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Discussions

Interactive comment on "Impacts of beaver dams on hydrologic and temperature regimes in a mountain stream" *by* M. Majerova et al.

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Thank you for your feedback. We copied your comments and provided our responses below.

Review #2 (Megan Klaar)

The manuscript by Majerova et al. entitled "Impacts of beaver dams on hydrological and temperature regimes in a mountain stream" reports on the fortuitous investigation of beaver colonisation on a small tributary in Northern Utah. The occurrence of an earlier investigation on the Creek by Schmadel provides baseline hydrological and temperature data prior to beaver colonisation, allowing a before-and-after comparison of thermal and hydrological regimes over the course of beaver dam construction. Given

the current focus of river restoration and 're-wilding' of landscapes, the manuscript is very topical and has the potential to add important information to help river managers understand the impacts and benefits of restoration efforts, and in particular beaver management as adopted by the state of Utah, on the river environment.

The manuscript does a good job of making the most of the rare opportunity to study this event, and is generally very well written and engaging. However, I feel there are a few clarifications and limitations to the methodology which should be addressed to provide perspective to the results.

1. Generally, my comments are in line with Reviewer 1 with respect to tracer recovery results and methods and I am also of the opinion that differences in climate and hydrological conditions between years, and resultant changes in water resource management (i.e. irrigation) should be addressed to ensure that these factors are not compounding perceived beaver dam effects.

We have expanded the tracer methods and added the explanation of mass recoveries and error estimates. There was a mistake in original manuscript (p. 852, L11 in HESSD) stating the mass recovery %. The percentages reported are not mass losses, but % gross water losses. The MS will be updated with the following near HESSD page 852, L11.

"To estimate tracer mass losses and gross stream losses, mass recoveries were quantified using (Payn et al., 2009):

(equation cannot be displayed)

For 2008, the error in flow estimates for individual sub-reaches was about 8% for both Q and %ΔQ. For 2010, the errors ranged from 6% to 28% for Q and 8% to 29% for %ΔQ. Most of the error was due to incomplete mixing and larger errors in 2010 were attributed to higher variability in flow and flow paths. The mass recoveries from the dilution gaging showed that the percent of mass loss and gain changed significantly

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from 2008 to 2010. In 2008, the mean percent mass losses for individual sub-reaches were -2.8, -12.9, -18.1, -18.8, and -4.7%. In 2010, the mean percent mass losses were -69.0, -0.2, -8.3, -62.0, -7.6% for the same sub-reaches."

To address the concerns regarding the differences in climate and hydrologic conditions between years, we have made a number of changes to the MS. First, air temperature and solar radiation for all three years has been incorporated into Figure 4. To illustrate climate differences and to provide a context for differences in discharge between years, we have added cumulative precipitation and snow water equivalent for each year in SI Figure 5. As explained in our responses to Reviewer 1 comments, 2010 was drier year due to less snowfall. The snow water equivalent at its peak was about 500 mm in 2008 and 2009, and 300 mm in 2010. However, precipitation accumulation in 2010 increased in late spring/ summer, and the cumulative amounts were comparable with that of 2008 at the end of the water year (October) (SI Fig. 5). While the discharge in 2010 could have been influenced by irrigation practices in the nearby field, irrigation usually occurs only from mid-May to mid- or end-July at the latest and therefore only had a potential impact during this time. However, water rights require irrigation in this area to stop when the flow in Blacksmith Fork reaches a minimum instream flow. Because of low flows in 2010, irrigation stopped earlier than usual (likely early July, personal communication, Kelly Pitcher, Hardware Ranch operations). It is also important to note that the trend of gaining conditions persists past the irrigation season (with more beaver dams being built) (Figure 3). This suggests that reach gains in 2010 were due primarily to groundwater influences rather than irrigation influences. In our opinion, the human impact is likely not a driving factor of the hydrologic and temperature changes we observed.

2. In addition, I feel that the use of a single temperature and pressure logger at locations used to represent overall reach and sub-reach conditions may be stretching the data and conclusions reached; particularly so when no detail of how the locations were chosen, or in what conditions (depth of water, location in the channel) they have been

placed within. For example, why are there differences in upstream and downstream logger locations between dams, as reported in Table 2?

We understand this concern and have added more detail regarding sensor placement. We have added the following explanation –page 846, L26.

"At the finer, beaver dam scale, temperature measurements were collected upstream of ponded water of beaver dams and downstream of individual beaver dams at 10-minute intervals using Onset$^®$ HOBO$^®$ Temp Pro V2 (Bourne, Massachusetts) deployed from September 2 to October 15, 2010 (Fig. 1, Table 1, Table 2). The temperature sensors were initially placed in the flowing water to ensure well mixed flow. The sensors downstream from the beaver dams were placed outside of the scour pool. The sensors were attached to metal stakes and placed in the middle of the channel about halfway through the water column. Individual sensors were wrapped in aluminum foil to reduce solar radiation influence in slower moving waters."

