BEAVERS AND THEIR ROLE IN RIPARIAN RESTORATION IN MONTANA

Version 1.0

BEAVERS AND THEIR ROLE IN RIPARIAN RESTORATION IN MONTANA

Torrey Ritter - Region 2 Nongame Wildlife Biologist, FWP

Michelle McGree - Future Fisheries Coordinator, FWP

David Schmetterling - Fisheries Research Coordinator, FWP

Claire Gower - Region 3 Nongame Wildlife Biologist, FWP

Vanna Boccadori - Butte Area Wildlife Biologist, FWP

Contents

Acknowledgments........4
Executive Summary........5
How to Use This Document........11
Acronyms Used in This Document........12
Introduction........13
Overview of Beaver Restoration........13
Beaver Restoration in Montana........20
Beaver Restoration and FWP........23
FWP's Tenets of Beaver Restoration........23
FWP's Responsibilities........24
FWP's Approach to Beaver Restoration........25
Common Scenarios........27
#1. Beavers are causing property damage........28
#2. I want beavers to become established in my project location........31
#3. I want to implement beaver restoration in a stream that is not yet suitable for beavers........34
Project Planning........36
Defining the Project Area and Timeline........41
Spatial Scale for Beaver Restoration: Project size expectations and recommendations........45
Temporal Scale for Beaver Restoration: Project timeline expectations and recommendations........47
Permitting........48
Project Planning Checklist........52
Fish and Wildlife Considerations........53
Fisheries and Aquatic Considerations........53
Hydrology and physical habitat........53
Fish passage........54
Prairie Streams........56
Wildlife Considerations........56
Potential negative effects on terrestrial wildlife........58
Species Considerations........59
Species of Concern........59
Threatened and Endangered Species........60
Fish and Wildlife Considerations Checklist........63
Maintenance and Monitoring........64
Maintenance........64

Monitoring ... 65
Timeline ... 69
Maintenance and Monitoring Checklist ... 70
Additional Resources ... 71
Appendices: The Beaver Restoration Toolbox ... 74
Appendix A: Conflict Management ... 76
Beaver-Human Conflict Laws, Regulations, and Permitting ... 77
Tools for proactively preventing beaver conflicts ... 79
Tools for mitigating beaver damage that is already occurring ... 80
Permitting ... 89
Additional Information ... 89
Appendix B: Land Management Changes ... 90
Grazing systems ... 90
Forest management ... 92
Water management ... 97
Trapping regulations ... 101
Permitting ... 110
Additional Information ... 110
Appendix C: Beaver Mimicry ... 111
Using LTPBR to support an existing beaver population ... 114
Using LTPBR to make a restoration site attractive to beavers ... 119
Permitting ... 119
Additional Information ... 120
Appendix D: Encouraging Natural Colonization ... 121
Assessing the habitat potential for beavers to successfully colonize an area ... 121
Assessing the potential for beaver dispersal into the project area ... 127
Habitat manipulation to encourage colonization (e.g., BDAs and human-built lodges) ... 129
Permitting ... 132
Additional Information ... 132
Appendix E: Beaver Transplantation ... 133
FWP Approval Process for Beaver Transplant Projects ... 134
Montana Beaver Transplant Policy ... 137
Protocol for Transplanting Beavers in Montana ... 139
Permitting ... 155
Additional Information ... 156

Acknowledgments

Many people beyond the authors of this paper helped with bringing it to fruition. Specifically, a big thank you to the people who spent time editing and providing comments: Nathan Kluge, Vanna Boccadori, Claire Gower, Jarrett Payne, Ladd Knotek, Matt Jaeger, Bryan Wakeling, Ken McDonald, Steve Dalbey, Peggy O'Neill, and Sarah Bates. Bob Inman, Claire Gower, and Vanna Boccadori provided some of the initial materials used in a separate project that got incorporated into portions of this document. We also want to thank Elissa Chott, beaver conflict resolution specialist with Defenders of Wildlife, for allowing us to modify and incorporate her content related to non-lethal beaver conflict mitigation techniques. Kristi Dubois, Sharon Ritter, Kate Stone, Jessy Coltrane, Brandi Skone, Shannon Hilty, and Zach Shattuck were instrumental in helping us with portions of this project related to the effects of beavers on Species of Concern in Montana. Thank you to Jennifer Ramsey for helping us develop the transplant protocols and procedures. We would like to thank the myriad of people who offered advice on beaver transplant policies and protocols both from within Montana and from many other western states. All photos and figures are by Torrey Ritter unless otherwise indicated.

Beaver dam on Cougar Creek near West Yellowstone

Executive Summary

Prior to European colonization of North America, most low-gradient streams in western Montana were heavily modified by beaver activity, as were substantial portions of eastern Montana streams. Beavers (*Castor canadensis)* built dams, cut vegetation, dug channels, and flooded vast areas, resulting in broad wetland complexes. Stream systems filled entire valley bottoms and formed diverse mosaics of ponds, backwaters, side channels, and dense thickets of emergent and woody riparian vegetation. These systems slowed and stored snowmelt as it left the mountains and provided productive and abundant habitat for Montana's fish and wildlife species.

The historical combination of the fur trade and subsequent overgrazing of western rangelands by settlers led to extensive degradation of beaver-modified stream systems. Across thousands of miles of streams, stream incision and over-widening has led to a landscape that has lost much of its water storage capacity, and some of the most biologically rich habitats in the West have been diminished to a fraction of their former size and complexity. While the impacts of western colonization paved the way for a thriving economy, the West now faces a burgeoning human population, a warmer and drier climate, significant reductions in key plant and animal species, and increasing demand for water resources. These challenges bring the importance of healthy, intact stream systems to the forefront of water and wildlife conservation efforts.

Reestablishing beavers to areas of their former range can help restore degraded stream systems to benefit plants, wildlife, fisheries, and humans. The primary benefits of beavers for Montana streams include increased landscape-scale water storage, improved late-season streamflow, greater ecosystem resilience to disturbances, enhanced floodplain connectivity, and the creation and maintenance of abundant and diverse fish and wildlife habitats. Because much of the long-term stream restoration work is delegated to the beavers themselves, restoring beavers and beaver-modified habitats has the potential to take stream restoration from small-scale projects to landscape-scale restoration. Restoration at this scale can have a significant impact on some of the most pressing problems facing western communities. The effort to restore beavers and beaver-mediated processes in streams is broadly known as "beaver restoration". Beaver restoration has five major forms:

- **Conflict management** helps people deal with the negative aspects of beaver activity, builds tolerance for beavers on the landscape, and can be a source of beavers for transplant efforts.

- **Changes to land management**, such as grazing regimes and timber harvest, result in changes to habitat that allows beavers to recolonize areas of their historical range.

- **Beaver mimicry** involves people building their own beaver-related structures to mimic the effects of beavers without having beavers on-site.

- **Encouraging natural colonization** of historical habitats through direct habitat manipulation of specific stream sections that provides the conditions for beavers to occupy and thrive in the area.

- **Beaver transplants** to reestablish beavers in areas they have been unable to colonize on their own or into relatively empty habitats.

Effectively planning for and implementing these five forms of beaver restoration requires careful consideration of the underlying biological, hydrological, geomorphological, and social context of the stream systems in which practitioners work. Beaver restoration can therefore be a daunting task, as practitioners must figure out which areas are and are not suitable for beavers, determine how to return beavers to suitable habitats, and avoid or mitigate negative impacts to landowners and land managers. Questions of temporal and spatial scale for beaver restoration permeate each of these complexities. Practitioners must also consider the range of factors beaver activity may affect, from bull trout spawning habitat to irrigation systems to old-growth cottonwood stands.

In recognition of the complexity of undertaking beaver restoration projects, **the overarching goal of this document is to outline the settings and situations where beaver restoration can be implemented to achieve the benefits of beavers while discussing the limitations or pitfalls of restoration that can limit the use of these techniques.**

Specific goals of this document are:

- Consider beaver restoration in the context of FWP's expertise and responsibilities in stream and watershed restoration.

- Highlight common beaver restoration project types and suggest broad-level best management practices that harmonize with FWP policies and are specific to the types of habitats and situations in Montana watersheds.

- Provide an overview of the social, biologic, hydrologic, and geomorphic context under which FWP can support, promote, fund, design, and/or implement beaver restoration projects in Montana.

- Highlight the need for, and utility of, post-project monitoring, adaptive management, and assessments of success.

- Compile and clarify laws, regulations, and agency policies relevant to the five forms of beaver restoration.

As the state agency tasked with managing and conserving the state's fish, wildlife, and state park resources, Montana Fish, Wildlife & Parks (FWP) plays a critical role in stream and riparian habitat management in the state, including beaver restoration projects. FWP has both similar and unique perspectives compared to our partners regarding the design and implementation of beaver restoration. The agency must balance the needs of all fish and wildlife species while navigating the social and political landscape that guides decisions about staff time, funding, and conservation priorities. FWP therefore aspires to be a resource, leader, student, and partner when it comes to beaver restoration projects in the state. This document is intended to increase transparency of FWP's perspectives on beaver restoration while providing background and guidance to FWP staff, our restoration partners, and interested public.

The principles, techniques, and guidelines in this document are best applied to smaller stream systems in the more mountainous parts of the state. These are systems where dominant vegetation types are woody riparian vegetation, and spring runoff pulses from snowmelt are a critical component of the overall disturbance regime. Willow (*Salix* spp.), cottonwood (*Populus* spp.), aspen (*Populus tremuloides*), alder (*Alnus* spp.), red osier dogwood (*Cornus sericea*), and/or birch (*Betula* spp.) are essential forage and construction resources for beavers in these streams. There is relatively scant information about beavers in prairie streams but abundant evidence of historical occupation, so additional research and monitoring is needed in those systems before broadly applicable guidelines and considerations can be developed. Within those sideboards, site selection for beaver restoration projects is further refined by the amounts and types of human infrastructure that could be disrupted or damaged by beaver activity. Areas with low amounts of infrastructure are attractive sites for beaver restoration because of the low potential for conflict, while sites with more infrastructure will require ongoing and potentially expensive conflict mitigation work for beavers to be tolerated in the area.

The primary form of restoration brought about by beavers is through dam-building. However, vegetation flooding and harvest, digging of dens and channels, and tree-toppling also have important effects on streams. To maximize the potential benefits of restoring beavers to areas of their former range, practitioners need to focus on the ability of beaver damming activity to reintroduce and/or promote natural processes in stream systems that lead to system recovery and long-term maintenance of the restored state. These natural processes include introducing structural elements to the stream channel, sediment accumulation behind dams, raising of the water table around dam complexes, enhanced floodplain connectivity, and changes in vegetation in and around beaver colonies. These processes can result in dramatic changes to the stream channel and floodplain. Practitioners need to understand what those changes may be based on the characteristics of the site, how the natural processes lead to those changes, and what the eventual end-goal of the restoration project could or should look like. Being able to plan for and articulate these “process pathways” is critical to proposing, implementing, and ultimately succeeding in beaver restoration.

There are three common scenarios that people encounter when it comes to beavers and beaver restoration in Montana, and the five forms of beaver restoration can be used independently or in combination to help address these three scenarios, depending on the context and available resources:

1) **Beavers are causing property damage.** There are a variety of lethal and nonlethal techniques for dealing with beaver damage issues. Fencing trees can thwart beaver cutting activity. Simple, in-stream devices can mitigate the effects of beaver damming at culverts, bridges, and headgates, and, in some cases, flooding due to free-standing dams. However, there are still many situations where beavers will need to be lethally removed from the area by experienced trappers. Beaver transplants can be used to alleviate some damage issues, though the use of this technique is limited to ideal situations where landowner conflicts are minimized.

2) **Seeking to restore beavers to a stream that consists of marginal or suboptimal beaver habitats.** Changing land management by adjusting grazing, timber harvest, water, and trapping management can result in habitat or beaver population changes that allow beavers to recolonize areas of their former range. In other instances, simple and low-cost stream restoration techniques such as beaver dam analogs can provide beavers the “boost” they need to overcome mild to moderate stream degradation issues, allowing the beavers to take over and perpetuate the restoration actions. In more rare cases, beavers can be transplanted to suitable or near-suitable habitats to jump-start restoration.

3) **Seeking to restore a stream that is unsuitable for beavers using beaver mimicry or other stream restoration techniques.** In streams with more severe degradation issues, beavers may

not be able to occupy the area until drastic habitat changes occur. Practitioners may use "low-tech, process-based restoration" to mimic the beaver-induced disturbance regime to fast-forward stream evolution to a restored state. This involves building beaver dam analogs and post-assisted log structures at high densities and in multiple phases in the degraded stream sections. More heavy-handed channel and floodplain restoration, such as floodplain regrading, bank sloping, and extensive riparian plantings, are also effective techniques for restoring heavily degraded stream systems, and much of the work can be done in one or two seasons. However, the cost per unit of stream length can be high.

People and practitioners facing one of these three scenarios must engage in careful project planning to arrive at the best solution for the challenges at hand. Because beavers and their effects on streams can vary widely based on the underlying context of the system, beaver restoration techniques require careful forethought, adaptive management, and some acceptance of uncertainty to be successful. Practitioners need to figure out the stream processes that have been lost or altered due to degradation, identify limiting factors for the recovery of the stream, determine how they will reestablish those natural processes, and predict how those processes lead to a desired outcome. And, as is the case with other species restoration efforts, recognizing and addressing social factors is just as important as ecological processes and management techniques.

Guiding principles for planning a beaver restoration project include:

- Surveying the existing beaver population in an area and considering the restoration project in the context of that existing beaver population.

- Accounting for the potential for beavers to expand into and outward from the restoration area.

- Considering the restoration reach or reaches in the context of the larger watershed and accounting for how upstream inputs may influence the success or failure of the project components.

- Understanding the underlying geomorphology of the floodplain in which the project will take place and managing expectations based on that understanding.

- Identifying and assessing possible impacts to humans and other fish and wildlife species.

- Carefully considering the appropriate spatial and temporal scale needed to achieve the goals of the restoration project.

Successful beaver restoration projects focus on establishing long-term beaver colonies that become self-sustaining, meaning the beavers can colonize and abandon sections of streams throughout the restoration area without the system unraveling and returning to a degraded state. A healthy beaver population is characterized as a "shifting mosaic," where a range of beaver colonies in various states of succession exist in a drainage, and beaver colony establishment and abandonment occur due to natural processes and not due to stream degradation or human intervention. Therefore, the focus should always be on the beaver population in an area and not individual beaver colonies.

Even a well-planned beaver restoration project can face hurdles when it comes to the potential impacts of the project on other fish and wildlife resources. Beaver restoration has the potential to radically transform aquatic and terrestrial habitats, often to the benefit of a wide range of species, but potentially to the detriment of other species in certain contexts. Permitting for the various forms of beaver restoration will involve articulation of how the project will affect other natural resources, including other species whose habitats overlap with beavers.

The effects of beavers on fish and other aquatic life are complex and, as always, highly context dependent. Beavers can affect hydrology and physical fish habitat through changes to the way water moves through the system, effects on water temperature, changing the distribution and deposition patterns of fine sediments, and introducing woody material to the stream channel. Beaver effects on water movement can vary widely between gaining and losing reaches of streams, with associated impacts on project goals and outcomes. Beaver dams can also influence the movement of fish up and down stream channels. Fish passage can be majorly affected when beavers build dams in incised stream channels, whereas fish passage may be enhanced where the dams result in robust overbank flows that result in lots of secondary channels and pool habitats. We know relatively little about how beavers affect water and physical habitat in prairie streams, highlighting a significant need in the form of research and monitoring in the less mountainous parts of Montana.

On the wildlife side, the effects of beavers are far less complex, and there are few wildlife species for which the effects of beavers are negative. In fact, one of the most powerful motivations for the restoration of beavers and beaver habitats is the disproportionate positive impacts they can have on wildlife like amphibians, small mammals, semi-aquatic mammals, songbirds, waterfowl, and bats. Negative impacts to wildlife usually only arise when beavers are encouraged to settle in areas that are not in the appropriate state to thrive under the effects of beaver activity. Understanding the underlying context of the beaver restoration project, followed with careful project planning, can avoid most of these uncommon, negative impacts to wildlife.

There is a relatively short list of specific species practitioners need to be cognizant of when designing and implementing beaver restoration projects. These include state Species of Concern and species listed under the Endangered Species Act. On the fisheries and aquatics side, beavers are of particular concern in areas with Westslope and Yellowstone cutthroat trout, arctic grayling, or bull trout. Coordination with regional fisheries biologists is critical to successful beaver restoration projects as these professionals will have the best knowledge and information on where these sensitive species reside and what the potential impacts of beavers on these species might be. On the wildlife side, there are very few specific species that beavers affect negatively. Most wildlife species either do not overlap with beaver-modified systems or generally benefit from beaver activity.

Across the five forms of beaver restoration, there are almost no situations where a project will be implemented and completed in one season. Beaver restoration projects require multiple phases. Maintenance of project inputs is a critical component of a successful project. Nonlethal conflict mitigation structures require periodic removal of debris, replacement of parts, and adjustment of components to keep up with beaver activity and the effects of high-water periods. Beaver dam analogs and post-assisted log structures require repair and resizing, and additional structures often need to be built in subsequent years to keep the project on the process pathways that lead to the desired end goal. Multiple beaver transplants at a site may be needed to establish a long-term, self-sustaining population, and those beavers may require person-built structures to help them overcome stream degradation issues. Even land management changes that are somewhat tangential to beaver restoration (e.g., grazing management) will require upkeep of riparian fences, water gaps, or off-stream watering systems to be successful. Maintenance is a key part of all forms of beaver restoration until the system recovers and the situation becomes self-sustaining. Maintenance needs must therefore be incorporated at the planning stage and become a non-negotiable part of the restoration plan.

Relative to other forms of stream and riparian restoration, beaver restoration is a new field. There is still a lot we don't know about how to best implement these kinds of projects and what the long-term results will look like. Furthermore, beavers can occupy and thrive in an astounding variety of habitats and situations, so their effects can vary widely across stream systems. Practitioners should have robust monitoring plans in place, with specific measures of key metrics that speak to the breadth of goals outlined in the project planning stage. Learning from other projects' successes and failures will be highly valuable to beaver restoration as a whole and will allow practitioners to communicate knowns and unknowns to landowners, managers, and permitting agencies.

One of the most effective ways to monitor stream restoration projects is through changes in streamside vegetation, as many hydrological, geomorphological, and biological goals are manifested by changes in vegetation. Conflict management project monitoring is simpler and involves measures of project success relative to maintenance needs and landowner satisfaction with the project. Beaver activity surveys, both pre- and post-project, are an essential component of any beaver-related project, as the beaver activity is often one of the most prominent and relevant metrics of the effects of restoration actions.

Complexities and site-specific considerations are unavoidable features of each of the five forms of beaver restoration. To provide relevant information to practitioners and those just starting to explore beaver restoration techniques, each form of beaver restoration is outlined in detail in the appendices of this document. Anyone interested in applying one or several of these techniques is encouraged to explore these appendices to get important background information on the topic and best management practices for planning and implementing projects.

Beaver lodge and cache in a tributary to the Gallatin River

How to Use This Document

This document is intended as a guidance tool for individuals and organizations in Montana looking to undertake stream restoration that involves beavers, either as a short-term or long-term project component. This includes establishing beavers in an area, mimicking beavers for their restoration benefits, or finding solutions for beavers that come into conflict with people.

The **Introduction** discusses the benefits and challenges associated with beavers on the landscape and provides information on their status. FWP's perspectives and responsibilities related to beaver restoration are described and set the tone of the document with overarching themes and goals related to the practice. "Beaver restoration" is defined, setting the stage for the types of streams and situations where these principles apply.

In the next section, the three most **Common Scenarios** regarding beavers and beaver restoration are highlighted, and a brief overview of the problems, goals, and solutions associated with each scenario are provided.

Project Planning describes suitable conditions for beaver restoration projects with a specific emphasis on appropriate spatial and temporal scales for project success as well as the important role of beaver conflict mitigation in any project.

The **Fish and Wildlife Considerations** section provides a guide to potential effects of beaver restoration on fisheries and wildlife resources beyond the beavers themselves. This section is meant to help practitioners weigh unintended consequences and navigate necessary coordination with FWP staff as well as incorporate permitting processes that involve assessment of effects on species and habitats from beaver restoration projects.

Finally, the **Maintenance and Monitoring** section describes expectations and measures of success that will provide clear markers of project efficacy, allowing for adaptive management as well as the advancement of the field of beaver restoration in Montana.

This document ends with **Appendices** that provide in-depth information on the five forms of beaver restoration, from mitigating beaver damage to transplanting beavers into new areas. The appendices are meant to serve as guides for groups and individuals that want to move from understanding the basics of beaver restoration to on-the-ground projects. Citations, references, and links to other sources of information on these topics are provided throughout this document.

Acronyms Used in This Document

Agencies and Organizations

- FWP: Montana Department of Fish, Wildlife and Parks
- MTNHP: Montana Natural Heritage Program
- BWG: Montana Beaver Working Group
- DNRC: Montana Department of Natural Resources and Conservation
- DEQ: Montana Department of Environmental Quality
- USFWS: United States Fish and Wildlife Service
- ACOE: Army Corps of Engineers

Permitting

- SPA: Stream Protection Act
- NWP: Nationwide 27 Permit
- SMZ: Streamside Management Zone
- MEPA: Montana Environmental Policy Act
    - EA: Environmental Assessment
    - EIS: Environmental Impact Statement
    - ROD: Record of Decision
- NEPA: National Environmental Policy Act
- MCA: Montana Code Annotated
- ESA: Endangered Species Act
- SOC: Species of Concern

Tools and Techniques

- LTPBR: Low-tech, Process-based Restoration
    - BDA: Beaver Dam Analog
    - PALS: Post-assisted Log Structure
- BRAT: Beaver Restoration Assessment Tool
- LIDAR: Light Detection and Ranging
- NAIP: National Agriculture Imagery Program
- GPS: Global Positioning System
- HUC: Hydrologic Unit Code
- VHF: Very High Frequency
- HDPE: High Density Polyethylene
- LWD: Large Woody Debris
- PPE: Personal Protective Equipment

Other

- CPUE: Catch Per Unit of Effort
- AIS: Aquatic Invasive Species
- WCO: Wildlife Control Operator

Introduction

Overview of Beaver Restoration

Beavers are considered ecosystem engineers and a keystone species (Naiman et al. 1988, Muller-Schwarze 2011, Pollock et al. 2017). Beavers, through dam building and vegetation harvest, exert profound influence on the habitats they occupy and drastically modify hydrologic, geomorphic, and biologic processes across spatial and temporal scales. It is well supported that, in the types of stream systems found across much of Montana, the effects of beaver activity are mostly positive, resulting in:

- Increased landscape-scale water storage (Naiman et al. 1986, Naiman et al. 1988, Westbrook et al. 2006, Jin et al. 2009, Nyssen et al. 2011, Majerova et al. 2015)
- Reconnection of stream channels to their floodplains (Westbrook et al. 2006, Polvi and Wohl 2012, Polvi and Wohl 2013, Pollock et al. 2014, Majerova et al. 2015)
- Water-quality improvements (Pollock et al. 2017)
- Attenuation of flood events (Puttock et al. 2020)
- Bolstered landscape resilience to disturbances such as fire and drought (Fairfax and Small 2018, Silverman et al. 2018, Fairfax and Whittle 2020)
- Enhanced biodiversity (Naiman et al. 1988, Russell et al. 1999, Wright et al. 2002, Cooke and Zack 2008, Bartel et al. 2010, Kivinen et al. 2020)
- Creation of diverse fish habitat, including overwintering, spawning, and rearing areas (Jakober et al. 1998, Collen and Gibson 2000)

It is beyond the scope of this document to provide thorough documentation of the wide range of effects beavers can have on stream ecosystems. However, a variety of publications are available that summarize the topic, including: Naiman et al. 1988, Collen and Gibson 2000, Rosell et al. 2005, Kemp et al. 2012, Pollock et al. 2017, and Larsen et al. 2021.

Restoration practitioners, state and federal agencies, and other organizations are increasingly interested in using beavers or mimicking their activity to address the seemingly insurmountable task of restoring degraded stream systems across landscapes. These practices and projects are widely known as “beaver restoration”. For the purposes of this document, beaver restoration is defined as:

Beaver Restoration

The suite of techniques that rely on, mimic, or mitigate beaver activity to improve and maintain the ecological integrity of the stream channel, floodplain, and riparian system. There are five major techniques covered under beaver restoration, and they are 1) conflict management, 2) changes to land management, 3) beaver mimicry, 4) encouraging natural colonization, and 5) beaver transplants.

Beavers can occupy and thrive in an astounding variety of habitats, from large rivers and reservoirs to seeps in high-mountain basins to intermittent prairie streams. Therefore, it would be difficult to write a concise and widely applicable document covering the range of conditions beavers can occupy in Montana. It is important to define types of waterbodies where the principles, techniques, and information presented in this document are best applied.

While beavers can have dramatic effects on waterbodies and associated riparian areas wherever they live, the primary focus on beavers as an agent of stream, riparian, and floodplain restoration is around dam construction. Dam construction by beavers initiates important stream processes defined later in this section. Whether that dam building is by humans seeking to mimic beaver dams or by beavers themselves, the information in this document should only be applied to streams where beavers need to build dams to survive. Focusing on dam building by beavers necessarily narrows the scope of this document to streams that have the intrinsic potential for beaver damming activity (e.g., low gradient, stable water supply, woody vegetation; Macfarlane et al. 2015, Dittbrenner et al. 2018).

The Beaver Restoration Assessment Tool

Streams that can support beaver dam building can be mapped and assessed using the Beaver Restoration Assessment Tool (BRAT; Macfarlane et al. 2015), which is available through the Montana Natural Heritage Program:

(https://www.arcgis.com/apps/webappviewer/index.html?id=f26958e584384ea89e6c5fc0d3775d1b)

The BRAT model provides a myriad of information on stream suitability for beaver dams using publicly available, remote-sensing data that evaluates intrinsic measures of habitat suitability (i.e., streamflow, vegetation, and stream gradient). Assuming that beavers were present and active in almost all suitable streams of North America prior to colonization (Goldfarb 2018), the BRAT dam capacity model can function as a rough map of historically occupied beaver habitat. The BRAT model also characterizes stream reaches based on the potential for conflicts with human infrastructure, so the combined models provide a good overview of the potential for beaver restoration based on the ecological and social suitability of stream reaches.

Even in streams where beavers build dams, there are additional limitations to the information presented in this document. There is comparatively little information about beavers in systems where they do not rely on woody riparian vegetation (e.g., aspen, alder, cottonwood, willow) as a food source and construction material. An example would be large swaths of the northern Great Plains where some beavers survive on aquatic and emergent, non-woody vegetation and where dams are constructed out of mud, sagebrush, cattails, and other non-woody materials. While principles related to conflict resolution and land management changes are more widely applicable, specific information around suitable habitat for beavers and how to create conditions that will maximize the chances of beaver occupancy in a restoration area may not be. Therefore, the scope of this document must be further limited to stream systems where there is sufficient scientific information and case studies to form defensible guidelines and recommendations.

The beaver restoration principles in this document best apply to smaller stream systems in the more mountainous parts of the state, which are also the systems most commonly dammed by beavers historically. The disturbance regime of these stream systems is driven by high-water events, primarily spring runoff. High-water events cause lateral channel migration, inputs of large wood into the stream channel, and the creation of exposed sediment beds. This disturbance regime provides the conditions for establishment and dominance by woody riparian vegetation in the floodplain. These are stream systems that, in their naturally functioning state, support or can support riparian areas composed primarily of willow (*Salix* spp.), cottonwood (*Populus* spp.), aspen (*Populus tremuloides*), alder (*Alnus* spp.), red osier dogwood (*Cornus sericea*), and/or birch (*Betula* spp.).

Several of the techniques covered under “beaver restoration” can be used to help restore streams that are currently unsuitable for beaver colonization (i.e., beaver mimicry and land management changes). Other techniques are relevant to situations where practitioners are attempting to get beavers established in an area under current conditions (i.e., encouraging natural colonization and beaver transplantation). Providing general guidelines for suitable habitat for colonization by beavers is difficult because of their ability to occupy a wide range of habitats and the complexity of interactions between the various components. Those components include available size and abundance of woody vegetation, the size of the stream and drainage area, the geomorphic conditions of the stream channel, and subsequent effects of beaver dams on those components as well as the effects of those components on beaver dams. A general overview of considerations for suitable beaver habitat for western Montana streams is summarized in Table 1, and more details on suitable habitat are provided in the appendices that are specific to the individual beaver restoration techniques.

Table 1. Guidelines for suitable beaver habitat in Montana streams dominated by woody riparian vegetation. These guidelines are generalized to be widely applicable, but beavers can occupy and thrive in a wide variety of habitats, so careful evaluation is required when assessing habitat for potential beaver colonization. Habitat components that are included in the Beaver Restoration Assessment Tool (BRAT) model can be mapped and evaluated remotely before a field visit to the site. Information for these guidelines was acquired from Vore 1993, Muller-Schwarze 2011, and Pollock et al. 2017. See the Methow Beaver Project Release Site Score Card, provided in Appendix E (Figure E1), for an on-site, rapid evaluation protocol for assessing suitable beaver habitat.

