File: 6111 January 19, 2024

Beaver Dam stability

A record of an e-mail conversation with Professor Richard Brazier of the University of Exeter, UK on the stability of the beaver dam in Coats Marsh Regional Park on Gabriola Island, BC, Canada.

A copy of a summary paper on beaver dam stability and evolution by Dr. Alan Puttock, Research Fellow, also at the University of Exeter.

To: R.E.Brazier@exeter.ac.uk November 2, 2021

Dear Professor Richard Brazier

This is a long shot attempt at seeking an informal or otherwise opinion on a beaver dam from somebody who knows about the topic.

My interest is in stability (likely failure modes and the risk of a dam failing in its entirety). I have read your research literature on the web, and note that some of the comments refer to data collected up until 2019, and am wondering if you could informally up-date this. I'm thinking specifically about the comment to the effect that catastrophic failure in well-established, low-order channels is "rare”.

The dam I am interested in is at the outlet of a shallow-water wetland, very low energy, fed by two 1st-order streams, well vegetated (bulrushes etc.), stable height for the last three years, easily walkable (photo), has slides that the beaver uses to cross the dam that act as spillways in high water, never been breached. Hydraulic head peaks at about one metre.

I'm fighting against local government who consider catastrophic failure a possibility that would damage downstream infrastructure (not residential) that is getting on in years and was not built with endurance in extreme events in mind, so they would get sued if it were damaged. "Liability" is probably the only word that their legal department has read..

My approach is renovate the infrastructure, don't destroy the dam or drastically lower the water level as is being done (photo) . The wetland behind it is very shallow and the beaver has raised the water level over the last decade providing more attractive habitat for waterbirds. He is a hermit beaver.

Thanks. Any comment or literature references appreciated and I'll only quote you as you desire . You'd think that here in Canada we’d know about beaver dam structures but apparently not.

[2 attachments]

Nick Doe

From: R.E.Brazier@exeter.ac.uk November 3, 2021

Good to hear from you. See below and attached for some responses. Happy to help and look forward to the day when I can visit some of your Beaverlands when all is back to normal?!?

Cheers, Rich

Richard Brazier,
Professor of Earth Surface Processes,
Director, Centre for Resilience in Environment, Water and Waste (CREWW)

Geography,
College of Life and Environmental Sciences,

University of Exeter, Amory Building, Rennes Drive, Exeter, Devon, UK EX4 4RJ
T: +44(0)1392 724 443
E: r.e.brazier@exeter.ac.uk
Homepage
Google Scholar profile

Dear Professor Richard Brazier

This is a long shot attempt at seeking an informal or otherwise opinion on a beaver dam from somebody who knows about the topic.

Hopefully you would consider this as a professional opinion – I have been researching beaver dams and a wide range of other aspects of beaver impacts on hydrology, ecology, society etc… since 2013.

My interest is in stability (likely failure modes and the risk of a dam failing in its entirety). I have read your research literature on the web, and note that some of the comments refer to data collected up until 2019, and am wondering if you could informally up-date this. I'm thinking specifically about the comment to the effect that catastrophic failure in well-established, low-order channels is "rare".

I would still stand by this statement and indeed reinforce it as we rarely see beaver dam failure at our study sites and when we do, it is on higher-order, high-energy stream/river systems during times of flood. Even in these cases, we most often see partial failure, where a notch in the beaver dam fails, and is subsequently repaired the following evening by the beavers. This is because beaver dams are very coherent structures, far more so than the analogous dams that we humans construct, which of course we rarely, if ever, maintain.

Considering the system that you refer to - which is a low energy lake system, in my opinion, especially given the maturity of the dam, the chance of any catastrophic failure is non-existent.

The chance of partial failure is also very low and thus I would not consider there being any enhanced risk to infrastructure downstream, above and beyond the 'normal' risk that such a system might afford to any infrastructure that is in place.

