 4 of the previously mentioned causes for preferential flow?

→ To clarify, we assume that Referee #2 refers to P 8235, Line 25ff: "Other studies highlight the important role of the underlying bedrock. . ." → Reply: No, the later studies consider the bedrock as a potentially conductive layer contributing to lateral runoff (thus acting as a flowpath), whereas point (4) considers flow along the soil-bedrock interface, assuming that the bedrock is more or less impermeable.

10. P8240 paragraph sprinkling experiments: here I would expect details of how long and with which intensity you sprinkled for the different rainfall? I saw you give them later on, but they should be in methods rather than in results.

→ Reply: We agree and will move this information about the duration and intensity of sprinkling from later in the text to this paragraph.

11. P8240 line 5: please give the return period of this August 2005 event

→ Reply: For individual rainfall gauges the return period of the August 2005 storm event are quite variable. Most rainfall gauges near lake Zug measured more than 150 mm/48h, several stations recorded rainfall sums for 48h significantly above 200 mm and some stations even more than 300 mm. Return periods for the August 2005 storm for areas without rainfall gauges in the reports of Bezzola & Hegg (2005, 2007, 2008) were thus estimated from discharge rather than from individual rainfall return periods. The August 2005 storm was considered to have a return period on the order of 50 to 200 years for catchments in the Lake Zug area and at the Rufiberg (Bezzola &

Hegg, 2005, 2008). We will add this information about the August 2005 storm to the manuscript.

12. P8240 line 7: a return period of 2 to 20 years? This is quite a big range?

→ Reply: The Hydrological Atlas of Switzerland (HADES, chapter 2.4) gives the following values for the north-central frontal ranges of the Swiss Alps: 24h-total-rainfall (return period 2.33 years) 77 mm, 24h-total-rainfall (return period 10 years) 110 mm, 24h-total-rainfall (return period 20 years) 120 mm, 24h-total-rainfall (return period 50 years) 150 mm, 1h-total-rainfall (return period 2.33 years) 25 mm, 1h-total-rainfall (return period 10 years) 40 mm, 1h-total-rainfall (return period 20 years) 50 mm, 1h-total-rainfall (return period 50 years) 65 mm.

The HADES (chapter 2.4) includes a map of extreme precipitation values with the following values for the Rufiberg area (SE coast of Lake Zug): 24h-total-rainfall (return period 2.33 years): 70 mm, 24h-total-rainfall (return period 100 years): 215 mm, 1h-total-rainfall (return period 2.33 years): 26 mm, 1h-total-rainfall (return period 100 years): 125 mm.

We applied in the 1st sprinkling 65 mm in 3h; and 85 mm in 4h in the 2nd sprinkling at the Rufiberg. If we interpolate the data given in HADES (chapter 2.4), we would derive the following return periods (RP) for the two sprinkling experiments: 1st experiment: total rainfall (65 mm in 3h) approx. RP 20 years, 1-h maximum rainfall intensity (25 mm/h) RP 2.33 years. 2nd experiment: total rainfall (85 mm in 4h) approx. RP 20 years, 1-h maximum rainfall intensity (25 mm/h) RP 2.33 years.

However, as the precipitation data were not measured continuously at the Rufiberg test site for this rather short period of less than 2 years, thus we prefer to name the high uncertainty of rainfall return periods for locations instead of giving rough estimates with an artificial accuracy. For point measurements such as at an individual rainfall gauge (or the plot scale, as our experiments at the Rufiberg) the determination of return periods is less precise than for areas such as meso-scale catchments (Bezzola