Habitat Component	BRAT Model	General Guidelines
Patch size	No	In willow/cottonwood/aspen dominant systems in southwest Montana, approximately 400 yards of stream is suitable for a beaver colony to establish and persist for at least three years (Ritter 2018). However, a smaller stream length may be suitable if preferred woody riparian vegetation is abundant, and the stream gradient is low. If the stream gradient is steeper, the valley bottom more confined, and/or the woody riparian vegetation available is limited to a narrow strip along the stream channel, then the length of stream needed for a colony will be longer (up to approximately 1.5 miles of stream).
Stream gradient	Yes	Less than 3% stream gradient is ideal for beavers. However, they frequently colonize sites up to 6% gradient and less-often colonize sites up to 25% gradient. Higher gradient sites will require smaller streams so that runoff flows do not completely destroy dams. Generally, beaver colonies in stream gradients higher than approximately 15% are located on small springs or seeps.
Valley-bottom width	No	Refers to the width of the valley bottom that could be flooded if a beaver dam were built to bank-full height, assuming no stream degradation has taken place that would limit the spread of water. Valley-bottom width can usually be delineated based on the presence of riparian vegetation or a shift away from the dominant upland vegetation of the area (e.g., conifers, sagebrush, bunchgrasses). A valley-bottom width of approximately 200 feet is a good minimum width to work from, which allows approximately 90 feet on either side of the stream bank for foraging and pond creation by beavers. However, beavers can colonize valley bottoms as narrow as 60 feet. As the valley-bottom width gets smaller, the length of stream beavers need for a colony increases. However, valley bottoms wider than approximately 700 feet are non-restrictive for beavers because beavers will generally not forage more than 350 feet from the stream bank.
Substrate	No	As the size of substrate gets larger, beavers have a harder time building dams and anchoring them in place. Beaver dams will rarely persist in streams where the dominant substrate is rocks, boulders, or bedrock. Beaver dams tend to last the longest in streams with a silty substrate as beavers can use the silt to seal the dam and can shove sticks into the substrate both on the stream bed and into the banks where the dam attaches on each side of the stream. Generally, the size of the substrate is directly related to the stream gradient, so if practitioners are accounting for stream gradient in site selection, they should be covering suitable stream substrate as well.
Hydrology	Yes	Beavers need a year-round supply of water to colonize a site and overwinter. They also need enough water to be flowing in the dry parts of the year to maintain pond depths of at least 3 feet, with deeper waters preferred. As streams get larger, the probability of dam persistence generally decreases, and eventually beavers no longer need dams and become bank-denning beavers. Dams built in very small streams (e.g., springs and seeps) may last for decades, while dams in large streams may need

		to be rebuilt annually. Surveying for evidence of previous beaver dam building in the area can be a good indicator if the stream is small enough for dam-building beavers. Use of time-series aerial imagery of the target stream or nearby, similar streams can be valuable for evaluating dam persistence if beaver dams can be found on the imagery.
Geomorphology	No	Stream incision is a major limiting factor for the persistence of beaver colonies and subsequent potential positive effects of their presence in an area. Unless there are existing dams in the area, it can be difficult to evaluate if stream incision will limit beaver success. The most important metric is that if a channel-spanning beaver dam that is 3-5 feet in height will not force water to flow out of the stream channel and onto the floodplain, then the stream is likely too incised for beaver colonization to result in desired benefits to the stream system. Please see Appendix B - Land Management Changes, Water Management, for a more in-depth discussion on this topic. Similarly, a stream channel that is too wide and shallow can also limit beaver colonization in an area because beavers may be unwilling to build a wide and tall enough dam to colonize the site. Alternatively, the bank height may be too low for a channel-spanning dam to result in a pond depth of at least 3 feet before the water flows out onto the floodplain.
Vegetation - Food	Yes	There must be an ample supply of willow, aspen, or cottonwood in an area for beavers to colonize the site. Beavers can also make use of alder, red osier dogwood, birch, and other deciduous shrubs, but they rarely subsist for more than 1-2 years in an area that is exclusively made up of these less-preferred plant species. Exact quantities of preferred woody riparian vegetation needed for beaver colonization and persistence are difficult to provide. In general, in streams dominated by one or several of the three preferred species, beavers will need a zone of vegetation within 90 feet of the stream that is at least 30 feet wide with at least 30% canopy cover. As the zone of preferred woody riparian vegetation gets wider, the canopy cover can be less out to approximately 90 feet from the stream channel, at which point the vegetation begins to get outside the preferred foraging range of beavers. It is important to note that, when beavers colonize an area and build dams, woody riparian vegetation that is flooded over the root crown will die within 2-5 years. Therefore, site evaluations should account for potential loss of preferred woody riparian vegetation due to flooding over time. An effective way to evaluate if a site has enough preferred woody riparian vegetation for beavers is to look for beaver colonies in similar streams in the area and asses the amount of woody riparian vegetation on which those colonies are persisting.
Vegetation – Building materials	Yes	Beavers can use almost any woody vegetation for dam building, including conifers and non-preferred forage like maples, sagebrush, or cattails. As the size and strength of the dams needed by beavers increases (e.g., on larger streams), the size of the woody vegetation needed for dam building also increases. Beavers in small, low-gradient systems can build dams that are able to survive high-water pulses with mud, rocks, sagebrush, and pencil-sized willows. Beavers in larger or higher-gradient streams will need tall willows, conifer trees, and other large materials for dams to persist through high-water pulses.
Shelter	No	Beavers colonizing new sites will be highly vulnerable to predation until they build up dams and lodges. Initial shelter for beavers can therefore be a limiting factor for where they will attempt to start a new colony. Previous beaver lodges, even those that are overgrown and decrepit, are favored sheltering spots for dispersing beavers, and new colonies are often built around a key piece of cover (Ritter 2018). Other forms of cover can be rip-rapped banks where beavers can find or excavate a cavern in the rocks, root wads of trees that have been undercut by the stream or that have fallen into the stream, log jams, and large brush piles or deadfall near the stream channel.

Beaver damming, associated flooding, and vegetation harvest can cause major conflicts with humans through damage to infrastructure or loss of desired vegetation. Therefore, the types of streams that are suitable for beaver restoration are further refined by the amount and types of human infrastructure present in and around the stream channel, and whether that human infrastructure is vulnerable to being affected by beaver activity. So even though a stream may be *ecologically* suitable for beaver restoration, that does not mean the stream is *socially* suitable for beaver restoration. Beaver conflicts with humans can be mitigated through a variety of techniques, but there will always be situations where beavers are not tolerated in an area, regardless of the intrinsic habitat suitability.

Streams and associated floodplains that can support beaver colonies, as defined earlier, have the potential for wetlands and riparian areas to occupy large areas of valley bottoms over time (Shahverdian et al. 2019). Beaver-mediated restoration of streams is associated with a desire to return to multi-thread channels, vegetated islands, inefficient conveyance of water, valley bottom inundation during high-flow events, and a strong connection between the stream channel and floodplain (see Figure 1; called Stage 0 or Stage 8 in the stream evolution model, defined by Cluer and Thorne 2014 and further refined by Pollock et al. 2014 and Wheaton et al. 2019). Beaver restoration planning must consider if it is acceptable that the stream and valley setting accommodate eventual colonization and restoration by beavers to this condition.

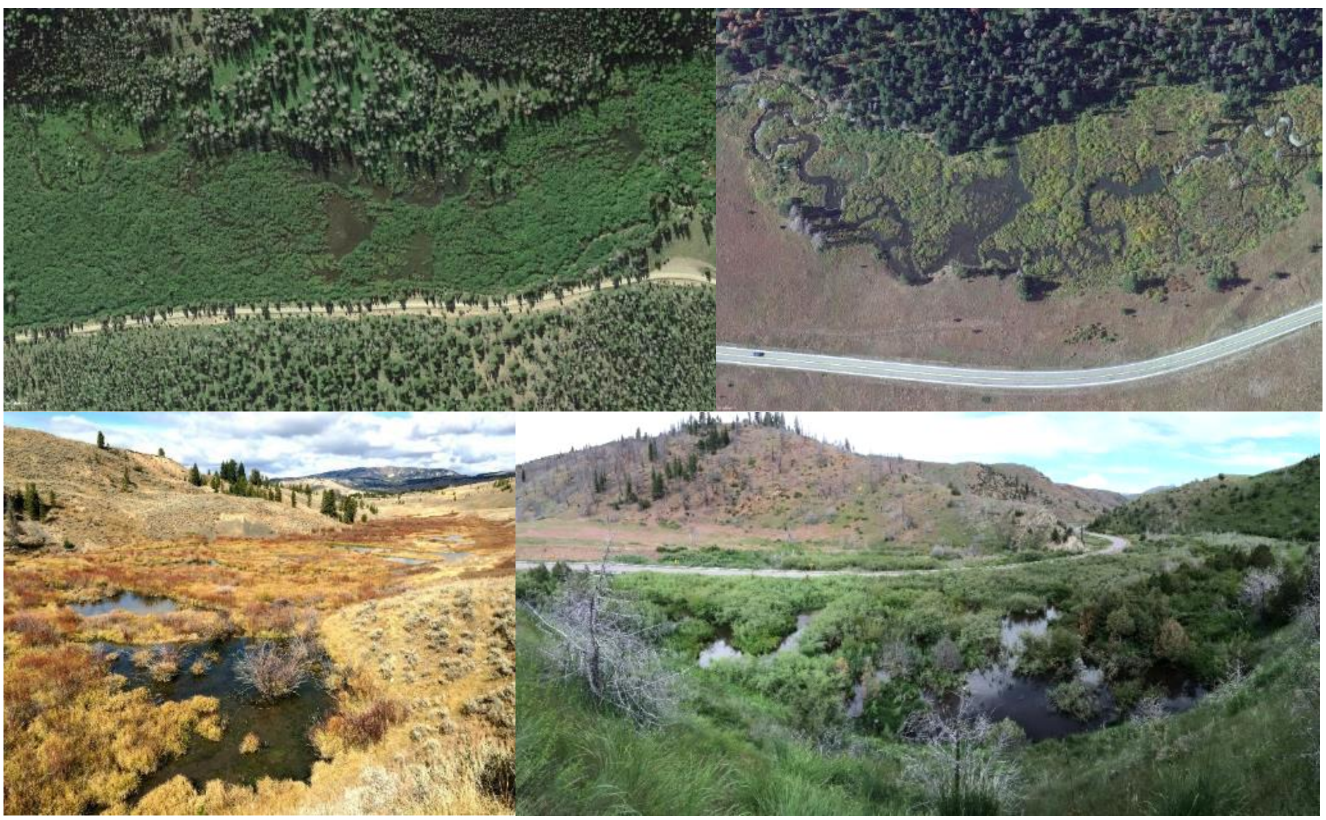


Figure 1. Examples of streams in Montana exhibiting the potential end-goal of beaver restoration where the stream occupies much of the valley bottom and forms multiple channels that shift over time. While beaver restoration goals may focus on simple measures of stream response to restoration initially, practitioners should expect that eventually the stream may reach a stage 0 or stage 8 form (Cluer and Thorne 2014, Wheaton et al. 2019). Top photos supplied by Google Earth.

Because beaver impacts can manifest at such a large scale, the main question when considering beaver restoration is whether the desired condition of the stream is one that is highly braided and has the potential to unpredictably move within the valley bottom over time. While there is a gradient of potential outcomes from beaver restoration, from a single dam backing up water at a strategic point to a valley-wide wetland complex, there is always the possibility that beaver activity will be so influential as to make the stream system shift to a dynamic state like those shown in Figure 1. This may take decades, but practitioners should be thinking that far ahead when designing and implementing stream restoration projects in areas that may eventually be occupied by beavers.

The primary purpose of restoring beavers to a stream is often to reintroduce or mimic natural processes and disturbance regimes that would have functioned on these streams prior to degradation. Throughout this document, the terms “natural processes,” “stream processes,” and “process-based restoration” are used frequently. Since these terms cover a broad range of potential processes that occur in stream systems, it is important to specifically define the processes being referred to in the context of what beaver activity can bring about in stream systems. Those processes are:

- Woody debris input into the stream channel and floodplain resulting in the introduction of structural elements through dam, lodge, and cache construction and subsequent abandonment; tunnel and channel digging that can undermine streamside vegetation; vegetation death and toppling due to flooding; or through direct tree/shrub felling into the stream channel and floodplain through beaver harvest.

- Sediment accumulation behind dams that either largely stays in place after beavers leave the area resulting in a wet meadow characterized by sedges and other hydrophytic vegetation or that may be fully or partially vacated downstream after dam failure resulting in variable pulses of sediment to the stream system.

- Raising of the water table around dams and dam complexes that sub-irrigates surrounding floodplain habitats and may kill off certain plant species (e.g., conifers, grasses) while encouraging the growth of others (e.g., willows, sedges).

- Greater channel-floodplain connectivity through a combination of effects including those listed above, resulting in a greater propensity for the stream channel to braid and to migrate across the valley bottom over time.

- Changes in streamside and floodplain vegetation types, communities, and age classes through a combination of effects including those listed above, and associated changes in stream form and function that can result.

It is important to emphasize that the beavers themselves are not the end-goal of beaver restoration, it is the disturbance regime and underlying processes involved in those disturbances that beaver activity can restore and sustain in a stream system. Beaver restoration efforts must therefore be catered to the unique hydrologic, geomorphic, and biologic conditions of individual stream systems, and must focus on an appropriate spatial and temporal scale to allow natural stream processes to be restored. It is the repeated dam building and abandonment, vegetation harvest and regrowth, and shifting of beaver colony territories and territory boundaries over time that reinstate these natural processes at meaningful spatial and temporal scales. Therefore, the emphasis should always be on the beaver population in a stream system and not on individual beavers or beaver colonies.

Beaver Restoration in Montana

Beavers are a native species whose dams and impoundments once dominated low-gradient streams in Montana, but they now occupy a fraction of their former range.

Montana, like most of the western United States, has thousands of miles of streams that were once characterized by extensive beaver-modified habitats. Many of the single-thread, meandering streams seen across Montana today look completely different than they did prior to European colonization of North America. Over-exploitation of beavers by trappers in the 1700s and 1800s, followed by rampant overgrazing and widespread stream channel, riparian, and wetland manipulations, left many watersheds in a degraded state. Degraded stream systems often suffer from channel incision and/or over-widening, loss of woody riparian vegetation, simplification of stream channels, and perched floodplains that shift to upland vegetation types. While the cumulative impact of this level of degradation is impossible to accurately quantify, it is likely that widespread stream degradation in Montana has resulted in decreased landscape-scale water storage, which exacerbates the effects of drought. Subsequent impacts include loss of important riparian and instream habitats for fish and wildlife species, degradation of water quality, and diminished ecosystem connectivity and resilience to disturbance (Wohl 2019, 2021).

Beavers have rebounded to somewhere between 3% and 15% of their pre-colonization numbers in North America (Naiman et al. 1988). While this rebound is encouraging, the widespread loss of beaver-modified habitats has greatly reduced in-stream and riparian habitat quality and quantity as well as the capacity of streams to provide important ecosystem services to humans (Wohl 2019, 2021). Given the ongoing threats of drought and the increasing demand for water resources, it is critical that natural resource agencies and organizations work to restore the ability of the landscape to soak up water and slow its movement from snowmelt to the large rivers, to benefit all aspects of a functioning watershed. These include other fish and wildlife species, farmers, ranchers, and municipalities that all depend on reliable water resources.

Restoration of beavers to areas of their former range in Montana is a worthwhile endeavor.

As the potential benefits of beaver activity on streams systems have gained recognition, the desire to use beavers as a tool for stream and riparian restoration has increased across many parts of the U.S. and Europe. The restoration of beavers and beaver-modified habitats has the potential to address stream degradation issues at a landscape scale in Montana, as this type of restoration generally relies on low-cost techniques and works toward allowing beavers to take over and expand the restoration work once a stream is suitable for colonization.

The potential benefits of beaver restoration in Montana include:

- Increased landscape-scale water storage capacity through expanding beaver-influenced riparian habitats in headwater streams leading to improved late-season streamflow and greater ecosystem resilience to disturbances like drought, fire, and flooding.

- Encouraging floodplain connectivity to promote natural processes that create biologically rich habitats while reducing downstream damage to human infrastructure or degradation of stream systems due to excessive flooding and sedimentation.

- Expanding and enhancing stream, riparian, and floodplain habitats to benefit a wide range of game and nongame fish and wildlife species, included economically important game species as well as many Species of Concern.

- Maintaining a viable and accessible population of an important furbearing animal to sustain trapping opportunities and heritage into the future.

- Addressing beaver conflict issues in partnership with other forms of beaver restoration, alleviating property damage concerns while providing opportunities to engage with landowners on wildlife management and drought resilience issues.

- Enhancing opportunities for community engagement and education around the importance of riparian areas and wetlands to overall ecosystem health and the value of learning to live with wildlife where possible.

The scale of stream degradation across Montana is enormous, and while some efforts by FWP and its partners have been successful at restoring natural stream processes and attributes in specific areas, the amount of money and person-power available is insufficient to address the need. Beavers naturally work toward and facilitate beneficial watershed processes without direct human interference. Beavers therefore offer an opportunity to transfer the restoration work to the ecosystem, after some guidance by humans, so that the system can essentially repair and maintain itself. Tapping into that potential, with careful consideration of impacts to people and other natural systems, can address stream degradation and drought issues at a scale that more closely matches the scale of degradation that occurred over the past century.

Beaver restoration has substantial benefits and comes with significant challenges.

The remarkable engineering capabilities of beavers that can benefit stream systems can also lead to negative outcomes when beavers try to settle in biologically or socially unsuitable habitat. Whether beaver restoration will negatively or positively affect a given ecological setting depends on a wide range of biotic and abiotic factors as well as human influences in the area. This makes predictions regarding the effects of beaver restoration a challenging endeavor for biologists, land managers, and restoration professionals who want to use beaver restoration as an efficient and effective method to achieve project goals.

Challenges of getting beavers established

There is an important difference between haphazard encouragement of beaver colonization and thoughtful encouragement of colony formation in appropriate areas where natural ecological benefits are likely to be successful and sustainable. The effects of beaver activity can vary widely across stream systems based on the valley setting, underlying geology, current state of riparian vegetation, and the current state of stream channel and floodplain degradation (Nash et al. 2021, Roper 2022). Therefore, restoration of beavers to a site requires careful consideration and articulation of the desired outcomes of their activity, mediated by the ecological setting.

Potential challenges of getting beavers established include:

- The potential for further degradation of stream and riparian habitats when beavers occupy stream systems that are not in the appropriate ecological state to flourish under the influence of beaver colonization (e.g., insufficient riparian vegetation, severely incised channel, etc.).

- Some streams may have degraded to the point of maintaining a new stable state that requires significant investment in more heavy-handed restoration techniques (e.g., earth-moving and vegetation planting) before beavers could get established. Alternatively, the new stable state may be more desirable in terms of land management or fish and wildlife management goals than a beaver-modified state.

- The desired future condition of some stream systems, reflective of management goals and social values, is not one with extensive beaver-modified habitats (e.g., many private properties).

- Public ignorance of the ecological benefits of beaver, resistance to change, and generally engrained opposition to active disturbance and instability in stream systems.

- High mortality of beavers and initial instability of beaver structures when beavers are first getting established in a new area can lead to premature conclusions around project efficacy.

Challenges of established beavers

Beavers are ecosystem engineers, a title that recognizes the profound changes they make to waterbodies and associated riparian corridors. Because of the scope and scale of their effects, human infrastructure that is located near waterways may be highly vulnerable to changes caused by beaver engineering. A large portion of stream reaches and waterways that were formerly suitable for beaver colonization now flow through landscapes changed by human activity, limiting the habitat that is functionally available for beaver colonization. Furthermore, beaver activity may not be acceptable in all areas of suitable habitat even if human conflict issues are unlikely. Other land and resource management goals may take precedent, and, in some situations, beaver activity may lead to changes that threaten other species.

Potential challenges of established beavers include:

- Beavers can come into conflict with humans when they cut down desired trees; plug culverts, headgates, and bridge spans; or when roads and other infrastructure are built too close to streams and riparian areas and are then flooded by beaver damming. While effective mitigation measures are available for many beaver conflicts, they do not work in all situations. In addition, the consistent maintenance associated with infrastructure impacts from beavers is not acceptable to some landowners and land managers.

- Beaver activity has been documented as having both negative and positive impacts to fish populations, depending on the species and context (Collen and Gibson 2001, Kemp et al. 2012), and these effects are highly site-specific. There are more limited potential negative impacts to terrestrial species, but it is still possible that established beavers can conflict with wildlife habitat goals in specific areas or specific habitats.

From a statewide perspective, the best available science demonstrates that the potential positive effects of beavers on the types of stream systems in Montana far outweigh the potential negative effects (Naiman et al. 1988, Collen and Gibson 2001, Rosell et al. 2005, Goldfarb 2018, Wohl 2019, Rosell and Campbell-Palmer 2022). This statement remains true if restoration of beavers is done carefully and with adequate attention paid to social implications and current ecological context. For instance, considerations must be made on a local scale when beaver dams or dam-like structures will be built in habitats with certain sensitive plant, fish, or wildlife species, or in areas where the potential for damage to human infrastructure or use of the land exists. Additionally, care must be taken where streams and riparian areas have been altered to the point where a functional ecological condition is not currently possible without intermediary, non-beaver related restoration actions (e.g., floodplain regrading, inset floodplain formation, vegetation planting, etc.). Within those sideboards, beaver restoration can and should become a common and widespread practice in Montana.

Beaver Restoration and FWP

FWP's Tenets of Beaver Restoration

FWP strives to base recommendations and decisions based on scientifically sound information, including both social and political science, to manage the state's fish and wildlife resources (State Wildlife Action Plan 2015, Montana Statewide Fisheries Management 2019). While the locations and situations appropriate for beaver restoration are complex and site-specific, some overarching tenets guide the types of projects that FWP may implement or support:

- **Comprehensive Ecological Approach.** A stream process-based, ecological approach that considers all biotic and abiotic factors is the most effective. The resulting beaver restoration project is implemented at an appropriate spatial and temporal scale that will eventually result in self-sustaining benefits to the system.

- **Natural Processes**. Seeking to re-establish natural, self-sustaining processes (see Introduction for an overview of natural processes) that guide a stream toward recovery to an appropriate reference condition and maintain the stream in that state. If a project includes establishing beaver colonies, those colonies can become self-sustaining (see definition in Project Planning) and are established in an area that is within the historical range of beavers.

- **Natural Expansion.** Consider the potential for beavers to expand and occupy the entire drainage in which a project occurs, which could increase the area of impact. FWP strives to be a good neighbor to landowners and land managers in Montana and expects practitioners of beaver restoration projects to consider effects on adjacent and nearby landowners.

- **Consider Harm to Other Species.** Beaver restoration actions do not benefit fish and wildlife resources at the expense of a vulnerable species. This does not mean a beaver restoration project cannot impact any fish or wildlife species, only that the impact does not cause negative, population-level consequences for a sensitive or protected species, or for a population of a species with economic or social importance. An example would be beaver ponds silting in spawning gravels in a critical spawning reach for bull trout.

- **Social Considerations.** The project fully considers and addresses social implications, especially those centered on the potential for beaver-human conflict situations to develop. A high potential for beaver-human conflict does not preclude a project from happening, but a plan for mitigating potential conflicts is necessary.

- **Adequate Resources for Completion.** The project has adequate planning, funding, and personnel to be fully completed, including multiple phases and any needed maintenance or post-project monitoring that results in tangible measures of success or failure.

FWP's Responsibilities

Because FWP has specific responsibilities related to fish, wildlife, and recreational resources, the agency plays a critical role in statewide beaver management and beaver restoration projects. Regarding beaver restoration, FWP's primary responsibilities are:

- Wildlife management, including fish and aquatic resources and managing beaver populations through trapping and conflict management via non-lethal techniques and damage permits.

- Land management, including state-owned Wildlife Management Areas, where extensive beaver habitats exist.

- Regulations and permitting, including regulatory control over stream permitting, beaver harvest, beaver conflict resolution, and the transplant of beavers.

- Collaboration with local, state, and federal government entities, private landowners, non-profit organizations, and recreation groups on restoration projects and land management decisions.

FWP's Approach to Beaver Restoration

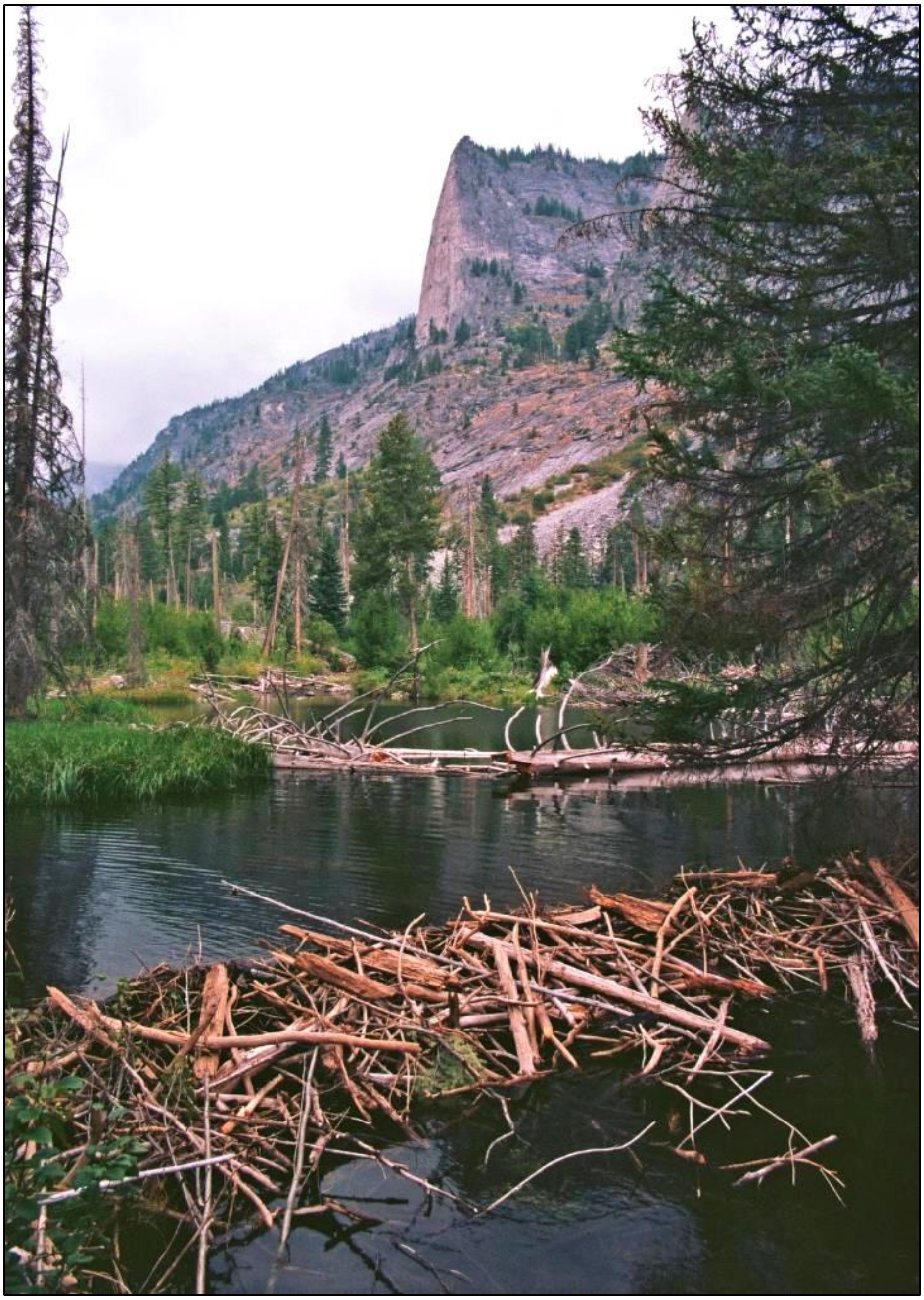
Beavers, if properly managed, provide substantial benefits to Montana's fish, wildlife, and recreational resources at a scale that is unmatched by any other wildlife species. Under well-thought-out circumstances, and with approval from appropriate regulatory entities, FWP supports and encourages the five forms of beaver restoration outlined in this document.

- **Conflict management** helps people deal with the negative aspects of beaver activity, builds tolerance for beavers on the landscape, and can be a source of beavers for transplant efforts.
- **Changes to land management**, such as grazing regimes and timber harvest, result in changes to habitat that allows beavers to recolonize areas of their historical range.
- **Beaver mimicry** involves people building their own beaver-related structures to mimic the effects of beavers without having beavers on-site.
- **Encouraging natural colonization** of historical habitats through direct habitat manipulations to specific sections of streams that provides the conditions for beavers to occupy and thrive in the area.
- **Beaver transplants** to reestablish beavers in areas they have been unable to recolonize on their own or into relatively empty habitats.

Beaver colonies along Little Wapiti Creek in the Gallatin River drainage

Common Scenarios

There are many types of beaver restoration, and each type consists of many considerations and components. The methodologies for the various forms of beaver restoration are complex and nuanced. To provide focused and summarized information on the FWP perspective regarding beaver restoration, three common scenarios are summarized below. More detailed information on the five forms of beaver restoration, which can be applied in various combinations to these scenarios, are provided in the appendices located at the end of this document.



Beaver dam in Blodgett Canyon

#1. Beavers are causing property damage.

Problem: Beavers are cutting desired trees, plugging culverts or headgates, flooding property with free-standing dams, or causing bank instability through digging. Beavers settling in an area likely indicates suitable habitat, and therefore the site may become a repeat issue. Up-front costs may be higher to deal with problem beavers at these locations but may be more cost-effective in the long-term if the initial investment can prevent repeat damage issues.

Goals: Mitigate beaver-related damage using the simplest, most efficient, and least expensive methods that will lead to a long-term solution to the problem.

Solutions

- *Issue:* Concerned landowner or land manager.

  Solution: Clearly identify the type and severity of beaver damage that is acceptable and not acceptable at the location. If consulting with a landowner or land manager, ask them to articulate what the beavers are doing and why it is a problem. It could be that beavers are not causing any tangible conflicts, but the expectation of inevitable conflict can spur people to seek solutions immediately upon identifying beaver activity. Long-held beliefs that beaver damming or tree cutting activity is inherently bad can bias the discussion. Involved parties must clearly describe the damage that is occurring before moving to specific solutions.

- *Issue:* Beavers are cutting down trees or other desirable vegetation.

  Solution: Simple, low-cost fencing can be used to deter the beavers (see Appendix A - Conflict Management). If most of the preferred vegetation in the area can be fenced, beavers may move on due to lack of food and construction resources. If not, then landowners should expect that non-fenced vegetation may be removed by the beavers. Preferred vegetation for beavers, from most to least palatable, is aspen, willow, cottonwood, and alder. Without a substantial supply of one or more of these plant species, beavers are unlikely to inhabit an area for more than a few months and are unlikely to overwinter in the area. Therefore, if preferred vegetation can be fenced or if a landowner can tolerate preferred vegetation being removed, then waiting for the beavers to move on may be an acceptable solution. An exception to these guidelines may be eastern Montana, where beavers can subsist on aquatic vegetation in areas with little to no woody riparian vegetation.

- *Issue:* Beavers are plugging culverts, bridge spans, pond outlets, or other natural or manmade pinch-points.

  Solution 1: Exclusion fencing can be used to prevent flooding and damage to infrastructure (see Appendix A - Conflict Management). Exclusion fences prevent beavers from being able to entirely plug a culvert or bridge span, allowing water to flow back into a single channel before entering the structure. Exclusion fences interrupt beavers' preferred method of impounding water (i.e., plugging a small gap to form a big pond). Instead, the beavers must try to dam around a three-sided structure where water flow is less predictable. As a result, they are unable to form the type of dam structure they prefer, as they cannot access a major part of the dam (i.e., the part inside the fence). Exclusion fences can also be easily modified to include a pond leveler device, described next, in case beavers are able to outsmart the fence.

Solution 2: Explore options to install a bridge or culvert with appropriate span and much greater cross-sectional capacity to prevent beavers from being able to dam across or plug the structure.

- *Issue:* Beavers are causing flooding damage due to a free-standing dam.

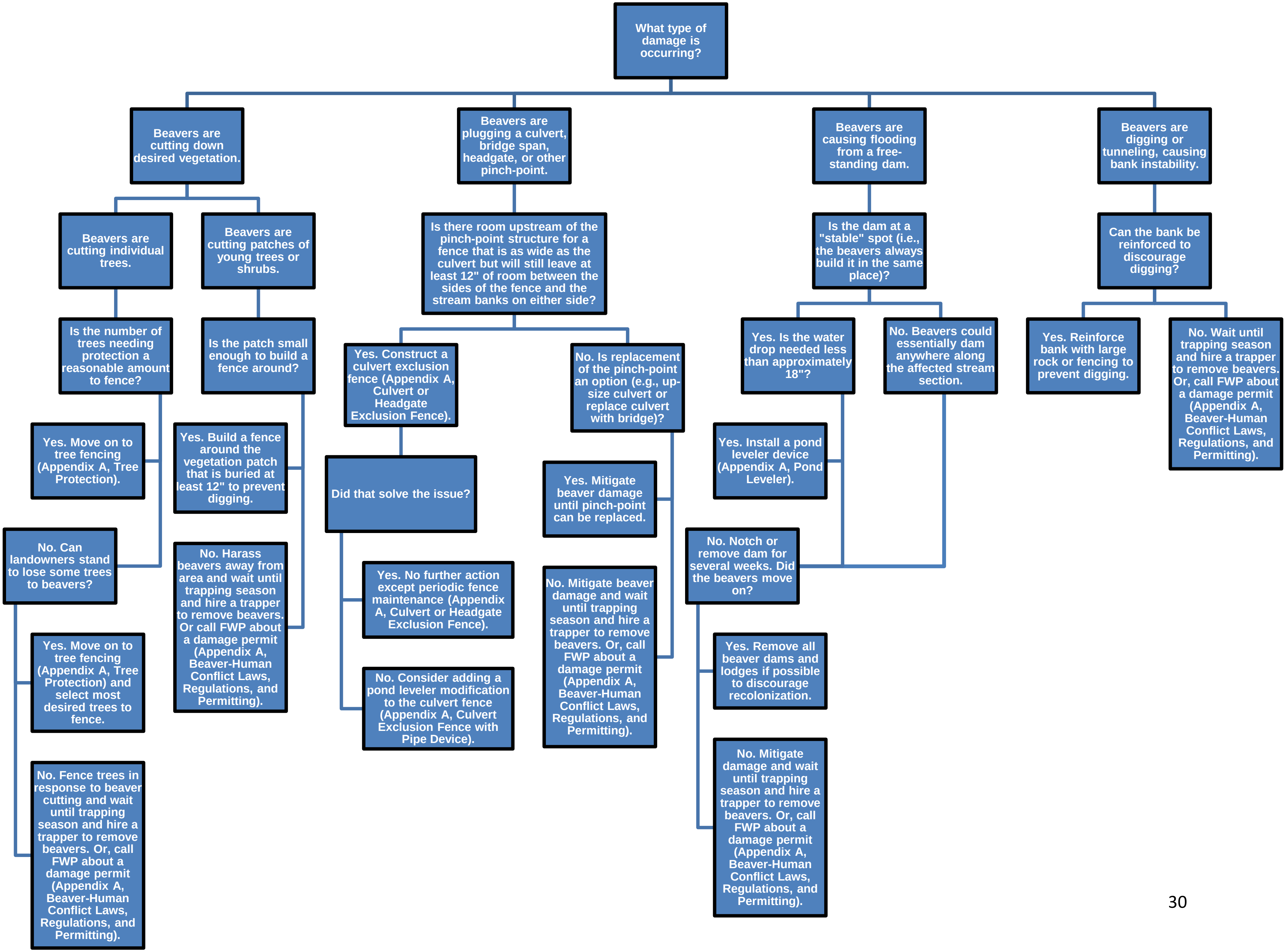
  Solution: A pond leveler device can be used to maintain the impounded water at an acceptable level (see Appendix A - Conflict Management). A pond leveler is a large, corrugated, flexible pipe that is installed by notching the beaver dam down to the water level that is acceptable to the landowner or land manager. The inlet of the pipe is fenced so that beavers cannot plug it and the outlet of the pipe is staked downstream of the dam. Beavers will try to repair the dam and get the water level back up, but the pipe creates a permanent leak that the beavers are unable to patch.