On this point, it is often the case that the risk to infrastructure – including culverts, roads, bridges etc… is due to the inadequate design of older infrastructure that renders it less resilient to the rainfall:runoff regimes that we currently experience - and perhaps even more so to the regimes that we will experience under climate change scenarios. Ironically, beaver dams can enhance the resilience of such structures, as we prove in the attached paper from earlier this year which demonstrates natural flood management, protecting villages downstream of beaver sites, by the beaver dams themselves.

https://doi.org/10.1002/hyp.14017

The following downloaded January 2024 from Alan Puttock 2019

https://www.exeter.ac.uk/media/universityofexeter/research/microsites/creww/riverottertrial/appendix3/Summary_paper_on_beaver_dam_failures_-_UoE_November_2019.pdf

Beaver Dams: stability and evolution, risk of partial or complete failure and impact upon sediment and water dynamics

The extent to which beavers alter river systems depends on habitat suitability, population numbers and catchment characteristics (Butler and Malanson, 2005). In addition to altering flow regimes, (Puttock et al., 2017) by promoting deposition, beaver dams can lead to the infilling of beaver ponds with sediment which, over time, can be colonised and stabilised by vegetation and are referred to as beaver meadows (Naiman et al., 1988, Johnston et al., 2014, Burchsted and Daniels, 2014).

As long as supply continues, sediment will continue to accumulate until either the pond infills and sediments are colonised by plants forming a beaver meadow (Polvi and Wohl, 2012) or a dam collapses releasing sediment (Butler and Malanson, 2005). In catchments with high stream power, and associated risk of dam failure, there may be lower and less stable long term sediment associated stores of nutrients than presented herein (Błędzki et al., 2011). However, where local factors, such as channel gradient, support the stable construction of dams and the resulting stream discontinuity, nutrients may be retained in sediments as shown in this study. Plant colonization and the creation of beaver meadows can further immobilise these sediments and associated nutrients (Naiman et al., 1994). Furthermore, as a considerable volume of potential storage capacity within the 13 yet remains (> 55 %), without accounting for ongoing dam building, it may be expected that beaver damming continues to enhance or at least maintain a dynamic equilibrium of sediment storage at the site (Giriat et al., 2016).

Dam failures, particularly in high energy environments, may also cause infrequent but significant pulses of water and sediment (Butler and Malanson, 2005). Such pulses may, in some cases, exert significant impacts upon river geomorphology (Bigler et al., 2001; Butler and Malanson, 2005). However, different sediment retention dynamics have been reported following dam collapse. Giriat, et al. (2016) found that there were very minimal losses of sediment from the Beaver ponds studied, following a dam collapse. Similarly, Butler and Malanson (2005) reported that the majority of sediments were retained in ponds and subsequently stabilised following colonisation and dam reconstruction. Levine and Meyer (2014) reported large sediment losses but the remnants of the dam structure were found to trap sediment, which was rapidly colonised by plants and stabilised. In contrast, other studies have observed rapid loss of pond sediments following dam collapse (Levine and Meyer, 2014, Curran and Cannatelli, 2014). It is likely, that as with the site studied, where closely-spaced, multi-dam complexes exist, these will provide a major buffering effect, reducing the likelihood of dam failure and, in so doing, also reducing the downstream release of sediment from any single dam failure.