To further clarify, temperature data were gathered above the backwater of the ponded areas (see responses to Reviewer 1 comments). The temperature sensors for our beaver dam scale study were initially placed in the flowing water above the ponded area or below the beaver dam. We tried to choose locations where flow was well mixed (e.g., in areas with multiple channels below the dam, we placed the logger downstream where the flow converged to ensure it was well mixed flow from both channels (BD4)). Also, loggers placed below the dams were placed outside of the scour pool where temperatures could be cooler due to upwelling. There is a possibility that due to beaver activity, some of the sensors were caught in slow/stagnant water for short periods of time. Regardless, as discussed within the paper, we believe that the variability in temperatures observed at the beaver dam scale is due to different surface flow paths, individual beaver dam characteristics such as their size and subsequently the size of the beaver pond, and residence times in the ponds.

As for the pressure transducers, the upstream pressure transducer (PT515, inflow)

was installed close to river bank (RR) in a section between two bends with an average bed slope of 0.017. Based on 2009 data, the average depth recorded at the inflow (PT515) was 0.13 m and minimum and maximum values were 0.08 m and 0.57 m, respectively. The downstream pressure transducer (PT1252, outflow) was installed near a foot bridge about 1.5 m from river left with an average bed slope of 0.0239. Based on 2009 data, the average water depth recorded at the outflow (PT1252) was 0.16 m and minimum and maximum values were 0.08 m and 0.32 m, respectively. The pressure transducer at the upstream end of the control reach (PT0) was installed about 1.0 m from river right with an average bed slope of 0.018. Based on 2009 data, the average depth recorded was 0.21 m and minimum and maximum values were 0.09 m and 0.37 m, respectively. It is important to note that the pressure transducer locations bounded the entire reach influenced by the beaver dams. Therefore, these data provided reach scale information to be made as the number of dams increased.

3. There appears to be large differences in the distance the loggers were placed away from the dams, ranging for example from 8m to 81m upstream of dams. Would the differences in placement and location of the loggers not have an effect on the temperature data collected, and hence conclusions reached? Without an explanation of why and how the loggers were placed where they were, I do not have confidence that they are representative of the temperature conditions found in these locations, and hence provide sufficient information on the effects of beaver colonisation on hydrologic and temperature regimes.

This comment relates to our response in comment 2. We understand the variability is somewhat drastic, but we did focused on placing the sensors in flowing water above the ponded area or below the beaver direct influences of the dams. The large differences in the distances where loggers were placed are due to different size of beaver dams and channel geometry resulting in smaller/larger beaver ponds.

4. As stated by Reviewer 1, given the incomplete data and explanation of hydrological conditions and methods, I feel the current draft of the manuscript is more of a

'qualitative' study, which although interesting, does not meet the expected aims of the manuscript as it stands.

We hope that our clarifications and changes to the MS have provided the information necessary to see the quantitative value in the data collected. Our intent in saying this study is "quantitative" is to point out that we have collected a significant amount of data at different spatial and temporal scales representing actual responses due to beaver colonization.

Minor comments: 5. Please state the units of the stream bed slope on page 843, line24 (I assume %?).

The slope is the ratio of vertical and horizontal distance where units cancel out (meter/meter).

6. An explanation of how subreaches were determined would be beneficial on page 845, line 24.

The individual sub-reaches were chosen so the requirement for complete mixing for dilution gaging was met. Initially, the sub-reaches were equally spaced but later adjusted to provide good locations for injections that resulted in complete mixing. We have added the following statement to the manuscript – HESSD page 846, L1.

"The boundaries for the sub-reaches were chosen to ensure completely mixed conditions necessary for dilution gaging."

7. How often were groundwater surface levels monitored, as detailed on page 846, line 20-23? Were these the only measures of groundwater, or were pressure-level loggers used as well?

The groundwater levels were measured 4 times in 2008 (June, July – 2x, August), 5 times in 2009 (June, July, August – 2x, November), and 4 times in 2011 (April, June, July, November). We have included this information in the MS – page 846, L22.

"The groundwater levels were measured four times in in 2008 (June, July (twice), August), five times in 2009 (June, July, August (twice), and November), and four times in 2011 (April, June, July, and November)."

8. What is the n of the data presented in Figure 8?

Please see previous response to comment 7.

9. If groundwater was only manually measured using a dip meter, was sampling equal throughout the years and seasons?

Please see response to comment 7.

10. More detail on methods please. Without a better explanation of the locations of the loggers, I do not currently have confidence that the data shown in Figure 10 represents the variability in temperature differences between dams, as stated by the authors, but instead, could be a relict of logger placement; more detail is needed to qualify this statement.

Please see response to comment 2.