- *Issue:* Beavers are causing instability of a bank or berm due to digging tunnels and bank dens.

  Solution: Relatively few options are available. Large rocks or logs may be used to stabilize the bank, but these structures often become attractive den sites for beavers as they slow water near a lodge entrance and can create large and relatively stable chambers without much digging. Bank damage due to digging may be offset by beaver damming activity, which can slow water enough to prevent scour, but if the beavers are living in an undammable stream, river, or pond, then the only solution may be trapping. Alternatively, if enough preferred vegetation can be excluded with fencing, beavers may move elsewhere. Use of large rocks or logs may be a feasible solution for private ponds of irrigation reservoirs but will likely not be permitted for streams and rivers due to negative impacts associated with bank hardening.

If none of these solutions work, or if there is substantial damage to irrigation infrastructure or a threat to human health and safety, then trapping is an option to remove beavers quickly and effectively. Beavers can be trapped during Commission-approved trapping seasons by licensed trappers and can be removed outside the trapping season under certain circumstances (see Appendix B - Land Management Changes, Trapping Regulations). Trapping may need to be combined with removal of dams and lodges the beavers built, which can reduce the likelihood that other beavers seeking a territory may occupy the area. Most regional FWP offices maintain a list of area trappers that may be willing to help remove beavers from a conflict situation, or local Wildlife Control Operators (WCO) may provide beaver removal services. Non-lethal solutions for problems caused by beavers are often less likely to escalate conflicts among people, but trappers and WCOs provide a valuable service toward the goal of beaver tolerance on the landscape when the situation cannot be resolved by non-lethal conflict methods.

Conflict situations that develop directly from a beaver restoration project should be addressed as part of project planning, implementation, and monitoring. If a beaver conflict situation can be attributed to a restoration project, it is the responsibility of the practitioners to help landowners deal with the conflict situation. This may be accomplished through the methods outlined above, or practitioners may need to pay a trapper to remove the beavers causing the conflict if that is the only acceptable solution.


What type of damage is occurring?
Beavers are cutting down desired vegetation.
Beavers are cutting individual trees.
Is the number of trees needing protection a reasonable amount to fence?
Yes. Move on to tree fencing (Appendix A, Tree Protection).
No. Can landowners stand to lose some trees to beavers?
Yes. Move on to tree fencing (Appendix A, Tree Protection) and select most desired trees to fence.
No. Fence trees in response to beaver cutting and wait until trapping season and hire a trapper to remove beavers. Or, call FWP about a damage permit (Appendix A, Beaver-Human Conflict Laws, Regulations, and Permitting).
Beavers are cutting patches of young trees or shrubs.
Is the patch small enough to build a fence around?
Yes. Build a fence around the vegetation patch that is buried at least 12" to prevent digging.
No. Harass beavers away from area and wait until trapping season and hire a trapper to remove beavers. Or call FWP about a damage permit (Appendix A, Beaver-Human Conflict Laws, Regulations, and Permitting).
Beavers are plugging a culvert, bridge span, headgate, or other pinch-point.
Is there room upstream of the pinch-point structure for a fence that is as wide as the culvert but will still leave at least 12" of room between the sides of the fence and the stream banks on either side?
Yes. Construct a culvert exclusion fence (Appendix A, Culvert or Headgate Exclusion Fence).
Did that solve the issue?
Yes. No further action except periodic fence maintenance (Appendix A, Culvert or Headgate Exclusion Fence).
No. Consider adding a pond leveler modification to the culvert fence (Appendix A, Culvert Exclusion Fence with Pipe Device).
No. Is replacement of the pinch-point an option (e.g., up-size culvert or replace culvert with bridge)?
Yes. Mitigate beaver damage until pinch-point can be replaced.
No. Mitigate beaver damage and wait until trapping season and hire a trapper to remove beavers. Or, call FWP about a damage permit (Appendix A, Beaver-Human Conflict Laws, Regulations, and Permitting).
Beavers are causing flooding from a free-standing dam.
Is the dam at a "stable" spot (i.e., the beavers always build it in the same place)?
Yes. Is the water drop needed less than approximately 18"?
Yes. Install a pond leveler device (Appendix A, Pond Leveler).
No. Beavers could essentially dam anywhere along the affected stream section.
No. Notch or remove dam for several weeks. Did the beavers move on?
Yes. Remove all beaver dams and lodges if possible to discourage recolonization.
No. Mitigate damage and wait until trapping season and hire a trapper to remove beavers. Or, call FWP about a damage permit (Appendix A, Beaver-Human Conflict Laws, Regulations, and Permitting).
Beavers are digging or tunneling, causing bank instability.
Can the bank be reinforced to discourage digging?
Yes. Reinforce bank with large rock or fencing to prevent digging.
No. Wait until trapping season and hire a trapper to remove beavers. Or, call FWP about a damage permit (Appendix A, Beaver-Human Conflict Laws, Regulations, and Permitting).

#2. I want beavers to become established in my project location.

Problem: Suitable or near-suitable habitat for beavers exists in a project area but beavers are not established or are struggling to create long-term, self-sustaining colonies (see definitions in Project Planning).

Goals: To establish a beaver population in the project area or to expand an existing beaver population into the project area.

Solutions: Lack of beavers in seemingly suitable habitat can generally be rectified through:
- Land management changes (Appendix B)
- Encouraging natural colonization (Appendix D)
- Beaver transplantation (Appendix E)

Land management changes can address one or more issues that may be keeping beavers from establishing in the project area. Land management changes or adjustments to current management may be all that is required for habitat to become suitable for beavers. More often, land management changes will be required in concert with more direct restoration actions like planting willows or constructing beaver dam analogues (BDAs) and post-assisted log structures (PALS). Land management changes relevant to beaver colonization include:

- Grazing: Riparian fencing, rotational grazing systems, and off-site watering can invigorate riparian vegetation beavers prefer, reduce beaver conflicts with livestock operations, and prevent damage to the bed and banks of streams that may keep beavers from colonizing.

- Timber: Thinning of over-crowded stands, removing encroaching conifers from riparian zones, and placement of large wood in streams can deliver more water to the stream to bolster flows beavers need for dam-building, reduce excessive sediment loads that can rapidly silt in beaver ponds, remove encroaching conifers that shade out preferred vegetation for beavers, and provide woody structure to stream channels beavers can use as a basis for dam and lodge sites.

- Water: In-stream flow leases and channel plugs can reduce powerful flows that blow out beaver dams in incised streams or bolster flows in dewatered streams allowing beavers to colonize and expand.

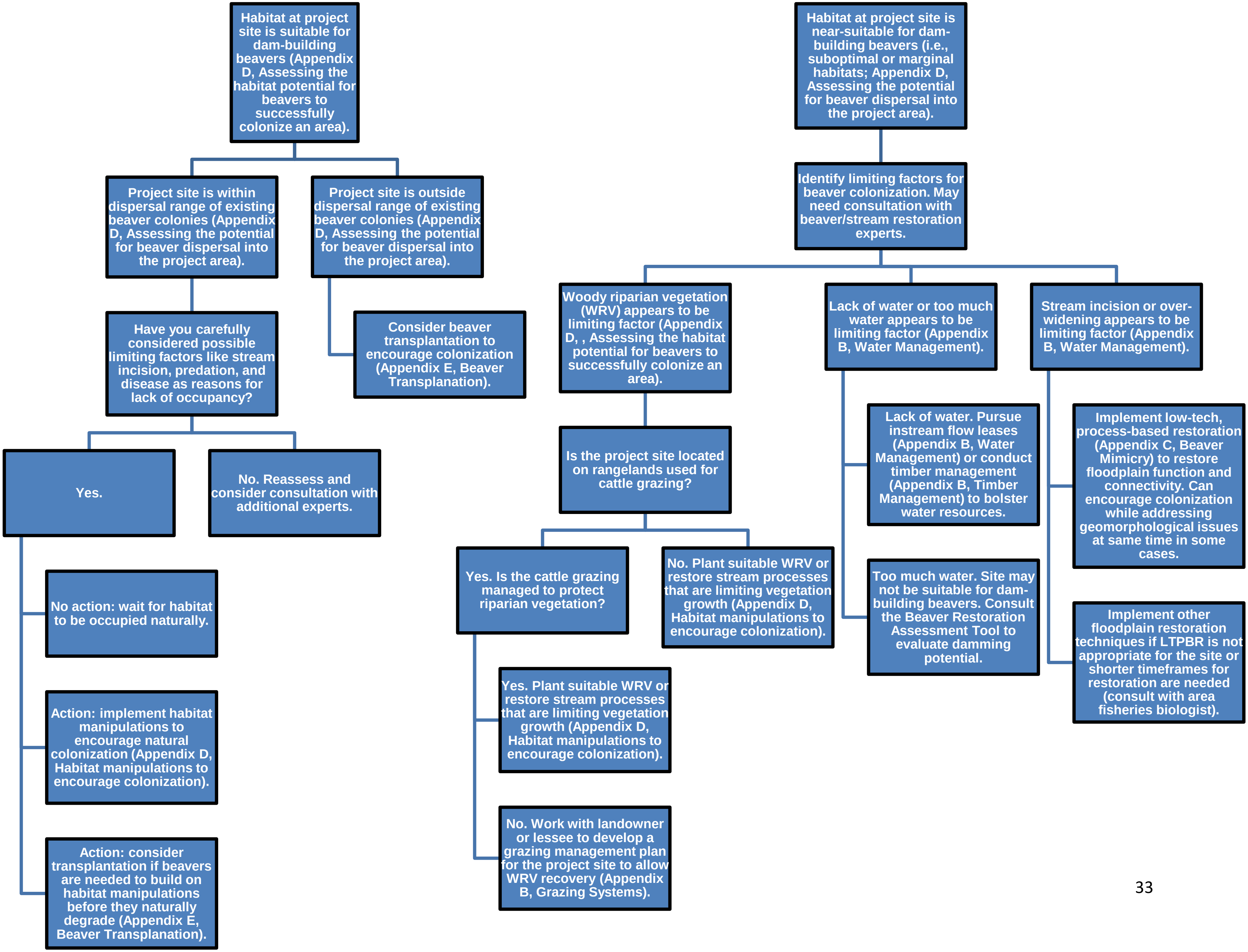
- Predation (including trapping): Voluntary or mandatory trapping closures that are temporary can improve survival of beavers and allow for colony expansion as well as provide dispersers to move across the landscape and start new colonies nearby.

- See Appendix B - Land Management Changes for more detail on each of these forms of land management that can be supportive of beaver colonization.

Encouraging natural colonization is dependent on the availability and quality of habitat. If dispersing beavers are likely encountering the area and there are no obvious habitat issues that would prevent them from colonizing (e.g., insufficient riparian vegetation, unstable water supply, severe incision), the habitat is likely suboptimal or marginal. The presence of blown-out dams and lodges from previous beaver colonization attempts is one of the strongest indicators of beavers encountering a site but not being able to successfully colonize the area at a spatial or temporal scale that will bring about desired restoration benefits.

Suboptimal and marginal habitats are often ideal locations for recovering beaver populations and beaver-modified habitats because minimal human input is needed to restart lost or diminished stream system processes. Transplants are usually not needed as beavers are already in the area. The most effective technique for encouraging beavers to colonize an area is providing starting infrastructure for beavers to build on. Dispersing beavers are highly attracted to old or abandoned beaver infrastructure like dams, dens, and lodges (Harris 1991, Smith 1997, Sun et al. 2000, DeStefano et al. 2006, Ritter et al. 2019). Restoration practitioners can mimic this existing beaver infrastructure by building beaver dam analogs (BDAs) or other dam-like structures in the project area to provide beavers with safety cover and give them a starting point for their own dam construction. See Appendix D - Encouraging Natural Colonization for more detail.

Beaver transplantation is reserved for situations where: a) the project area is isolated from potential source colonies such that natural colonization of the site via dispersing beavers is unlikely, b) there is substantial unoccupied habitat that is unoccupied because of disease or predation and not because of natural habitat succession, or c) restoration actions in the project area require beaver colonization at a level natural colonization is unlikely to provide within the lifespan of the restoration structures. In any of these cases, careful project planning and comprehensive evaluations must be completed to determine if transplants are warranted and could be successful. If a project considers transplants, it must comply with the Montana Environmental Policy Act and receive approval from the Fish and Wildlife Commission. Transplant sites should be treated like areas where practitioners want to encourage colonization and should therefore be supplemented with human-built dams and lodges if such structures are not already available in the project area. For more detail, see Appendix E - Beaver Transplantation.


Habitat at project site is suitable for dam-building beavers (Appendix D, Assessing the habitat potential for beavers to successfully colonize an area).
Project site is within dispersal range of existing beaver colonies (Appendix D, Assessing the potential for beaver dispersal into the project area).
Project site is outside dispersal range of existing beaver colonies (Appendix D, Assessing the potential for beaver dispersal into the project area).
Have you carefully considered possible limiting factors like stream incision, predation, and disease as reasons for lack of occupancy?
Consider beaver transplantation to encourage colonization (Appendix E, Beaver Transplantation).
Yes.
No. Reassess and consider consultation with additional experts.
No action: wait for habitat to be occupied naturally.
Action: implement habitat manipulations to encourage natural colonization (Appendix D, Habitat manipulations to encourage colonization).
Action: consider transplantation if beavers are needed to build on habitat manipulations before they naturally degrade (Appendix E, Beaver Transplantation).
Habitat at project site is near-suitable for dam-building beavers (i.e., suboptimal or marginal habitats; Appendix D, Assessing the potential for beaver dispersal into the project area).
Identify limiting factors for beaver colonization. May need consultation with beaver/stream restoration experts.
Woody riparian vegetation (WRV) appears to be limiting factor (Appendix D, , Assessing the habitat potential for beavers to successfully colonize an area).
Lack of water or too much water appears to be limiting factor (Appendix B, Water Management).
Stream incision or over-widening appears to be limiting factor (Appendix B, Water Management).
Is the project site located on rangelands used for cattle grazing?
Yes. Is the cattle grazing managed to protect riparian vegetation?
No. Plant suitable WRV or restore stream processes that are limiting vegetation growth (Appendix D, Habitat manipulations to encourage colonization).
Yes. Plant suitable WRV or restore stream processes that are limiting vegetation growth (Appendix D, Habitat manipulations to encourage colonization).
No. Work with landowner or lessee to develop a grazing management plan for the project site to allow WRV recovery (Appendix B, Grazing Systems).
Lack of water. Pursue instream flow leases (Appendix B, Water Management) or conduct timber management (Appendix B, Timber Management) to bolster water resources.
Too much water. Site may not be suitable for dam-building beavers. Consult the Beaver Restoration Assessment Tool to evaluate damming potential.
Implement low-tech, process-based restoration (Appendix C, Beaver Mimicry) to restore floodplain function and connectivity. Can encourage colonization while addressing geomorphological issues at same time in some cases.
Implement other floodplain restoration techniques if LTPBR is not appropriate for the site or shorter timeframes for restoration are needed (consult with area fisheries biologist).

#3. I want to implement beaver restoration in a stream that is not yet suitable for beavers.

Problem: Many degraded streams are disconnected from their floodplain, which can lead to a lower water table, diminished riparian vegetation, and a lack of flood attenuation. Water storage within the valley bottom may be reduced, leading to lower late-season streamflow. Some of these streams will have moved beyond the point of being marginal or suboptimal habitats for beavers to the point of being entirely unsuitable, yet they are still within the range of historical beaver habitat and could present a high potential of colonization if restored to the appropriate ecological state.

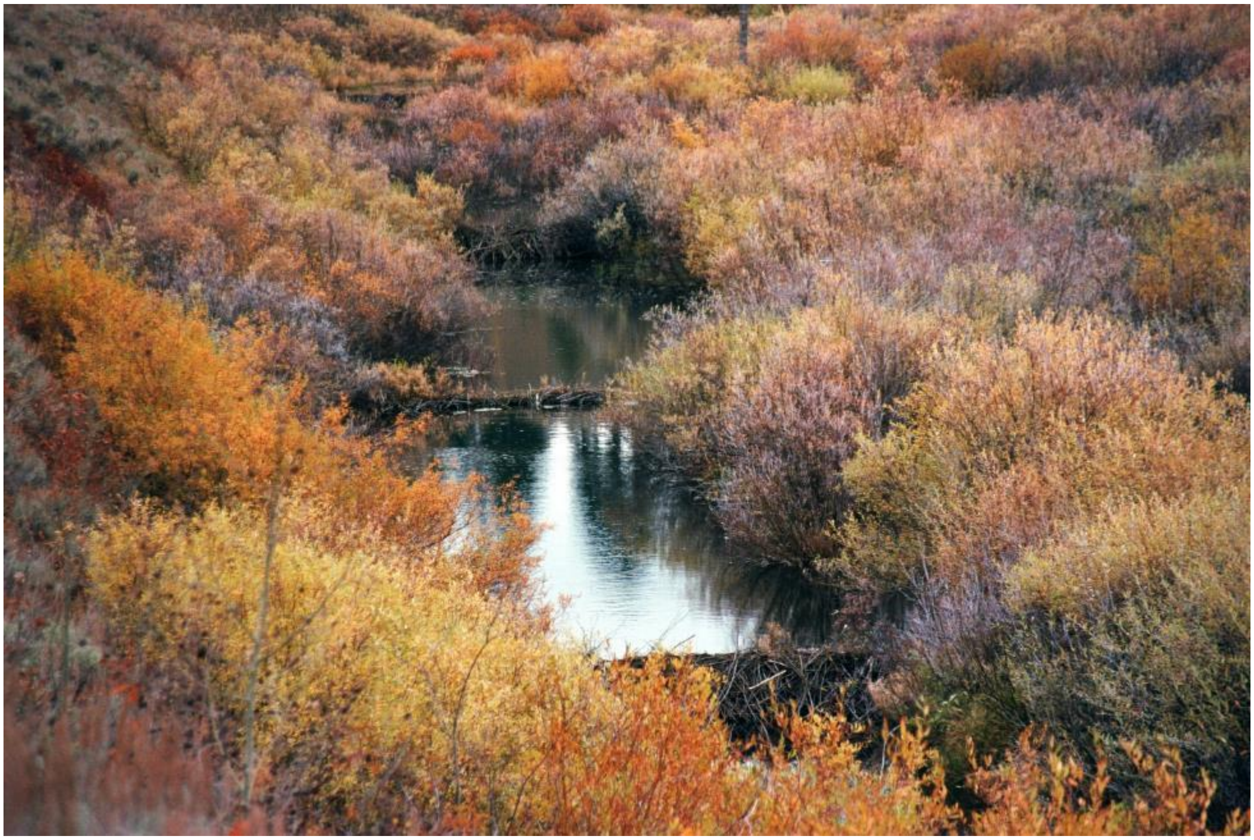
Goals: To re-initiate natural processes that can improve the connection of the stream channel to its floodplain and begin recovering suitable vegetation and channel geomorphology that could eventually lead to beaver colonization.

Solutions: Beaver restoration can address these problems by reintroducing natural processes to a stream system. Primarily, natural processes introduced by beaver activity or beaver mimicry result in a shift in the disturbance regime of a stream system, specifically through introduction of structural elements to a stream, interruption of longitudinal connectivity, attenuation of flood events, and sediment deposition in the stream channel and floodplain and/or forced widening of an inset floodplain to encourage balanced erosion and deposition processes. These natural processes are achieved through low-tech, processed-based restoration, stream and floodplain restoration, or changes to land management. Each strategy has pros and cons and a different expected timescale.

Low-tech, Process-based Restoration is a set of concepts and procedures described by Wheaton et al. (2019) as simple, low-cost structures that are introduced to a stream system and are intended to mimic the function of debris and beaver dams to initiate natural processes. These techniques typically use large numbers of hand-built structures made with natural materials installed at relatively high densities in a stream with the goal of letting the system do the work. This option may be less expensive than other methods of restoration, but the timescale for recovery may be longer in some situations and will likely require several phases of structure building and repair which may span many years. Beaver mimicry, comprised of channel-spanning structures called beaver dam analogs (BDAs), fall under this category, as do post-assisted log structures (PALs) that may or may not be channel spanning. For more detail, see Appendix C - Beaver Mimicry.

Channel and Floodplain Restoration includes physical channel and floodplain manipulation (e.g., bank sloping, stream re-routing). It is a relatively fast and effective method for improving floodplain reconnection and natural stream function but is also expensive and difficult to implement over large areas. Designs can include wetland cells and other features to encourage groundwater storage and late season streamflow (DNRC 2020). In areas with heavily incised stream channels, where natural beaver dams are unlikely to create floodplain connection, re-routing of the stream channel and abandonment or filling-in of the incised channel may be the best option for restoring a degraded floodplain. Remote-sensing data (e.g., LIDAR, aerial imagery) can help identify historical stream channels in the floodplain and strategic channel plugs can be used to route streamflow into old channels where beavers may form dams more easily. It is important to remember that even though a channel and floodplain restoration project may not have an explicit goal of restoring beavers, if it is reasonable to assume the stream is within the historical range of beavers then practitioners should expect that beavers will eventually show up and begin messing with the restored channel and vegetation.

Land Management Changes, typically in the form of grazing management and/or riparian fencing, may be all that is needed to encourage natural recovery of a stream system. However, the recovery may take place over a long time period and may need to be combined with some of the other techniques outlined above. For more detail, see Appendix B - Land Management Changes.



Series of beaver dams along Campanula Creek in Yellowstone National Park

Project Planning

The first step in a restoration project is identification of the problem in the form of the type of degradation and the factors that have led, or are continuing to lead, to that degradation. Then, practitioners must identify site-specific limiting factors to recovery to determine the potential goals, strategies, and outcomes of a restoration project at the site. When it is clear what is limiting the site or its wildlife (aquatic and terrestrial), and how potential changes might meet restoration goals, the appropriate restoration tools can be identified. For example, when considering a project to benefit water storage, streamflow, and floodplain reconnection, beaver restoration is one method of reaching those goals. Other techniques that can reconnect floodplains include induced meandering, channel reconstruction, post-assisted log structures, or allowing a stream to recover on its own over a longer time period.

If beaver restoration is a chosen strategy, project planning will require consideration of numerous factors, many of which can affect, and be affected by, areas beyond the project site. Practitioners must examine the unique vegetation, geomorphic, and hydrologic factors of the site and attempt to predict potential process pathways (see definition below) through which manipulation of one or several of those factors can guide the system toward recovery (Nash et al. 2021). Stream and riparian systems are unique in the restoration world because they experience semi-predictable, annual disturbance events (i.e., floods) that offer a consistent “test” on the system. These periodic disturbances allow practitioners to evaluate their actions annually and use those evaluations to look forward to potential process pathways that are developing in the target system. Then, practitioners can use adaptive management to continue guiding the system along process pathways that lead to the desired conditions outlined in the original project goals.

What are Process Pathways in stream restoration?

Process pathways are conceptual models of how a stream system may or may not recover based on the complex interactions between the processes being impacted by restoration as well as other factors that are outside the control of practitioners (e.g., climate, flood timing and magnitudes, natural beaver colonization/abandonment). It is important to keep in mind the specific processes that can be affected by beaver restoration outlined in the Introduction section when considering potential process pathways for a given restoration site. Practitioners should attempt to sketch out potential process pathways, like the schematic provided below (Nash et al. 2021), when designing and implementing a beaver restoration project. Revisiting those sketches on an annual basis will allow practitioners to evaluate if their actions are leading down the pathway they predicted and adjust if needed to keep the system on the road to achieving project goals.

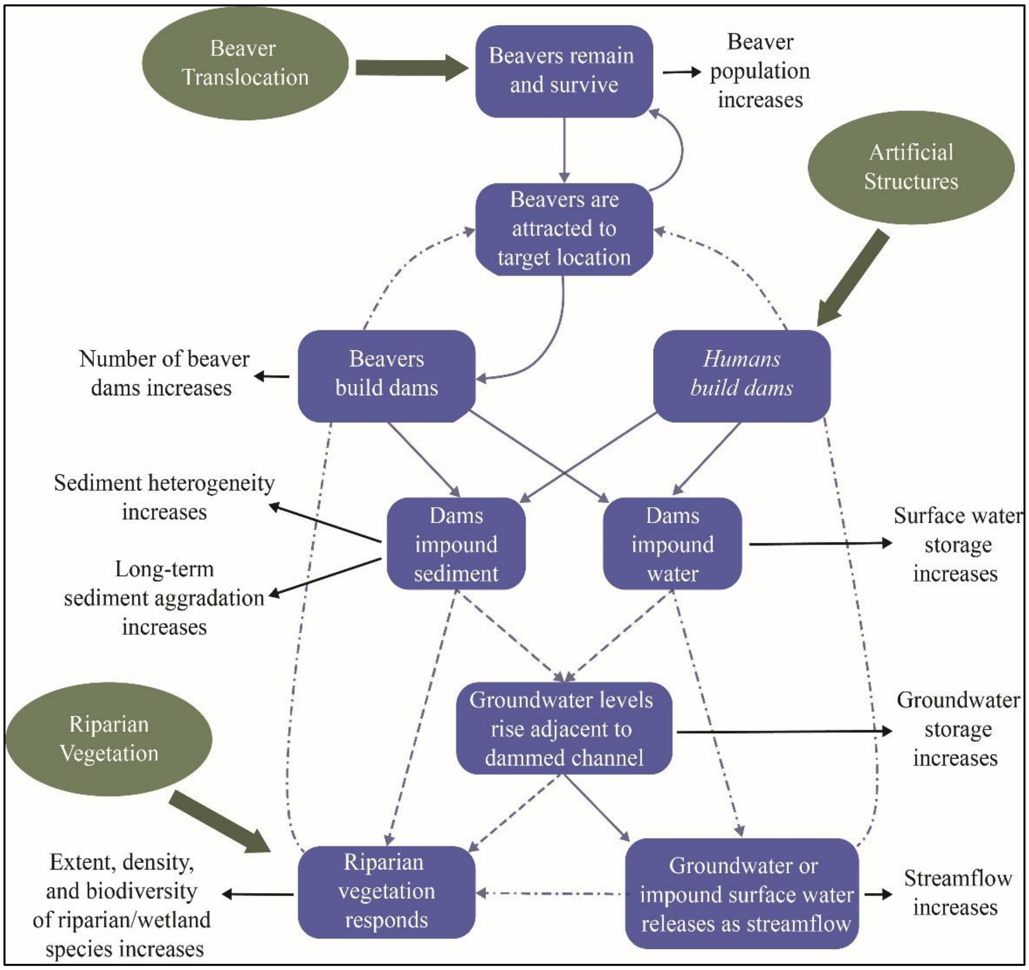


Figure 2 from Nash et al. 2021. Flow chart documenting the sequence of processes (the blue boxes and the arrows with solid lines) that must occur for each beaver-related restoration tactic (the green circles and the black arrows) to achieve commonly expected outcomes (the black text). The arrows represent the sequence in which the steps must occur: The solid lines indicate a causal relationship; the dashed lines indicate that one of two mechanisms can lead to the next step, and a dot-dash line indicates that the preceding step can amplify the following step, but it is insufficient to lead to changes on its own. For example, an increase in sediment deposition can increase the surface area in which riparian vegetation can grow, but only if the water table has also risen to provide plant-available water. The processes outlined in the present article reflect expectations about how beaver-related restoration should work on the basis of stated project goals, not necessarily how it does work in practice.

Beaver restoration adds an additional layer of complexity to the consideration of process pathways. Most of the techniques covered under beaver restoration are inherently unpredictable. Most of the restoration actions involve relatively small adjustments to the way a stream-floodplain system behaves rather than major manipulations of the form and function of the system (e.g., floodplain regrading, channel reconstruction, heavy planting efforts). The goal with these major manipulations is often then to “keep the system from unraveling” before the restoration actions take hold and become self-sustaining.

In beaver restoration, a level of system “unraveling” is often the point. Practitioners implement these techniques to collect large amounts of sediment, force floodplain widening, introduce large quantities of wood to the channel, and/or get beavers established and let them do as they may. Therefore, trying to predict and guide that “unraveling” toward a longer-term recovery can be complicated, and a greater level of uncertainty is required. Adaptive management is therefore an absolute in beaver restoration, and if the restoration area or the partners involved are not aware of and prepared for this level of uncertainty and adaptation through time, then beaver restoration may not be the best approach. In other words, just because there is the potential to do beaver restoration does not mean that is the most effective and efficient strategy.

If beaver restoration can help achieve project goals, practitioners should consider the logistics of beaver restoration in that area and how that could affect project success. Some examples of these considerations include the potential for human conflict and the required resources to maintain and monitor a project that may need many phases over a long period of time and a substantial reliance on allowing the system to do the work. One of most common issues preventing a beaver restoration project from succeeding is inadequate forethought regarding the breadth of biological and social implications of the project, as well as unrealistic expectations around what is possible in the target system and the timeline for recovery.

Given the complexities of using beaver restoration as a tool to recover degraded stream systems, the following over-arching guidelines can help practitioners consider key factors important for a successful project at the planning stages:

- **Understand the existing “beaver landscape”.** It is critical for practitioners to start a beaver restoration project by understanding the current state of beaver populations in and around the stream system where the restoration will take place. A high-density beaver population within dispersal distance of the restoration site may mean rapid colonization of the site soon after restoration. An isolated project site may mean that beaver transplants will be required for colonization. A big swath of suitable, unoccupied beaver habitat nearby the restoration site may make encouraging colonization much more difficult as the restoration site must “compete” with nearby areas for the attention of dispersing beavers. Beaver activity surveys (see Table 2 in Maintenance and Monitoring) are critical to understanding the local beaver population and available habitat and should be done prior to any beaver restoration project. Beaver activity surveys should also be done during and after the project as a critical form of monitoring. Practitioners should evaluate existing beaver colonies and potential beaver habitat within approximately 6 air-miles of the restoration site (higher end of average dispersal distance for beavers; Table D1) as a prerequisite to continued project planning. This level of evaluation can usually be accomplished using remote sensing data.

