Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2017-521-AC2, 2018

Hydrology and Earth System Sciences Discussions

Open Access

Interactive comment on "Beaver dam influences on streamflow hydraulic properties and thermal regimes" *by* Milada Majerova et al.

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Received and published: 24 January 2018

Thank you for the Reviewer 2 comments! We responded to individual comments below. The numbering of the comments follows the original RC2.

Reviewer 2 Comments:

This study aims to extend our understanding of the spatial stratification of thermal regimes in streams. It examines the role of geomorphic unit classification and beaver dam complexes on select stream hydraulic properties, which are used to explain observations of high variability in stream thermal regime. To do this, studied was Curtis Creek in northern Utah, which beaver re-colonized in 2009. Concluded in the manuscript was that "geomorphic units within beaver dam complexes exhibit highly unique thermal re-

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sponses in part due to the variability in flow velocities and depths” (L404). Honestly, this was one of the most clearly written phrases in the manuscript. If true, this manuscript would provide a meaningful contribution to the literature. The problem for me is that I was unable to assess the validity of this conclusion from the material presented. I recommend the authors focus their revisions to the manuscript around this idea, and describe clear objectives/hypotheses to evaluate/test it. I think much of the density of the manuscript stems from an attempt to capture variations in stream temperature resulting from geomorphic stratification, stream depth and velocity distributions and also beaver dam influences of the geomorphic template – all at varying spatial scales. It caused me to lose focus of the main new insights generated by this study. And, it has led me to recommend rejecting publication of this manuscript in HESS, at least until substantial improvements are made.

- Thank you for the constructive comment. Your summary of the intended objectives within this paper are correct. Our primary objective is to determine if the variability in hydraulic characteristics (depth, velocity) associated with the dominant geomorphic units in beaver dam complexes can explain the variability in observed temperature responses. The original introduction did not clearly outline the knowledge gap or state these objectives and needs to be clarified. Beyond the original more qualitative measures provided in the manuscript, as discussed below, we will add some multivariate statistical analyses to strengthen the insights gained regarding the relationships between hydraulic, geomorphic classification, and observed temperature responses. Further, we will extend the discussion regarding the implications of this hydraulic and thermal variability on native fish species to provide context and a more direct link to expanded habitat.

Substantial comments: a) The introduction section lacks clear focus and clear questions to drive the research. The authors nicely lay out evidence for spatial stratification in stream temperature regimes. They also argue in the introduction that beaver dams add hydraulic diversity to streams but that their influence on stream temperatures is uncertain as results from previous studies have been contradictory. I was expecting that statement to be followed by some key outstanding questions. Instead, it was simply stated that many questions remain on how to relate different stream temperature responses to varying channel complexity and stream hydraulic properties, especially for streams with beaver living in them. So, I was left confused at the end of the Introduction as to the goal of the study. I ended up thinking that the focus of this manuscript was on characterizing temperature regimes across a range of stream geomorphic units (in a stream that just happens to be beaver habitat), rather than a study of beaver dam influences on stream energetics (as the title suggests). I recommend the authors rethink their focus and write a more compelling introduction that lays out specific gaps in understanding and questions that relate to those gaps. Specially, I think the Introduction needs to be re-worked to more clearly outline how beaver-mediated changes to stream geomorphic structure are unique (or not) from channel complexities found in streams lacking beaver, and why such differences might lead to unexpected impacts on the temperature regime (if that is to be the focus). I do think there is merit in using the geomorphic template to explain thermal heterogeneities in streams, and that such an approach is likely to resolve some of the contradictory findings of the impact of beaver dams that exists in the literature.

- Thank you for this constructive comment. As stated above, we agree that the introduction needs to be revisited to clearly articulate our primary objectives. We can also see that a new title could be developed that highlights the key contributions. Something along the lines of “Linking beaver dam geomorphic complexity and hydraulic characteristics to thermal variability.” We also agree that this approach will help explain some of the contradictions present within the literature.

b) There is inadequate description of the in-field configuration of the temperature sensors (paragraph starting at L124). Were the loggers placed in some sort of radiation shield to prevent direct solar heating? Were any manual temperature measurements made to ensure solar heating was not occurring? Were the sensors installed at a consistent stream depth? I also think it would be useful to report the expected measurement uncertainties here.

