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Interactive comment on "Major flood dominates 14 year sediment and nutrient budgets for two subtropical reservoirs" *by* K. R. O'Brien et al.

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The following includes the complete review by reviewer 2, and our response to each point and the overall review.

Interactive comment on "Major flood dominates 14 year sediment and nutrient budgets for two subtropical reservoirs" by K. R. O'Brien et al.

Anonymous Referee #2 Received and published: 8 July 2016

Reviewer 2 General comments: This paper deals with some important issues about the challenges that are faced in some catchments and reservoirs where peak flows, despite very rare, have a huge influence on the load budget. On the same time these peak flows are the most difficult to monitor and represent very short time periods which complicates data interpretation.

The paper is generally well written with a fluent and precise language and very few grammatical errors. The paper is well structured and both data and methods are described in sufficient detail and it is an interesting data set with a long time series of both flow and nutrient and sediment concentrations. In that sense I find that the paper does have a sufficient quality and some relevance for the general readership of HESS. However, I find that the weak part of the paper is the fact that I do not see that this paper makes a substantial contribution to our current knowledge about nutrient budget estimations or nutrient and sediment transport processes. It is fairly well known that peak flows can contribute substantially to transport of nutrients and sediment and that monitoring of these peak flows are difficult because any time averaging (which is mostly done during normal flow periods) introduces a huge uncertainty on the peak flow load estimates. Therefore I suggest that it could be considered if this paper might be more suitable for a targeted engineering journal, for instance with special interest in reservoir and dam dynamics and their impacts on freshwater ecosystems.

Author response: We thank the reviewer for their detailed response, and constructive advice. The reviewer recognizes the quality and importance of the paper, and noted that it was "well-structured", with "interesting data set with a long time series of both flow and nutrient and sediment concentrations" and of "sufficient quality and some relevance for the general readership of HESS." We agree that the paper is suitable for HESS readership, and that we must ensure it makes a "substantial contribution to our current knowledge about nutrient budget estimations or nutrient and sediment transport processes".

To this end, our paper highlights the hazards of presenting sediment and nutrient budgets in static form, particularly in catchments with highly episodic flow. This finding applies to catchment budgets generally, and is not restricted to reservoirs. The evidence is taken from a comprehensive long-term dataset. Our paper does not therefore simply convey that peak flows contribute to nutrient and sediment budgets or that these events are difficult to monitor, but goes far further, making a substantial contribution to current knowledge on the fundamental nature of budget estimations and transport processes.

We agree there is room to articulate this important contribution more clearly and have clarified this in our revision, for example by: âĂć Modifying the title to “Sediment and nutrient budgets are inherently dynamic: evidence from a long-term study of two subtropical reservoirs”. âĂć Modifying the Discussion, as outlined below, to emphasize the paper’s key conclusion: that catchment budgets are inherently dynamic, particularly in river systems with episodic flow. âĂć The Discussion now also explains the significance of the reservoir siltation rates for regional water supply.

Reviewer 2: There is an excessive use of references to supplementary material. I find it somewhat problematic that such a large part of the paper relies on supplementary material. In my opinion supplementary material should function as a supplement, not as an essential extension of the paper. I therefore suggest that the supplementary material is critically reviewed and condensed.

Author response: Constructing a comprehensive catchment budget is difficult, due to the issues in reconciling data collected over a variety of spatial and temporal scales, and in estimating uncertainty (Walling and Collins 2008, Parsons 2011, Carpenter et al. 2015).

We have included in Supplementary Material the calculations and assumptions we used in our robust quantification of uncertainty. This ensures confidence in our final uncertainty estimates, and provides a thorough method for others constructing a catchment budget. This highly detailed and specific technical information would distract from the main findings if included in the main body. Additionally, we are confident that readers who choose not consult this Supplementary Material will understand our paper. We have therefore decided to retain the information in the Supplementary Material. We would certainly agree, under the Editor’s advice, to this material being critically reviewed.