- **Consider Spatial Expansion and Ecological Context**. Beaver restoration has the potential to expand beyond the boundaries of the original project area as colonies develop and beavers produce offspring that disperse and settle other areas. There are many different beaver restoration techniques and not all of them involve the goal of establishing self-sustaining beaver colonies to a site. However, all the techniques could be expected to eventually result in beaver occupation whether the practitioners want that outcome or not. Practitioners must understand the context of the project area both in terms of the influence of any existing beaver population on the restoration project (i.e., potential for beavers to naturally disperse or expand into the project area), as well as the influence of the restoration project on any existing beaver population (i.e., potential for beavers to become established at the project site and then expand to other areas in the drainage). While colonization and expansion can be somewhat predictable through habitat surveys and modeling, it is far less predictable than other forms of restoration where the project area can be easily delineated, and restoration work can be restricted to those boundaries.

- **Focus on the Reach and the Watershed.** Practitioners must work to understand and articulate how their project area fits into the larger watershed. Drainage-scale project consideration and management is rooted in recognition of the interconnected nature of a watershed. Stream sections are not isolated habitat patches that can be manipulated and managed as one might manage their yard or a depressional wetland. The characteristics and functions of any given stream reach reflect upstream inputs and are also factors affecting the characteristics and functions of downstream reaches. Inputs such as sediment loads, high and low flows, availability of woody material, and the presence and distribution of existing beaver colonies can all affect a restoration site even though the primary controls on those inputs may be miles upstream of the project site in the headwaters of a drainage. Any project that addresses a section or multiple sections of streams must take into consideration whether the techniques used will be resilient to the inputs of that watershed and how the system could recover or possibly revert to the original degraded state due to factors beyond the restoration practitioner's control.

- **Understand and Account for Geomorphology.** The potential benefits of beavers are mediated by the geomorphic context of the target stream system. Sediment types, landforms, stream gradient, and underlying geology can all have major implications for the expected response of the stream system to beaver restoration. For example, instream flow and water storage potential are directly linked to the underlying geology of the valley bottom. Restoration of beaver dams and dam-like structures will have vastly different effects when they occur in a gaining stream section versus a losing stream section (Lautz et al. 2006, Scamardo and Wohl 2019, Wohl 2019, Larsen et al. 2021, Roper 2022). In a gaining stream section, water flows from groundwater into the stream channel, versus a losing stream channel where water flows from the stream channel into groundwater. Beaver dams in losing stream sections often result in a net loss of in-stream flow as water in the channel is pushed into groundwater. Therefore, a beaver restoration project that seeks to bolster late-season flows to benefit fish may have the opposite effect if the geomorphic context is not well-understood prior to project implementation.

- **Identify Goals, Limiting Factors, and Process Pathways.** Practitioners should identify the goals of the project ahead of time and determine if beaver restoration can help meet those goals. Practitioners should weigh their goals against potential limiting factors, such as the geomorphic context, habitat availability, potential for human conflict, and available resources to initiate, complete, maintain, and monitor the project. There are a wide variety of potential effects of beaver activity and not all those effects can be expected at every site. Practitioners should be able to articulate the process pathways through which the stream will recover and achieve the project goals. There are often multiple pathways to get to the same goal, and some may be more appropriate than others depending on the context (Nash et al. 2021). For example, if a practitioner wants to restore floodplain connectivity in an incised stream, one method may be to build BDAs to collect sediment to try and aggrade the incised stream channel. But will that accumulated sediment behind the BDAs stay in place once they are not maintained anymore? Will the stream carve a new meandering channel through the sediment bed, or will it re-incise? In this example, practitioners must be able to articulate how their project will guide the system toward the goal of “floodplain connectivity” and how that becomes a self-sustaining state for the system after the restoration project is completed.

- **Consider the Spatial and Temporal Scale.** Beavers can colonize an astounding variety of habitats and can occupy those habitats for anywhere from a few months to many decades. The potential benefits or costs of beaver activity in a restoration context are heavily dependent on how long beavers can occupy an area and how well they are able to expand their construction activities as the stream system reacts to their presence. This same thing is true when considering beaver mimicry projects, except that practitioners themselves may have to act as beavers until the system reaches a state where beavers could occupy the site and succeed on their own. Generally, the positive effects practitioners wish to see from beaver restoration occur when beaver dams are actively maintained in an area at a sufficient spatial scale and for a sufficient amount of time to cause long-term or permanent changes to the stream system resulting from the reintroduction or enhancement of natural stream processes (see Introduction for a discussion of these natural stream processes). The key to using beavers as a restoration tool is finding areas where beavers can form long-term, self-sustaining colonies existing in a shifting mosaic (Naiman et al. 1988, Wohl 2019).

What is “long-term” in beaver restoration?
Most often this will be many years to decades; it is long enough for beavers to occupy an area and become an essential component in the overall disturbance regime of the system. More specifically, long enough for their activities to produce the restoration goals identified during project planning. Using the example from earlier, if a restoration goal is to get beavers to move into an area to accumulate sediment behind dams and rebuild an incised stream channel, the beavers need to be active in the area long enough for significant amounts of sediment to accumulate behind dams and not be washed away immediately if the dam breaches or decays. Beavers would therefore need to be active long enough to build dams in series so that there is redundancy and the whole restoration effort is not hinging on the stability of a small number of dams. In systems with a heavy sediment load, the impoundments above the dams may fill in with sediment in 1-2 years. In systems with a light sediment load, the impoundments above the dams may never fill in with sediment. This emphasizes the need to not only understand the process pathway (i.e., filling in the incised channel with sediment), but also the geomorphic context (i.e., sediment loads), and how those will interact to achieve the project goal of floodplain reconnection.

What is “self-sustaining” in beaver restoration?
The restored system can maintain the restored state or continue to improve without sustained human intervention. The beaver dams in a stream or drainage reach a cycle where they can survive multiple runoff events. Beaver colonies are abandoned due to silting in of ponds, natural disease outbreaks, or predation, and not because of repeated, catastrophic dam blow-outs (i.e., whereby all the dam material is broken apart and washes downstream), or woody vegetation harvest by beavers that out-paces

regrowth. A self-sustaining beaver population will lead to substantial changes in sediment erosion and deposition patterns along the affected stream length, expansion of beaver activity and influence away from the main channel of the stream, reintroduction of structural elements to the stream channel and floodplain, and expanded woody vegetation recruitment around active and abandoned colonies.

What is a "shifting mosaic" in beaver restoration?
Defined in Naiman et al. 1988 (pages 756-760). Beaver colonies should be spread throughout suitable habitat in a stream or drainage with a mix of colonies ranging from newly established to old and abandoned. All successional states of beaver colonies have their own unique and beneficial effects on the environment. For example, damaged and blown out dams due to colony abandonment can be a critical structural component of the stream system that allows for lateral migration of the stream channel, floodplain widening, induced meandering, and creation of complex stream bed morphology. The lack of beavers in an area of suitable habitat does not necessarily indicate a problem. In fact, dominance of an entire stream system by active beaver colonies may indicate a current or impending problem, such as a major die-off of beavers or system stasis, whereby not enough erosion and deposition is occurring to spur sufficient vegetation growth to keep up with beaver harvest.

Defining the Project Area and Timeline

Once the source and current state of stream degradation and potential limiting factors for recovery have been identified, and potential restoration strategies have been considered, the next step in developing a beaver restoration project is to define the project area and the timeline that the project will be implemented and monitored. Consideration of the various beaver restoration strategies, as well as the specific hydrologic, geomorphic, and biologic features of the site, will influence the spatial and temporal scale of restoration for a given project. The over-arching goal of beaver restoration projects should be to achieve self-sustaining beaver colonies and natural processes and therefore the project area and timeline should be direct reflections of that goal.

A self-sustaining system is one where the stream system can withstand common and repeated disturbance events (e.g., floods, ungulate grazing/browsing, well-managed livestock use, fire) without shifting to a degraded state. For example, projects that use Beaver Dam Analogs (see Appendix C – Beaver Mimicry) in heavily incised streams must be implemented over a sufficient area and time period to either aggrade the stream channel or create an inset floodplain to the point that practitioners could walk away from the area and the stream would not re-incise. For heavily degraded streams, this could be a decade or more of iterative work and potentially hundreds of structures to restore the stream and floodplain to pre-degradation conditions (Bouwes et al. 2016, Wheaton et al. 2019).

Regarding projects with the goal of beaver occupancy, simply getting beavers to form a colony in an area is not enough to achieve success. Many of the ecological benefits attributed to beavers are not achieved until beavers have become well-established enough (in space and time) for the following outcomes to occur:

- **Aggradation.** Dams collect enough sediment so that when the dams breach or degrade the sediment is not largely vacated from behind the dam and washed downstream, or the stream re-incises through the accumulated sediment. This outcome generally applies to smaller headwater streams dominated by finer substrates and with low stream power.

- **Inset Floodplain Development.** As an alternative to the first bullet above, repeated dam building and blow-outs widen an inset floodplain leading to geomorphic conditions that restore multi-thread channels and an active, well-connected floodplain. This outcome generally applies to larger streams with larger substrates and greater stream power that more frequently damages or destroys dams (Figure 2; Cluer and Thorne 2014, Wheaton et al. 2019).

- **Series of Dams.** Dam complexes develop where dams are built in series and therefore support one another by backing up water and accumulated sediment to the base of the next dam upstream (Figure 3). This arrangement of dams smooths out the gradient of accumulated sediment between dams as well as along the length of stream encompassed by the beaver colony. A series of dams helps avoid extreme differences in the bed elevation above and below the dams that can lead to geomorphic instability (Figure 4).

- **Riparian Vegetation Expansion.** Woody riparian vegetation growth on the periphery of impoundments and downstream of dams outpaces or at least keeps up with vegetation harvest by beavers and vegetation death from prolonged flooding in impounded areas.

- **Territory Expansion.** Beavers are able of to expand their colony boundaries upstream and/or downstream or shift the territory boundaries significantly without bumping into major barriers (e.g., incised stream, lack of vegetation).

Restoration of a self-sustaining, beaver-influenced system cannot be reliably accomplished within a set timeframe or over a certain spatial extent that can be widely applied. The conditions outlined above can occur over vastly different spatial and temporal scales depending on the intrinsic properties of the stream system, characteristics of the valley bottom (e.g., gradient, sediment), level of degradation, and the state of the beaver population in the area prior to restoration. This emphasizes the importance of a thorough understanding the stream-floodplain system where the work will occur and clearly defining project goals and process pathways prior to implementation.

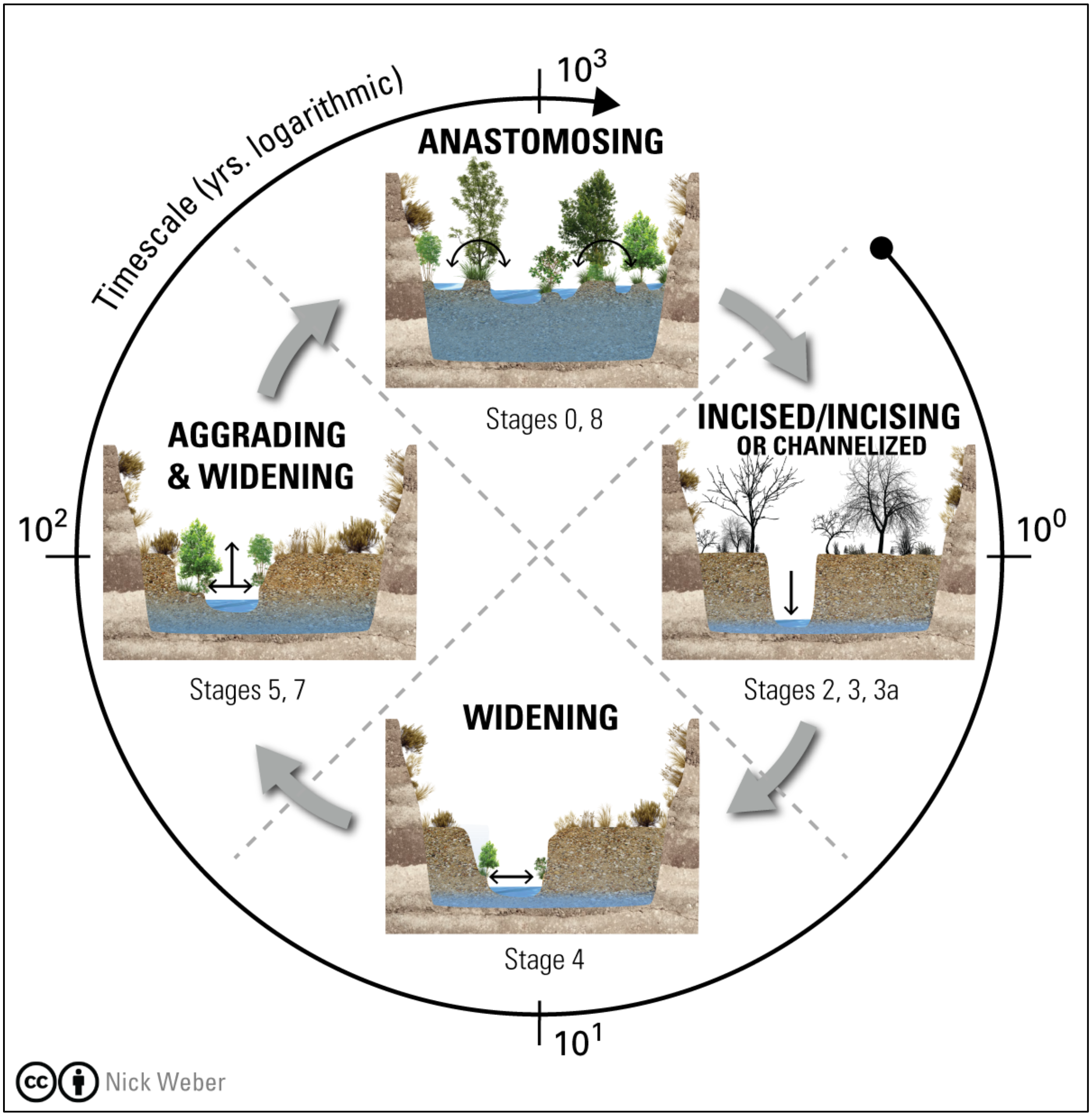


Figure 2. Simplified stream evolution model adapted from Cluer and Thorne 2014 by Wheaton et al. 2019. In this figure, the typical stream evolution pathway after stream incision has occurred is depicted (inset floodplain development). Beaver restoration can substantially accelerate this pathway through the introduction of structural components (i.e., dams and downed wood) to the stream channel that force inset floodplain development and create conditions suitable for continued beaver damming that leads to aggradation. It is also possible to reverse this pathway at the second stage by accumulating sediment behind beaver dams to the point of reconnecting the stream to the floodplain. Practitioners seeking to restore a degraded stream with beaver restoration techniques should be aware of the current stream state prior to any restoration actions. They should be able to predict the process pathways that would be restored and would move the stream toward the desired anastomosing stage (e.g., sediment accumulation behind dams in an incised channel to rebuild a floodplain or development of an inset floodplain leading to aggradation and widening; Nash et al. 2021).

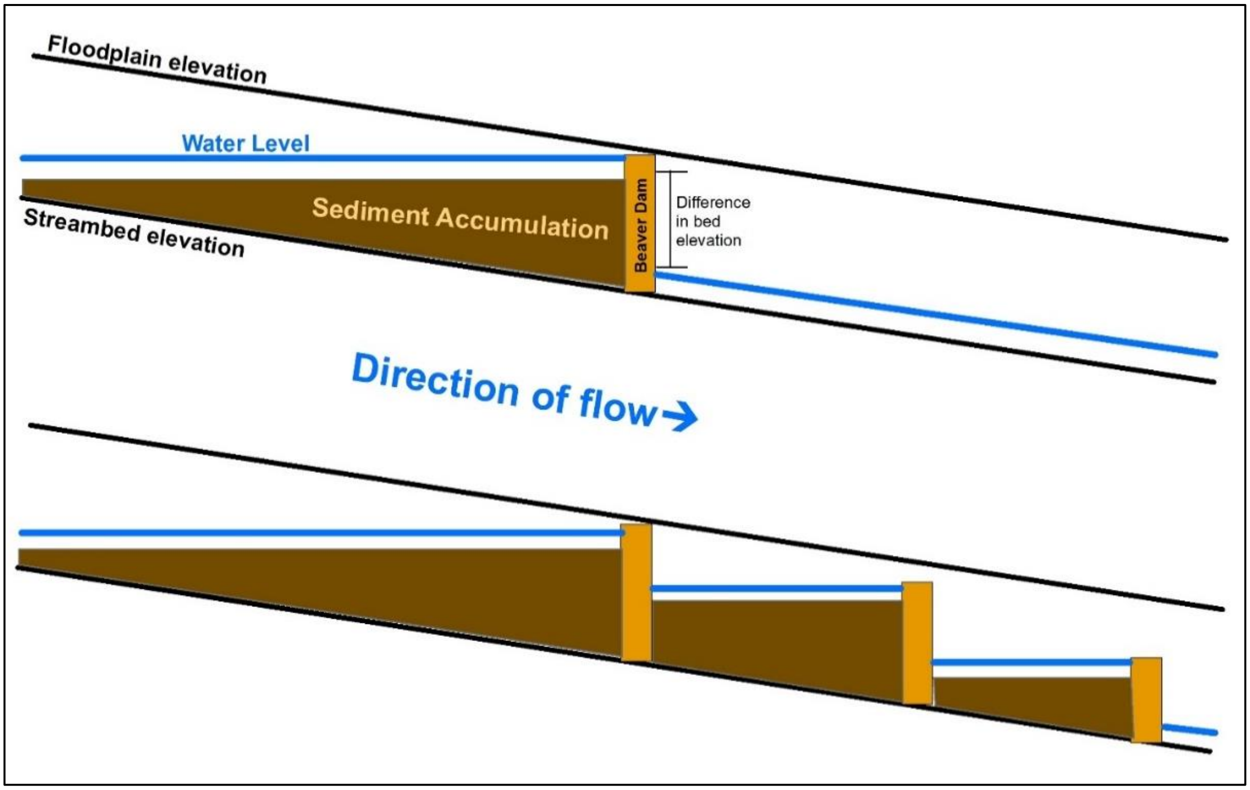


Figure 3. The effect of a series of beaver dams on sediment accumulation patterns. In the top schematic, a single, large beaver dam (or BDA) causes a dramatic difference in the stream bed elevation above and below the dam. Should the dam no longer be maintained, the stream will almost certainly re-incise through the accumulated sediment as the water seeks the "path of least resistance" down to the original bed elevation. In the bottom schematic, where beaver dams (or BDAs) are built in a series, the slow water and accumulated sediment of a downstream dam are backed up to the base of the next dam upstream. This reduces the difference in bed elevation above and below the dams and therefore diminishes the importance of any one dam for overall system resilience.

Figure 4. While this dam is impressive in its height, it is a stand-alone dam in an incised section of stream and is therefore unstable and will be unlikely to result in positive, self-sustaining changes to the stream system. Although nearly 4 feet of sediment has built up behind the dam, because there are no additional dams downstream a dramatic difference in bed elevation has developed above and below the dam. When this dam is no longer maintained by beavers the stream will re-incise through the accumulated sediment, largely vacating the sediment from the area and resulting in little to no long-term, positive changes to this incised section of stream.

Spatial Scale for Beaver Restoration: Project size expectations and recommendations

Expectations of the total area restored or affected by restoration actions need to be adjusted to fit the realities of various project opportunities. If beaver occupancy is not an explicit goal of the restoration project, the project area can easily be defined by the area over which land ownership, project resources, permitting, social and biological considerations, and geomorphic conditions allow the work to occur. Even if beaver occupancy is not the goal, if the restoration is occurring within the historical range of beavers, then practitioners should account for the possibility that beavers will move into the restored area. Beavers moving into the area may be a positive outcome for the restoration if beavers can take over and enhance the restoration work, or it could be a detriment to the restoration if beavers move into the area too soon and damage or degrade restoration efforts.

Beavers may expand their area of influence in two distinct ways:

1) Beavers construct dams and lodges on the periphery of their existing infrastructure, thereby extending territory boundaries up- and/or downstream.

2) Established beaver colonies produce young beavers that disperse and start new colonies nearby.

These two forms of beaver expansion can occur on their own or simultaneously, with the potential for rapid expansion if conditions are right. Therefore, if beavers are established in a project area there must be an option for the beavers to move to a different site within the same drainage if the original site is abandoned. Or there should be room within the drainage for dispersers from the original colony or colonies to settle and start a colony of their own. Under this definition, a project that seeks to establish a single beaver colony in a single segment of stream without contemplation of the rest of the drainage is not considered self-sustaining and will be unlikely to positively influence the stream and riparian area long-term. Similarly, if the target restoration reach is the only stream reach in the area where beaver activity will not conflict with human infrastructure, then it would be irresponsible to try to get beavers established there as they have no avenue to expand where they will not cause problems for other people.

Beaver restoration involving establishing beaver colonies must focus on large sections of stream, or more appropriately, focus on the entire length of a stream or an entire stream drainage. This necessarily limits the options for beaver restoration project locations. But, it does so in recognition of the dynamic nature of beaver colonization and abandonment processes on the landscape, increasing the odds of a successful restoration effort.

Essentially, partnering with beavers for stream restoration involves assuming that the effort will be successful and therefore trying to predict the area over which beavers will expand in the future. This has implications not only for the restoration of natural stream processes, but also for the potential creation of future conflict issues with nearby landowners. Every stream, pond, and lake within dispersal distance of the restoration site has the potential to be impacted by the project and deserves consideration. Similarly, every culvert, bridge, irrigation canal, riparian road, and substantial patch of woody riparian vegetation within dispersal distance of the restoration site has the potential to be impacted by the project.

Specific spatial scale considerations that may affect beaver restoration projects include:

- The use of beaver mimicry structures like BDAs and PALSs can help restore smaller stream reaches (e.g., 300 ft to 2 miles), but may not be efficient or effective over long stream reaches or entire drainages without substantial funding and staff time (Pollock et al. 2017, Wheaton et al. 2019). Building, maintaining, and expanding BDAs should occur in large enough areas and with close enough spacing that major differences in above-dam and below-dam stream bed elevations do not develop (Figures 3 and 4) and that high-water events can be attenuated to the point of preserving BDAs. PALSs need similar close spacing so that treated stream reaches are not isolated amongst other reaches that remain incised or otherwise degraded. Small numbers of beaver mimicry structures are unlikely to bring about long-term restoration benefits except in streams with mild degradation issues.

- Generally, the smallest section of stream that can sustain a beaver colony for at least three years is 1,300 feet (as measured along the stream channel; based on willow-dominated streams in southwest Montana, Ritter 2018). However, limiting factors for beaver colony establishment and persistence change from stream to stream and among different segments of the same stream. For example, if a floodplain allows for significant lateral expansion of beaver activity from the stream channel, beavers may need to take up a smaller overall stream length than in a more constricted floodplain.

- Focusing on establishing a beaver population in the area with a network of beaver colonies in various states of succession will lead to the largest-scale effects of a beaver restoration effort. However, this type of restoration introduces more uncertainty because practitioners are less focused on restoring single sites and are instead allowing long-term restoration of the area to be deferred to the colonization and abandonment dynamics of the entire beaver population in the area rather than individual beavers or beaver colonies.

Temporal Scale for Beaver Restoration: Project timeline expectations and recommendations

The project should be implemented over a sufficient time period to accomplish self-sustaining improvements in stream conditions and associated riparian areas. If beaver occupancy is an explicit goal of the restoration work, then the timeline should be long enough to assure the beaver population can become self-sustaining. In this context, self-sustaining means colony boundaries can expand and new colonies can become established without human intervention. It is not difficult to get beavers to establish in an area for 1-3 years, but longer-term colonization and expansion may be more difficult, especially in heavily degraded streams.

The project timeframe will almost always be over many years and may require several decades for full recovery of the target system. As such, one-time treatments (e.g., a single set of BDAs/PALS, a single beaver transplant, etc.) will rarely be successful. Effective projects should be planned over enough years to achieve the goal of self-sustaining beaver colonies and/or restoration outcomes. If part of the project involves conflict management with surrounding landowners or infrastructure within the boundaries of the project area, then attention to conflict management techniques should occur on an annual basis to make sure any fencing or other structures are maintained and are alleviating repeat conflict issues (see Appendix A - Conflict Management). If part of the project involves changes to land management, the project should cover a sufficient time period that a well-planned return to the original land management action will not reverse the recovery of the restored stream system (see Appendix B - Land Management Changes).

Temporal scale considerations that may affect beaver restoration projects include:

- Beaver mimicry structures like BDAs rarely can recover a degraded stream with a single treatment. The structures are inherently low-tech, and they deform and degrade with freezing and thawing, high-water pulses, and animal use. BDA and PALS treatments are much more effective when implemented over many seasons and under an adaptive management framework where structures are added to or supported by other structures depending on stream system response and structure degradation. Just as beavers build and repair dams each year leading to their immense benefits to stream systems, practitioners must plan for multiple seasons of work to accomplish self-sustaining recovery of degraded systems.

- A healthy beaver population consists of beaver colonies of various successional states spread throughout suitable habitat in a drainage. Practitioners should expect that beaver activity and presence within localized areas will ebb and flow over time. Abandonment of an area does not indicate the restoration has failed or is failing. This remains true as long as the cause for abandonment is not repeated, catastrophic dam-blowouts due to channel incision that is not recovering or over-harvest of woody riparian vegetation by the beavers. In other words, colony abandonment should be natural and not due to poor habitat conditions linked to stream degradation.

- Colony longevity for beavers is not well understood and depends on a wide range of factors. Hydrologic and geomorphic conditions have a major influence on how long a colony will remain active. These conditions include runoff and flood severity, water reliability, opportunity for lateral and longitudinal expansion, and the rate of sediment accumulation behind dams (Howard and Larson 1985, Scrafford et al. 2018). Biological and ecological conditions also play a role and include the rate of woody riparian vegetation harvest/death vs. the rate of woody riparian vegetation regrowth in and around the colony, predation including trapping, disease outbreaks, and inter- and intra-colony territoriality (Muller-Schwarze 2011).

- If a self-sustaining beaver population is established in the restoration area, expansion of that population may mean that nearby areas experience conflict issues and beaver colonization long after the initial project work is complete. Community outreach and broad spatial planning for the long-term are essential to understand the wider impacts of a restoration project and to head-off potential landowner conflict issues that may be attributed to the restoration work, whether directly related or not.

Permitting

Permitting for the various forms of beaver restoration can be a confusing and time-consuming process. It is always a good idea to identify what types of permits are needed as the next step after the location and techniques used in the project have been developed. Often, practitioners will need to develop their plan for implementing the project around permitting deadlines, as some permits are time-consuming both in the data-gathering stage to apply for the permit and in the stage where practitioners are waiting to hear back from the regulatory agencies.

In the box below, we lay out the basics of permitting for the five forms of beaver restoration outlined in this document. However, the details of these permits are up to the responsibility of the practitioner. If you have not dealt with permitting for stream restoration projects before, we highly recommend reaching out to other practitioners to help guide you through the process. The Montana Beaver Working Group is a great source of expertise and guidance on permitting for beaver restoration projects (see Additional Resources). In some cases, it may even be worth budgeting to contract out the permitting when intense data collection is required. For example, wetland delineations for Army Corps of Engineers 404 permits can be a lot of work and require detailed knowledge of soils and plants, so hiring someone experienced with collecting those data may be more efficient.

Much of the information summarized below is from the Montana Department of Natural Resources and Conservation (DNRC) website. To learn more about stream permitting, visit DNRC's website and navigate to "Licenses and Permits," then "Stream Permitting". This site includes points of contact for each permit type and a more detailed explanation of the who, what, when, and where of these permits.

At the end of this document, each appendix covers one of the five forms of beaver restoration referred to in this document. At the end of each appendix is a brief discussion of potential permits needed for that activity.

Common Permits Needed for Beaver Restoration Projects

Natural Streambed and Land Preservation Act (310 Permit)

This permit is administered by county Conservation Districts and applies to private lands. The purpose of the 310 Permit is to keep rivers and streams in as natural or existing condition as possible, to minimize sedimentation, and to recognize beneficial uses. Any individual or corporation proposing work in a perennial stream must apply for a 310 Permit through the local conservation district.

While the 310 Permit is administered by the county Conservation District, FWP's fisheries biologists review all 310 Permit applications and conduct site visits, just like they do for the next permit below (SPA 124 Permit).

Montana Stream Protection Act (SPA 124 Permit)

This permit is administered by the Fisheries Division of FWP. The SPA 124 Permit is essentially equivalent to the 310 Permit but only applies to public lands. The SPA 124 Permit is required when any agency of city, county, or state government proposes a project affecting the bed or banks of a stream. Federal agencies also comply with this law via a Memorandum of Understanding with FWP.

The 310 Permit and the SPA 124 Permit are the "baseline" permits that are needed for any manipulation that may affect a waterway. There are almost no beaver restoration projects that will not require one of these permits. Remember, the 310 Permit applies to private lands and is acquired through the county Conservation District and the SPA 124 Permit applies to public lands and is acquired through FWP.

Federal Clean water Act (404 Permit)

This permit is administered by the Army Corps of Engineers. The 404 Permit is required for anyone proposing an activity that will result in discharge or placement of dredged or fill material into Waters of the United States. Waters of the United States include the area below the ordinary high-water mark of river and stream channels, lakes or ponds connected to the tributary system, and wetlands adjacent to these waters. In this case, "fill material" includes, but is not limited to: rock, sand, soil, clay, plastics, timber, mats, construction debris, wood chips, overburden from mining or other excavation activities, and materials used to create any structure or infrastructure. Therefore, this permit is required for all LTPBR-related activities such as constructing BDAs and PALSs, as well as any more heavy-handed stream restoration that may involve channel plugs, floodplain regrading, or placement of large wood in the channel.

The 404 Permit can represent a heavy burden to practitioners as it requires detailed wetland delineations before and after the project. This will often require contracting or long days in the field for practitioners, and therefore may affect project timelines significantly.

Nationwide Permit 27 (NWP-27) – Aquatic Habitat Restoration, Enhancement, and Establishment Activities

This permit is also administered by the Army Corps of Engineers and is meant to streamline projects that can prove a net increase in aquatic resource functions and services, and the restoration "results in habitat that resembles an ecological reference". Nationwide Permits (NWPs) are a way to receive Clean Water Act 404 authorization for impacting wetlands and streams for specific activities, given that those activities only cause minimal adverse environmental effects.

Most BDA projects and other forms of LTPBR will go through this permitting process with the Army Corps of Engineers rather than the 404 Permit. Practitioners should consult with the Army Corps of Engineers to determine which route to take once their project proposal has been developed.

Short-Term Water Quality Standard for Turbidity (318 Authorization)

This permit is administered by the Montana Department of Environmental Quality (DEQ). The 318 Authorization is required for anyone proposing work in and around a stream that may cause temporary violations of the state surface water quality standards for turbidity. In other words, if your beaver restoration project is going to cause an excess amount of sediment in the stream for any period of time, this permit will be needed. Most LTPBR and more heavy-handed restoration projects will require this permit even if structures are built by hand.

Fortunately, the 318 Authorization may be waived by FWP as part of their review of the project for the 310 Permit or SPA 124 permit. Alternatively, FWP may be able to issue the 318 Authorization on behalf of the DEQ.

Streamside Management Zone Law (SMZ Law)

This law is enforced by the DNRC. The law only applies to timber harvest for commercial purposes on private, state, or federal lands. There are no permits involved, the law simply states that timber harvest cannot take place within 50 feet of any stream, lake, or other body of water. However, the DNRC can approve exceptions if there is a reasonable need to conduct such activities. In beaver restoration, this law would come into play if practitioners were seeking to harvest conifers from around the stream channel for construction materials for BDAs and PALSs, to open up the canopy to encourage shrub growth along the stream, or to provide large wood to the stream channel.

Water Rights

Water rights is a broad and complex topic in the state of Montana, and therefore we will not try to cover everything about water rights in this document. Practitioners should consult an expert on water rights if a proposed project has the potential to impact such resources. However, establishing beaver colonies in a stream that is within their historical range does not trigger water rights issues because beavers are considered a natural part of stream systems in Montana. However, there is a chance that some of the techniques outlined in this document aimed at encouraging natural colonization could trigger water rights issues. For example, the construction of BDAs or channel plugs that impound water could affect water rights.