It is notable that, at the Mid-Devon Beaver site reported upon in Puttock et al., 2017, 2018 or across other monitoring sites in GB full dam failures and resulting large sediment releases have not been observed since beaver release. However, in other environments i.e. steep alpine environments dam collapses have the potential to cause significant change to river and floodplain morphology (Butler, 1991) and are more common (Butler and Malanson, 2005). Beaver dam collapses typically follow significant discharge events (Butler, 1989) and are common in alpine environments where seasonal meltwater can dramatically increase river flows (Butler, 1991). An experimental study by Klimenko and Eponchintseva (2016) investigated the hydrological impact of dam collapses by instigating two dam collapses in Perm Oblast, Russia. The dams that were collapsed contained 800 m^3 and 144 m^3 of water and it was shown that the release of this water created a hydrograph that resembled a natural flood event. However, It was considered that failure of the entire dam structures is unlikely and that the chance of peak flows exceeding natural maximum flood discharges was just 10%. There are two key factors not considered in this study: (i) the strength of beaver dams increases with age (Meentemeyer and Butler, 1999); the study does not consider the age and therefore structural integrity of the dams when assessing the chance of collapse; and (ii) it does not consider the combined effect of high flood flows and the collapse-surge. It is clear from the literature that significant mechanistic uncertainty regarding dam failure dynamics exists (Anderson and Shaforth, 2010; Klimenko and Eponchintseva, 2015) and is an area in need of continued research.

Experience from hydrological monitoring across beaver sites nationally since 2014

Key observations from monitoring across multiple sites nationally:

- At monitoring sites on 1st-4th order channels, sites complete failure of established dams has not been observed.
- On 1st-3rd order channels (where beaver dam capacity modelling has classed reaches as having a pervasive or frequent capacity for damming), dams are commonly stabilised by vegetation over time becoming integral component part the landscape (i.e. figure 1)
- On 1st-4th order channels partial damage to dams of varying magnitudes has been observed during high energy winter storm events (i.e. figure 2-4). This damage is typically more severe on larger streams which experience higher stream power.
- In dam sequences, the impact on downstream flow regimes of damage to a single dam is mitigated/negated by the overall combined impact of dam sequence, rarely producing discernible downstream results.
- At Mid-Devon site, a breach in a mid-sequence pond resulting in a ca 40 cm pond depth reduction and the proceeding dissipation by downstream ponds and minor increase in downstream water level (ca peak 12 cm increase in stage and elevated flow for ca 1 hour) was captured by level sensors located in each pond with results illustrated in Figure 7.
- Damage typically manifests itself as minor nick pints allowing overtopping (i.e. figure 3) or partial breach in bottom of dams (i.e. figure 2). These partial beaches are commonly rapidly repaired by beaver.
- The most severe damage observed has not been to dams themselves but in neighbouring banks which in two locations (one on a 4th order reach figure 5 and one on a 2nd order reach figure 6) have breached leading to localised bankside erosion. In both these cases damage has also subsequently been repaired to beavers and has resulted in increased channel heterogeneity.
- In larger 4th order channel reaches where dam capacity has been classed as occasional, small temporary dams built during low flow conditions have been removed when normal or high flow conditions resume. When such dams do break down it is often gradual. They often erode slowly from the top or following a partial blow out and the material is gradually washed away. They are held together with soft sediment and mud, in amongst the sticks and other more solid material. The material tends to dissipate very effectively in the high flow events that cause them to fail.
- Only one case of damming has been experienced on a channel with a stream order of 5th order or larger. This dam was built during very low flow summer conditions and would have expected to have been breached in the next high flow conditions. However, it was removed by fishermen before this could be confirmed.

