Point-by-point reply to referees’ comments

Article: EGUSPHERE-2025-244

Anonymous Referee #2:

Report #2

Submitted on 15 Jul 2025
Anonymous referee #2

Anonymous during peer-review: Yes No
Anonymous in acknowledgements of published article: Yes No

Checklist for reviewers

1) Scientific Significance Does the manuscript represent a substantial contribution to scientific progress within the scope of this journal (substantial new concepts, ideas, methods, or data)?	Excellent **Good** Fair Poor
2) Scientific Quality Are the scientific approach and applied methods valid? Are the results discussed in an appropriate and balanced way (consideration of related work, including appropriate references)?	**Excellent** Good Fair Poor
3) Presentation Quality Are the scientific results and conclusions presented in a clear, concise, and well structured way (number and quality of figures/tables, appropriate use of English language)?	**Excellent** Good Fair Poor

For final publication, the manuscript should be

accepted as is
accepted subject to **technical corrections**
accepted subject to **minor revisions**
reconsidered after **major revisions**
rejected

Were a revised manuscript to be sent for another round of reviews:
I would be willing to review the revised manuscript.
I would not be willing to review the revised manuscript.

Suggestions for revision or reasons for rejection

(visible to the public if the article is accepted and published)

I thank the authors for their careful consideration of my questions, comments, and suggestions on the previous version of the manuscript. I especially appreciate the additional explanation provided in several parts of the paper to clarify interpretation of the analysis. My questions have been addressed sufficiently - I can now recommend the manuscript be accepted for publication.

Suggestions for revisions or reasons for rejection:

I thank the authors for their careful consideration of my questions, comments, and suggestions on the previous version of the manuscript. I especially appreciate the additional explanation provided in several parts of the paper to clarify interpretation of the analysis. My questions have been addressed sufficiently - I can now recommend the manuscript be accepted for publication.

Response: *Thank you for your thorough and positive feedback on our study and confirming that the questions have been addressed sufficiently.*

Referee #3 – Marcus Gomes Jr - marcusnobrega.engcivil@gmail.com

Report #1

Submitted on 09 Jul 2025
Referee #3: Marcus Gomes Jr., marcusnobrega.engcivil@gmail.com

Anonymous during peer-review: Yes **No**
Anonymous in acknowledgements of published article: Yes **No**

Checklist for reviewers

1) Scientific Significance Does the manuscript represent a substantial contribution to scientific progress within the scope of this journal (substantial new concepts, ideas, methods, or data)?	**Excellent** Good Fair Poor
2) Scientific Quality Are the scientific approach and applied methods valid? Are the results discussed in an appropriate and balanced way (consideration of related work, including appropriate references)?	**Excellent** Good Fair Poor
3) Presentation Quality Are the scientific results and conclusions presented in a clear, concise, and well structured way (number and quality of figures/tables, appropriate use of English language)?	**Excellent** Good Fair Poor

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Suggestions for revisions or reasons for rejection:

Thank you for submitting the paper. This article contrasts the idea of time-invariant baseflow parameters and proposes an event-based calibration approach that enhances the performance of baseflow estimation in a small catchment. The article is clear, all sections are well written, and the article has clear merits, in my opinion. I do, however, have a few comments and suggestions listed below:

Suggestion: Please specify why the authors chose these 15 events in Table 1. Give the rationale for why they were selected.

Response: We thank the reviewer for this comment, which highlights the need for clarity regarding the selection of the 15 events presented in Table 1. The events were selected to represent a diverse range of hydrological conditions (hydrological variability) in the studied small rural catchment, ensuring robust calibration and validation of the RDFs. Moreover, the selected events had high-quality tracer-derived and streamflow data (DSi) available, which were critical for accurately distinguishing baseflow from quickflow components. Events with missing data or poor-quality measurements were excluded to maintain the integrity of the analysis. To address the reviewer's comment, we have added a paragraph in Section 2.1 Study site and data collection to clarify the selection criteria for the 15 events.