and Hegg, 2008). However, even for meso-scale catchments (250 km2) with several rainfall gauges and rainfall data records of more than 40 years, the 90% confidence interval of the return period for 80 mm total rainfall in 24 hours ranges from 2-10 years for catchments in the Northern front ranges of the Swiss Alps (Bezzola & Hegg, 2008). This value applies for a 'fixed' 24h-time-span, for a 'free' 24h-time-span these values should be multiplied by a factor of 1.15. In addition, the uncertainty increases with distance from the precipitation gauge. Bezzola & Hegg (2008) give a 'uncertainty factor' of 1.5 for 24h-rainfall sums for locations 6-8 km distance from the rainfall observation (for 24h total rainfall derived by radar Bezzola & Hegg give a constant uncertainty factor of 1.58 for distances of 0-14 km). For the Rufiberg, the next Meteoswiss rain gauge with a long data record (daily rainfall data, record starting in 1910) is located at Zugerberg (920 m NN) 6.5 km N of the Rufiberg test site. We will specify the given return periods in the manuscript for total rainfall and 1-h maximum rainfall intensity and add a sentence describing the uncertainty of these interpolated statistical values, which are not based on measurements at the site.

13. P8242-p8243, soil moisture content paragraph: please use a consistent accuracy in your soil moisture contents.

→ Reply: We will use a consistent accuracy (two decimal digits) for the soil moisture as suggested.

14. P8243, l 12: why is W6 not in figure 4?

→ Reply: The Odyssey-logger in W6 was malfunctioning during the first sprinkling experiment on 03.08.2011. We will add this information in the caption of Fig. 4.

15. P8243, l 13: increase instead of increasing

→ Reply: We will change that typo accordingly.

16. P8244, l5: I would delete the sentence: "Rainfall intensities higher than...to... at the Rufiberg." As you show straight away in the next lines, this intensity at which runoff

starts is probably dependent on the initial moisture content, so with drier or wetter initial conditions the amount /intensity at which runoff starts may be even higher or lower.

→ Reply: We will reformulate the sentence to: “Rainfall intensities continuously above 20 mm/h for longer periods (> 20 minutes; dependent on antecedent soil moisture in the H horizon) produced saturated overland flow in addition to subsurface stormflow in the H horizon (organic layer interflow).”

17. P8244, l 20: Just a very rough calculation: If the smc for the top 70 cm of the profile was raised from approx 0.4 to approx 0.45/47 you would need at least 35-40 mm to saturate the soil profile, considering that in the mean time there may be some water percolating even deeper into the profile or flowing out laterally. When the overland flow starts after 20 or 25 mm, is the profile really fully saturated?

→ Reply: We did not state in our manuscript that SOF starts after 20 or 25 mm of total rainfall; instead, our statement is that the onset of SOF is forced by rainfall intensities above 20 mm/h for longer periods (> 20 min). For more details please see our reply to point 21 later in this text. Porosity values for the H, Go and Gr horizon where 36%, 36 to 31% and 31 to 39% respectively (see Maries, 2011 data given in table 2 in Brönnimann et al., 2013). A table will be added to the manuscript to provide data about total porosity and saturated hydraulic conductivity of the Rufiberg’s Gleysol based on experiments performed by Maries (2011). Unfortunately, the saturated hydraulic conductivity ksat in the topmost layer (7-16 cm) could not be determined with the applied method (Oedometer measurements to determine soil properties of undisturbed soil samples in the lab). The quality of the topsoil sample in 7-16 cm depth – specifically in terms of root-holes and organic content – made it impossible to produce meaningful data. We did not measure soil moisture in the H horizon (all TDR’s in 0.25 m depth were placed in the topmost section of the Go horizon); thus we have no TDR data reflecting the antecedent soil moisture conditions in the soil layer with probably the highest SMC variability. We argue that the (lateral) drainage capacity of the H horizon is approx. 20 mm/h, whereas the deeper soil horizons do not contribute to (lateral) drainage. Our