11. Air temperature and data from a 'control' location (e.g. upstream) of the beaver dams should be added to Figure 11 if possible to put the data in context with the atmospheric and hydraulic conditions during this study period.

We have added the air temperature and stream temperature from the inflow (PT515) to New Figure 10.

12. The authors may wish to consider using more descriptive rather than numerical names for their upstream and downstream temperature loggers (PT515 and PT1252) to help improve the flow of the manuscript and assist readers in immediately grasping their locations.

We have added "inflow" and "outflow" description to the existing nomenclature in the manuscript.

Please note figure captions uploaded with this reply do not cover the entire caption from the original manuscript. There is only limited space for captions in the uploading window. For better reference, please find full captions here:

Figure 1. Aerial image from 2006 (pre-beaver period) and beaver dams constructed between 2009 and 2010. The main beaver dams are numbered from 1 to 10 from upstream to downstream and the time of dam construction is noted in the table. The study reach was further divided into 6 sub-reaches. The spatial scales investigated are illustrated below the map. The most downstream beaver dam and beaver pond are located in the old channel but overlap in the Beaver Dam Scale schematic in this figure. Channel in 2006 is illustrated by black outlines while flowing and ponded water area in 2010 are represented by different shades of blue.

Figure 2. Daily average discharge estimated from continuous pressure transducer records spanning 2008-2010 (A-C). The black dashed line represents upstream, inflow conditions at PT515 and the red solid line represents downstream, outflow conditions at PT1252. The individual 95% confidence intervals around discharge estimates are represented by grey shading.

Figure 3. A) Change in discharge over the study reach calculated from daily average flows where ΔQ is the discharge at outflow (PT1252) minus the upstream discharge at inflow (PT515). Positive values represent increases in discharge and negative values represent decreases in discharge. B) %ΔQ is the percent change relative to the discharge at inflow (PT515). The 95% confidence interval in three different shades of grey correspond with each individual year. Arrows represent time of individual beaver dam construction. Blue and red arrows correspond with year 2009 and 2010, respectively, while the arrow size is proportional to size of the dam.

Figure 4. Average daily temperature (absolute) representing reach scale responses at inflow (PT515, black dashed line) and outflow (PT1252, red solid line) during 2008 (A), 2009 (B), and 2010 (C). Average daily air temperature (D) and average daily solar

radiation (E) show similar weather patterns for all three years.

Figure 5. A) Reach scale change in temperature (ΔT) calculated from temperatures at outflow (PT1252) minus the temperature at inflow (PT515). B) %ΔT is the percent change relative to the temperature at inflow location (PT515). Positive values represent warming throughout the reach and negative values represent cooling relative to the upstream inflow temperature at PT515. Arrows represent time of individual beaver dam construction. Blue and red arrows correspond with year 2009 and 2010, respectively, while arrow size is proportional to size of the dam.

Figure 6. Change in discharge (ΔQ) and temperature (ΔT) over the study reach from 2008 to 2010. Five day period in July was used as an example of shorter temporal scale. The %ΔQ and %ΔT are relative to the discharge and temperature at the upstream inflow location (PT515). The %ΔQ were averaged over a one hour interval, while %ΔT represents 5-minute temperature values.

Figure 7. Groundwater elevation throughout the study reach grouped by individual sub-reaches and water surface elevation in the channel for each sub-reach. The groundwater elevations were measured four times in 2008, five times in 2009, and four times in 2011. The water surface elevation in the channel represents the average yearly value for each sub-reach. There is a gradual increase in groundwater elevation and channel water surface elevation in all sub-reaches over the years.

Figure 8. Sub-reach stream discharge (Q) estimates for 2008 and 2010 representing longitudinal flow variability before and after beaver colonization. %ΔQ is calculated from flow at the end of the sub-reach minus the flow at the beginning of the sub-reach relative to the upstream value.

Figure 9. Spatial variability in stream temperature throughout individual beaver dams (BD). Temperature differences (ΔT) values were calculated based on 10-minute temperature records from locations downstream and upstream of the beaver dam and pond. These data illustrate that there is a time lack between air temperature and

stream temperature and also that there can be measurable differences in temperatures at the beaver dam spatial scale that vary diurnally. It further shows the variability in temperature differences between the dams.

Figure 10. A) Daily ranges (daily maximum minus daily minimum values) of temperature differences downstream and upstream (ΔT) of each beaver dam (BD) based on 10-minute temperature records. Beaver dam 7 and 8 were considered to be one complex. The air temperature (blue line) and stream temperature at the inflow (PT515, black dashed line) illustrate diurnal pattern while the time offset between the two can be observed. B) 24-hour moving average of ΔT.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C1143/2015/hessd-12-C1143-2015-supplement.zip

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 839, 2015.