Figure 1. Dam stabilised by vegetation

Figure 2. Breach in bottom of a dam on 3^{rd} order channel

Figure 3. Breach and overtopping of a dam in 2nd order channel

Figure 4. Breach and reduction in water storage in dam on 2^{nd} order channel

Figure 5. Bankside breaching and erosion on 4th order channel

Figure 6. Bankside and bottom of dam breach on a 2nd order channel

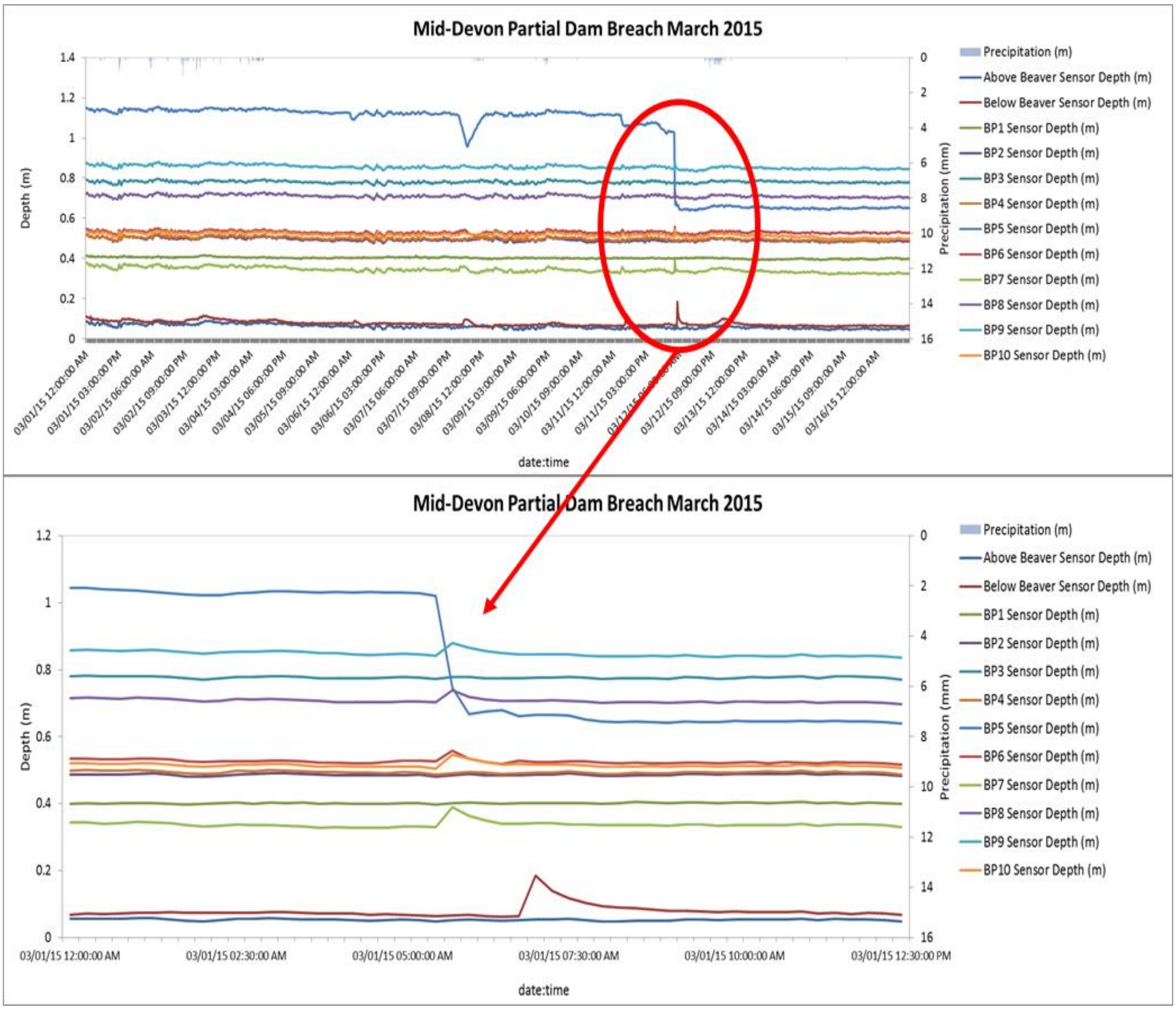

Figure 7. Downstream impact of beaver pond breach in a mid-sequence pond (BP =beaver pond). Blue line showing large drop on 12th march is Pond 5 in a sequence of 10 ponds. Effect can be seen to propagate through/be dissipated by beaver ponds 6 -10 resulting in a minor and temporary increase in downstream water level (Below Beaver sensor – red line).

References

Andersen DC, Shafroth PB. 2010. Beaver dams, hydrological thresholds, and controlled floods as a management tool in a desert riverine ecosystem, Bill Williams River, Arizona. Ecohydrology 3: 325–338.DOI: 10.1002/eco.113.