Suggestion: Please justify the rationale behind adopting 2 hours after the peak to determine the recession period. The literature includes different approaches for this—some use rainfall data, others use topographic information to determine catchment response times, etc. Did the authors perform a master recession curve analysis as well? If so, that would be interesting to include, at least as supplementary information.

Response: We appreciate the reviewer's important question about our recession period determination. The 2-hour threshold was selected based on several catchment-specific considerations:

- *The Arvorezinha catchment exhibits a rapid hydrological response due to its size and topography, as described in 2.1 Study Site. Analysis of multiple observed hydrographs showed that quickflow contributions typically decline significantly within 1-2 hours after the peak, with baseflow dominating thereafter.*
- *Visual and statistical inspection of various hydrographs observed at this catchment, indicated a transition to a smoother, exponential decay pattern approximately 2 hours post-peak, suggesting baseflow dominance. This was confirmed by examining the rate of streamflow decline across multiple events.*
- *The 2-hour threshold provided a standardized starting point for analyzing recession behavior across 204 hydrographs, facilitating the estimation of the recession constant.*
- *Rainfall-based approaches were less suitable due to variability in rainfall cessation timing, which could introduce inconsistencies in a flashy catchment.*
- *Topographic methods were not adopted because event-specific factors (e.g., antecedent moisture) dominate the catchment's response, better captured through hydrograph analysis.*

How we derived the recession constant: The recession constant in our study (0.952 or ≈ 0.0492 h^{-1}) was derived using 204 observed hydrographs, yielding over 17,000 pairs of consecutive streamflow values (q(t),q(t+1)). Recession periods were identified starting 2 hours post-peak to approximate baseflow dominance. All q(t) and q(t+1) pairs were compiled into two Excel columns, and a scatter plot of q(t+1) versus q(t) was created. A linear trendline, forced through the origin, was fitted, yielding a slope of 0.952, This approach assumes a consistent exponential decay model across all recession periods, capturing the catchment's average recession behavior. It is therefore, an MRC approach based on correlation between q(t) and q(t+1) for all observations available.

*To address the reviewer's suggestion, we conducted another MRC analysis using a sub-set of 20 randomly-selected hydrographs to validate our correlation-based approach described above. In this method, streamflow data were normalized (qt/q0) starting 2 hours post-peak (i.e. q0 is the first flow at the beginning of the recession phase for each hydrograph), and the average normalized streamflow was calculated for each time step to form a composite recession curve representing the 20 events. Linear regression of the log-transformed data (ln(qt/q0)=t*ln(a)) yielded an MRC recession constant of a=0.949 (≈ 0.053 h^{-1}). This value is close to the value found using the approach that we described in the paper, with all recession periods combined. This also confirms the robustness of the 2-hour criterion. The slight difference reflects the MRC's smoothing of event-specific variability through normalization and averaging, whereas our method treats all q(t),q(t+1) pairs equally, potentially amplifying short-term fluctuations.*

To reflect this additional validation, we have substantially revised Section 2.2 (methodology for recession constant estimation) to include detailed description of both the original paired-data approach and the MRC analysis, and Section 3.1 (recession constant results) to present the comparative findings. The plots for both methodologies are included in the Supplementary Material section (Figure S1), as suggested by the reviewer.

Suggestion: Please specify which optimization algorithm was used to find the near-optimal or optimal BFImax and Betamax. In which programming language was it developed?

Response: We thank the reviewer for requesting clarification on our optimization methodology. The BFImax and Beta parameter optimization was performed using the bisection method implemented in MATLAB. This robust numerical root-finding algorithm iteratively narrows the search interval [0.001, 0.999] for BFImax and [0.900, 0.999] for Beta by evaluating PBias at successive midpoints until convergence within a precision tolerance of 0.001. The bisection method was selected for its guaranteed global convergence, robustness against local optima, and computational transparency in demonstrating parameter sensitivity across the full feasible range. Complete algorithmic details have been added to Section 2.3 of the revised manuscript.

Suggestion: Please provide the rationale for choosing PBIAS as the objective function.