Reviewer 2: Generally I think that the Conclusion section is more a Perspectives section. I suggest that the conclusion should be rewritten to sum up the findings rather than discussing perspectives and implications.

Author response: We differ from the reviewer on this point: we have deliberately focused on the significance of our results, rather than writing a summary. We leave it to Editor to adjudicate this matter of style.

Specific comments Reviewer 2: P. 7 line 5: You write that you do not expect a good relationship between TN and turbidity. However in the plot (Fig. S2) the relationship looks just as good as for TP and TSS? Could you comment on this?

Author response: Relationships with turbidity are commonly used to estimate [TSS], and less commonly for [TP], which is strongly associated with sediment. It is unusual to estimate [TN] from turbidity because dissolved compounds typically make up a large component of total nitrogen, we have done so here because no other data is available during the critical January 2011 flood period. We have modified the text to clarify this point.

Reviewer 2: P 8 line 15: For output loads the uncertainty is estimated as deviation of Method 3 from method 4, but why is method 4 used? and not one of the others?

Author response: We have added the following sentence to the text: "Thus the estimated uncertainty is the difference between loads estimated from monthly monitoring, and the loads estimated from daily turbidity readings. Monthly monitoring and turbidity datasets were both complete for these time periods (water years 2008 and 2009)."

Reviewer 2: P 8 line 6: In method 3 why are loads not calculated based on the two monthly measurements, rather than just one? Would two measurements not give a better estimate, simply due to less interpolation and more real data?

Author response: Monthly monitoring occurred once per month, at the surface and the bottom. Surface and/or bottom concentrations were used to calculated loads, depending on the method of reservoir release, as explained in section 2.3.1.

Reviewer 2: P. 11 line 19: Do you mean flow-TSS correlations as conducted by Grinham et a. (2012). Slightly confused with what is your method and what is done by others.

Author response: Agreed, this is ambiguous, we have modified the sentence to read "Thus the TSS inputs to Wivenhoe calculated by Grinham et al. (2012) using the event-mean and flow correlation methods are one and two orders of magnitude, respectively, above our estimate of 0.2 Mt (Table 2)."

Reviewer 2: P. 13 line 3-4: You repeat what you just said above about the size of the relative uncertainty compared to input and output uncertainty.

Author response: Agreed, we have deleted the second sentence.

Reviewer 2: P 13 line 7: That uncertainty is high in unmeasured elements is quite trivial I think. You could either leave this out or state it differently.

Author response: Agreed, we have rephrased this to state "uncertainty is particularly high in quantities which are calculated from other budget terms, rather than independently determined".

Reviewer 2: P. 12-13: There is a really large focus on this other study, but I do not see clearly how this study advances our knowledge compared to the Parson (2011) paper?

Author response: We have clarified this significantly in the text, and particularly in the final paragraph of this section: "Therefore we propose that Parsons' three principles of catchment budgets can be refined to two principles: 1. Budgets should be presented as time-series rather than static quantities to clearly display temporal variability and 2. Uncertainty should be quantified for all budget terms, and accounted for in any interpretation of results. "

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Discussion paper

Reviewer 2: P. 13 line 13-15: Do you mean comparison between methods 1-4 or comparison be- tween the two different reservoirs? Please clarify.

Author response: We agree, this sentence was ambiguous, and has been rephrased as follows “This point is illustrated by the uncertainty in retention and trapping efficiency of water, sediment and nutrients (Tables 2-3), as follows.”

Reviewer 2: P. 13 line 20-24. Are you more confident using trapping efficiency during peak flows or in general? I do not find it completely clear why you come to the conclusion about more confidence in trapping efficiency than in retention, since both are a function of inflow?

Author response: Both. We’ve modified the paragraph as follows to make these points clearer:

"Correct propagation of uncertainty also affects interpretation of reservoir budgets. Uncertainty is higher over shorter time periods, and thus confidence in budget values is lower for the flood year than for the whole study period (Tables 2-3). Net retention of TSS, TN and TP occurred over the 14 year study period in both reservoirs, except for TP in Wivenhoe, where uncertainty was higher than the difference between input and output loads. The flood year dominated the retention of TSS, TN and TP in both reservoirs (e.g. 25 % and 40 % of TSS retained in Somerset and Wivenhoe were captured during the flood year), however the higher relative uncertainty in the values determined for this shorter timeframe means that retention of water, sediment and nutrients in both reservoirs in the flood year was only significantly different to zero for TSS in Somerset.