Bigler W, Butler DR, Dixon RW. 2001. Beaver-pond sequence morphology and sedimentation in Northwestern Montana. Physical Geography 22: 531–540.DOI: 10.1080/02723646.2001.10642758

Błędzki et al. 2011. Downstream effects of beaver ponds on the water quality of New England first- and second-order streams. Ecohydrology 4: 698–707.DOI: 10.1002/eco.163

Burchsted D, Daniels MD. 2014. Classification of the alterations of beaver dams to headwater streams in northeastern Connecticut, U.S.A. Geomorphology 205: 36–50.DOI: 10.1016/j.geomorph.2012.12.029

Butler DR, Malanson GP. 1994. Beaver Landforms. The Canadian Geographer/Le Géographe canadien 38: 76–79.DOI: 10.1111/j.1541-0064.1994.tb01519.x

Butler DR, Malanson GP. 1995. Sedimentation rates and patterns in beaver ponds in a mountain environment. Geomorphology 13: 255–269.DOI: 10.1016/0169-555X(95)00031-Y

Butler DR, Malanson GP. 2005. The geomorphic influences of beaver dams and failures of beaver dams. Geomorphology 71: 48–60.DOI: 10.1016/j.geomorph.2004.08.016

Curran JC, Cannatelli KM. 2014. The impact of beaver dams on the morphology of a river in the eastern United States with implications for river restoration. Earth Surface Processes and Landforms 39: 1236–1244.DOI: 10.1002/esp.3576Deasy C, et al. 2009. Mitigation Options for Sediment and Phosphorus Loss from Winter-sown Arable Crops. Journal of Environment Quality 38: 2121.DOI: 10.2134/jeq2009.0028

Giriat D, Gorczyca E, Sobucki M. 2016. Beaver ponds' impact on fluvial processes (Beskid Niski Mts., SE Poland). Science of The Total Environment 544: 339–353.DOI: 10.1016/j.scitotenv.2015.11.103

Johnston CA. 2014. Beaver pond effects on carbon storage in soils. Geoderma 213: 371–378.DOI: 10.1016/j.geoderma.2013.08.025

Klimenko DE, Eponchintseva DN. 2015. Experimental hydrological studies of processes of failure of beaver dams and pond draining. Biology Bulletin 42: 882–890.DOI: 10.1134/S1062359015100064

Levine R, Meyer GA. 2014. Beaver dams and channel sediment dynamics on Odell Creek, Centennial Valley, Montana, USA. Geomorphology 205: 51–64.DOI: 10.1016/j.geomorph.2013.04.035

Naiman RJ, Johnston CA, Kelley JC. 1988. Alteration of North American Streams by Beaver: The structure and dynamics of streams are changing as beaver recolonize their historic habitat. BioScience 38: 753–762.DOI: 10.2307/1310784

Naiman et al. 1994. Beaver Influences on the Long-Term Biogeochemical Characteristics of Boreal Forest Drainage Networks. Ecology 75: 905–921.DOI: 10.2307/1939415

Polvi LE, Wohl E. 2012. The beaver meadow complex revisited - the role of beavers in post-glacial floodplain development. Earth Surface Processes and Landforms 37 : 332–346. DOI: 10.1002/esp.2261 [online] Available from: http://doi.wiley.com/10.1002/esp.2261 (Accessed 31 March 2014)

Puttock et al. 2017. Eurasian beaver activity increases water storage, attenuates flow and mitigates diffuse pollution from intensively-managed grasslands. Science of The Total Environment 576: 430–443.DOI: 10.1016/j.scitotenv.2016.10.122

Puttock A, Graham HA, Carless D, Brazier RE. 2018. Sediment and Nutrient Storage in a Beaver Engineered Wetland. Earth Surface Processes and Landforms DOI: 10.1002/esp.4398 [online] Available from: http://doi.wiley.com/10.1002/esp.4398 (Accessed 6 April 2018)