Restoring Western Headwater Streams with Low-tech Process - Based Methods*: A Review of the Published Science and Case Studies*

LTPBR project | Photo Credit: Jackie Corday

Executive Summary

This report reviews published research and unpublished case study information on the effects of restoring incised and degraded headwater streams in western states with low-tech process-based restoration methods (LTPBR). LTPBR is a subset of process-based restoration (PBR) that seeks to re-establish natural stream processes by reconnecting incised streams with their floodplains and adjacent wetlands so that more frequent inundation of the floodplain occurs. Projects involve the use of simple, temporary, hand-built wood and rock structures that mimic natural beaver structures, acting as speed bumps that capture sediments to aggrade the stream. LTPBR approaches are substantially less expensive than form-based stream restoration approaches that employ heavy equipment.[i] This approach is appealing in part because low project costs enable implementation at a scale that can respond to the extent of floodplain alteration, which is estimated at 45% of headwaters streams in Colorado.[ii] Negative effects of disconnected floodplains include lower groundwater tables, lower summer base flows, warmer water temperatures, and substantial loss of riparian habitat.[iii]

A key to the success of LTPBR is having sufficient space for natural fluvial processes to occur. Generally, suitable locations for this type of restoration will be on first- to fourth-order streams with a gradient of less than 6% located on rural public or private lands where there is room for the stream to utilize its full floodplain without causing infrastructure or water use conflicts. These headwater areas were historically occupied by beaver.[iv] A goal of many LTPBR projects is for beaver to recolonize the site, maintaining and expanding the LTPBR structures.[v] Grazing management can be an important intervention to enable the growth of sufficient riparian vegetation to provide adequate food and building material for beavers, as well as to address one of the common root causes of stream degradation.[vi]

Note: This paper was written by Jackie Corday for American Rivers with funding from a Colorado Water Conservation Board grant. This Executive Summary is an excerpt of the full report that is expected to be released in Fall 2022. It is currently undergoing full review and graphic design.

State of the Science – Reported Effects of LTPBR

Research surrounding the effects of connected floodplains and beaver complexes is growing. The following effects of LTPBR projects and beavers have been widely documented:

- **Drought and flood resilience**. Studies indicate that healthy natural stream systems and restored headwater floodplains and wetlands recharge local aquifers. Enhanced water storage capacity in floodplains allows for slow infiltration of runoff into soils and wetlands, providing natural storage during spring runoff that can be slowly released to streams during the summer months.[vii] There are numerous examples in which beavers increase surface and subsurface water storage. This was observed to reduce the impact of recent drought on pond levels in a long-term study in Minnesota.[viii] Another study found that beaver dams, even failed ones, helped delay downstream flood peaks during a large flood in the Canadian Rocky Mountains.[ix]
- **Increased water quality**. Beaver dams have been shown to retain sediment and nutrients,[x] as well as heavy metals,[xi] reducing downstream pollution levels.
- **Wildfire resilience**. A 2020 study of large western US wildfires found that riparian vegetation around beaver complexes had a three times greater rate of survival than around stream segments without beavers.[xii]
- **Improved habitat**. By enhancing wetlands, LTPBR and beaver dams enhance important terrestrial habitat, and have also been shown to enhance fisheries.[xiii]
- **Increased forage**. A 2018 study of LTPBR projects in Colorado, Oregon and Nevada showed that the projects increased vegetation productivity and extended it longer into the year. The authors noted that increased soil moisture due to the projects enabled vegetation to keep growing well during periods of low precipitation.[xiv] A USDA study of LTPBR projects in dryland areas of Oregon, Nevada and Idaho involved extensive interviews of 53 ranchers, the large majority of whom expressed great enthusiasm for beavers returning to their ranches due to the "increased availability of water and better forage" for livestock "that can translate into financial gains."[xv] One Idaho rancher said that taking actions to assist the return of beaver to his ranch "*worked well for everything because, one, it provided water, year-round water all the time, which is a godsend for wildlife, for my cattle, everything. Two, it enhanced the wet meadows that were there, so you had better forage production for cattle, wildlife, everything else*."[xvi]
- **Reducing Sedimentation**. A study in England monitored 13 beaver ponds built from beavers re-introduced to a controlled 4.5-acre site – the ponds represented 9% of the land surface. They determined that the beaver ponds trapped on average 7.8 tons of sediment, totaling 101.5 tons.[xvii] The authors concluded beaver ponds may help mitigate the downstream impacts of erosion and nonpoint source pollution.[xviii]

The hydrologic effects of LTPBR projects and beavers, including increased late-season flows and the potential for increased evaporation and water use by additional wetland vegetation, needs additional research. Demonstration projects in different locations and elevations are needed to allow for more scientific understanding of these effects. Existing research on the hydrologic effects have found the following:

- Key factors influencing the degree of LTPBR and beaver impacts on late-season flows include the extent of floodplain inundation and the length of time the inundation is sustained, as well as the porosity of structures.[xix]

- In regard to the potential for LTPBR to cause higher late-season flows and lower flows during the period when water is initially retained, one review found that small LTPBR projects tend not to have observable effects on streamflow, while larger projects can attenuate runoff and increase baseflows.[xx]
- Research conducted for this report did not find any documented cases of LTPBR projects that resulted in measurable harm to water rights from increased evaporation due to more surface water and increased evapotranspiration (ET) from riparian vegetation. A 2020 Montana study found that three years after the installation of a LTPBR project, the riparian vegetation had increased by ~25%, which resulted in a 0.7gpm increase in ET per BDA.[xxi] This small amount of decreased flow (0.0015cfs) was well below an amount that could be detected by a stream gage. [xxii]

Despite the documented benefits and low cost of LTPBR projects, significant challenges impede scaling up these projects. These include the potential impacts to human infrastructure from beaver dams, such as road flooding. This has stimulated the development of numerous solutions for preventing beaver from blocking water conveyances and ensuring sufficient water passage through beaver dams to prevent flooding problems.[xxiii] Concerns about whether or not LTPBR projects can impact downstream water rights can also hinder projects. Consulting with local stakeholders prior to developing an LTPBR project, carefully choosing location and project design, as well as ensuring compliance with any permitting requirements, can help overcome these challenges and enhance the chances for project success.