brilliant blue data show that the Gr horizon is not drained laterally and we did not find evidence for preferential lateral drainage of the Go horizon. As shown in both sprinkling experiments, overland flow was produced after longer periods of sprinkling intensities continuously higher than the drainage capacity of the H horizon. This threshold value of 20 mm/h was consistent for both sprinkling experiments with different settings and antecedent soil moisture. As we did not measure instantaneous overland flow shortly after the sprinkling intensities reaching 25 mm/h we excluded infiltration excess overland flow (= ’hortonian overland flow’, HOF) as a significant runoff formation process. It should also be mentioned that in the 1st experiment approx. 7 mm of natural rainfall occurred in the hours before the onset of the sprinkling (see Figure 5 in Brönnimann et al. 2013, showing rainfall data from the closest Meteoswiss Station with hourly rainfall data: Cham/ZG (440 m), approx. 13.5 NW of the Rufiberg test site). However, this natural rainfall of approx.7 mm did not produce any runoff at the Rufiberg. We will add this information to the text and explain the difference in thresholds for total rainfall and rainfall intensities.

18. P8245, l13-17: “Following this theory. . . (Rohde, 1987).” This is slightly confusing, but I think this is mainly due to the term runoff. The surface overland flow /runoff cannot be a form of subsurface stormflow. Subsurface stormflow is really a rapid lateral flow through the soil.

→ Reply: We will change that accordingly and reformulate this section of the manuscript.

19. P8252: point 1: this 20 mm threshold, is not that straightforward: in the first experiment the surface runoff started only after a short period of 23 mm/h. In the second experiment it took almost an hour before surface runoff started.

→ Reply: In the first experiment the H-horizon was at least nearly – or already fully – saturated and draining as its maximum drainage capacity. Shortly (approx. 20 min) after we increased the rainfall intensity beyond 20 mm/h (approx. after 2:20 h the onset of the sprinkling) in the first experiment SOF significantly contributed to runoff. In the second experiment, when we directly started with a sprinkling intensity of 25 mm/h, the H-horizon was not saturated at the onset of the irrigation and thus had capacity to store water for approx. 50 min (this corresponds to approx. 20 mm of total precipitation). Saturation of the H-horizon occurs after 50-55 min, followed by saturation overland flow (SOF); infiltration access = 'Hortonian overland flow' (HOF) could not be observed. The onset of 'saturation overland flow' (SOF) and 'subsurface stormflow' (SSF) out of the drainages occurs almost simultaneously. We assume that some subsurface drainage (in the H horizon) might have occurred, even if we would have stopped the irrigation after 45 min, but this flow would probably have been delayed. When we quickly (< 5 min) cleaned the filters in the sprinkling system (indicated by the black triangles) in the second experiment (resulting in a short interruption of the irrigation) SOF decreased immediately. However, when the sprinkling continued again at 20 mm/h, the overland flow quickly reached the high values observed before. A probable explanation of this behavior is that return flow out of the H-horizon significantly contributes to overland flow measured in the surface flow collector when the H-horizon is draining near or at saturation. To clarify, we will change the text to: "…significant contribution of SOF to runoff occurs when rainfall intensities continuously reached or exceed 20 mm/h for longer periods, thus probably exceeding the lateral drainage capacity of the H horizon (organic layer interflow)".

20. P8256: first paragraph in the conclusions, I do not really see how the different experiments lead to different ideas: as far as I understood everything they led to the same idea, namely that the main runoff/ lateral flow is in the topsoil until the threshold rainfall amount is exceeded and the surface overland flow dominates.

→ Reply: Referee #2 is stating earlier that (comment P8234, Line 21-22) "in the unsaturated zone a macropore network, which indeed is not soil piping, may also cause preferential flow at hillslope scales". We agree with Referee #2 (point 2 of this response) that we could not exclude preferential flow structures in the deeper horizons

(e.g. macropore network or transmissivity feedback) without the brilliant blue experiments. This is reflected in the first paragraph of the conclusions.