According to the DNRC, as long as BDAs do not use control gates, culverts, headgates, ditches or pipelines, they typically do not require a water right. Human-made projects that pool or pond more than 0.1 acre-foot of water per structure or series of structures in close proximity may require a water right and a project manager should consult with their regional DNRC office.

Montana Environmental Policy Act (MEPA)

MEPA is a law requiring public review of any action taken by state government that has the potential to significantly affect the human environment. The "human environment" includes a wide range of things such as impacts to soils, vegetation, water, air quality, recreation, fish and wildlife, local economies, and social structures.

The MEPA process involves the development of public documents known as Environmental Assessments (EA) for Environmental Impact Statements (EIS). These documents outline the proposed project and detail all potential negative and positive effects of the project on the human environment. These documents are drafted by the state agency seeking to take an action and then released for public review and comment. The comments are then reviewed, the EA or EIS is adjusted based on feedback from the public, and then a Record of Decision (ROD) is released to the public. The ROD recommends whether or not the project should move forward based on the analysis and subsequent public comments.

For beaver restoration projects, MEPA review will be required for any project that will take up FWP staff time or resources, or that will occur on state-owned properties. Beaver translocations, LTPBR and other stream restoration projects on state lands, and many changes to land management on state lands will all require MEPA review, and most will also be paired with Fish and Wildlife Commission review and approval.

It is important to note that similar projects on federal lands may require National Environmental Policy Act (NEPA) review and approval, though there are more exceptions and exclusions included in NEPA for these types of practices as compared to MEPA. The exception is any project seeking to transplant beavers to federal lands. Because these projects involve capturing and moving animals that are under the authority of the State of Montana, MEPA review is still required for transplantation projects.

Project Planning Checklist

- ☐ The type of degradation, source of degradation, and whether that degradation is completed or ongoing, have been clearly identified and articulated in the project proposal.
- ☐ Site-specific limiting factors to stream and riparian habitat health have been identified and articulated in the project proposal.
- ☐ Specific goals of the project have been considered and outlined and process pathways to achieve project goals have been included as part of the project proposal.
- ☐ Other potential options for restoration (i.e., other than beaver restoration) have been considered.
- ☐ The project area has been evaluated using the BRAT to determine expected level and spatial extent of damming activity in the project area.
- ☐ An assessment of existing beaver colonies in the project drainage has been completed. At a minimum, this should include an aerial imagery survey of existing beaver dams/colonies within approximately 6 stream-miles of the project area for the most recent year where reliable imagery is available.
- ☐ An assessment of geomorphic and hydrologic considerations has been completed, and a geomorphologist and hydrologist have been consulted.
- ☐ Potential conflict hotspots have been identified and conflict mitigation measures (both lethal and non-lethal) have been incorporated into the project plan and timeline.
- ☐ Specific people have been identified and contacted that will do any necessary conflict mitigation work.
- ☐ Surrounding landowners in the drainage have been contacted and consulted about the project.
- ☐ The project area has been well defined and potential areas for beavers to expand, both through colony boundary expansion and through dispersal and new colony establishment, have been identified.
- ☐ A timeline for the project has been developed with all project partners and conflict mitigation specialists. This includes timelines not only for direct work on the stream and riparian areas, but also for maintenance and monitoring of the site into the future.
- ☐ Permits for the various activities that will take place as part of a restoration project are identified and a plan/timeline for acquiring permits has been developed.

Fish and Wildlife Considerations

Beavers are ecosystem engineers and a keystone species, so their influence can spread beyond the beavers themselves and affect hundreds of other species in an area. Therefore, beaver restoration projects must carefully consider the potential positive and negative effects of beavers and beaver activity to fish and wildlife species.

Potential impacts to wildlife, fish, and other aquatic life are important from both an ethical and regulatory standpoint. Considering how an action may affect an ecosystem is a necessary part of restoration and a critical component of natural resource stewardship. Practitioners also must consider potential effects to the stream, streambanks, riparian habitats, vegetation, and aquatic life as part of permitting processes (see Project Planning, Permitting, for more detail, and consult DNRC 2020). Permitting requires articulation of how the project will not result in negative impacts, or if negative impacts are anticipated, how those impacts can be mitigated.

Fisheries and Aquatic Considerations

In most locations, beaver restoration can be highly beneficial for aquatic species. Whether it is natural beaver activity or beaver mimicry, beaver impoundments can result in increased water storage, improved late season flow, floodplain reconnection, increases in available side channel and backwater habitats, increases in overwinter habitat, and increased habitat complexity (see Introduction for a discussion on beaver benefits). In certain situations, however, consequences of beaver restoration can be counter to aquatic management goals.

Even though beavers and fish evolved together historically, current human-modified landscapes combined with declining or threatened aquatic species can lead to negative outcomes. **The effects of beaver impoundments on aquatics are highly site-specific and consultation with local fisheries biologists is critical to understanding the benefits and risks.** The factors involved in assessing the potential outcomes of beaver restoration are dependent on species present; those specific discussions are below, under *Species Considerations*.

Hydrology and physical habitat

The amount and duration of water in a stream directly affects aquatic species through stream temperature, water quality, habitat availability, and connectivity. Increased water quantity is associated with stream temperature reduction, higher oxygen content, increased opportunities for fish movement, and access to additional habitat features through increased wetted widths and greater channel complexity. Streams that are wetted for longer periods of time typically are desirable for growth and survival, especially when it comes to gravel-bottom spawning areas (i.e., “redds”) that require water during egg incubation and hatching. However, in prairie systems of Montana, establishment of perennial flows can be a concern as this may lead to invasion by non-native piscivorous fishes and/or impacts to amphibian life cycles.

If beaver restoration is initiated in a hydrologic gaining reach, there may be a benefit to streamflow and water storage. If beaver restoration is initiated in a hydrologic losing reach, water may move from the stream into groundwater and not return to the stream until a downstream location, leading to negative impacts to aquatic connectivity even if there is an overall water storage benefit. The effects of beaver restoration on stream temperature are not well understood and may depend on many factors, including the amount and kinds of riparian vegetation present, interactions with hyporheic flow exchanges, and the character of beaver impoundments (Weber et al. 2017; Majerova et al. 2015, 2020, Munir and Westbrook 2021, Roper 2022).

Impoundments lead to sediment deposition, which can affect available spawning substrate. In many systems, fine sediments collecting behind beaver dams can bury gravels, which are required for salmonid species to spawn (Collen and Gibson 2001). Alternatively, deposition of sediment behind beaver dams can reduce sediment loading downstream, ultimately supporting additional suitable spawning sites. The likelihood of both scenarios is affected by the frequency of dam breaching, which directly affects sediment storage and transport. It is critical to understand the geomorphic and physical characteristics of the stream, the possible outcomes, and the limiting factors of the fish populations when considering sediment and habitat availability (Roper 2022). Many cold-water tributaries that are candidates for beaver restoration are critical spawning areas for salmonids and therefore require thorough scrutiny of proposed restoration projects.

Impoundments also create pool habitats, which are beneficial for fish populations that need refuge during low flow periods or over winter (Jakober et al. 1998, Roper 2022). In contrast, other populations may have a greater benefit from faster moving water and riffles or to maximize spawning areas. Determining the overall advantage or disadvantage of beaver restoration relates to the species present, limiting factors of the fishery, and what will result in a more robust population of desirable species.

Impoundments can lead to overbank flooding, which may create side channel and backwater microhabitats for young fish to grow. Lateral habitats created along the shallow littoral areas of beaver ponds are typically beneficial to juvenile fish growth and survival (Wathen et al. 2019). The increased habitat complexity can provide additional areas to forage, rest, evade predators, and avoid high streamflow (Bouwes et al. 2016). If juvenile recruitment and growth is a limiting factor in the fishery, beaver restoration could be highly beneficial. The needs of aquatic species can differ by stream segment or location so the pros and cons must be determined on a case-by-case basis.

In many areas of western and central Montana, vegetation harvest by beavers can be a significant source of woody material input into stream systems, which is an important component of fish habitat (Roper 2022). Large wood in streams can provide resting and overhead cover for fish and is important in creating side channels and other forms of channel complexity, forcing bed scour, and providing food for aquatic invertebrates. In some areas of Montana, beaver foraging and dam/lodge building activities are the primary avenue for wood entering the stream. In stream systems that are lacking structure from woody inputs, beaver activity may be highly beneficial to fish, especially if there are adequate sources of large wood such as mature cottonwood and aspen trees. In areas without a consistent supply of large wood near the stream channel, beavers can create and maintain pools using smaller diameter wood materials (i.e., < 1” diameter). Beavers therefore have the unique ability to create critical aquatic habitats in streams that do not have the capacity to do so without beaver damming activity (Roper 2022).

Fish passage

Habitat connectivity is critical for long-term fish population sustainability. Movement and migration are important for locating new habitats for food, reproduction, shelter, or to escape extreme temperatures or streamflow. Whether it is a native mussel that must be transported by a fish, a bull trout that is dependent on long migrations, a resident cutthroat trout colonizing new habitat, or a small-bodied fish with limited swimming and jumping abilities, fish passage must be considered on a site-specific level. Some species require movement in the spring when water is typically higher and beaver dams are less likely to impede movement; others may move in the fall when streamflow is typically lower and beaver dams are at their most robust state.

Fish species have different abilities to swim and leap over barriers, and these abilities also change with factors like permeability, impoundment height and plunge pool depth, streamflow, and body size. Larger fish can typically leap over structures that small fish cannot. Small-bodied fish are likely most successful passing through the gaps or interstitial spaces within a beaver impoundment. In many cases, fish passage may not be a concern. In some cases, notching of beaver impoundments may be recommended, or alternative structures like post-assisted log structures may be used, which do not span the entire channel (Shahverdian et al. 2019). A management strategy may be to breach dams in low water years or in some cases, when spawning migration is critical and limited, beaver or beaver dam removal may be warranted.

Fish passage in relation to beaver dams is also highly dependent on the geomorphic state of the stream channel. Beaver dams on streams that are better connected to their floodplains often force overbank flow, which can provide alternative flow pathways that fish can use to pass the dams (Cutting et al. 2018). In incised streams or streams that are naturally laterally confined, beaver dams may not cause overbank flow and can therefore represent partial or full movement barriers (Cutting et al. 2018). Recovery of floodplain connection is often an explicit goal of beaver restoration. Therefore, beaver dams in a degraded stream may be movement barriers when the project is started but can become more passable as the stream recovers. Consideration of impacts to fish should account for these changes over time. Practitioners should consider if the fish population can handle shorter term movement barriers in the context of a long-term goal of re-establishing floodplain connection.

Similarly, intact beaver dams change over time as sediment accumulates behind the dams and beavers work on repairing and/or expanding the dams. A newly established beaver dam may have plenty of interstitial spaces for small-bodied fish to pass through the dam, but as sediment fills in those interstitial spaces passage for those same fish may be significantly reduced or cut off completely. Long-term dams that have accumulated large amounts of sediment can also fail from the bottom, whereby a hole is formed at the base of the dam that allows the upstream pond to partially or fully drain without major damage to the channel-spanning aspect of the dam. In these situations, over-dam or over-bank flow that fish may have used to pass the dam may be reduced or cut off, forming a potential movement barrier.

When it comes to fish passage, there is potential in almost every system for movement barrier beaver dams to form. However, beaver damming activity is dynamic, and a movement barrier dam is likely not going to stay a movement barrier for very long. Therefore, considerations around fish passage and beaver dams need to focus on whether the fish population of interest can survive occasional interruptions of their movement, or if the fish population is so threatened that potential movement barriers cannot be tolerated even if they are temporary in nature.

Prairie Streams

When it comes to prairie streams, there is substantially less published research and on-the-ground projects from which to build a knowledge base around beaver ecology and effects on stream systems. Therefore, the potential positive and negative effects of beaver restoration in prairie streams are not well understood. Fortunately, there has been a recent increase in interest around beavers in prairie streams, and new research should be available within the next 5-10 years that will be helpful in better understanding beaver effects in these systems.

When beaver restoration is proposed in prairie streams, practitioners must be extra careful and consider some key questions for which there is little research or case studies to draw from. These same questions also highlight areas where additional research and detailed project monitoring and reporting are needed. These questions include:

- Is there evidence that beavers were in these types of streams historically?
- In what settings can beavers subsist without woody riparian vegetation and what does that mean for plant communities and their associated effects on stream form and function in and around beaver impoundments?
- How do beaver dams and associated impoundments affect passage for small-bodied fish?
- How is grazing managed in the restoration area and how will it affect restoration activities?
- Would conversion from lotic to lentic habitats favor nonnative northern pike, bass, or other species that may increase piscivory of native fish?
- Would conversion from ephemeral and intermittent stream flows to perennial flows affect timing of life history events for fish and amphibian species (e.g., emergence from diapause or initiation of reproduction), or allow invasion by nonnative species (Pilliod et al. 2018)?
- How might restoration affect geomorphology and water management in intermittent prairie streams which are commonly altered by high-density stock dam construction?
- Could dam breaching result in stream incision in highly erosive systems?

A well-designed evaluation and monitoring plan is essential when working on beaver restoration projects in prairie streams so that the outcomes of beaver restoration can be better understood in these systems. Partnership with universities for developing scientifically sound research projects is highly encouraged to work toward answering some of the questions outlined above.

Wildlife Considerations

While beavers can have negative consequences for fish and other aquatic resources in some situations, there are relatively few wildlife species in Montana that may be negatively impacted by beavers returning to areas of their historical range. In fact, one of the primary motivations for returning beavers to these areas is to improve habitat for a wide range of wildlife species (Figure 5). Potential effects on terrestrial wildlife are less strictly managed through permitting processes than for fisheries, and that is reflective of the fact that potential negative impacts of beaver restoration to terrestrial wildlife are much less common and of much less concern to regulatory agencies. Still, practitioners who wish to work on public lands or with FWP on projects must be able to articulate and understand potential effects on terrestrial wildlife, how the project may or may not affect them, and how any negative impacts can be mitigated.

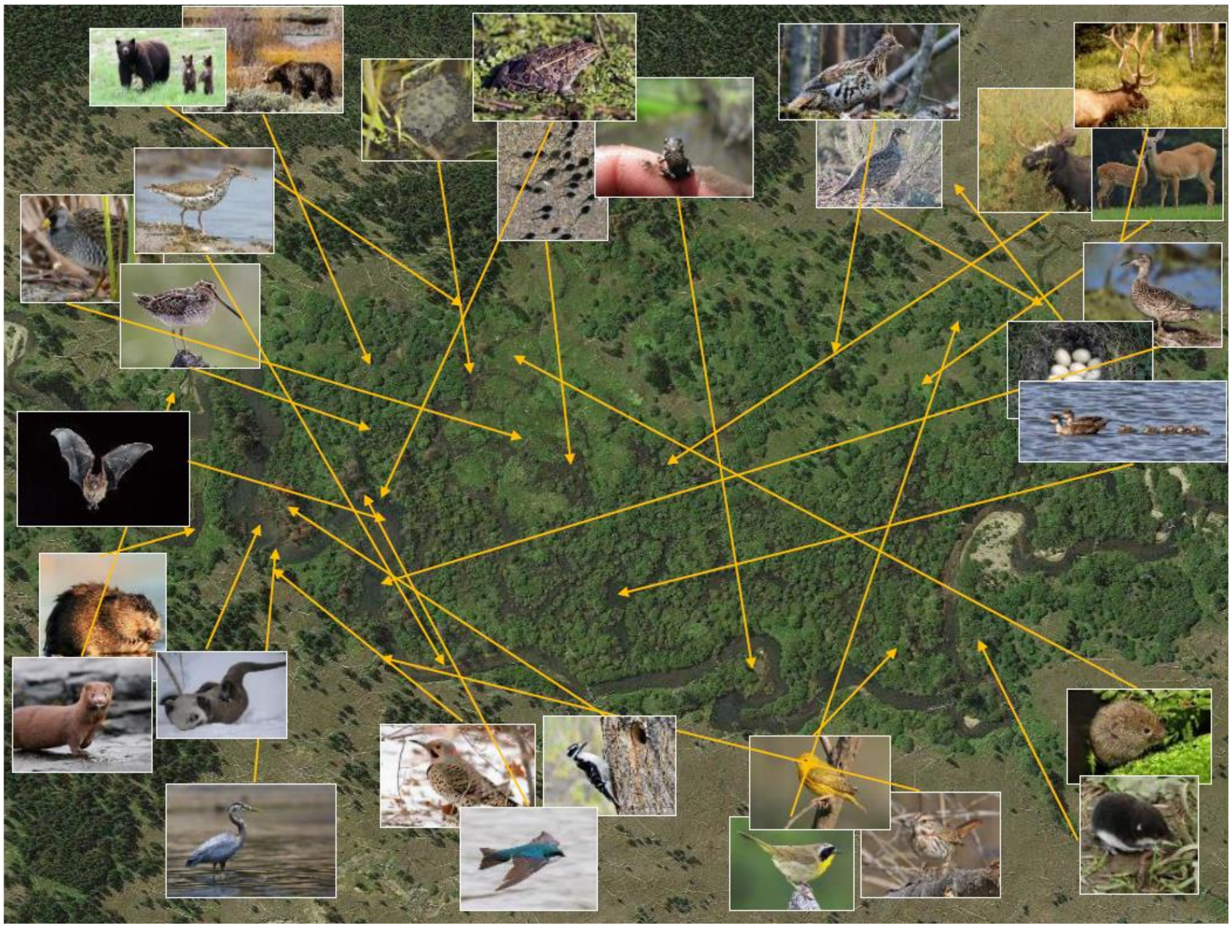


Figure 5. Beavers are considered a keystone species, meaning their presence allows certain plant and animals species to exist in an area where they may not otherwise occur. The species and groups of species in this figure are those for which scientific evidence suggests beaver-modified habitats can have a substantial benefit to all or portions of their life cycle. Background photo supplied by Google Earth.

The positive effects of beaver activity to terrestrial wildlife are well-documented in the scientific literature and summarized in a variety of publications (Naiman et al. 1988, Rosell et al. 2005, Muller-Schwarze 2011, Pollock et al. 2017). Many beaver restoration projects in Montana are undertaken with the express goal of improving wildlife habitat for a large number of terrestrial species (Figure 5). This document is meant to help users navigate permitting and considerations to be made before implementing beaver restoration projects and therefore will focus on potential negative impacts to terrestrial wildlife that may affect the likelihood of a project moving forward.

Potential negative effects on terrestrial wildlife

Regarding beaver restoration, the potential negative effects on terrestrial wildlife are usually related to beavers being relocated to, or encouraged to settle in, habitats that are not yet ready for their presence. As discussed earlier in this document, there is a big and important difference between beavers being able to build a colony *at all* in an area, and beavers being able to build a long-term and self-sustaining colony that can bring about restoration benefits. In the former situation, beavers can leave the stream in worse shape than before they arrived, potentially negatively affecting streamside vegetation and the songbirds, small mammals, ungulates, and other species that rely on it. Therefore, the most reliable way to make sure a beaver restoration project will not negatively affect terrestrial wildlife is to take into consideration the breadth of spatial and temporal considerations outlined in the earlier sections of this document. These considerations ensure the project is occurring within the appropriate habitat and landscape context to result in successful stream, riparian, and floodplain recovery.

If a beaver restoration project is occurring in the right area and under the right conditions, there are limited ways in which beaver activity in areas of their historical range can negatively affect terrestrial wildlife. Potential negative effects can arise when:

- There are sensitive or rare species present in the project area.
- Beaver activity may interrupt species during sensitive times of year (e.g., breeding season).
- Beaver activity disturbs rare habitat types on which sensitive or rare species rely.

It is prudent to examine the list of Montana Species of Concern as well as species listed under the Endangered Species Act to determine if beaver restoration may negatively affect some portion of their life cycle or their habitats. In general, species that may be affected include:

- Species reliant on higher gradient, clear, highly oxygenated streams may be negatively affected depending on the valley context. Examples include the Idaho giant salamander (*Dicamptodon* aterrimus) and the harlequin duck (*Histrionicus histrionicus*).
- Species reliant on large-diameter cottonwood trees and old-growth stands may be negatively affected if substantial beaver harvest occurs. Although human disturbance is the root cause of most of the diminished or vulnerable cottonwood forests in the state, this reality does not change the fact that certain cottonwood galleries need enhanced protection. Examples include cuckoos (*Coccyzus* spp.) and several tree-roosting bat species.
- Possible interruption of movements across floodplains. If an easy stream-crossing is turned into a beaver colony, migratory species may be forced to look for another area to cross, potentially guiding them toward roads, houses, or other forms of human conflict. Examples include large and small carnivores that can come into conflict with humans like bears and raccoons.
- Although not considered wildlife, cattle and horses may be negatively affected by beaver activity through creation of mud pits that livestock can become stuck in or waste energy navigating through and/or loss or redirection of travel routes livestock use to navigate their range. However, this potential impact should be addressed as part of considerations around

neighboring landowners and permittees on public land and conflict issues related to a beaver restoration project.

We present these generalities to get users thinking about potential multi-species impacts that can come from beaver colonization of areas of their historical range. In the next section, we will look at specific species these general impacts may affect.

Species Considerations

Species of Concern

As of spring 2022, Montana has 128 species listed as state Species of Concern (SOC). For more detail on how and why certain SOC rankings are applied to a given species, visit the Montana Natural Heritage Program's website at mtnhp.org. As a supplement to this document, FWP and its partners have developed a database of Montana Species of Concern and the potential effects beaver restoration may have on those species (for now, available upon request; torrey.ritter@mt.gov).

In summary, out of 128 vertebrate SOC in Montana, 84 are potentially affected by beaver activity. Of those, in 52 species beavers have mostly positive effects, 22 have a mix of positive and negative effects depending on the context, 10 have unknown effects because we know so little about the species, and 0 have only potential negative effects. Key groups of species that greatly benefit from beaver activity include amphibians, songbirds, bats, and small mammals. Not surprisingly, fish SOC are the most common in the "mix of positive and negative effects depending on the context" category. There are also 85 invertebrate SOC in the state, but they have not yet been evaluated in terms of potential effects of beaver activity.

Cutthroat Trout

Montana's state fish, the cutthroat trout, includes both the Westslope cutthroat trout (*Onchorynchus clarkii lewisi*) and Yellowstone cutthroat trout (*Onchorynchus clarkii bouvieri)*. Regarding beaver restoration, the main considerations for cutthroat trout are fish passage and species interactions. Because cutthroat trout are spring spawners, beaver dams may be less of a problem, as they can usually pass flooded dams during high water in the spring.

Impoundments typically shift habitat from lotic to lentic, altering stream habitat characteristics. This shift can result in a competitive advantage of some species over others, which may be positive or negative and must be part of the decision-making process. Brook trout is a species that has flexible life history characteristics, allowing them to successfully inhabit warmer, low-elevation sites as well as colder, high-elevation sites (Kennedy et al. 2003). They also may be better adapted to pond conditions than many other salmonid species (Collen and Gibson 2001). Shepard (2004) found that brook trout invasion and displacement of Westslope cutthroat trout in Montana streams was influenced by water temperature, debris and pool frequencies, erosion and deposition of fine sediments on the stream bed, or a combination of factors. Although beaver restoration was not specifically studied, the effects of beaver impoundments align with all these factors and some FWP biologists have observed this displacement in the field. Practitioners must use caution when planning beaver restoration in waters that contain both brook trout and cutthroat trout.

Displacement of native species like Westslope cutthroat trout can have negative consequences on other aquatic species like the western pearlshell mussel (*Margaritifera falcata*), which is a Species of Concern in Montana and relies on the movement of Westslope cutthroat trout, its host fish, for distribution.

Arctic Grayling

Arctic grayling (*Thymallus arcticus*) is a Montana SOC and is designated federally sensitive due to its very limited or rapidly declining population, range, and habitat. Because of the low abundance of Arctic grayling, it is particularly important to ensure restoration activities are not harmful. These fish may not be able to tolerate fragmentation from partial or full barriers that even natural impoundments can create. Similarly, chronic dewatering of streams is a major issue in Arctic grayling conservation, and low water levels have been demonstrated to have negative effects on grayling spawning, especially when low water interacts with beaver dams (Cutting et al. 2018). Therefore, any beaver restoration project undertaken or proposed within the range of Arctic grayling must carefully consider things like fish passage, effects on water temperature, and if the project is to be implemented in gaining or losing stream reaches and how that may affect instream flow.

Cutting et al. (2018) studied passage of Arctic grayling at beaver dams in Montana and found that upstream passage of fish was strongly influenced by breached status (if the dam was missing sections of material), hydrologic characteristics, and temperature. In this study, passage was influenced more by low water than by jump height or body size. The researchers found an average passage probability of Arctic grayling over beaver dams of 88%, indicating that, in general, Arctic grayling are capable of passing beaver dams. However, passage fell below 50% for some individual dams and to less than 20% in situations where many dams were present in a series. In the year of study with low flows, zero Arctic grayling reached their historical spawning grounds. Though this cannot be entirely attributed to beaver dams, it is likely they played a significant role.

The results of Cutting et al. (2018) demonstrate that Arctic grayling passage at beaver dams is highly dependent on the form of dams and their position within the channel, as well as the characteristics of dam complexes, and that these factors interact considerably with water levels. However, it is clearly possible to get to a level of passage that may or may not be suitable to Montana's small populations of Arctic grayling, especially during low flows. Even if passable, dams could be energetically costly and delay arrival to spawning areas. If beaver restoration is planned for an area within the range of Arctic grayling, practitioners must consult with local fisheries biologists and be prepared to mitigate any potential negative impacts or abandon a project entirely if negative effects are documented.

Threatened and Endangered Species

The Endangered Species Act (ESA) falls under the jurisdiction of the U.S. Fish and Wildlife Service (USFWS) and seeks to "provide a framework to conserve and protect endangered and threatened species and their habitat" (USFWS 1973). The legislation provides federal government oversight for recovery of species listed as "threatened" or "endangered". As such, when a listed species occurs in Montana, anything that may affect that species receives intense scrutiny both from FWP and the USFWS, and both agencies share management responsibility.

The ESA protects the listed organisms themselves and their "critical habitat", so any project or action that may affect the species must consider both direct and indirect impacts. While FWP has some flexibility in management actions that affect SOC, ESA-listed species and their habitats are much more complicated to work on. Those complications will necessarily extend to any beaver-related restoration projects.

In Montana, four species are classified as “Threatened” under the Endangered Species Act: bull trout (*Salvelinus confluentus*), grizzly bear (*Ursus arctos horribilis*), Canada lynx (*Lynx canadensis Kerr*), and piping plover (*Charadrius melodus*). Any beaver restoration that may occur in streams containing bull trout or within the range of Canada lynx or grizzly bear will need to involve coordination with FWP fisheries and wildlife biologists and will likely also require consultation with USFWS. See the sections below for additional detail.

Bull Trout

Bull trout is a federally threatened species and a SOC in Montana. Populations of this species have declined substantially, and they are now found in a fraction of their historical range. Bull trout are sensitive to sediment, particularly as it relates to spawning substrate. They are also a highly migratory species, traveling long distances to spawn in the summer and fall. Beaver dams can become barriers to fall spawners, as the dams are generally in their most robust state and stream flows are low (Grasse and Putnam 1955, Munther 1983, Dupont et al. 2007). This is particularly true for stream-resident life forms where adults are typically smaller, which requires the ability to move along stream reaches during low water periods for staging, spawning, overwintering, and access to thermal refugia. In some cases, fish managers may remove or notch beaver impoundments to ensure passage to critical spawning areas. Beaver restoration projects in bull trout waters require frequent and careful consultation with the local fisheries biologist.

Because of the sensitivity of bull trout populations in the state, their propensity for undertaking important movements during times of the year when beaver dams are most likely to form movement barriers, and the general lack of knowledge around impacts of beaver dams on bull trout, beaver restoration in important spawning streams or stream sections for bull trout may not be approved. In fact, beaver and/or beaver dam removal in important bull trout spawning streams may be necessary to maintain local spawning populations of bull trout.

Canada Lynx and Grizzly Bear

Beaver activity generally affects both the Canada lynx and grizzly bear in the same way; beaver activity can broaden and enhance riparian areas along streams, potentially improving important movement corridors for these species as they navigate an increasingly humanized world. Therefore, impacts to grizzly bear and lynx habitat can be considered almost entirely positive, and little needs to be done to account for effects on these species except in specific areas and situations. For example, if beaver activity results in flooding of a valley bottom that may redirect traveling bears or lynx into areas of potential conflict or mortality (e.g., roads or residential areas), then those potential impacts would need to be outlined and potentially mitigated as part of the EA/EIS process for a beaver restoration project. However, it is unlikely federal oversight of such projects would be needed as they relate to grizzly bears and lynx because the effects are minor, difficult to prove as a significant threat (reasoning is mostly theoretical), and likely mostly positive.

Piping Plover

Beaver activity, even on a large scale, is unlikely to have major negative impacts to the piping plover, and so there is no need for practitioners to be concerned about this species when designing or evaluating beaver restoration projects.

In Montana, four species are classified as “Endangered” under the Endangered Species Act: the black-footed ferret (*Mustela nigripes*), pallid sturgeon (*Scaphirhynchus albus*), white sturgeon (*Acipenser transmontanus*), and whooping crane (*Grus americana*). Generally, beaver activity will have negligible or slightly positive effects on the black-footed ferret, least tern, pallid sturgeon, and white sturgeon, and so there is no need for practitioners to be concerned about these species when designing or evaluating beaver restoration projects. Beavers may have a positive effect on whooping cranes as they can create, expand, and maintain wetland habitats the cranes use as stopover areas, but overall whooping cranes are very rare in Montana, and it is highly unlikely beaver restoration projects will end up impacting this species to the point that practitioners need to account for potential whooping crane impacts of specific projects.

Western toad at the edge of a beaver pond along the Bitterroot River

Fish and Wildlife Considerations Checklist

☐ The Montana Natural Heritage Program has been consulted, and a list of observed and potential species that may use the habitats within the restoration area has been produced as part of the project proposal. The MTNHP species list can be used to address the next five checklist items.

☐ Aquatic species listed as Threatened or Endangered under the Endangered Species Act or listed as state Species of Concern (SOC) that may use the project area have been identified, and potential impacts to those species assessed.

☐ Terrestrial species listed as Threatened or Endangered under the Endangered Species Act or listed as state SOC that may use the project area have been identified, and potential impacts to those species assessed.

☐ Consultation with FWP staff has occurred relative to any aquatic or terrestrial Threatened or Endangered species or SOC that may be negatively impacted by the project, and potential mitigation measures and/or monitoring plan have been developed.
  - Consultation with the FWP fisheries biologist in the area has been completed.
  - Consultation with the FWP game and nongame wildlife biologist in the area has been completed.

☐ Potential fish spawning substrate issues have been identified and discussed with the area fisheries biologist.
  - Fish species present in the stream and potential important spawning areas that overlap with the beaver restoration project area have been identified.
  - Potential mitigations have been identified and discussed with the area fisheries biologist.

☐ Potential fish community composition issues have been identified and discussed with the area fisheries biologist.
  - Fish species present in the stream and the potential for conversion to beaver-modified habitats favoring non-native fish have been identified.
  - Potential mitigations have been identified and discussed with the area fisheries biologist.

☐ Potential fish passage issues have been identified and discussed with the area fisheries biologist.
  - Fish species present in the stream and likely spawning periods have been identified.
  - The level of incision and subsequent potential for alternate flow pathways around beaver dams or beaver mimicry structures that spawning fish can use have been assessed.
  - Potential mitigations have been identified and discussed with the area fisheries biologist.