Discussion Paper
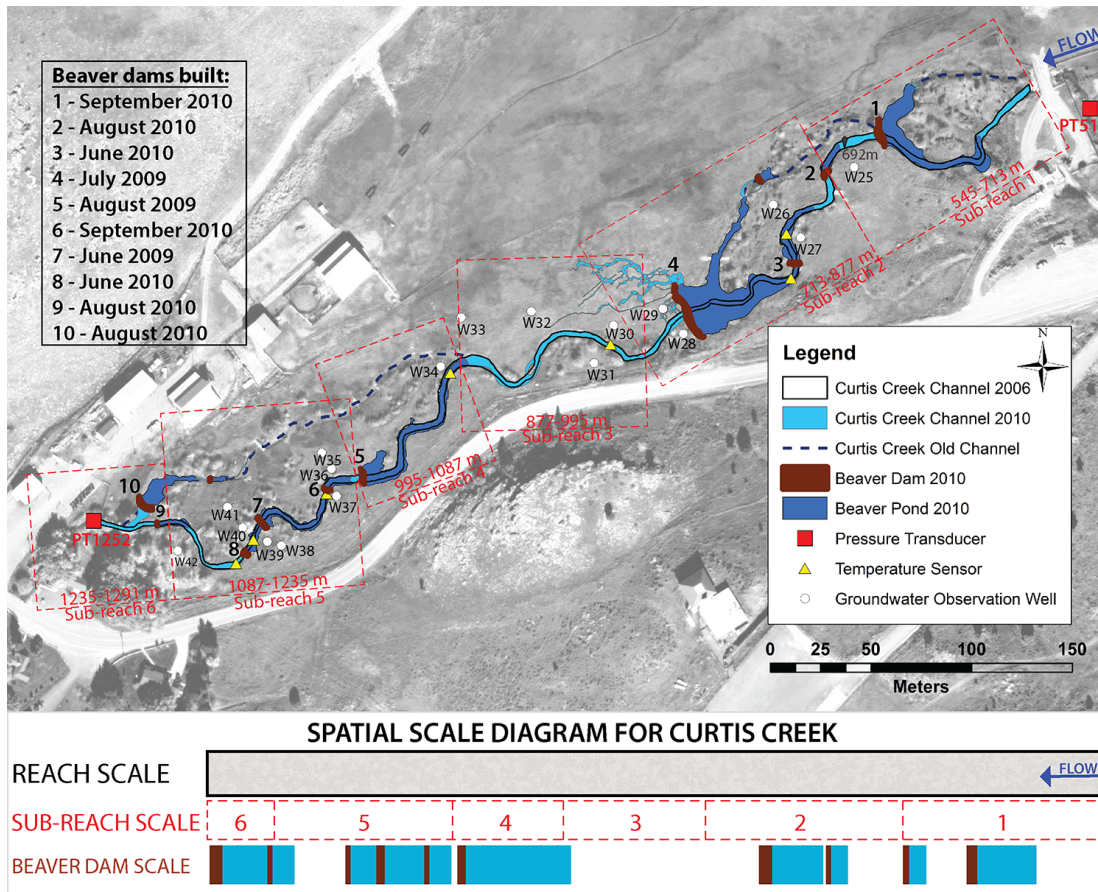
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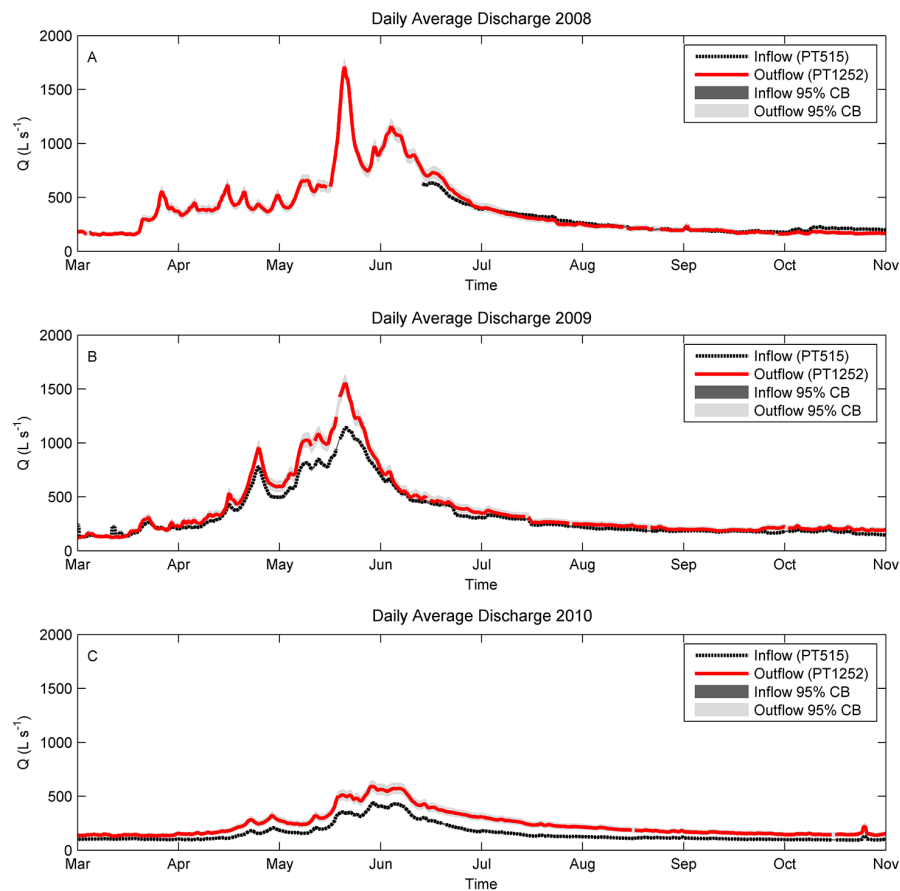
Fig. 2. Daily average discharge estimated from continuous pressure transducer records spanning 2008-2010 (A-C).
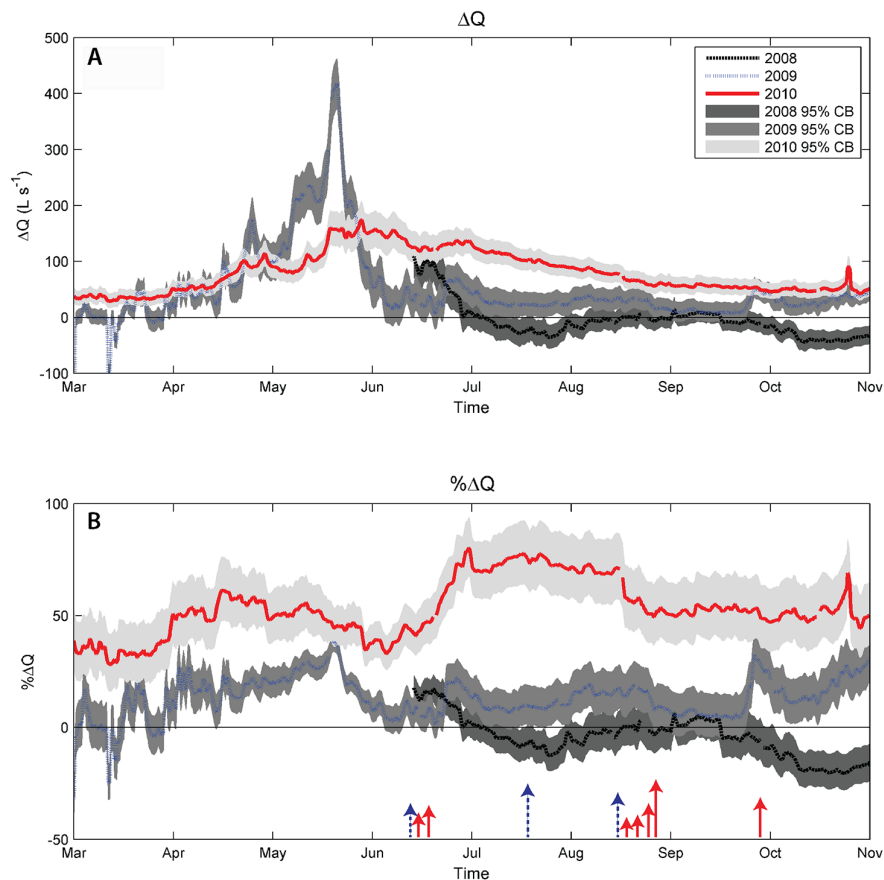