Response: We thank the reviewer for this important methodological question. PBias was selected as the objective function because it directly quantifies systematic bias in baseflow volume estimates, has a clear optimal target of zero that is well-suited for our bisection method optimization, provides dimensionless percentage errors enabling comparison across events of different magnitudes, and is widely used in hydrological calibration studies, ensuring consistency with established literature. While PBias served as the primary optimization criterion, we also evaluated model performance using complementary metrics (NSE, *KGE, NRMSD) to provide comprehensive assessment. The rationale for this choice has been added to Section 2.3 of the revised manuscript.*

<u>Suggestion:</u> Fix the typo in line 455 (BFImax).

<u>Response:</u> We have fixed this typo.

<u>Suggestion:</u> In the conclusions, please specify the overall catchment characteristics when providing the optimal values of Beta and BFImax. The authors mention this later, but it would be better to include it at the beginning.

<u>Response:</u> We thank the reviewer for this excellent suggestion to improve clarity and applicability. We have revised the conclusions section to specify the catchment characteristics (small area, steep slopes, rapid baseflow recession, fractured basalt geology, mixed soil types) upfront when presenting the optimal BFImax and Beta values of 0.653 and 0.965, respectively. This modification makes it immediately clear to readers under what hydrological and geological conditions these parameter values are applicable, enhancing the practical utility of our recommendations for researchers working in similar environments.

<u>Suggestion:</u> Do the values of BFImax and Beta, when calibrated using event-based formulations, represent a characteristic response of the catchment, or are they more reflective of uncertainty? Please clarify. The recession constant is generally considered a characteristic response of the catchment and is typically assumed to be time-invariant, but apparently, Beta and BFImax are not.

<u>Response:</u> We appreciate this insightful question. We agree that the recession constant reflects a time-invariant, physical characteristic of the catchment — primarily governed by geomorphology, topography, and aquifer properties — and we have treated it as such in our study.

In contrast, BFImax (Eckhardt's filter) and Beta (Lyne & Hollick filter) are calibration parameters that are more sensitive to hydrological conditions during individual events, particularly the relative contributions of baseflow and quickflow. Therefore, the variations in BFImax and Beta under different event magnitudes should not be interpreted as uncertainty in the methodology, but rather as an expression of dynamic catchment response under varying hydroclimatic forcings. This interpretation aligns with previous findings (e.g., Zhang et al., 2013; Okello et al., 2018), which demonstrated seasonal and event-dependent variation in these parameters.

Our event-based calibration shows systematic trends: for example, BFImax decreases with increasing event magnitude, reflecting the dilution of baseflow by quickflow during intense storms. Similarly, Beta values increase with event magnitude, as fast quickflow components dominate and slow responses are proportionally reduced. These variations are not arbitrary or uncertain — they are hydrologically meaningful and reflect how the catchment's flow partitioning behavior changes across events, despite having a stable recession constant.

We now clarify this interpretation in Section 3.5 (last paragraph) of the revised manuscript.

<u>Suggestion:</u> In the original publication by Eckhardt (2005), several criticisms of BFImax estimation were discussed, since it is not directly measurable like the "a" parameter. Given this, the authors developed an event-based framework to estimate BFImax, varying across all events. The coefficients of variation from the Eckhardt filter were relatively low compared to other methods, indicating some convergence of BFImax values. This may suggest that BFImax is a characteristic response of the catchment. In contrast, such convergence was not clearly observed using methods like Lyne-Hollick (LH). Please discuss this further.