Maintenance and Monitoring

As beaver restoration techniques rapidly gain popularity and expand in scope, it is becoming clear that the most successful projects incorporate maintenance of restoration actions to make sure self-sustaining restoration goals are achieved (Nash et al. 2021). Similarly, robust monitoring of the outcomes of these projects has been lacking (Pilliod et al. 2018), leading to difficulty determining the level of project success or failure. The lack of follow-up on projects leads to reduced project success if a project does not have the needed repairs over time or there is not an assessment of how the restoration worked, further leading to an overall misunderstanding of when and where these types of projects are appropriate. This diminishes projects' value to other restoration practitioners and the beaver restoration field as a whole. Therefore, we emphasize that post-project maintenance and monitoring must be incorporated into a beaver restoration project from the design stages, including adequate funding, personnel hours, and established data-collection techniques. Preparation ensures tangible measures of success or failure are available to practitioners looking to learn from others' work.

Maintenance

With many of the beaver restoration techniques, maintenance beyond the initial construction or implementation of the project will be critical to overall project success. As a simple example, if riparian fencing is installed to help recover an over-grazed riparian area, the fence will need to be maintained for many years to make sure the project is successful. Adaptive management is especially useful in beaver restoration scenarios because so much of the restoration work is delegated to the stream itself and/or beavers that colonize the restoration area. This introduces enough uncertainty relative to other forms of stream restoration that practitioners should be prepared to adjust plans and actions annually based on the response of the stream channel and the response of any beavers that may be involved in the project.

Beaver conflict resolution projects often require some maintenance to remove accumulated debris on fences and pond levelers and to keep up with beavers' attempts to thwart the structures. Fences around trees may need to be adjusted or repaired as the effects of vegetation growth, high water pulses, and beavers trying to get around the fences can cause issues. For in-stream structures, high water pulses and beaver activity can undermine the intended effects of the structures. Adjustments may need to be made or additional structures or components of structures installed to make sure they remain in working condition (see Appendix A - Conflict Management). There are almost no non-lethal conflict resolution solutions that are installed and work long-term without maintenance. If installed on private land, practitioners need to be clear with landowners about maintenance needs and techniques, and who is responsible for that maintenance. If installed on public lands, long-term maintenance needs to be planned for and incorporated into the workload of employees that cover those areas.

Adaptive management may be needed on a beaver mimicry project, to include post-project monitoring of vegetation recovery, structure resilience, sediment dynamics, and beaver activity. Based on that monitoring, mimicry structures may need repair and/or resizing, or more structures may need to be added to accommodate changes to the stream channel or the distribution of beaver activity. There is a preponderance of one-time beaver mimicry treatments implemented throughout the western U.S., and although these can be effective in small headwater streams without much degradation, they are rarely effective in larger streams or heavily incised streams. In almost every case, beaver mimicry projects should be planned for multiple years and multiple treatments as practitioners observe how the stream, and any beavers that may be present, react to the structures (see Project Planning).

For projects that encourage natural colonization of a site by beavers, beaver activity surveys need to be completed annually to document if and when beavers move into the area. If beavers move in, surveys can help document which, if any, structures such as BDAs, human-built lodges, or existing beaver infrastructure were repaired and used by the beavers. This will be important information for planning future projects. If beavers do not move in, practitioners may want to improve starter infrastructure (more or bigger BDAs and human-built lodges), undertake additional restoration actions to make the habitat more attractive to dispersers, or they may decide to seek permission to transplant beavers into the area.

In the case of transplanted beavers, BDAs may be needed to support the colony or colonies as they expand. Beaver-built dams may need to be structurally reinforced to survive runoff pulses, especially in incised streams. Additional beavers may need to be moved to the area if the initial stock is killed by predators or disease, or simply move on from the release site. In almost every successful beaver transplant project, multiple releases at a site were necessary to establish self-sustaining beaver populations (McKinstry and Anderson 2002, Pollock et al. 2017, Brick and Woodruff 2019). If transplanted beavers leave the release site and settle on nearby lands where they are not tolerated, then a form of maintenance for the project will be to help those landowners deal with those beavers, including lethal removal if needed.

Monitoring

Post-project monitoring can come in many different forms but should be specifically tailored toward the goals of the project identified in the planning stages (see Project Planning). If beaver colonization is an explicit goal of the project, then beaver activity surveys should be incorporated into the monitoring plan to directly measure if the project resulted in an expansion or shift in beaver activity in the area. There should also be monitoring of habitat and/or geomorphic goals, such as expansion of desirable riparian vegetation (e.g., sedges, bullrushes) vs. non-desirable (e.g., non-native graminoids) or introduction of large wood to the channel. Funding and staff are almost always limited, and therefore practitioners should identify a few key monitoring objectives that are achievable, speak specifically to the project's goals, and are mediated by available resources. Engaging with partners, such as local watershed groups or universities, for monitoring can be an effective way to gather key measurements to assess project success while building understanding and acceptance of beaver restoration benefits on the landscape.

Project success can be defined in many ways and will always be project specific. There may be certain aspects of the project that are a success and others that are a failure, and project failure does not mean that post-project monitoring should stop. Monitoring can lead to important insights that can inform future projects undertaken by other agencies or individuals. Always report on project successes and failures and follow through with monitoring plans regardless of the restoration outcome. This will lead to a better understanding of beaver restoration projects across the landscape and a more connected community of practitioners undertaking this kind of work (Pilliod et al. 2018).

Monitoring of beaver conflict resolution projects can be relatively simple because a process-based restoration outcome is usually not an explicit goal of these types of projects. Monitoring should include regular visits to the project area on at least a bi-annual basis to determine if the conflict mitigation technique used is still functioning as intended. Annually, there are three key times to check on conflict mitigation structures:

1) Right before runoff to make sure the fencing or structures are clear of debris and haven't been damaged by ice formation and movement over winter.

2) After runoff has subsided to check for debris build-up and flood damage from high waters.

3) Right before winter as this is just after beavers' busiest time of year for dam, lodge, and cache construction, when beavers will likely spend the most time and energy trying to thwart conflict mitigation fencing or structures.

Monitoring of conflict mitigation projects may mean physically visiting the sites or calling landowners where projects have taken place and asking about issues or concerns. It is worthwhile to track the success of beaver conflict mitigation structures via metrics such as the amount of time and money spent to maintain them and the ways in which beavers have figured out how to outsmart the structures. This information is valuable for providing realistic expectations for future projects and to help advance the field of non-lethal beaver conflict mitigation generally. If lethal removal or transplantation was the method used to deal with the conflict, it is important to track re-colonization by beavers in the area as frequent re-colonization may indicate a need to try other techniques if appropriate for the situation.

Beyond conflict-resolution projects, the other four forms of beaver restoration necessarily are tied to expected stream and riparian restoration outcomes. While project goals like increasing water storage, initiating natural processes, or moderating high-water events can be achieved through restoration of beaver-modified systems, they are relatively vague objectives and therefore difficult to measure without substantial funding and person-power. Therefore, we recommend practitioners focus on monitoring techniques that seek to assess the broader goals of beaver restoration. Those goals are to reintroduce natural disturbance regimes that push the stream toward recovery of riparian plant communities through expanding the riparian zone and enhancing connectivity between the stream channel and the floodplain.

One of the most efficient ways to monitor difficult-to-measure changes to hydrology and geomorphology brought about by beaver activity is through assessments of changes in the plant community. A higher water table, sediment deposition, channel widening and inset floodplain formation, expansion of the riparian zone, and enhanced floodplain connectivity will all manifest in changes to the vegetation community along the stream channel and in the floodplain. Therefore, fairly rapid and simple techniques for measuring vegetation change associated with restoration projects can be an effective way to speak to multiple project goals in one assessment. These assessments, combined with monitoring of beaver activity in and around the restoration area, can provide a thorough evaluation of the successes and failures of a beaver restoration project without dedicating practitioners to time and money-intensive data collection and analyses.

The sampling protocols developed by Winward (2000) are a good example of rapid monitoring protocols that can speak to multiple goals of beaver restoration projects by focusing on vegetation communities and changes to those communities over time. Importantly, the protocol is specifically designed to be applied to dynamic stream systems where banks, channels, and vegetation shift over relatively short periods of time. As the goal of most beaver restoration projects is to create a dynamic system out of a degraded, often stabilized system, these can be appropriate monitoring tools.

If beaver colonization or expansion is an explicit goal of the project, then practitioners need to include a plan for monitoring beaver activity at the restoration site and in the surrounding landscape. Beaver activity surveys can be done on-the-ground by walking along the stream channel, from the air in a helicopter or fixed-wing aircraft, remotely using drone imagery, or from a computer using publicly available aerial imagery such as the National Agriculture Imagery Program (NAIP) or Google Earth. Table 2 shows the pros and cons of each survey type and relevance to the various forms of beaver restoration. Surveys should be conducted the year of and the year after the restoration actions take place, then again at least every other year for the next 5-10 years to determine if beavers have expanded into the area and reached a self-sustaining state. This also highlights the need for pre-project assessments of beaver activity, as discussed in Project Planning, to assess if the restoration actions resulted in an expansion or shift of beaver activity.

Beaver dam surveys in the Spotted Dog Wildlife Management Area. Photo by Desiree Cozad.

Table 2. Overview of beaver activity survey techniques for monitoring beaver restoration sites.

Survey Type	Time to complete	Cost to complete	Level of detail	Timeliness	Pros	Cons
On-the-ground	High	Moderate	High	High	Greatest amount of detail as clippings, castor mounds, caches, and lodges/dens can be easily identified. Subtle activity can be identified (e.g., bank dens, clippings, starter dams, building upon BDAs). Provides up-to-date information.	Takes a lot of time and energy. Can be dangerous in moose or grizzly bear country. May not need that level of detail to achieve monitoring needs.
Aircraft	Moderate	High	Moderate	High	Survey large areas in short amount of time. Provides up-to-date information. Can identify lodges and caches.	Expensive. Will only be able to identify large dams, lodges, and caches. Abandoned colonies may appear active. Use of BDAs by beavers may not be identifiable. Dangerous. Not accessible to non-agency people. May be overkill if restoration area is small.
Drone flights	Low	Moderate	Moderate	High	Survey large areas in short amount of time. Provides up-to-date information. Can identify lodges and caches.	Can be expensive. Will only be able to identify large dams, lodges, and caches. Abandoned colonies may appear active. Use of BDAs by beavers may not be identifiable.
Aerial imagery	Low	Low	Low	Moderate	No cost except staff time. Survey large areas in short amount of time. Can provide up-to-date information depending on project timing and imagery availability.	Beholden to available imagery dates so may not coincide with restoration actions. Use of BDAs by beavers may not be identifiable. Will only be able to reliably identify large dams, no starter activity. Not recommended except for long-term project monitoring at stream or drainage scale.

Timeline

The Project Planning section outlined the need for establishing a realistic and ecologically relevant timeline for the project to be implemented and to be considered “complete”. Post-project maintenance and monitoring should be incorporated into that timeline from the beginning, just as it should be incorporated into budgeting and personnel management. If a project requires post-implementation actions or adaptive management to meet the project goals, then the original timeline may change, or additional projects in the area may need to be proposed, planned, and implemented to supplement the original project. Proper restoration of stream processes in degraded systems often takes many years, even decades of work, and practitioners should be looking ahead within these time frames when deciding which projects to take on and in what kinds of stream systems. A single project that works to restore critical stream processes in a stream drainage is always preferable to a large number of small projects scattered across the landscape that address small sections of stream and are unlikely to result in large-scale and long-term results.

Starter beaver dam on Cache Creek in the Taylor Fork area

Maintenance and Monitoring Checklist

- ☐ Has an adaptive management plan been developed for maintenance of the restoration site and associated restoration actions?
- ☐ Does the maintenance plan incorporate both potential responses from the stream channel and floodplain as well as potential responses from any beavers that may be involved?
- ☐ Have resources (staff time, funding, etc.) to implement the maintenance plan been secured? If not, is there a solid plan to acquire these resources in a reasonable timeframe to complete the project?
- ☐ Has a monitoring plan been developed that identifies a reasonable set of monitoring objectives that are achievable?
- ☐ Does the monitoring plan incorporate both potential responses from the stream channel and floodplain as well as potential responses from any beavers that may be involved?
- ☐ Do the monitoring methods outlined in the monitoring plan speak specifically to the project's goals identified in the planning stages?
- ☐ Have resources (staff time, funding, etc.) to implement the monitoring plan been secured? If not, is there a solid plan to acquire these resources in a reasonable timeframe to monitor the project until it reaches a self-sustaining state (i.e., no more input needed from practitioners)?
- ☐ Is there adequate staff time and resources budgeted for detailed project reporting to partners and interested parties?

Additional Resources

For those interested in learning more about the various forms of beaver restoration, recommended resources are listed below. This is a good starting point, but practitioners should always contact and involve their local fish and wildlife biologists as early in the project as possible to streamline consideration of impacts and help develop a greater tolerance for beaver restoration projects on the landscape.

- **The Montana Beaver Working Group.** Led by the National Wildlife Federation, the Montana Beaver Working Group is made up of a wide range of people from various agencies and organizations with a common interest in expanding beaver-influenced habitats in areas of their historical range in Montana. The Group develops and maintains the Montana Beaver Action Plan, which "offers applied direction to advance work with beavers for resilient, healthy watersheds". The Plan outlines specific goals, strategies, and actions aimed at enhancing and expanding beaver-modified habitats on Montana's landscapes.

  -Contact Shelby Weigand, head of the Montana Beaver Working Group, at sweigand@nwf.org, or Torrey Ritter, FWP's representative at the Montana Beaver Working Group, at torrey.ritter@mt.gov.

- **The Beaver Restoration Guidebook.** Prepared by U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration, U.S. Forest Service, and the University of Saskatchewan. This is a comprehensive resource on beaver biology/ecology, restoration, conflict mitigation, and project planning. This is the go-to guide to start looking into all things beaver restoration.

  https://www.fws.gov/media/beaver-restoration-guidebook

- **The Low-tech Process-based Restoration of Riverscapes Manual.** Prepared by Wheaton et al. out of Utah State University. This is a comprehensive guide to the suite of techniques and strategies under the umbrella term "low-tech process-based restoration". This includes the use of beaver dam analogues and post-assisted log structures to restore stream systems, and the underlying hydrologic, geomorphic, and ecological principles that form the basis for these techniques.

  https://lowtechpbr.restoration.usu.edu/manual/

- **The Beaver Institute.** Nonprofit organization out of Massachusetts. Their mission is "To be a catalyst for advancing beaver management and watershed restoration by providing technical and financial assistance to public and private landowners experiencing beaver conflicts, supporting scientific research, training mitigation professionals, and increasing public appreciation of the beaver's critical role in creating climate resilient wetland ecosystems". The Beaver Institute website is the most comprehensive resource available for learning about non-lethal conflict management techniques for beavers. These resources can help people deal with tree cutting, plugging of culverts and other man-made pinch-points, and flooding of human infrastructure due to free-standing dams. The Beaver Institute also offers professional training courses on non-lethal conflict management.

  https://www.beaverinstitute.org/

- **Best Management Practices for Pond Levelers and Culvert Protection Systems.** Produced by The Beaver Coalition with input from some of the leaders in the realm of non-lethal beaver conflict resolution. This is the go-to guide for all the beaver conflict techniques other than tree fencing. It includes detailed diagrams, decision support tools, and special considerations to make these types of projects successful.

  https://projectbeaver.org/flowdevicebmps

- **Beavers Northwest.** Organization on the front lines of beaver conflict mitigation in the Pacific Northwest. This group is testing and introducing new techniques to address fish passage at culvert fences and pond levelers.

  http://www.beaversnw.org/

- **Beaver Review Papers.** A variety of paper have been published that provide broad overviews of the environmental and ecological effects of beavers.

  - Naiman, R. J., Johnston, C. A. and J. C. Kelley. 1988. Alteration of North American Streams by Beaver. Bioscience 38:11, 753-762.

  - Collen, P. and R. J. Gibson. 2000. The general ecology of beavers (*Castor* spp.), as related to their influence on stream ecosystems and riparian habitats, and the subsequent effects on fish–a review. Reviews in fish biology and fisheries 10:4, 439-461.

  - Rosell, F., Bozser, O., Collen, P., and H. Parker. 2005. Ecological impact of beavers *Castor fiber* and *Castor canadensis* and their ability to modify ecosystems. Mammal Review *35*:3-4, 248-276.

  - Kemp, P. S., Worthington, T. A., Langford, T. E., Tree, A. R., & M. J. Gaywood. 2012. Qualitative and quantitative effects of reintroduced beavers on stream fish. Fish and Fisheries 13:2, 158-181.

  - Larsen, A., Larsen, J. R., and S. N. Lane. 2021. Dam builders and their works: Beaver influences on the structure and function of river corridor hydrology, geomorphology, biogeochemistry and ecosystems. Earth-Science Reviews 218, 103623.

- **FWP's Living with Beavers Webpage.** Concise and useful background information on beaver biology/ecology and ecosystem benefits, with links to additional resources. Includes a link to FWP's "Living with Beavers" pamphlet on conflict mitigation techniques that have been used in Montana.

  https://fwp.mt.gov/conservation/living-with-wildlife/beavers

Beaver on the South Fork of the Madison River near West Yellowstone

Appendices: The Beaver Restoration Toolbox

Contents

Appendix A: Conflict Management **57**
Review this section if you are dealing with beavers causing damage to desired vegetation and/or human infrastructure.

Appendix B: Land Management Changes **71**
Review this section before looking to other beaver restoration strategies as land management often forms the basis for more direct beaver restoration work.

Appendix C: Beaver Mimicry **90**
Review this section if you believe the stream you are working on is not yet suitable for beavers to successfully colonize but may benefit from artificial damming activity.

Appendix D: Encouraging Natural Colonization **100**
Review this section if you are working in marginal or suboptimal habitats and if there are likely beavers within dispersal range of your project area.

Appendix E: Beaver Transplantation **112**
Review this section if your project area appears suitable for beavers but has very low numbers or is geographically isolated from source populations.

Each appendix provides more detail about the various beaver restoration tools, including best management practices and important considerations. At the end of each section, references provide additional sources of information about the topic.

The various beaver restoration tools and strategies can be used on their own or combined to help restore degraded stream and riparian systems. Across the western United States, projects that incorporate a variety of strategies are often the most successful (Bouwes et al. 2016, Pollock et al. 2017). Implementation of one beaver restoration tool can augment conditions and allow another to occur. For example, when a grazing system is adjusted to increase vegetation growth in a riparian area, practitioners can then install BDAs to encourage beavers to move into the area with sufficient vegetation (Bouwes et al. 2016).

Appendix A: Conflict Management

Conflict management refers to the variety of techniques that help address or offset the potential negative effects of beaver damming, tree-felling, and burrowing activities. These techniques include tree wrapping and fencing; pond levelers, culvert fences, and other devices meant to mitigate flooding damage; trapping and lethal removal; and transplantation.

Traditionally, the primary method to address beaver conflict issues in Montana was lethal removal through trapping. While this technique is still effective and necessary in certain situations, there are now a wide variety of non-lethal techniques and devices that allow people to live with beavers or encourage them to leave a site where they are causing problems. Lethal trapping should be considered a last resort, reserved for situations when non-lethal or low-impact methods are not working or will not work.

While beaver conflict management might seem like an inconvenient hurdle to the use of other beaver restoration techniques, it is inseparably intertwined. Vast swaths of historical beaver habitat are now filled with various forms of human infrastructure, and beavers can cause significant damage to property and create headaches for landowners and land managers (Figure A1). If beaver restoration is successful in a project area, that project area will produce dispersing beavers that will be looking for a place to settle down. These settlement sites may be dozens of miles from the restoration site and may be on private land or in areas where their activities lead to damage or human safety concerns.

Figure A1. Where beavers and human infrastructure overlap, there is the potential for conflicts to arise. Conflicts can be minor, such as beavers cutting down ornamental trees, or they can be major, such as beavers flooding an entire roadway, as shown in this photo. Often, these more dramatic conflict issues develop because humans have built what essentially looks like a giant dam to beavers (i.e., the road grade through this riparian area), and all the beavers have to do is plug one small hole (i.e., the culvert) and they get a huge return on their investment. Photo by Google Earth.

Restoring beavers to areas of their historical range in Montana is dependent on both public and private landowner support. Restoration projects undertaken on public land must incorporate public comment processes and there must be support, or at least acceptance, from private landowners who own lands and properties adjacent to public lands where these projects occur. Private landowners who may desire some form of beaver restoration on their own lands must similarly consider potential impacts to their neighbors. If beaver restoration creates a burden for landowners and land managers, projects may lose support across broad areas of the landscape. Beaver conflict resolution, when addressed up-front and aggressively, provides landowners tools and support for dealing with beavers efficiently.

Conflict management can support the goals of beaver restoration by:

- Addressing site-specific issues in areas where beaver restoration is occurring.
- Increasing tolerance for beavers in a large area as neighbors, groups, and other agencies see and hear about successful projects.
- Mitigating areas where dispersing beavers get “hung up” and repeatedly removed, keeping a potentially important dispersing segment of the beaver population moving to new areas on the landscape.
- Maintaining active beaver colonies where possible that can provide dispersers to nearby habitats.
- Allowing beaver activity to remain close to human access points, providing education opportunities on coexistence techniques and fostering appreciation for beavers and their ecological role.

Beaver-Human Conflict Laws, Regulations, and Permitting

Montana laws and regulations establish the condition that, outside trapping seasons approved by the Montana Fish and Wildlife Commission (Commission), beavers can only be removed due to conflict with humans under two specific circumstances:

1) When the beavers and their dams occur in a settled area in a stream where sewage is dumped, and the dams therefore pose a public health risk.

2) When beavers are causing severe injury to or are a menace to the structures, canal banks, or other works of an irrigation project or district or to a stock water pond.

It is up to the discretion of FWP wardens and biologists to determine when a damage permit is appropriate, but laws and regulations generally limit the issuance of damage permits to these two situations. A damage permit may be issued for other circumstances if the landowner or land manager makes a reasonable attempt to remedy the issue through other techniques. During the Commission-approved trapping seasons for beavers, they can be removed by a licensed trapper without the need for a damage permit. Therefore, landowners experiencing damage issues that do not fit under one of the two categories above may need to mitigate the damage themselves until the trapping season if they desire that the beavers are completely removed.

FWP does not provide beaver removal services. Landowners seeking lethal removal of beavers must contact a local trapper or Wildlife Control Operator for lethal beaver removal. Most FWP regional offices maintain a list of local trappers that may be willing to help remove beavers that are in conflict with humans.

Beaver dams are located within the bed and banks of streams and tampering with or removing them may require a 310 permit from the local Conservation District (private land) or a 124 permit from FWP (public land). Some Conservation Districts waive this requirement and others do not, so consultation is required before any action can be taken on a beaver dam. Emergency permits may be available if beaver activity is posing an imminent threat to human safety or infrastructure.

Specific regulatory language:

MCA 87-1-224 The destruction of beaver and beaver dams for the protection of public health.

> *(1) When a complaint is made to the department of environmental quality that beaver are obstructing the free flow of a stream flowing through a settled area and into which stream sewage of a town or city is dumped and the obstruction endangers public health, the department of environmental quality shall immediately investigate the complaint. If it finds that the work of the beaver endangers public health, it shall report the facts to the department.*
>
> *(2) The department shall immediately issue a permit, free of charge, to the landowner upon whose land the beaver dams are located for the removal of the beaver, the number of which must be designated by the warden making the inspection. The landowner shall remove all beaver and beaver dams as provided by the permit within 10 days after its issuance. If the landowner refuses to remove the beaver or the dams in the 10-day period or if the landowner does not desire to do so and so advises the department, then the department may remove the beaver by trapping or transplanting and remove their dam by blasting or other means.*

MCA 87-6-602 Trapping during closed seasons.

> *(1) A person may not trap or hunt or attempt to trap or hunt any fur-bearing animal until the commission provides an open season on any fur-bearing animal. The furs and hides of fur-bearing animals legally taken during the open season may be possessed, bought, and sold at any time except as provided by law.*
>
> *(2) When it is shown that muskrats or beaver are causing severe injury to or are a menace to the structures, canal banks, or other works of an irrigation project or district or to a stock water pond, any employee or resident landowner on the project or district may kill or trap or cause to be killed or trapped any muskrat or beaver upon or in menacing proximity to the structures, canal banks, or other works of the project or district or the stock water pond during the closed season on muskrats or beaver after having secured from the director a permit to do so, except that from June 1 to August 31 of each year, a permit is not required.*
>
> *(3) A person convicted of a violation of this section shall be fined not less than $100 or more than $1,000 or be imprisoned in the county detention center for not more than 6 months, or both. In addition, the person, upon conviction or forfeiture of bond or bail, shall forfeit any current hunting, fishing, or trapping license issued by this state and the privilege to hunt, fish, or trap in this state for 24 months*

from the date of conviction or forfeiture unless the court imposes a longer period, and any pelts possessed unlawfully must be confiscated.

(4) A violation of this section may also result in an order to pay restitution pursuant to 87-6-905 and 87-6-906.

Montana FWP furbearer regulations (2021).

Beaver that have been lawfully trapped can be dispatched with a firearm. Beaver that have not been trapped cannot be taken with a firearm, except as outlined below in damage situations.

Owners and lessees of property being damaged by beaver or muskrats ***as described in MCA 87-6-602(2)*** [emphasis added] *may request a free permit to remove beaver or muskrat and may remove beaver and muskrat without a permit between June 1 -August 31. Please contact an FWP employee in your administrative region for further information and to request a damage control permit.*

A person participating in a beaver damage complaint must have in their possession the damage permit issued to the landowner (or a copy thereof) during control activities. Damaging beaver may be removed by trapping or shooting. A person may possess beaver under the damage permit.

***PLEASE NOTE: The period between June 1 and August 31 where beavers can be removed without a damage permit *does not* allow landowners to lethally remove beavers for any reason. The removal must still be in accordance with the situations described in MCA 87-6-602(2) (i.e., beavers are causing conflicts with irrigation infrastructure).**

Tools for proactively preventing beaver conflicts

When it comes to dealing with a beaver conflict situation, it is important to think ahead. A successful beaver restoration project will likely increase the beaver population in the target drainage, which can lead to beaver moving onto adjacent lands where they may or may not be tolerated. Any pre-project assessment of a project area must include an assessment of potential nearby conflict hot-spots and include a plan for addressing conflicts should they arise.

Many of the non-lethal techniques outlined in this document can be used proactively in areas that are likely to attract beavers (i.e., irrigation headgates, culverts, bridge spans, and dense patches of riparian vegetation near canals or structures). For example, if a beaver restoration project is to occur upstream of a series of culverts, exclusion fences could be installed on those culverts in preparation for the likely arrival of beavers. Alternatively, a pre-assessment of needed materials and labor to install the exclusion fence could be completed ahead of the project initiation to better plan for and rapidly respond to conflict issues.

Before deciding on a device or technique for dealing with beaver damage situations, it is important to emphasize that the strategy for dealing with beaver damage issues can vary by season. Beaver behaviors that appear similar can have different implications and solutions according to the time of year (Figure A2).

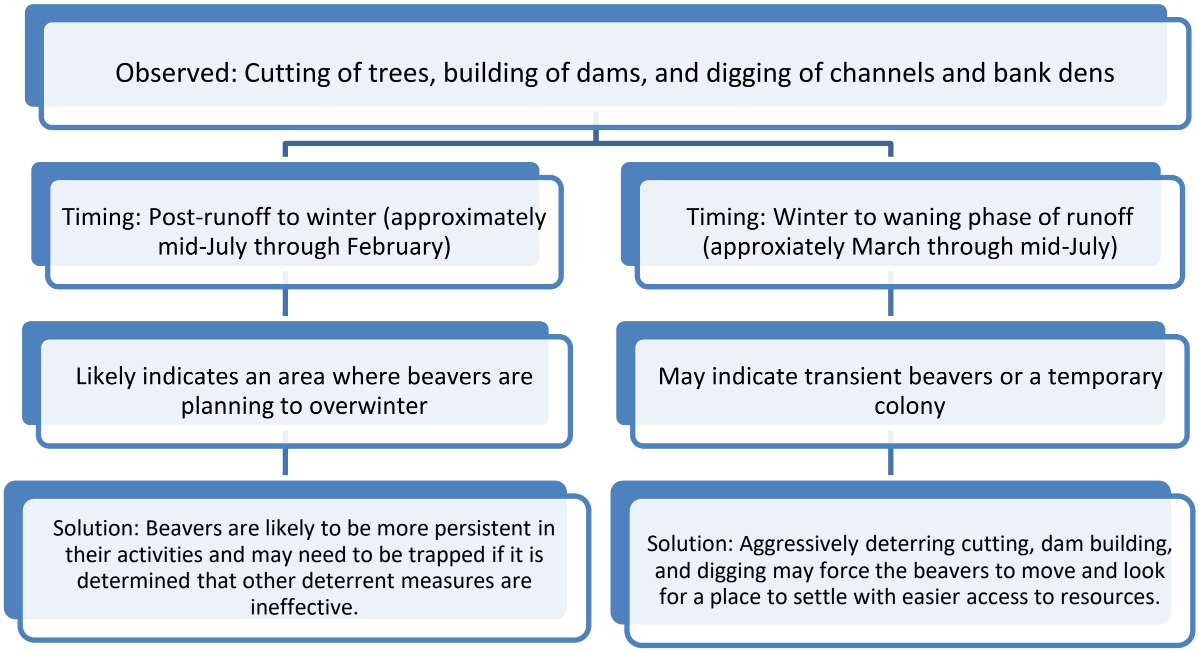


Figure A2. Beaver damage issues addressed in the context of seasonal beaver behaviors.

Tools for mitigating beaver damage that is already occurring

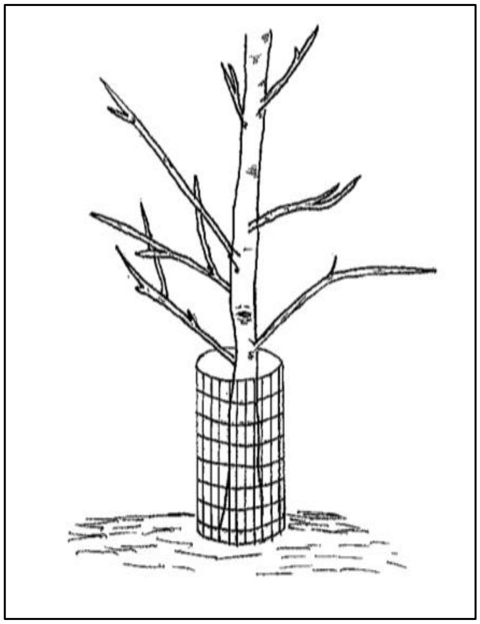
Most often, beaver conflict issues come to the attention of FWP staff because there is already some damage occurring or the landowner is foreseeing that continued activity will result in damage. As emphasized in the main portion of this document, it is important to ask the person with the conflict issue exactly what damage is occurring or is likely to occur. Often there is no damage occurring and people simply think beaver damming activity is inherently bad. These scenarios present a great opportunity for education. When people learn of the ecological wonders of beaver colonies, they may become proud of the fact that they have beavers settling on their property. Furthermore, often people want to remove an entire colony of beavers and multiple dams when it is just a few trees the people need to save or just one or two dams that are causing the problem. These are ideal scenarios for the non-lethal conflict techniques outlined in Table A1 and explored in more detail below.

A team of volunteers install a pond leveler in a long-term beaver dam at Lost Creek State Park.

Table A1. Summary of sources of conflict between beavers and humans and potential solutions. The “Solutions” column lists potential solutions in order from easiest and least impactful to most. Practitioners should explore their options in this order for each conflict type.