Uncertainty in trapping efficiency (retention divided by input) is lower than uncertainty in retention, as outlined in Section 2.4. Thus while retention was not significant for most loads during the flood period, trapping efficiency was quantifiable for all sediment and nutrients across the study period, and for TSS in both reservoirs and TN in Somerset during the flood year (Table 2). Together, these findings engender greater confidence in the proportion of sediment and nutrients retained by the reservoirs (i.e. trapping efficiency) than in the mass retained, and in budget terms calculated for multi-year periods." Reviewer 2: P. 13. Line 24. Do you have any suggestions to how this could be achieved? Author response: The sentence has been modified to clarify this point: "For a fuller assessment of trapping efficiency in reservoirs with variable flow, such as Wivenhoe and Somerset, hydraulic retention should be calculated on shorter (i.e. monthly) timescales, as outlined in Lewis et al. (2013).

Reviewer 2: P. 13 line 27 – P 14 line 1-4: I suggest that this should be moved to the results section?

Author response: Ideally this would appear in the results section, however we feel that it would confuse readers if presented earlier, because the calculations use information from Grinham et al. 2012 which is first introduced in the Discussion. The paragraph also uses the results to draw further conclusions. Therefore we propose to leave this section in the Discussion.

Reviewer 2: P. 13 line 27 – P 14 line 1-4: I miss a comment of the importance/implications. Do you believe in these numbers, given the uncertainty in loads, and what is then concluded? I suppose that loss of storage volume seems not to be an issue in these two reservoirs, despite and overall net retention of sediment and nutrients?

Author response: We have added extra text and an additional reference to verify the numbers, and explain the significance for regional water supply. The additional text reads as follows:

"Using the input loads calculated in this study, decline in storage volume is estimated as only 0.04 %-1.1 % for Wivenhoe over the 14 year study period (Table 4), i.e. 0.003 %-0.1 % per year. Average annual decline in storage volume is two orders of magnitude lower in Wivenhoe compared to Mosul Dam, Iraq, where reservoir volume reduced by more than 10 % due to siltation between 1986 and 2011, i.e. 0.4 % per year on average (Issa et al., 2015). While trapping efficiency of Wivenhoe is slightly less than that estimated for Mosul Dam, the large difference in siltation between these two reservoirs is due primarily to the difference in sediment loads. Mosul Dam has approximately ten times the storage volume of Wivenhoe, but sediment loads entering Mosul Dam are of order 100-1000 higher than those entering Wivenhoe (Issa et al., 2015).

While the relative siltation rates in both Somerset and Wivenhoe may seem low (Table 4), the corresponding loss in water supply volume is regionally significant. We estimated that the decline in storage capacity over the study period was approximately 4 000 ML for Somerset loss and 5 000- 12 000 ML for Wivenhoe (Table 4). Four of the 15 water supply reservoirs in the region have capacity of less than 5 000 ML, and fewer than half have a capacity greater than 12 000 ML (Leigh et al., 2010). Hence the volume of storage capacity lost in Somerset and Wivenhoe over the 14 year study period is equivalent to the closure of one of more of the smaller reservoirs. Somerset and Wivenhoe supply water to southeast Queensland, a region of rapid population growth which has recently experienced major drought, and where alternatives water sources have much higher greenhouse gas intensity than water supplied from existing reservoirs (e.g. Hall et al. 2011). Therefore any economic assessment of methods to reduce the catchment sediment load in this region should account for costs associated with reservoir siltation and associated loss of water supply volume. Direct measurement of reservoir volume is required for more accurate estimates of storage loss due to siltation."