Conclusion

Existing research indicates that LTPBR can be a useful, cost-effective tool for buffering western watersheds from the increasingly extreme droughts, wildfires and rainfall events associated with climate change. Additional pilot projects with extensive baseline data and ongoing monitoring are important to better understand and quantify the factors that maximize the benefits of LTPBR while minimizing conflicts. Recent increases in funding for natural infrastructure through the federal Infrastructure Investment and Jobs Act and Inflation Reduction Act, as well as state-level programs, makes this an opportune moment to develop and implement these projects.

---

[i] Wheaton, J., Bennett, S., Bouwes, N., & Shahverdian, S. (2019). *Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Version 1.0*. Utah State University.
[ii] Gentile, N. (n.d.) *The Disappearing West.* Center for American Progress, https://disappearingwest.org/rivers.html
[iii] Poff, B., Koestner, K. A., Neary, D. G., & Merrit, D. (2012). *Threats to Western United States: A Bibliography.* US Forest Service, Rocky Mountain Research Station.
[iv] Scamardo, J. E., Marshall, S., & Wohl, E. (2022). Estimating widespread beaver dam loss: Habitat decline and surface storage loss at a regional scale. *Ecosphere.*
[v] Castro, J., Pollock, M., Jordan, C., & Kent, G. L. (2018). *The Beaver Restoration Guidebook.* US Fish and Wildlife Service.
[vi] Swanson, S., Wyman, S. & Evans, C. (2015). Practical Grazing Management to Maintain or Restore Riparian Functions and Values on Rangelands, Swanson et al, *Journal of Rangeland Applications.*
[vii] Hood, G. & Bayley, S., (2008). Beaver mitigate the effects of climate on the area of open water in boreal wetlands in western Canada, *Biological Conservation*.
[viii] Johnson-Bice, S., Gable, T., Windels, S., & Host, G. E. (2022). Relics of beavers past: time and population density drive scale-dependent patterns of ecosystem engineering. *Ecography*.
[ix] Westbrook, C. J., Ronnquist, A., & Bedard-Haughn, A. (2020). Hydrological functioning of a beaver dam sequence and regional dam persistence during an extreme rainstorm. *Hydrological Processes*.
[x] Puttock, A., Graham, H. A., Carless, D., & Brazier, R. E. (2018). Sediment and nutrient storage in a beaver engineered wetland. *Earth Surface Processes and Landforms*.

[xi] Murray, D., Neilson, B. T., & Brahney, J. (2021). Source or sink? Quantifying beaver pond influence on non-point source pollutant transport in the Intermountain West. *Journal of Environmental Management*.
[xii] Fairfax, E., & Whittle, A. (2020). Smokey the Beaver: beaver-dammed riparian corridors stay greenduring wildfire throughout the western United States. *Ecological Applications*.
[xiii] Bouwes, N., Weber, N., Jordan, C. E.,. . . Pollock, M. M. (2016). Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (Oncorhynchus mykiss). *Scientific Reports*.
[xiv] Silverman, N. L., Allred, B. W., Donnelly, J. P., . . . Naugle, D. E. (2018). Low-tech riparian and wet meadow restoration increases vegetation productivity and resilience across semiarid rangelands. *Restoration Ecology*.
[xv] Charnley, S. (2020). Ranchers, Beavers, and Stream Restoration on Western Rangelands, *USDA Science Findings*.
[xvi] Charnley, S., Gosnell, H., Davee, R. & Abrams, J. (2020). Ranchers and Beavers: Understanding the Human Dimensions of Beaver-related Stream Restoration on Western Rangelands, *Rangeland Ecology & Management*.
[xvii] Sediment and Nutrient Storage in a Beaver Engineered Wetland, Puttock et al, Earth Surface Processes and Landforms, (2018).
[xviii] Puttock et al. (2018). A similar study in Russia determined beaver dams along the Sumka River reduced sediment mass per liter of water by 53% flowing downstream of the dams. Is it possible to use beaver building activity to reduce lake sedimentation? Gorshkov, *Lutra,* (2003).
[xix] Larsen, A., Larsen, J., & Lane, S. (2021). Dam builders and their works: Beaver influences on the structure and function of river corridor hydrology, geomorphology, biogeochemistry and ecosystems. *Earth-Science Reviews*
[xx] Clancy, N. G., & Wolf, M. (2022). *A Brief Summary of Beaver Mimicry and Streamflow.* University of Wyoming.
[xxi] Andrew Bobst, Sr. Hydrologist for Montana Bureau of Mines, PowerPoint presentation to the Riverscape Restoration Network on August 2020. Bobst has been working to prepare his research for publication.
[xxii] "We estimated actual ET (AET) using high resolution NDVI imagery obtained with drone flights. We combined NDVI with potential ET (PET) calculated at nearby Agrimet stations (Penman-Monteith) to get AET. Then to get the groundwater component of that we subtracted off the AET estimated in the uplands (where groundwater is not available to the plants)." Email from Andrew Bobst to Jackie Corday July 8, 2022.
[xxiii] Millman, K. (2022). *Beaver Management Along Roads and Within the Right-of-Way: Report and Recommendations for the Colorado Department of Transportation.* Colorado Department of Transportation.

LTPBR project | Photo Credit: Jackie Corday