<u>Response:</u> We appreciate the reviewer's insights. In the general calibration, the BFImax is fixed for all events. So the resulting baseflow ratios (BF ratio) are very similar across events, because the same parameter is applied universally. Even if some events are slightly under or overestimated, the output is numerically smooth. Therefore, both mean and standard deviation are small, and CV is low (0.04). In the event-based calibration, we used three different BFImax values — 0.809 (low), 0.701 (medium), 0.576 (high magnitude). This means low events yield high baseflow ratios (BFImax = 0.809), high events yield low baseflow ratios (BFImax = 0.576), and therefore this introduced a broader spread in BF ratios. This naturally increases the standard deviation of baseflow ratios, but the mean remains similar (around 0.65), leading to an increased CV (0.09). So, the increased CV is expected — it reflects that we're intentionally tailoring BFImax to reflect different hydrological conditions across events, resulting in more variability in the outputs. This is not a flaw — it shows

we are capturing real physical variability that the general model smoothed over. The physical interpretation for this result is that event-based calibration reflects hydrologic reality: In low-magnitude events, the catchment is dry and streamflow is mostly groundwater → high baseflow contribution → higher BFImax. In high-magnitude events, overland flow dominates → low baseflow contribution → lower BFImax. So the increase in CV under event-based calibration mirrors real differences in baseflow generation processes.

The Lyne-Hollick (LH) filter, on the other hand, has only one parameter, Beta, and it operates very differently from Eckhardt's filter: LH separates quickflow directly, and baseflow is just the remainder. It's more numerically damped and less sensitive to Beta than Eckhardt's filter is to BFImax. Even though we changed Beta for different event classes (0.921, 0.957, 0.970), the resulting baseflow ratios did not change much, because the structure of the LH filter is inherently less responsive to Beta adjustments; we already used a relatively high Beta (around the recession constant), so small changes had diminishing returns; and therefore, standard deviation of baseflow ratios didn't increase much, so the CV remained stable (~0.15 to 0.14). Physically, this suggests that LH's filtering behavior does not capture hydrologic variability across event magnitudes as well as the Eckhardt's filter does. In other words, Eckhardt's filter is more sensitive to parameter changes, and therefore better at reflecting true hydrological differences (at the cost of increased CV). LH is more rigid, so even when calibrated dynamically, it doesn't translate into much variability in baseflow ratios — hence the CV doesn't change much.

We have clarified this point in the revised manuscript (Section 3.6).

Since the parameters were only calibrated and no validation test was performed—due to the assumption of event-specific, time-varying catchment responses—the results might be overfitted. I would suggest quickly splitting the time series into two parts, calibrating the optimal BFImax on one set of events (event-based), computing the mean parameter, and evaluating the performance on the remaining events, if this is not too time-consuming. Would a time-invariant estimate of BFImax perform better than a time-varying parameter estimate using the LH method, for instance? If so, this would support better performance of the Eckhardt filter compared to LH. Please feel free to argue this point. Alternatively, since the authors used only 15 events out of potentially hundreds, a quick validation test would help increase confidence in the results.

Response: We appreciate the reviewer's suggestion for additional validation using independent events, which would indeed provide valuable insights into the generalizability of our event-based calibration approach. However, we respectfully note that implementing this validation framework presents significant practical constraints that prevent its inclusion in the current study.

Data availability constraints: While we have an extensive database of over 200 hydrographs for the Arvorezinha catchment, dissolved silica measurements were only collected during the 15 events presented in this study. Expanding silica monitoring to additional events would require substantial field campaigns and analytical resources that extend beyond the current study's scope.

Methodological foundation: Our event-based calibration approach was developed based on the established understanding that baseflow indices vary with hydrological conditions, as demonstrated in the literature (Minea, 2017; Okello et al., 2018; Zhang et al., 2013). Therefore, BFImax - which directly controls the maximum baseflow contribution - should logically vary with event magnitude. Our study confirms this theoretical expectation through empirical evidence, rather than challenging an established paradigm.

Acknowledgment of limitations: We acknowledge that the current calibration dataset is limited and that overfitting concerns are valid. However, this represents a foundational study that establishes the proof-of-concept for event-specific calibration. As additional tracer data becomes available through future monitoring campaigns, the robustness and transferability of our calibrated parameters will be systematically evaluated and refined.

Future research direction: The validation framework suggested by the reviewer represents an excellent direction for future research and will be prioritized as expanded datasets become available.

This has been articulated in the second-last paragraph of the conclusion section.