Fig. 3. A) Change in discharge over the study reach calculated from daily average flows where ΔQ is the discharge at outflow (PT1252) minus the upstream discharge at inflow (PT515).
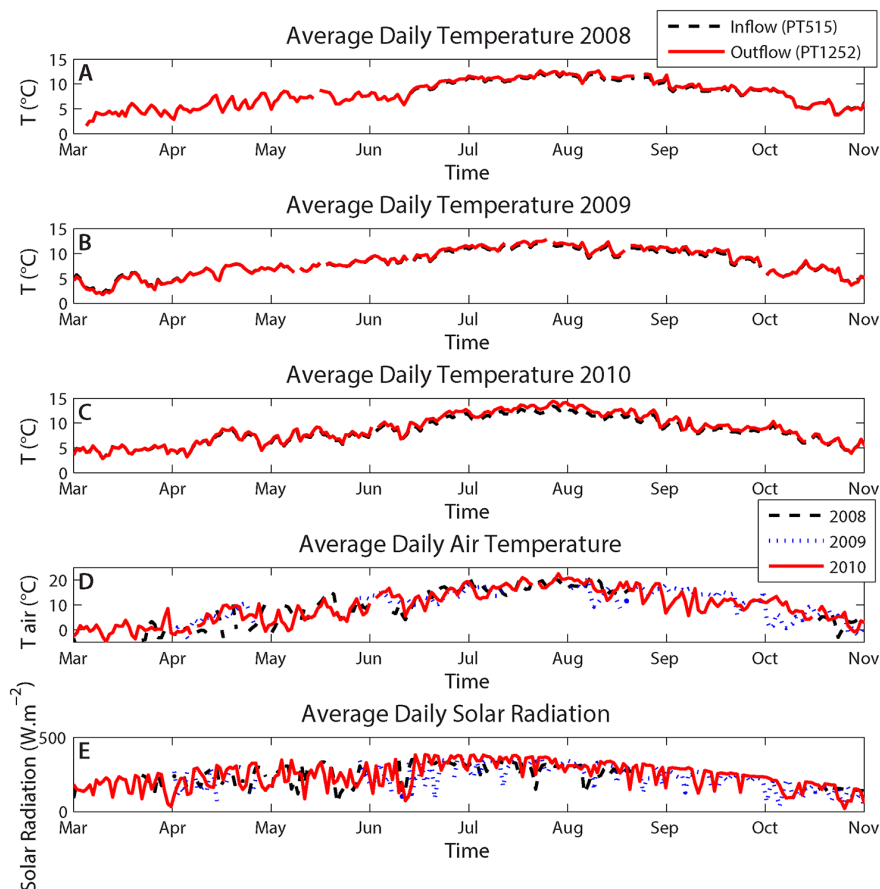
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ΔT