21. P8257: first paragraph, this rainfall intensity threshold is variable and depends on the antecedent moisture content and the intensity and duration of rainfall, it should be something like the capacity / volume of the macropore to store fresh rainfall with a little extra for their drainage capacity. Once the macropores fill up then the infiltration capacity to the macropores become equal to their lateral drainage capacity which is not that big and then the surface runoff dominates. In the first experiment it has been raining for 20mm/h for more than two hours before the runoff starts, this means that there was at least 40 mm of cumulative precipitation! In the second experiment you start off with 25 mm/h and it takes almost an hour for surface runoff to start. Also your colleagues had a different value for the precipitation threshold at this site than you do.

→ Reply: Fig. 4 shows that runoff ('subsurface stormflow', SSF) in the 1st sprinkling experiment starts after less than 30 mins (threshold for onset SSF approx. 10 mm of artificial rain +7 mm of natural rain (total = 17 mm) which fell earlier that day, see figure 5 in Brönnimann et al. 2013). This total runoff onset of 17 mm is given in Brönnimann et al. (2013) and matches our runoff threshold of 9-21mm given in Table 1. Thus our runoff threshold range for the Rufiberg are is agreeing well with the one given in Brönnimann et al. (2013). However, the onset of 'saturation overland flow' (SOF) does not depend on total rainfall (sum in mm), but according to both experiments at rainfall intensity (mm/h) of more than 20 mm/h. The onset of SOF started in the 1st experiment after 2 hours of continuous sprinkling with an intensity of 20 mm/h (= total artificial rainfall 40 mm, +7 mm natural rainfall before and + 2.2 mm natural rainfall during the event, see caption of Fig. 4 = 49.2 mm) and approx. 20 min of continuous sprinkling with an intensity of 25 mm/h (=> total rainfall: 49.2 mm + 8.3 mm = 57.3 mm). Consequently, we attributed the occurrence of SOF to continuous rainfall intensities of greater than 20 mm/h for a longer period. As explained before, the interpretation of the brilliant blue staining (including the excavation of the drainage pipes in 0.25 m and 1 m depth) provides strong evidence that all runoff was drained in the H horizon (SSF) – as long as the rainfall intensity did not exceed 20 mm/h for longer periods – and vertically percolated down to the drainage pipes along the trench-walls, which we consider as artificial preferential vertical flow structures. Finally, when the organic layer interflow was for longer periods (> 20 min) at (or beyond) its max. lateral drainage capacity (= rainfall intensity 20 mm/h), significant 'saturation overland flow' (SOF) was detected. [This overland flow might be to a large extent return flow (= 'pseudo-overland flow'), but we can't prove that with our data.] During all monitored natural rainfall events in 2010 and 2011 rainfall intensities never reached or exceeded 20 mm/h for longer periods (>20 min). However, when we sprinkled with rainfall intensities above a 'rainfall intensity' threshold of 20 mm/h for such longer periods, 'saturation overland flow' (SOF) significantly contributed to discharge in addition to shallow 'subsurface stormflow' (SSF) in the H horizon (= 'organic layer interflow'), independently of the total rainfall values (exp. I: 57 mm, exp. II: 21 mm). In the 2nd sprinkling experiment when starting with a rainfall intensity of 25mm/h, it took approx. 50 min until the H horizon was saturated and SOF started to significantly contribute to runoff. As surface runoff did not start at or shortly after the onset of high intensity rainfall (25 mm/h) in the 2nd experiment [in fact that was part of the motivation to start directly with the higher sprinkling intensity], we do not consider infiltration excess ('Hortonian overland flow', HOF) as a significant runoff process at the Rufiberg. Instead, this supports the interpretation that SOF (and possibly to a certain extend return flow) contributes significantly to runoff at the Rufiberg during conditions comparable to our sprinkling experiments. We will add text and clarify that in the manuscript.