- We will provide more detail regarding the temperature sensor deployment and sensor accuracy/resolution in this section of the MS. In short, all sensors were covered in aluminum foil to avoid radiation influences. All sensors were placed in the center of the water column, with the exception of the vertical arrays where they were spaced evenly throughout the water column. All sensors were placed in temperature baths regularly to ensure that the sensors were reporting values within the expected error of +/-0.2 C.

c) How were the simulated depth and velocity distributions (L152) verified and validated? The main conclusions from this manuscript are based on the model producing accurate and credible results.

- We provided a comparison of the observed and predicted water surface elevations (wsel) from the model calibration in SI Fig. 1. While the focus of the modeling effort was not on model performance per se, we understand the importance of maintaining a good representation of actual conditions. To further test the model abilities, we compared 28 observed and computed velocities within beaver dam complex #1 to show that model predictions are reasonable for this area. We found an RMSE value of 0.065 m/s. The greatest differences between observed and computed values were near the beaver dam structure where flow paths and velocities are mainly influenced by flow through the dam itself and in the inflow area to the dam where a log (not included in the model) is influencing flow velocities. As mentioned in the discussion, flow through dams were part of the channel topography, but were maintained via openings in the dam in the modeling to mimic observed water surface elevations immediately upstream of the structure. This may have led to computational inaccuracies near the dam structures. If these two areas (n = 6) are removed, the RMSE reduces to 0.028 m/s. We will expand the MS to clarify that these comparisons were completed and show that the modeling results were relatively accurate.

d) How much difference would an underestimate of stream depth of 0.056 m (from the modeling; L189) likely make to classification of the geomorphic unit type given the small differences in depth thresholds between the classes (classification rules are provided at L165)? I see high potential for mis-classification of geomorphic units. I think disclosure of some of the uncertainties regarding the research design would only serve to strengthen the manuscript. Without such disclosures, it is hard to assess the validity of the conclusions reached.

- We agree that the error in depth predictions could be acknowledged. While depth thresholds for units have small differences, velocity was used at the same time. If we vary thresholds by 10% and look at predicted average depth for each unit, we found that pool classification was most affected. If the lower threshold is varied from 0.45m and 0.55 m (from 0.5 m), the average predicted depth varies between 0.62 and 0.69 m (original prediction for pools was 0.66 m). In terms of pool area, when computation cell coverage is used, for example increasing the threshold to 0.55 m would mean decrease in pool area about 20 %, which translates to change of overall pool representation for the entire reach from 13 % to 10 %. Riffles and margins exhibit no significant change when their upper thresholds are moved by 10%, and the average depth holds at 0.13 m and 0.06 m, respectively. The backwater unit is also not affected by model under- or over-predictions as it covers the entire depth range of 0.03 m to the maximum depth. Even though pool boundaries would slightly change with threshold change, this would not affect the results regarding the geomorphic units and temperature as the temperature sensors were mainly placed in the middle of the geomorphic units.

e) It is useful to present an overall picture of variations in stream temperatures at each geomorphic unit, as was done starting at L258. In addition, I am wondering if there were differences in the diel stream temperature variability among geomorphic units or across the beaver complexes?

- This comment is a bit unclear. Based on our understanding, we have included these data and figures in the current manuscript. For example, Figure 6 in the MS shows the range of temperatures experienced within each geomorphic unit (and therefore between geomorphic units) as well as the differences in temperature across the entire pond (shown in red dashed line). Figure 5 in the MS shows the actual temperatures and temperature differences across the beaver dam complex and over the entire study reach.

f) Section 5.1 – I see this as useful information, but it is not a point worthy of analysis in the overall finding of this research. It is commonly known that small differences in the choice of Manning's n can have a large impact on simulated streamflows. So, I recommend removing this paragraph from the Discussion section, and adding the key components of it into the Methods section.