%ΔT
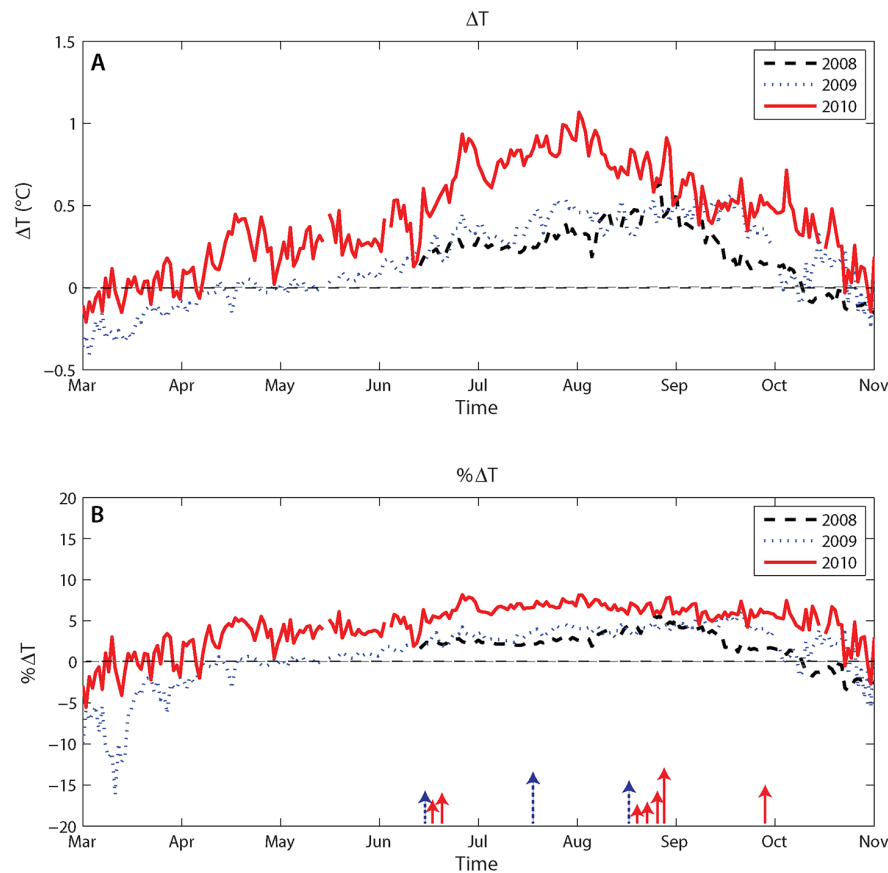
Fig. 5. A) Reach scale change in temperature (ΔT) calculated from temperatures at outflow (PT1252) minus the temperature at inflow (PT515).