Conflict Issue	**Description**	**Solutions**
Cutting and felling of trees	Beavers cutting and removing vegetation for food and construction materials that landowners may want or may be necessary for stream health.	1) Fence trees with wire mesh fencing (Figure A3). 2) Fence entire patches of vegetation if beaver cutting is not restricted to trees. 3) Lethal removal or transplant of beavers as a last resort. Damage permits should not be issued for tree cutting unless damage to irrigation infrastructure or imminent risks to human safety are identified.
Damming of natural or man-made pinch points	Beavers building dams at pinch points such as at culverts, bridge spans, and irrigation headgates, which are highly attractive dam sites.	1) Plan ahead when installing bridges, culverts, and headgates. Right-size culverts and bridges to make them hard to plug. Install mitigation structures as part of construction process if they are in a known occupied beaver area. 2) Exclusionary fencing on upstream end of pinch point structure (Figure A4). 3) Flexible pond leveler, beaver deceiver, or other flow device to lower pond level if exclusionary fencing does not work or only partially works (Figures A5 and A6). 4) Mechanical dam removal by hand or with heavy equipment depending on dam size. 5) Lethal removal or transplant of beavers as a last resort. Lethal removal can only be done with damage permit if beavers are causing damage to irrigation-related infrastructure or are an imminent threat to human safety.
Damming of areas without obvious pinch points (i.e., free-standing dams)	Beavers building dams at sites that do not seem to have a pinch point or other attractive structure. In this situation, beavers could essentially dam anywhere in the area and are not clearly focused on a single, convenient spot for the dam.	1) Plan ahead when installing human infrastructure near or across streams and avoid creating pinch points if possible. 2) Flexible pond leveler, beaver deceiver, or other flow device to lower pond level (Figures A4, A5, and A6). 3) Mechanical dam removal by hand or with heavy equipment. 4) Lethal removal or transplant of beavers as a last resort. Lethal removal can only be done with damage permit if beavers are causing damage to irrigation-related infrastructure or are an imminent threat to human safety.
Excavation of channels and bank dens	Beavers burrowing and tunneling into banks, roadway berms, irrigation dams/canals, and rip-rapped banks.	1) Plan ahead when installing human infrastructure near or across streams to avoid creating a tall and easily excavated bank right next to the stream that would be attractive for a den site. 2) Bank hardening to discourage digging is an option but should be a last resort and is unlikely be permitted solely for beaver conflict resolution due to negative effects on fisheries and general stream health. 3) Lethal removal or transplant of beavers as a last resort. Lethal removal can only be done with damage permit if beavers are causing damage to irrigation-related infrastructure or are an imminent threat to human safety.

Tree Protection



Why Beavers Cut Trees

Beavers cut trees for food, lodge, and dam-building material, and to wear down their continually growing teeth. Favored tree species include: aspen, cottonwood, willow, and alder, but many different species may be targeted. Beavers do not often cut evergreen trees. While these behaviors foster healthy and diverse ecosystems, tree cutting may cause damage for landowners. Simple wire fencing can prevent beavers from cutting trees.

How to Protect Your Trees

Welded 2" x 4" mesh galvanized wire fencing provides sturdy protection for trees. It stands up on its own and does not generally need to be anchored to the ground. The wire can easily be bent to fit around and protect roots or cut at angles to fit sloping banks. Measure and cut fencing so there is 9-12 inches of space between the trunk and fence to allow room for tree growth and to prevent beavers climbing the fence to cut the tree. Fencing should be at least 3 feet tall to account for snow levels. If snowfall is higher in your area, use taller fencing. Fencing should be at least 2 feet higher than snow level to prevent beavers from accessing trees during winter. Protect groups of trees using stakes or rebar to support longer runs of fencing.

Which Trees to Protect?

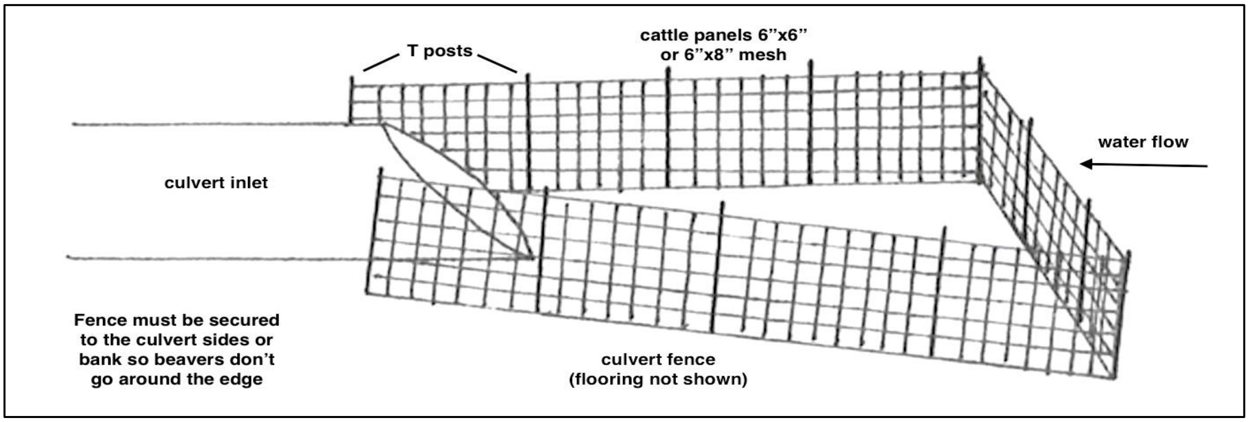
Fencing trees selectively can protect trees while leaving enough smaller shrubs and trees for beavers to use. If there are too many trees to wrap, select trees that are critical for bank stability, favorite trees, and any trees that may present a hazard to buildings or infrastructure if they fall. Beavers generally stay within about 100 feet of their water source when on land but may travel up to 300 feet for preferred forage plants.

Issues to Avoid

Do not use chicken wire to wrap trees. It is not sturdy enough to stand on its own and can girdle and kill the tree as it grows. Chicken wire is flimsy, and beavers may be able to pull it down, chew through it, or climb up it to access the tree trunk. Fenced trees in areas that flood during high water may collect large amounts of debris and so may need to be cleaned and repaired annually after runoff. Tin roofing material and pieces of culvert have also been effective at deterring cutting. However, these materials can also super-heat the trunks of trees during warm weather causing stress that may lead to reduced tree vigor or death. These materials also rarely last through runoff.

Figure A3. Aspen trees correctly fenced to prevent beaver cutting. Photo by Elissa Chott.

Culvert or Headgate Exclusion Fence



Where to Use

Beavers are attracted to culverts, bridge spans, and headgates because of the sound and feel of flowing water. From a beaver's perspective, these structures are just easily plugged holes in otherwise perfectly good dams. Beavers can plug culverts, bridge spans, and headgates with relatively little work using the road or canal embankment to flood a large area. As a result, these are some of the most common conflict sites.

How It Works

Installing an exclusion fence around the culvert inlet keeps beavers far enough away from the mouth of the culvert so they do not key into the sound and feel of flowing water. The fences also interrupt the preferred structure of their dams, so even if the beavers build on the fence they end up creating a much more leaky structure that cannot fully plug the hole. Designs vary and are site specific depending on culvert size and stream width, but all culvert fences need to be surrounded by water and have a floor to prevent beavers from digging under the fence. If space allows, flaring the fence sides outwards discourages beavers from damming on the fence. Rectangular fences may be used on narrower streams where flared sides would run too close to the bank.

Materials

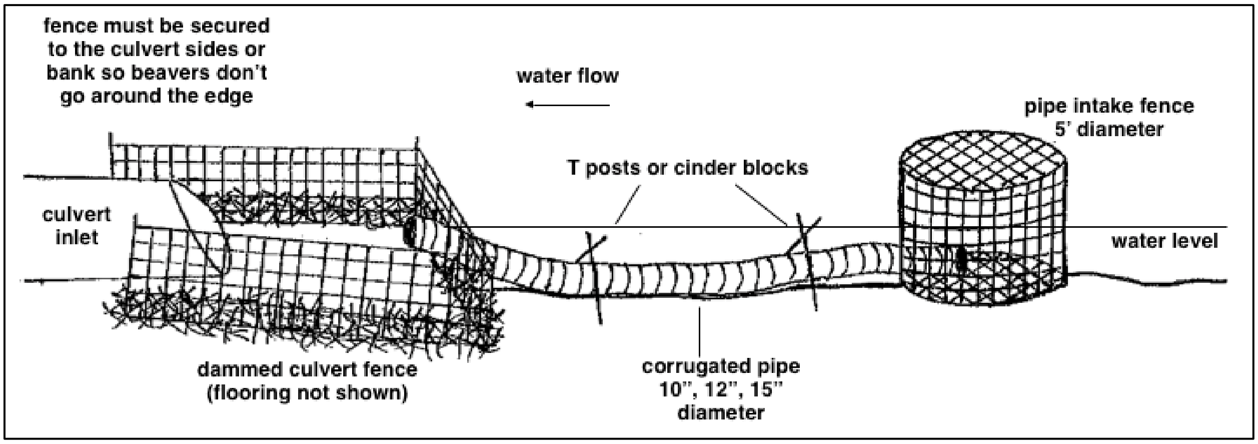
Sturdy materials and proper construction techniques are a must. Devices will fail if flimsy fencing is used. As a general rule, fencing that comes on a roll will not be sturdy enough for a culvert fence. Using quality materials ensures devices will hold up during high water and withstand ice flows. Rigid panel fencing used for cattle or hogs are the only materials appropriate for these devices.

Maintenance

Maintenance is critical for proper function and maintenance needs vary by site. Maintenance checks should be done 3-4 times per year, especially after high water, and usually take about 10-15 minutes per visit. More frequent maintenance may be needed if the device is on a stream with lots of debris flow. Maintenance usually involves using a potato rake or other metal rake to remove debris buildup from around the culvert fence. In some cases, adjustments to T-posts or fencing may be needed to keep the structure standing and functional. Properly constructed culvert fences can last for 10 years or more.

Figure A4. Examples of various types and shapes of fences used to keep beavers from plugging man-made pinch-points like culverts, bridge gaps, and headgates. Photos supplied by Google Images.

Culvert Exclusion Fence with Pipe Device



Where to Use

A culvert exclusion fence with a pipe device keeps beavers from plugging culverts and causing flooding. This design may be used in streams where the culvert fence needs to be smaller, making it likely that beavers will form a successful dam on or just above the culvert fence. The exclusion fence keeps beaver from completely blocking the culvert inlet, and the pipe regulates water levels. This design is ideal in areas that can support a pond directly upstream from the culvert but where there is not enough room for a large culvert fence.

How It Works

Beavers will be able to retain water by damming on the culvert fence but not cause damage because the pipe regulates flows by acting as a leak through the dam built on the culvert fence. The pipe is placed through a hole in the fence at the desired maximum water depth to control water levels. High flows will run over the top of any dam along the culvert fence and through the culvert inlet. Water will recede back to the previous pond depth because of the pipe.

Materials

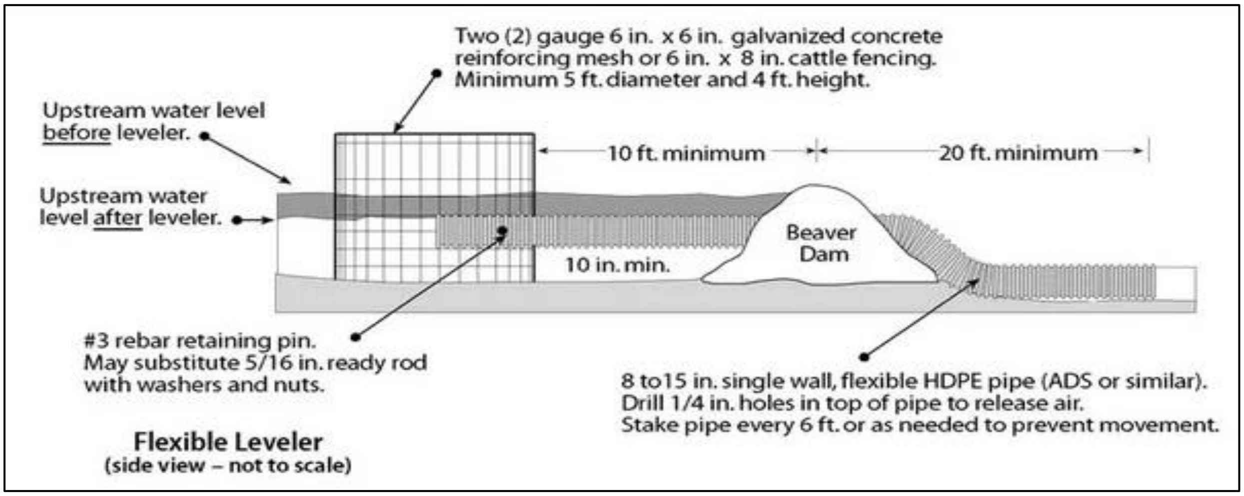
Sturdy materials and proper construction techniques are a must. Devices will fail if flimsy fencing or pipe is used. Using quality materials ensures devices will hold up during high water, withstand ice, and last for years. All culvert fencing includes flooring to prevent beavers from tunneling under and damming inside the culvert. Rigid panel fencing used for cattle or hogs are the only materials appropriate for these devices. Pipes should be high-quality, corrugated HDPE and sized to fit the size of the stream flowing through the culvert. Flexible HDPE pipe is preferred but may be hard to find.

Maintenance

Maintenance is critical for proper function. Remove debris buildup from the pipe intake fence and check the pipe for damage. Leave the beaver dam on the culvert exclusion fence in place because the pipe will bypass it. Maintenance checks should be done 3-4 times per year, especially after high water, and usually take about 10-15 minutes per visit. More frequent maintenance may be needed if the device is on a stream with lots of debris flow. Properly constructed devices can last for 10 years or more.

Figure A5. Culvert fence modified to include a pond leveler device. In this situation, it was pretty clear that an exclusion fence would need to be small given the small waterbody in which it was installed, so it was likely the beavers would be able to dam the culvert fence enough to raise the water level back up to the point of flooding the road. So, a pond leveler pipe was installed from the beginning. The culvert fence keeps the beavers from plugging the culvert and the pipe keeps the beavers from plugging the culvert fence.

Pond Leveler



Where to Use

Where freestanding dams are flooding roads or valuable property, pond levelers lower water depth upstream of dams while still allowing beavers to remain in the area. Flexible HDPE pipe is placed through a notch in the dam to control the pond depth and protect property. The intake is placed upstream of the dam and encompassed by a large, cylinder-shaped fence to ensure beavers do not feel the pull of water flowing into the pipe, triggering their damming instinct.

How It Works

The water level will drain to the level where the pipe is set at the notch through the dam. Generally, about a vertical foot of water can be drained before beavers start to notice a change in pond water depth. Draining more than a vertical foot risks the beavers damming upstream or downstream in an attempt to hold lost water. When lowering pond levels, it is important to lower water only enough to protect human interests. A functioning pond leveler allows beavers to stay at the location without causing damage, or may encourage them to move on.

Materials

Proper, sturdy materials are a must. Devices will fail if flimsy materials are used. Using rigid panel fencing for cattle or hogs ensures devices will hold up during high water and withstand ice flows. As a general rule, fencing that comes on a roll will not be sturdy enough for a flow device. Pipes should be high-quality, corrugated HDPE and sized to fit the size of the stream flowing through the culvert. Flexible HDPE pipe is preferred but may be hard to find.

Maintenance

Clearing the intake fence of debris build-up is important to ensure proper function. Clear any debris that builds up on the intake fence, check the pipe for damage, and make sure the outlet is clear. Maintenance checks should be done 3-4 times per year, especially after high water, and take about 10-15 minutes per visit. More frequent maintenance may be needed if the device is on a stream with lots of debris flow. Properly built and maintained flow devices can last up to 10 years.

Figure A6. Installed view of the flexible pond leveler device for controlling beaver-flooding issues. The beaver dam is notched to lower the pond water level to the point that is tolerable for the situation, then a flexible pipe is run through that notch in the dam. Photo by Elissa Chott.

Permitting

Non-lethal conflict mitigation that involves pond levelers and/or culvert fences requires work that takes place in and affects the bed and banks of a stream. Additionally, the techniques often involve manipulation of existing beaver dams. Therefore, these types of projects require a 310 Permit or Stream Protection Act (SPA) 124 Permit. Project managers must consult with their local Conservation District for a 310 Permit if the work will take place on private land, or contact FWP for a SPA 124 permit if the work will occur on public lands. To learn more about stream permitting, see Project Planning, Permitting, or visit DNRC's website and navigate to "Licenses and Permits," then "Stream Permitting". Fencing of trees does not require a permit to implement.

Additional Information

- The Montana Beaver Working Group (BWG) – sweigand@nwf.org (head of the BWG) or torrey.ritter@mt.gov (FWP representative for the BWG)
- The Beaver Coalition – Best Management Practices for Pond Levelers and Culvert Protection Systems; https://www.beavercoalition.org/flowdevicebmps
- The Beaver Institute; https://www.beaverinstitute.org
- Clark Fork Coalition - Beaver Conflict Mitigation; https://clarkfork.org/our-work/what-we-do/restore-the-best/beaver-conflict-resolution/
- FWP Living with Wildlife – Beavers; https://fwp.mt.gov/conservation/living-with-wildlife/beavers

Appendix B: Land Management Changes

In some situations, direct restoration actions within a stream or riparian area may not be needed for system recovery and/or for beavers to colonize the site. Across much of the western U.S., land management is one of the primary limiting factors for realizing the benefits of beavers in an area. Often, other beaver restoration strategies are partially or entirely reliant on changes to land management to be successful. In other situations, changes to land management may be all that is needed to allow beavers to colonize and succeed in an area. Land management that can influence beaver-modified streams includes grazing systems, timber harvest, water management, and/or trapping regulations.

Land management changes can support the goals of beaver restoration by:

- Addressing baseline habitat issues that may be precluding or limiting beaver activity over a relatively large area. For example, removing overly dense conifers from a riparian area to encourage growth of preferred plants for forage and construction materials for beavers.

- Adjusting harvest pressure to encourage beavers in some areas or suppress them in other areas. For example, using trapping to keep beavers out of a restored area until the area has recovered to the point of allowing for establishment of self-sustaining beaver colonies.

- Clearing a path for more direct beaver restoration techniques by removing or adjusting an impact that may limit the success of those direct beaver restoration techniques. For example, using riparian fencing to limit cattle use to water gaps so that riparian plantings can become established in previously heavily grazed areas.

Grazing systems

Livestock grazing was historically, and continues to be, one of the dominant land-use impacts that has led to diminished potential for streams to support beaver colonies (Chaney et al. 1990). Heavy grazing in riparian areas can lead to removal of woody riparian vegetation, damage to stream banks through removal of woody riparian vegetation or mechanical destruction through hoof-shear, and delivery of excessive amounts of sediments and nutrients to the stream channel (Kauffman and Krueger 1984, Trimble and Mendel 1995, Agouridis et al. 2005). Due to these potential major negative impacts, livestock grazing must be well-understood and properly managed if beavers are going to colonize rangeland stream systems (Fesenmeyer et al. 2018). Potential management strategies that may support beaver restoration include permanent or temporary removal of grazing animals, rotational grazing systems, riparian fencing, water gaps, and off-stream watering options.

The simplest and easiest way to allow a system to recover to the point of beavers being able to colonize is to remove livestock grazing from the riparian area. If the level of degradation is not too extreme, the system should begin to recover almost immediately. However, if the long-term presence of livestock has led to widespread removal of woody riparian vegetation and/or drastic stream incision or channel widening, more direct habitat restoration may be needed before beavers can colonize the area (e.g., BDA/PALS treatments, riparian plantings, heavy equipment).

If removing livestock from the area is not a viable option, rotational grazing systems can provide the area enough rest from grazing pressure in the long-term to allow woody riparian vegetation to recover and stabilize unstable banks (Baker 2003). Another option is to implement riparian fencing with water gaps to allow livestock access to water and green vegetation in the valley bottom but prevent them from spreading throughout the riparian area and affecting large stretches all at once (Figure B1). Fencing can be a good option to protect critical stretches that are found to have the highest potential for beaver habitat. Water gap areas may become heavily impacted (Figure B1), but this may be preferable to more widespread impacts.

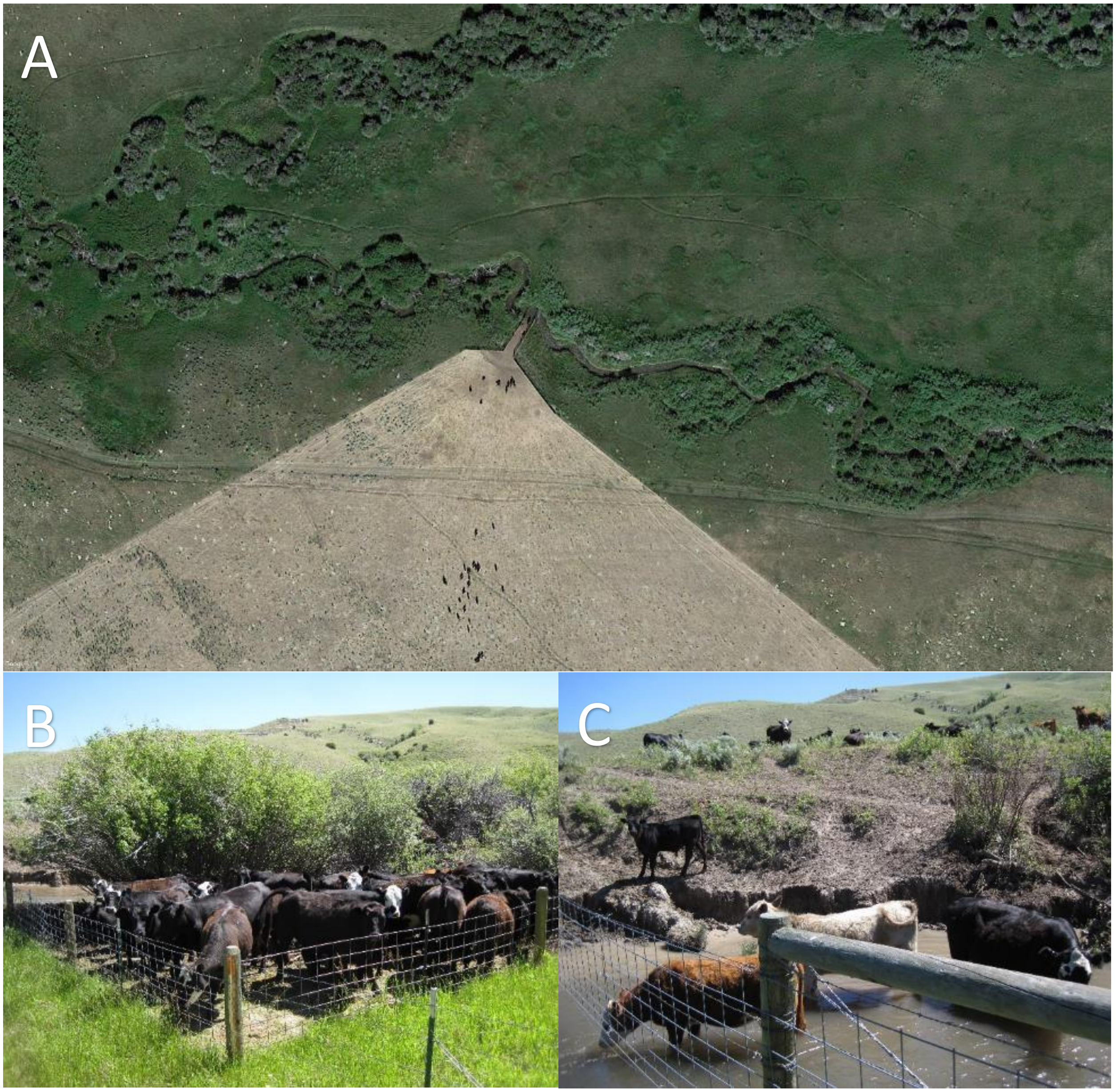


Figure B1. Water gaps, in association with riparian fencing (panel A), can be an effective way to reduce livestock impacts to stream systems while also providing a water source for livestock to use. Water gaps can result in a dense congregation of cattle in the water gap area (panel B), leading to a heavily impacted area of the stream bank and riparian vegetation (panel C). However, this outcome may be preferable to more widespread impacts that result if livestock can access any part of the stream they want and stay there for as long as they want. Top photo by Google Earth.

Often the most destructive effects of grazing come in late summer when livestock spend much of the day in riparian areas where shade and cool water are available. Therefore, one of the best options for allowing livestock and beavers to co-exist in an area is to draw the cattle away from the riparian area during hot and dry parts of the year. If resources allow, off-site watering systems can draw livestock away from riparian areas to drink, and shade structures or preservation of nearby forest patches can provide areas with shade. However, in mid-summer in dry and open country the combination of water and shade in riparian areas will be difficult to out-compete for livestock’s attention, and riparian fencing or rotational grazing may be the only viable options.

Overall, a beaver restoration project should not be implemented in areas grazed by livestock without a grazing plan that will allow the restoration efforts to be successful. Working with landowners or lessees will be essential to a successful project or may derail a project altogether if an appropriate grazing management plan cannot be developed.

Forest management

Stream and riparian systems reflect their upstream and upslope inputs, so watershed-scale management becomes an important factor in the health and productivity of stream channels and associated riparian areas. Forest management upstream from, and surrounding, a potential beaver restoration project has significant effects on water and sediment availability as well as the species composition and structure of riparian vegetation. Therefore, forest management can have implications for the trajectory and long-term success of a project.

Timber harvest on the hillsides surrounding a stream system can affect the amount of water delivered to the stream system because trees influence the distribution and melting rates of snowpack, and because trees take up and transpire water as it travels downslope from snowmelt. At the same time, tree roots, leaf litter, understory vegetation, and downed woody debris all effect sediment delivery to the stream, which in-turn affects water quality and may affect beaver colony longevity through silting in of ponds. Conifer encroachment into riparian areas is common in Montana and may suppress the growth of woody plants that beavers prefer for food and construction materials. Conifers falling into streams or being placed there by humans can have significant effects on stream function through the introduction of large structural elements to the stream channel. Large wood in the stream channel and along stream banks can also provide good lodge and dam construction sites for beavers.

Hydrology

Forest management upslope of streams and riparian areas in the larger watershed can affect the transport and availability of water. This is a broad and complex topic and an area of ongoing research (see review in Goeking and Tarboton 2020). Generally, water yield in a stream increases following removal of trees from a drainage (e.g., by timber harvest, insect/disease outbreaks, or fire) due to decreased evapotranspiration and soil moisture depletion (Potts 1984, Burton 1997, Pugh and Gordon 2013). However, removal of overstory vegetation allows more radiation to reach the understory and soil surface, potentially offsetting any water yield gains. These nuances highlight that the interaction of tree mortality or removal and water yield is highly dependent on the characteristics of the watershed, the level of disturbance, and subsequent effects on snowpack (Goeking and Tarboton 2020).

Effects on water yield in a drainage differ greatly between stand-replacing events like clearcutting or severe wildlife and more moderate disturbances like understory burns, insect/disease outbreaks, and forest thinning projects (Goeking and Tarboton 2020). While water yield may increase following stand-replacing events, snowmelt may occur more rapidly and earlier in the year because of the lack of overstory cover shading snowpack from solar radiation (Andréassian 2004, Bewley et al. 2010, Pomeroy et al. 2012), and may result in higher peak flows (Goeking and Tarboton 2020). For non-stand-replacing events, water yield is still more likely to increase but has a higher probability of decreasing or remaining the same depending on the intensity of understory vegetation invigoration and regrowth and the level of overstory canopy cover loss (Biederman et al. 2015, Bennett et al. 2018).

Studies on water availability following forest disturbance events emphasize that the effects are likely not predictable enough to use timber harvest as a “tool in the toolbox” for beaver restoration. This is especially true given that effects on annual water yield, peak flow magnitude and timing, and low flow magnitude often change considerably as a disturbed forest undergoes succession, sometimes within as little as 10-20 years (Goeking and Tarboton 2020). A good rule of thumb to follow may be that, when water availability is a potential limiting factor for beavers in a stream system that is forested upstream of the restoration area, practitioners should consult publications like Goeking and Tarboton (2020) to assess potential effects on streamflow that may impact the project. Alternatively, practitioners should consult with a local forester or hydrologist if one is available.

Overall, it is important to realize that no forested area in Montana stays the same forever. Practitioners should be considering the potential effects of timber management and forest disturbance on their projects by looking ahead decades, even if active timber management activities are not planned in the drainage where a beaver restoration project is occurring.

Riparian Vegetation

In the right situations, timber harvest can result in an opening of the understory around streams that can favor shrubby, deciduous vegetation that is more palatable to beavers. This can include preferred woody riparian vegetation (i.e., aspen, alder, cottonwood, and willow) as long as natural stream processes that result in suitable sites for woody riparian vegetation establishment and growth are still functioning (i.e., stream erosion and depositional processes facilitated by floodplain connectivity). Opening the understory around streams through forest disturbance may therefore make additional sections of streams suitable for beavers in a drainage (Roper 2022). However, practitioners need to consider the long-term trajectory of the site and potential successional pathways the area may undergo as it recovers from the disturbance. Any improvement of beaver habitat in an area through greater water availability, for example, may be temporary or at least highly unpredictable, while regrowth of preferred vegetation will last much longer, basically until a new overstory of conifers grows.

Practitioner should be aware that streamside management rules and regulations often prevent major timber harvest in riparian areas. Required consultation with FWP’s fisheries biologists as part of any beaver restoration project should include a discussion of timber management in the riparian area if conifer trees are identified as a possible limiting factor for beavers. Much time, energy, and money has been used to conserve and enhance streamside forests to benefit aquatic resources, so any manipulation of streamside forests should be, and will be, heavily scrutinized.

Sediment

Timber management and associated disturbance regimes greatly impact the rate and intensity of sediment delivery to a stream. Because one of the most prominent effects of beaver dams is relatively rapid sediment deposition upstream of the structures, the rate and intensity of sediment delivery to the stream will affect colony longevity. A primary mechanism driving beaver dam abandonment is when beaver dams collect so much sediment that beavers can no longer get the water deep enough for their needs.

Severe disturbances to forest structure in a drainage through intense timber harvest and/or wildfire can result in large amounts of sediment entering the stream channel during subsequent snowmelt and rainfall events. Beaver dams in streams with high sediment loads tend to silt in rapidly, sometimes within one or two runoff cycles (Bouwes et al. 2018). This may be a benefit to the stream system as sediment is kept from distributing more uniformly throughout the stream channel and can be “used” by beaver dams to aggrade an incised channel. However, it may lead to shorter-term and more dynamic beaver damming activity.

Woody Debris

Forest management can be an effective tool for delivering large woody debris (LWD) to streams. The benefits of LWD for increasing channel complexity and fish habitat diversity is well-known, but mid-stream structures can also form ideal dam-building sites for beavers (Pollock et al. 2017; Figure B2). When conifers are mechanically removed from a floodplain, material may be introduced to the stream to mimic historical processes that resulted in trees and tree parts being recruited into the stream channel (e.g., wildfires, tree death and toppling, windfall, etc.). Those mid-stream obstructions can also help beavers form strong dams, especially in systems where high-water dam blow-outs are common, such as in incised channels. Similarly, when insect/disease outbreaks or wildfire affects forested areas along streams, the resulting deadfall can create ideal dam-building sites for beavers while also opening the understory for the growth of preferred vegetation for beavers.

Figure B2. Examples of situations where beavers have used large woody debris in streams as anchor points for dams and lodges. When considering timber management in a drainage that supports or may be capable of supporting beaver dams, strategic felling or placement of large wood from timber management activities can be an effective way to increase in-stream channel complexity and create attractive dam and lodge building sites for beavers. In the top-right panel, beavers used the root wad of a fallen tree to build a lodge and used the matrix of branches sticking into the stream as scaffolding from which to construct a dam that survived multiple runoff pulses.

Conifer Encroachment

Conifer encroachment is a widespread habitat disturbance in Montana, and a lot of time, money, and resources are devoted to removing conifers from grasslands, sagebrush, and aspen stands to improve the vigor of those plant communities and to restore historical conditions that were generally mediated by fire. Conifer encroachment is also occurring across thousands of miles of streams and riparian areas in Montana.