Reviewer 2: P 14 line 15-17: Is this your conclusion (this is the impression I get) or one by Lewis et al. (2013)? Either rephrase so that this is clear or delete reference.

Author response: This sentence has been deleted.

Reviewer 2: P. 14 Line 22: I do not understand this sentence. Less is released and this leads to net export? And where is Brisbane water supply located? Are water pumped from lake Wivenhoe to the water supply? Could you rephrase this sentence?

Author response: We've clarified the sentence to reduce ambiguity as follows: "However Wivenhoe was frequently a net exporter of TN (Figure 7), typically during drought years when releases for water supply were less than reservoir inflows (Figure 3).”

Reviewer 2: P 1 line 30 p. 15 line 1-2: I suggest that this section is rewritten to be more specific about this particular study. It is a rather general statement but as I understand it is based on the findings in this study?

Author response: Yes, and it has been modified to make this clearer: “Ratios of total and dissolved inorganic N: P were substantially higher in both reservoirs than in the UBR.”

Reviewer 2: P. 15 line 9-10: This should be moved to the discussion session.

Author response: As outlined earlier, we differ with the reviewer’s opinion on this matter, and await the Editor’s decision.

Technical corrections Reviewer 2: P. 2 Line 16: please correct typing mistake in “reservpors”.

Author response: corrected.

Reviewer 2: Please be consistent in the use of spelling out “concentration” or writing in in brackets (example p. 10 line 2 and 16).

Author response: As a matter of style, we feel it’s preferable to write out concentration in some contexts, and use the bracket notation in others. We will take the Editor’s advice on this matter.

Reviewer 2: P. 13 line 6: please replace “than” with “that”.

Author response: corrected.

Reviewer 2: P. 14, line 27: You already defined DIN, no need to repeat it.

Author response: DIN replaced with [DIN].

Reviewer 2: P 14, line 29: Please replace “dissolve” with “dissolved” and write “N and

P" rather than N:P.

Author response: corrected.

Reviewer 2: Fig. 6. Please include units on y axis rather than in the figure text.

Author response: corrected

Reviewer 2: Figure S3. The figure would be easier to read if the plots were bigger relative to the text.

Author response: corrected

Reviewer 2: Figure S4. The figure would be easier to read if the plots were bigger relative to the text.

Author response: corrected

Reviewer 2: Table 1. I find this table very difficult to read and I suggest that it is restructured or left out as there is a quite comprehensive description of data in the main text.

Author response: We leave this to the editor's discretion

Reviewer 2: Table S4: What does "Method 3: Method 1", is it the deviation between the two?

Author response: the caption has modified to clarify the difference between the two methods for estimating output loads of sediment and nutrients: "Method 1 uses historical mean concentrations and Method 3 uses monthly monitoring data supplemented by turbidity profile data."

References used in response to reviewer 2: Carpenter, S. R., E. G. Booth, C. J. Kucharik, and R. C. Lathrop. 2015. Extreme daily loads: role in annual phosphorus input to a north temperate lake. Aquatic Sciences 77:71-79. Hall, M. R., West, J., Sherman, B., Lane, J., and de Haas, D.: Long-term trends and opportunities for managing regional water supply and wastewater greenhouse gas emissions, Environmental science & technology, 45, 5434-5440, 2011. Issa, I. E., Al-Ansari, N., Knutsson, S., and Sherwany, G.: Monitoring and evaluating the sedimentation process in Mosul Dam Reservoir using trap efficiency approaches, Engineering, 7, 190-202, doi: 10.4236/eng.2015.74015, 2015. Leigh, C., Burford, M. A., Connolly, R. M., Olley, J. M., Saeck, E., Sheldon, F., Smart, J. C., and Bunn, S. E.: Science to support management of receiving waters in an event-driven ecosystem: from land to river to sea, Water, 5, 780-797, doi:10.3390/w5020780, 2013. Parsons, A. J. 2011. How useful are catchment sediment budgets? Progress in Physical Geography:1-12. Walling, D., and A. Collins. 2008. The catchment sediment budget as a management tool. environmental science & policy 11:136-143.

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