Fig. 6. Change in discharge (ΔQ) and temperature (ΔT) over the study reach from 2008 to 2010.
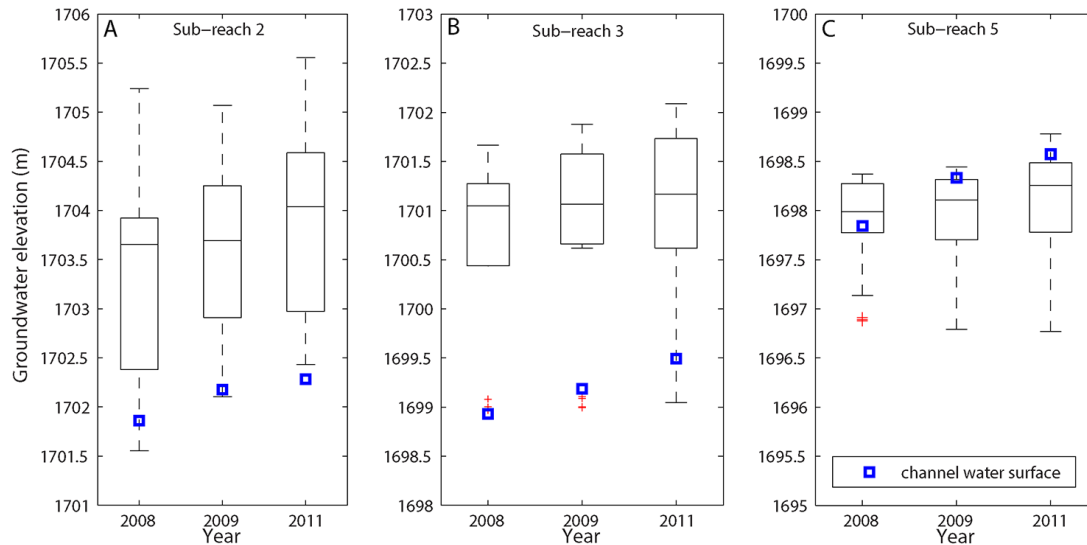
Fig. 7. Groundwater elevation throughout the study reach grouped by individual sub-reaches and water surface elevation in the channel for each sub-reach.