22. P8257: final paragraph is quite hypothetical and not really funded in the article.

→ Reply: We believe that our findings show that (our) sprinkling data at the Rufiberg test site alone could be interpreted in two ways, as the Referee #2 is suggesting, we could not exclude effective drainage through soil pipes connecting to the drainage pipes in the deeper soil horizons. Identification of 'organic layer interflow' in the H horizon as

dominant runoff formation process at the Rufiberg was only possible by the brilliant blue dye experiment. Thus we believe it is important to report the deficits of our instrumentation (e.g. fully filtered groundwater wells, which are still widespread in hillslope hydrology as illustrated in the text), so that future experiments and site instrumentation can avoid creating ambiguous data.

23. Table 1: I am always slightly surprised when seeing single numbers appearing for precipitation thresholds: the cumulative amount of precipitation before surface runoff starts is variable for each location and depends on the antecedent moisture content and the rainfall intensity, see comment on the conclusions

→ Reply: In Table 1 we put our results in context with other studies in the literature. As most total runoff threshold values (SSF, SOF, . . .) are not fixed values, some of the studies (including ours) are not using single numbers but rather give a range of thresholds, reflecting different antecedent soil moisture conditions and rainfall intensities.

24. Figure 5: was the rainfall really quite continuous in intensity or was it applied in pulses? It seems very strange that the overland flow can drop from more or less 11 to 6 mm/h while the rainfall continues. Also the top 25 cm have a slightly larger SSF than the 1 m depth. This is not that surprising; normally the topsoil has a higher conductivity. Here it seems not even to be a factors difference, which means it is not that different. I am not sure what this drainage unit means: mm/h, so is it recalculated to be comparable to the rainfall, that means that 1 mm per hour of rainfall on the top is flowing laterally through the 0.25 to 1 m depth layer, is that per m width of the drainage measurement or for the whole width? The lateral conductivity is in any case really not that bad, knowing that the hydraulic conductivity of the matrix is so low, I would think this is mainly flow through connected preferential flow paths.

→ Reply: The brilliant blue experiment showed that the drainage pipes where only reached via organic layer interflow, which first flowed laterally downhill in the H horizon and second vertically percolated along the trench walls (artificial preferential flow structure resulting from the installation of the drainage pipes) of the drainage pipes in 0.25 m and 1 m depth. We applied constant rainfall intensities (no pulses), which we ensured by continuously measuring the water level in the reservoir and the flux in the hose system with a flow meter. However, in the 2nd sprinkling we had to clean the hose system (indicated by the black triangles). The 2nd (unplanned) cleaning had to be conducted due to a reduced flow as the filters of the sprinklers experienced some clogging. Thus the sprinkling was reduced for about 5 min and we had to stop the sprinkling for approx. 5 min to clean all the filters. This lead to the significant drop in the SOF in the 2nd experiment. We will modify fig. 5 accordingly and add text to the manuscript that reflects this point.

25. Figure 6: this figure also shows that it is important not to get misled by the pattern on the E-profile, as this is completely the opposite of the A-profiles concerning the deeper infiltration. That you do not see lateral connections in the deeper soil does not mean that they are not connected; I know from experience that even with many profiles for one location you can still miss such connections. The top-soil is logically completely stained due to vertical infiltration from the soil surface, but it can lead to the idea that the main lateral flow takes place in the top soil, while the drainage in the top soil is not even that much more than in the next 75 cm.

→ Reply: Profile E is parallel to the slope (which we call lateral profiles), whereas the A-profiles are frontal profiles parallel to the contour lines. However, all the mentioned profiles are not located within the area of dye application, but one to two meters downhill towards the drainage pipes. Thus in none of the profiles of Figure 6 (profiles E, A1, A2, A3) the topsoil is "logically completely stained due to vertical infiltration from the soil surface". However, deeper soil horizons are stained when the topsoil is stained. When the topsoil was not stained, the subsoil typically was not stained. When we dug out the drainage pipes (which were colored with dye although being approx. 3 m outside of the dye application area), we could clearly see that the hydrological connection was realized only in the H horizon – no single stained matrix area or soil pipe could be

detected, although we dug 30 cm deeper than the deepest drainage and we cut out the soil in 10 cm steps.

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