- We agree. It is commonly known that small differences in the choice of Manning's n can have a large impact on simulated streamflows. We will remove this paragraph and add the key points to the methods.

g) Section 5.2 of the Discussion misses an excellent opportunity, in my view, as it focuses on the least meaningful aspect of the analysis. Instead, what I think is needed here is a discussion of the how beaver damming impacts the geomorphic classification of the channel, and a linkage of that to stream velocities and depths. Are the changes in channel hydraulics that beaver damming creates well described by geomorphic forms present in channels without beavers? What I am asking is are stream velocity and depth distributions in beaver dammed reaches similar to those in un-dammed reaches, and, how do the differences that occur play out in the thermal regime of the various components of a stream? I think a much more effective Discussion will be guided by a strengthen description of the research goal and objectives in a revised Introduction.

- Thank you for very helpful and constructive comment. We will expand the discussion to clarify the role of beaver dams on shifting the geomorphic variability based on our field/model based mapping efforts. We will look at the total area of each geomorphic unit in the portion of the study reach where beaver dams are present and compare

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it sections without beaver dams. Further, we will clarify how the findings of Stout et al. (2017) tie into this paper by discussing how the velocity and depth distributions differ between beaver impacted and non-impacted reaches as well as pre and post pre-beaver colonization. While Stout et al. differs in that a 1D hydraulic model was applied and the geomorphic unit level information is not captured, the reach depth and velocity distributions offer meaningful information on how dam complexes alter stream channel hydraulics and therefore, influence thermal responses.

Detailed comments: 1. Plant names should be italicized, for example, willow species should read Salix spp. on L100 with the Salix italicized.

- We will change this in the new version of the MS.

2. Generally, the manuscript needs a thorough grammar edit. Also needed is a consistent style of in-text citation.

- As we incorporate these edits, we will ensure consistency in citations and in writing.

3. L217-220: It is cumbersome to read and compare the depth and velocity values for each geomorphic unit as text, given the number of values. I recommend placing these values in a table to facilitate reader understanding.

- The attached table will be added to the manuscript (Table 1R).

4. L248: Please provide statistical evidence to support the existence of a warming trend of 1C during the day and a net cooling of 0.5C during the night.

- The statistics will be included in the manuscript and are provided in the attached table (Table 2R).

5. L319: Reflects variation of what in the reach – structural unit variations?

- The sentence will be changed to:

“The range of reach scale temperatures reflect temperature variability within the reach

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(Fig. 5A) and highlights the warming effects of a series of beaver complexes on longitudinal stream temperature patterns (Fig. 5B).”

6. L340: So, how do DOC concentration and turbidity affect the thermal regime? How important were these factors at Curtis Creek?

- Turbidity and DOC concentrations are extraordinarily low in Curtis Creek. Therefore, these are not factors that need to be considered here. This has been clarified by changing the sentence to:

“While both depth and velocities within pools are key to quantifying thermal stratification in Curtis Creek, other factors such as dissolved organic carbon and turbidity must also be considered in some systems. . .”

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2017-521, 2017.

Table 1R Model calculated depths and velocities for individual geomorphic units.

	Depth (m)			Velocity (m s^{-1})		
	Average	Min	Max	Average	Min	Max
Pools	0.660	0.500	1.080	0.110	0.001	0.730
Backwaters	0.380	0.030	1.080	0.030	0.000	0.100
Margins	0.060	0.030	0.100	0.030	0.000	0.100
Riffles	0.130	0.030	0.400	0.640	0.002	1.830

Fig. 1.

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Table 1R Statistics for downstream net warming during the day and net cooling during the night over the study reach (Fig. 5B) and beaver dam complex #1 (Fig. 5D).

	Study reach		Beaver Dam Complex #1	
	Warming (°C)	Cooling (°C)	Warming (°C)	Cooling (°C)
Min	0.024	-0.530	0.024	-0.655
Max	1.275	-0.024	1.432	-0.024
Mean	0.458	-0.147	0.227	-0.099
Standard Deviation	0.256	0.109	0.292	0.132

Fig. 2.

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