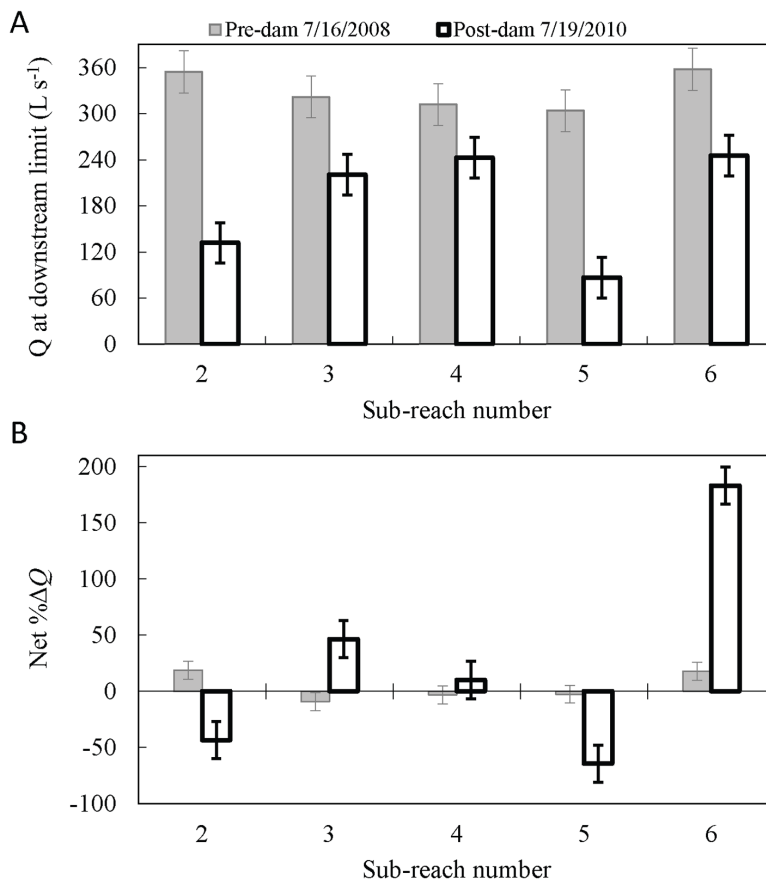
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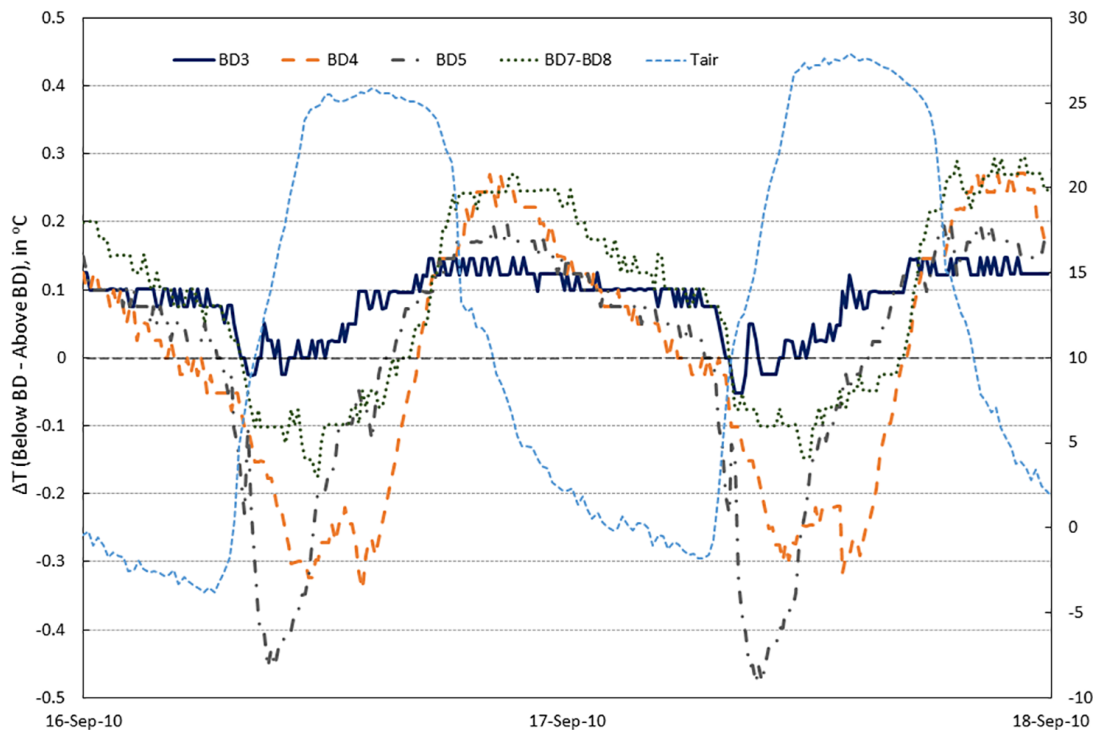
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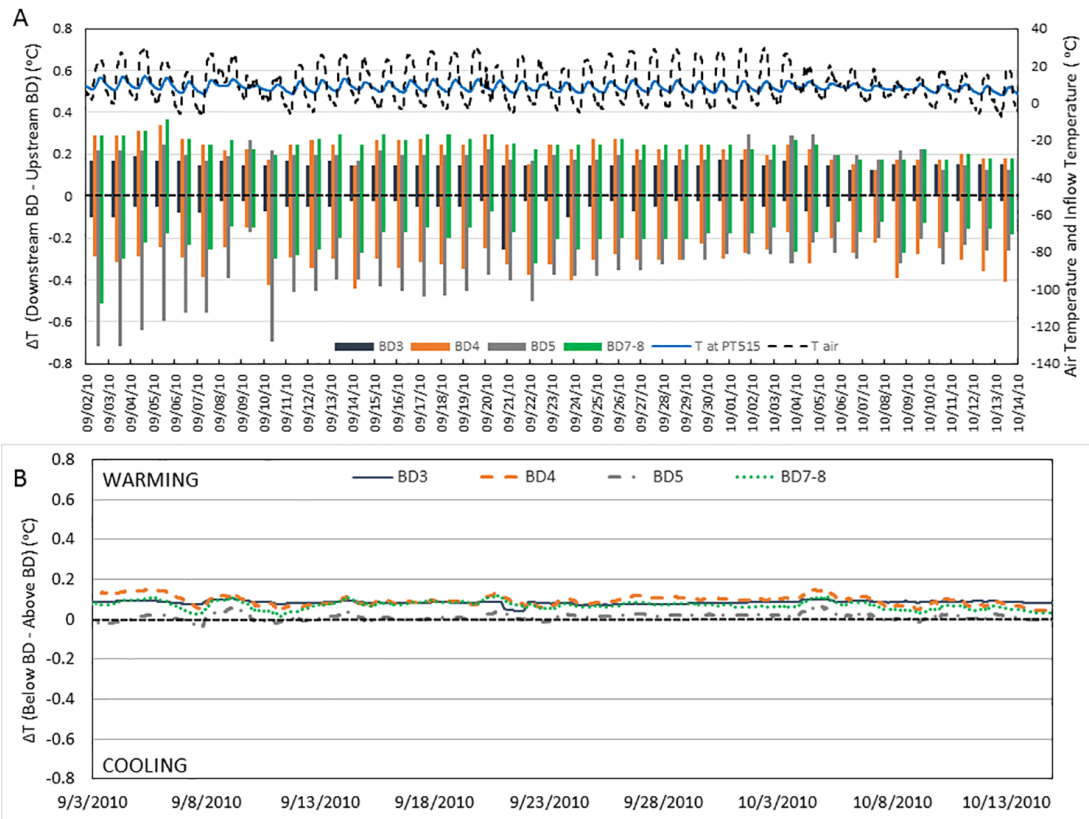
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