Abnormally high densities of conifers in riparian areas have the potential to crowd out woody riparian vegetation and other deciduous shrubs and forbs that beavers rely on (Roper 2022). Conifers also develop much different root systems than riparian plants, which can affect channel migration, water conveyance and storage in the floodplain, and the availability of water to beavers for their activities. However, this is an on-going area of research with much still to be learned and applied to beaver restoration scenarios.

Fortunately, if beavers can get established in an area and build channel-spanning dams, the raising of the water table can flood out and kill encroaching conifers. This effect has been observed throughout Montana (Figure B3), and may be especially important in sagebrush-willow systems where Rocky Mountain juniper is encroaching on riparian plant communities.

Figure B3. Examples of areas where flooding by beaver dams is killing off encroaching conifers in riparian areas (dead conifers are gray in the images). While not yet widely used, this may be an effective way to combat conifer encroachment while also restoring valuable stream processes (i.e., beaver damming activity). In other areas, mechanical conifer removal by people to benefit the riparian area can provide materials for the construction of BDAs and PALS that can further lead to stream and riparian recovery (Wheaton et al. 2019). Photos by Google Earth.

Removal of conifers that are crowding-out aspen stands can enhance those stands, thus increasing an important and highly desired food resource for nearby beavers. Aspens are preferred by beavers for food, and they will travel considerable distances over land and across obstacles to acquire aspens, even if other preferred forage is readily available. If forage and dam-building materials are diminished or lacking directly adjacent to a stream channel, enhancement of off-channel aspen stands can help supplement beaver food and construction resources in the area.

While beaver restoration practitioners may have little control over large-scale forest management and disturbances in the project drainage, understanding how those disturbance regimes may affect a project will be important for estimating the trajectory of recovery for the project area. At a smaller scale, addressing riparian conifer encroachment can encourage growth of riparian plants and can provide large woody materials that may benefit the restoration reaches and further encourage beavers to colonize the area.

Water management

Too much water-power acting on a beaver dam, especially in incised channels, can lead to frequent dam blowouts that may keep beavers from occupying the area more than a few years and may slow or stall the recovery of a degraded stream channel (Pollock et al. 2014; Figure B4). Too little water due to irrigation withdrawals or naturally losing stream reaches can similarly keep beavers from occupying an area at the spatial and temporal scales needed for meaningful stream restoration benefits. In the former situation, more heavy-handed restoration techniques may be needed to recover, abandon, or widen an incised channel to the point that beavers can successfully build dams, or existing dams may need structural support from restoration practitioners to help them survive high-water pulses. In the latter situation, water-rights purchases or in-stream flow leases may turn formerly de-watered streams into streams where beavers can gain a foothold. But naturally losing stream reaches may simply be unsuitable for beaver occupancy that will result in desired restoration benefits.

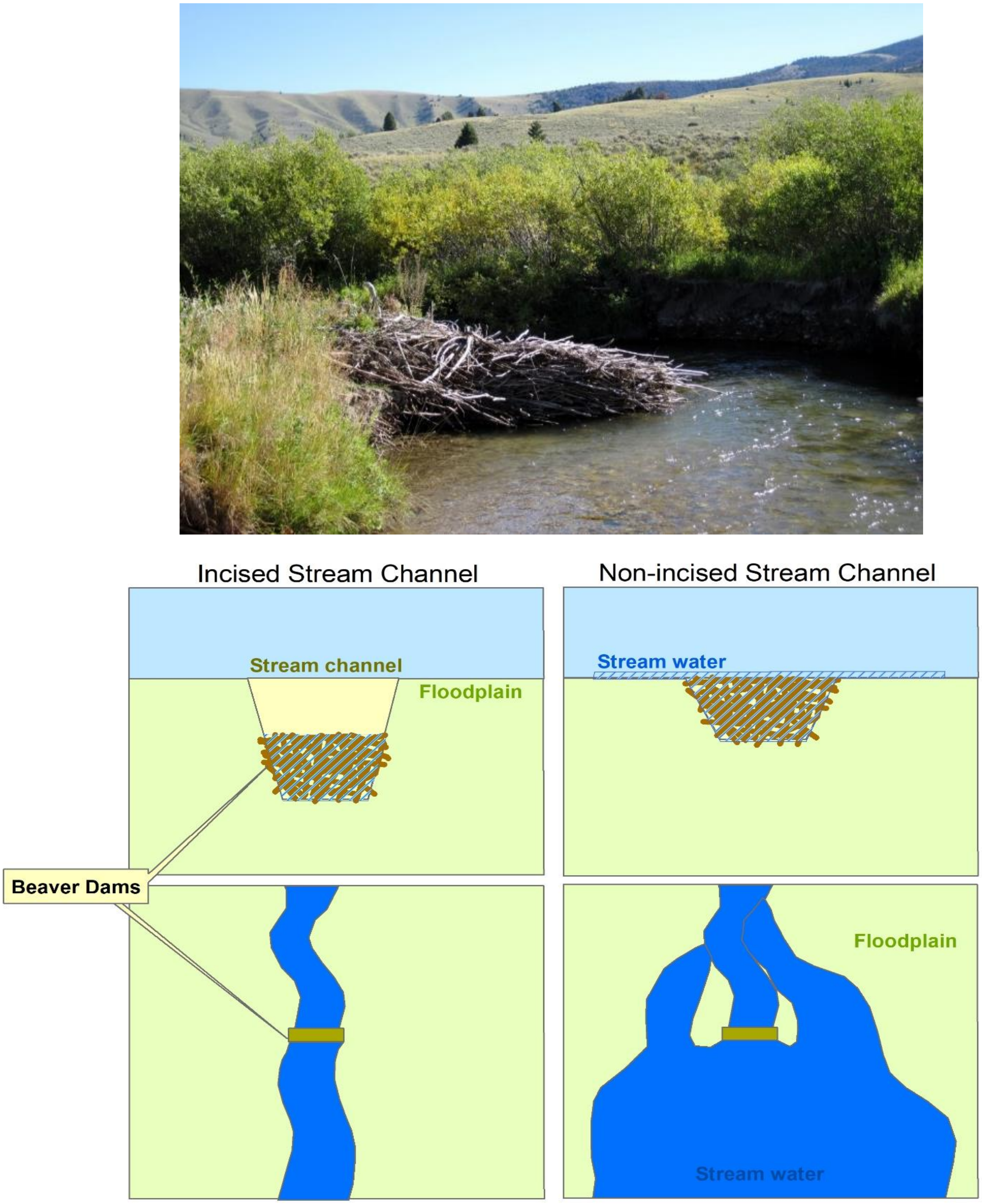


Figure B4. A classic sign of a stream with too much stream power for long-term and self-sustaining beaver occupancy is blown-out dams like the one in this photo (top panel). In incised streams like this one, all of the water-power is pushing on the dam leading to frequent blow-outs that can keep beavers from introducing processes that can lead to stream recovery (e.g., sediment accumulations, floodplain widening, floodplain connection). Generally, if beavers can build a dam high enough to allow the stream to escape onto the floodplain, then enough pressure can be taken off the dam to allow the structure to survive multiple high-water pulses (bottom panels).

If there is a year-round supply of water in a stream system, there should be no hydrologic limitation to beaver occupancy. However, there may still be a hydrologic limitation to damming activity when streams are too large for dams to be built or to persist through runoff. Therefore, the primary water management options for encouraging beaver occupancy involve returning perennial water to de-watered streams or stream sections, or manipulation of water-flow pathways to direct water into situations where beavers can use it to their advantage.

Many streams and stream sections in Montana are de-watered seasonally, either because of natural losing streams where surface flow enters subsurface flow pathways, or more commonly through water diversions for agriculture. FWP and other organizations work to acquire water rights to bolster in-stream flows in streams and rivers throughout Montana to benefit fisheries and other aquatic resources. These efforts can effectively enhance beaver activity by providing a larger section of stream that maintains year-round flow so beavers can colonize the area. Alternatively, maintaining surface flow can enhance stream connectivity to the point that it may keep dispersing beavers traveling up a drainage where they can encounter new settlement sites in the headwaters. Although not extensively documented, it is likely that dispersing beavers may be thwarted from traveling up a drainage if they encounter a de-watered section of stream, as they essentially have no cover from predators while traveling along such a stream.

Some streams and stream sections in Montana are so deeply incised that beavers have almost no chance of establishing self-sustaining colonies or are unable to occupy the area entirely (Figure B5). In these situations, it may be necessary to re-route the stream so that it no longer flows through those severely incised sections. Channel plugs can re-route a stream back onto the floodplain where it can flow through old channels and where it can be more easily and successfully harnessed by beaver activity (Figure B6). The resulting abandoned channel can be filled in either partially or fully, and may still accommodate flow during high water. The resulting diminished stream power in the severely incised portion of the channel can allow high-flow sediments to drop out and may begin to fill in the incised channel. Alternatively, or in concert, the abandoned channel may seasonally fill in with water due to a higher water table and saturated soils, providing seasonal off-channel wetland habitats that are used by a wide variety of species and are especially important as amphibian breeding sites.

Figure B5. Example of a stream that is so heavily incised it is unlikely beavers will ever reach a self-sustaining state due to repeated dam blow-outs and no floodplain access for dammed waters. Practitioners may want to use PALS to widen the incision trench to promote aggradation, use heavy equipment to regrade the floodplain, or use channel plugs to route the stream water out of the incision trench and back onto the floodplain. The latter option was used for this section of stream, and the results are shown in Figure B6.

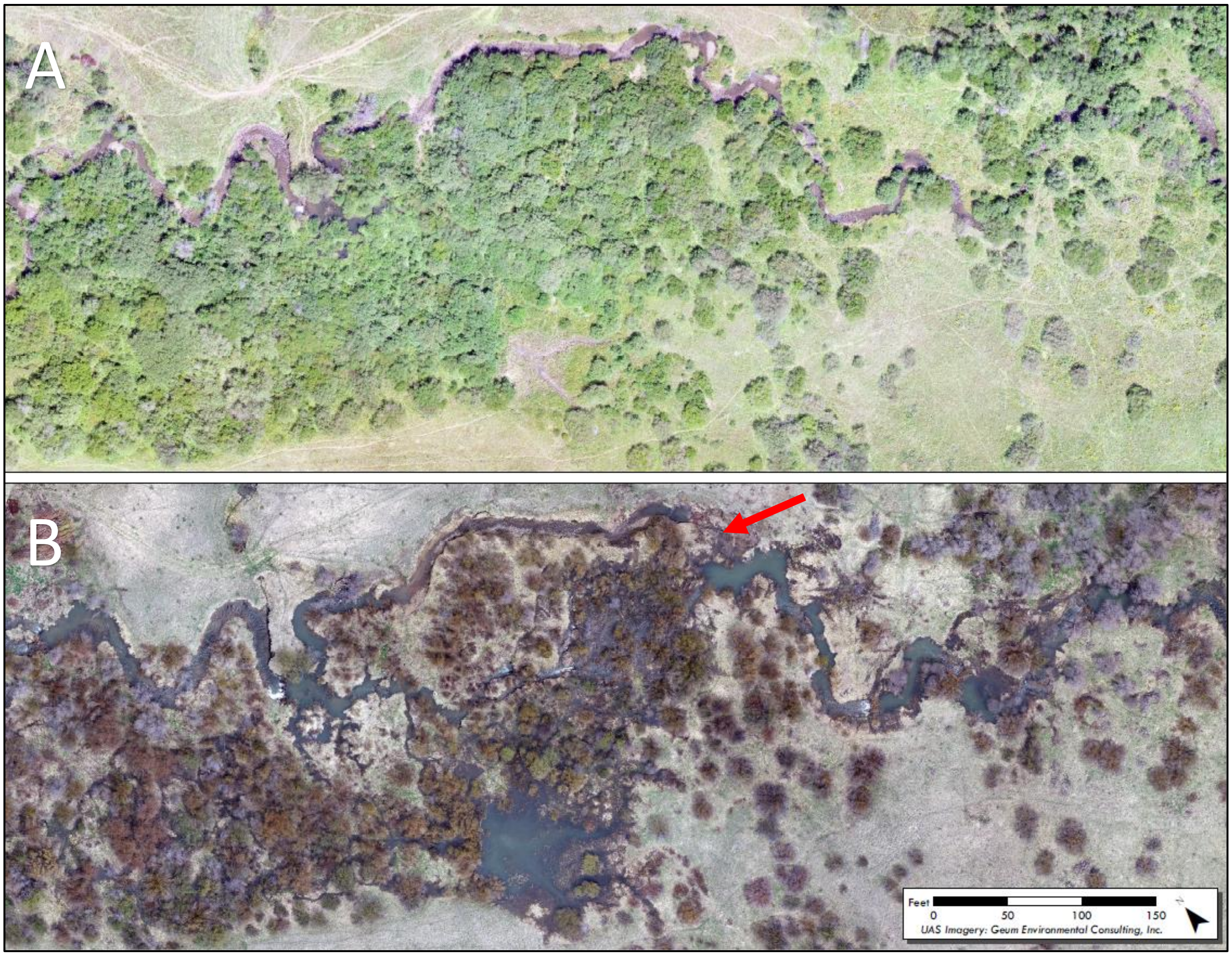


Figure B6. Aerial imagery of beaver-modified habitats on the Spotted Dog Wildlife Management Area in western Montana. Panel A shows the stream in July 2020 when the stream was stuck in an incised channel 4-8 feet deep with almost no chance of natural recovery (Figure B5). Panel B shows where a channel plug (red arrow) was installed in fall 2020 just upstream of the most severely incised portion, forcing the stream out onto the historical floodplain. Prior to the channel plug, LiDAR data were used to identify old channels and swales in the floodplain where the water would likely flow. Upon implementation, beavers immediately moved into the area and began repairing decades-old dam berms and constructing new dams to direct the water into multiple channels flowing through the floodplain. Imagery provided by Geum Environmental Consulting.

Trapping regulations

Historically, the most destructive and dramatic impact to beavers and beaver-modified habitats in North American was the fur trade (Muller-Schwarze 2011). Widespread, unregulated trapping of beavers in the 1800s drove them almost to extinction and began the process by which the majority of dam-able streams in North America degraded to the point of now existing in a different geomorphic and ecological state (Goldfarb 2018). Trapping can have major impacts on beaver populations if the trapping is concentrated in a specific area for an extended period. But the extent, duration, and severity of trapping impacts in modern times with regulated trapping seasons are not well understood, although it is expected to be substantially less than historical effects.

Managing trapping can reduce harvest of beavers in an area where trapping pressure may be suppressing local populations. Natural predation or disease may have a similar effect on local beaver populations and the relative contributions of each type of mortality may be difficult to quantify or predict. Since FWP has specific regulatory control over trapping, and because it is unlikely that any predator control program specific to beaver restoration would be effective or implementable, this section will focus on trapping management as a form of management directly relevant to beaver restoration. Trapping management does not always mean restricting trapping; increasing or decreasing trapping in an area may be desirable based on the goals of local landowners and managers, fisheries biologists, and other stakeholders.

Trapping management essentially manages one predator of beavers (i.e., trappers), potentially improving survival and allowing a beaver population to reach habitat saturation. Saturation of available habitats can create conditions where dispersing beavers are forced to occupy suboptimal and marginal habitats, which can lead to restoration of degraded systems (Ritter et al. 2019). However, a high population density of beavers can also cause dispersal to decrease and the density of colonies to stabilize (Frantisek et al. 2009, Nelson and Nielsen 2010, Scrafford et al. 2018). This situation develops if existing colonies have room to expand their territory boundaries to accommodate additional, non-dispersing adults rather than those extra adults dispersing and starting new colonies of their own (Muller-Schwarze 2011, Ritter 2018). It is difficult to predict the effect of trapping in any given area because the intensity and duration of trapping is often unknown, and other mechanisms like disease and natural predation are difficult to effectively quantify.

In general, in areas that have been closed to beaver trapping, the number of beavers and beaver colonies increases (Kebbe 1960, Parson 1975, Naiman et al. 1988, McCall et al. 1996, Demmer and Beschta 2008, Siemer et al. 2013). Trapping does not always result in a decrease in the number of beavers in populations and colony numbers (Boyce 1981, Payne 1984, McCall et al. 1996, Demmer and Beschta 2008). In some areas where beaver trapping is common, colony densities may remain relatively unchanged due to increased survival and successful colonization by dispersers (Boyce 1981), increased breeding by younger animals as a response to breeding adults being removed by trappers (Muller-Schwarze 2011), or through compensatory mortalities due to disease and natural predation (Payne 1984). In other areas, beaver populations still experience dramatic fluctuations despite trapping closures (Bushner and Lyons 1999, Demmer and Beschta 2008). Though increasing the number of beavers and colonies may be beneficial to stream and riparian habitats, unsurprisingly there are often subsequent increases in the number of conflict complaints where beaver trapping does not occur (Kebbe 1960, Parson and Brown 1978). Overall, the effects of trapping on beaver populations are variable and depend on accessibility, pelt prices, dispersal probability from adjacent populations, and the relative stability of existing beaver-modified habitats.

Modern beaver trapping is much less lucrative and more well-regulated than in the past and does not result in the level of harvest seen early in the 19th and 20th centuries. However, in Montana there are still long trapping seasons and no bag limits and the location and level of beaver harvest through trapping is not directly tracked. It is therefore not clear to what extent (if any) beaver trapping has affected beaver colonization and abandonment of suitable habitats in Montana.

Season Length

The 2022-2023 season for beaver trapping in Montana was November 1 – April 15 in trapping districts 1, 2 and 3 (western part of the state) and September 1 – May 31 in trapping districts 4, 5, 6, and 7 (central and eastern parts of the state; FWP 2022). Beavers can be harvested through legal means of take by a licensed trapper during those seasons.

Beavers can also be taken outside of the normal trapping seasons when their activities are causing damage to private property or are creating a safety concern as outlined in [Appendix A - Conflict Management](#).

Bag Limits and Means of Take

Beaver trapping in Montana is unlimited, hence there is no regional quota or per-trapper limit. However, there are exceptions to the number of beavers trapped in certain areas and/or per trapper in special management units and some state-owned Wildlife Management Areas. There are also closures (no beaver trapping allowed) in certain areas defined throughout the state (Figure B7). Beavers that have been legally trapped can be dispatched with a firearm, but beavers that have not been trapped cannot be taken with a firearm, except as outlined in damage situations.

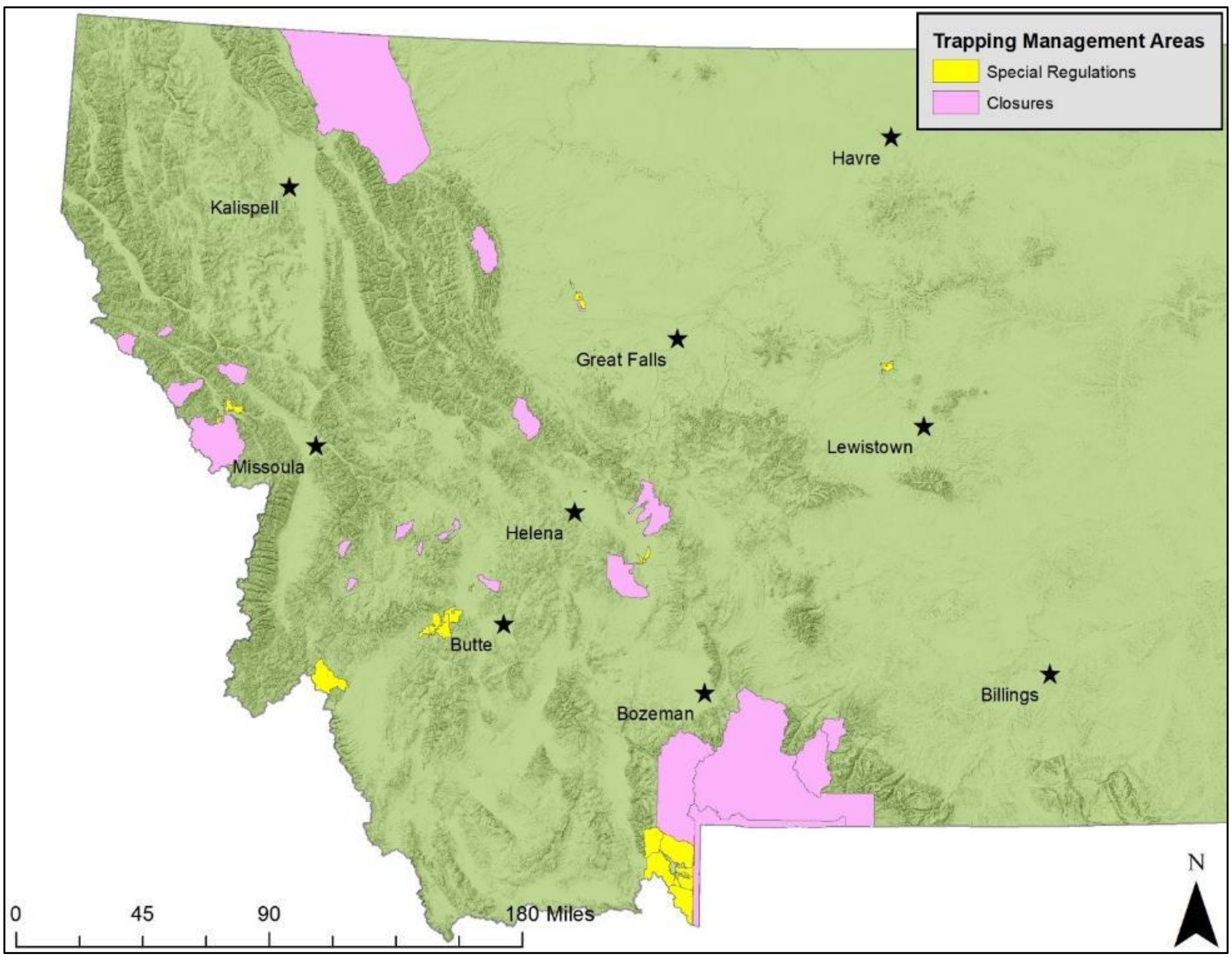


Figure B7. Map of drainages in Montana that are either fully or partially closed to beaver trapping or where special management areas regulate trapper harvest.

Damage Permits

See Appendix A - Conflict Management, Beaver-Human Conflict Laws, Regulations, and Permitting, for details on damage permits.

Reporting

There is no dedicated reporting of harvested beavers in the state of Montana. However, FWP mails out harvest surveys to everyone that purchases a trapping license annually. These mail-out surveys are voluntary but do provide some information on catch-per-unit effort for beavers and other furbearers in Montana (Figure B8).

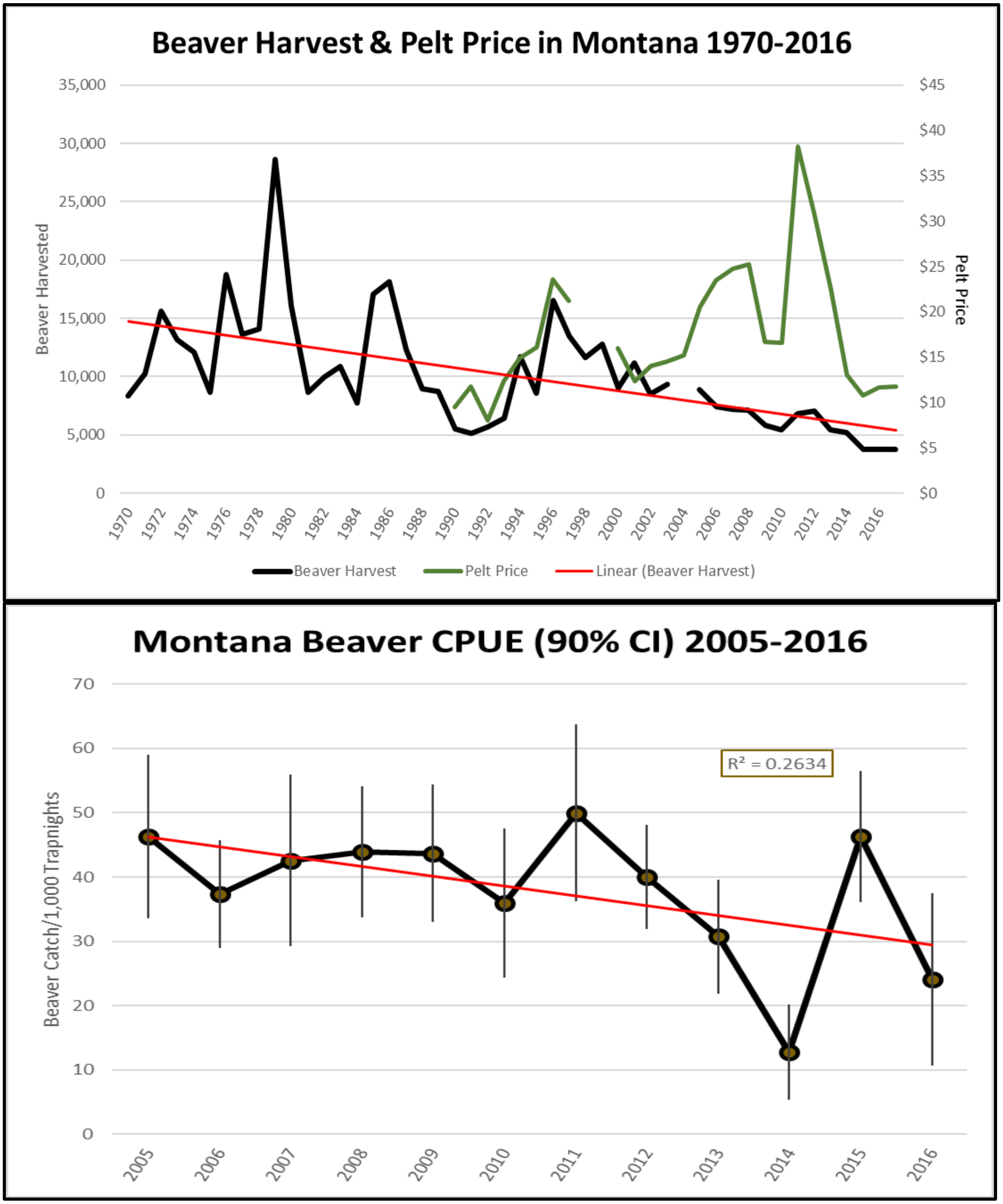


Figure B8. Voluntary, mail-out surveys are sent to Montana trappers annually and provide some information on beaver harvest in the state. In the top panel, estimated beaver harvest in Montana is plotted against beaver pelt prices, showing a long-term downward trend in beaver trapping despite some spikes in pelt prices. The bottom panel shows that catch-per-unit-of-effort (CPUE) for beavers may also be declining, though underlying reasons for this decline are not known. Figure by Bob Inman.

Best Management Practices

Best Management Practices (BMPs) are educational guides developed by wildlife professionals at the Association of Fish and Wildlife Agencies aimed at guiding trappers to use the most effective, selective, and humane tools and techniques for capturing furbearers. They are promoted on the FWP website (https://fwp.mt.gov/hunt/trapping) to encourage trappers to use the best equipment for humanely killing trapped animals, avoid non-target captures, increase the safety of the trapper, foster support for trapping and wildlife management, and improve the public's confidence that the agency is encouraging and supporting ethical and humane trapping. BMPs specific to beavers emphasize techniques and equipment that would minimize capture of otter and other non-target species, describe the specifications of traps, trap placement, and techniques for quick and efficient capture and dispatch of beavers, and emphasizes the correct use of body grip traps for the safety of the trapper.

Voluntary, Mandatory, and Temporary Closures

Voluntary

Although not yet used in Montana, there are no statutory or departmental policies preventing the implementation of voluntary trapping closures on streams or stream sections in the state. These types of closures would involve posting signs asking trappers to avoid the area to allow beavers to become established and/or expand their influence (Figure B9). Voluntary closures should be implemented in coordination with the area wildlife biologist and game warden to make sure the closure is known among FWP personnel and to make sure there is consensus from wildlife management professionals about the need for such a closure. Voluntary closures will be most effective if those wishing to implement them work with local trapper groups, such as the Montana Trappers Association. FWP biologists can assist in facilitating contact with trapping associations and/or local trappers to spread the word about the need for the closure and the expected timeframe it may be in effect.

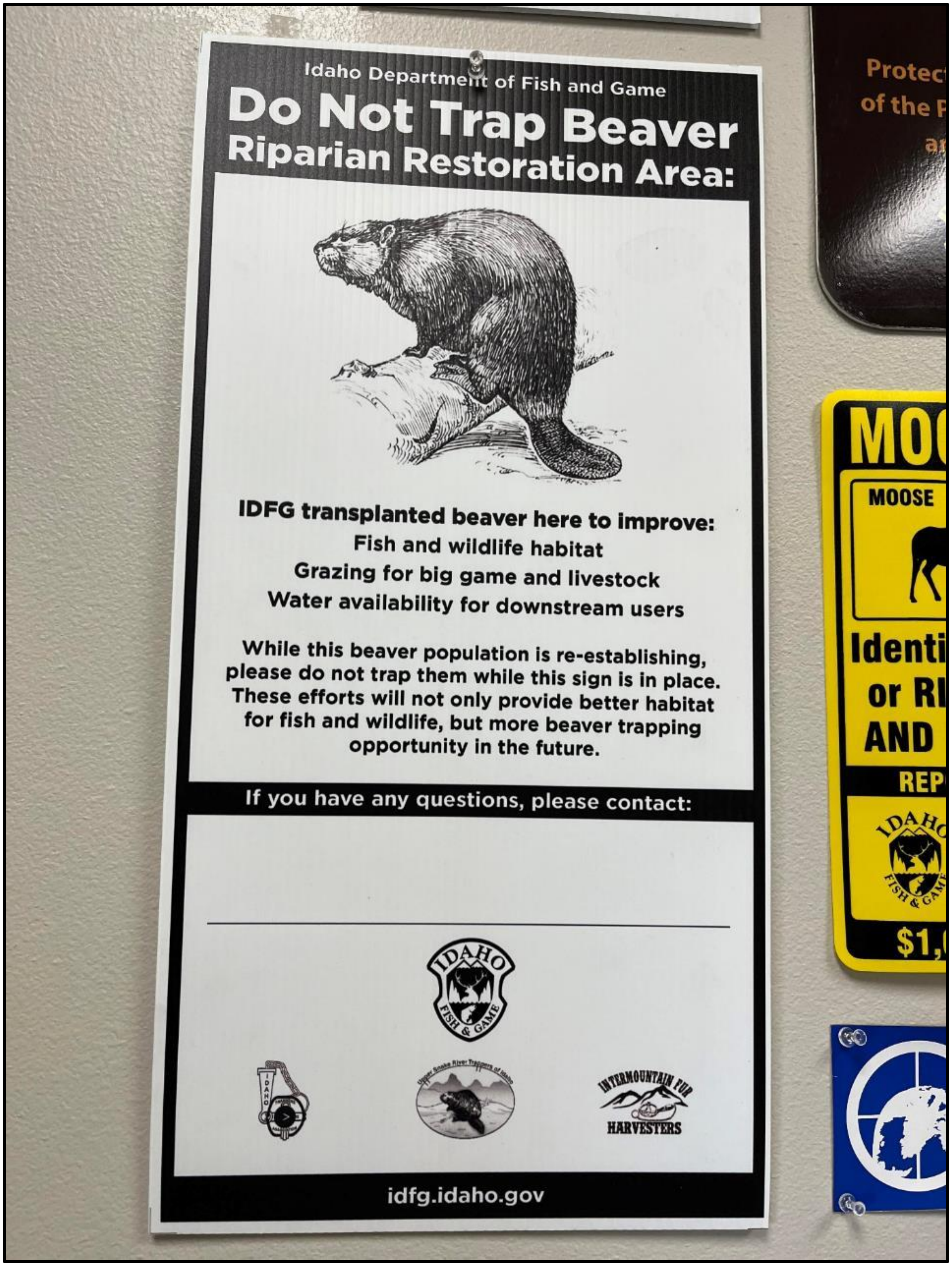


Figure B9. Example of a sign used by the Idaho Department of Fish and Game to implement voluntary trapping closures in areas where beavers are being encouraged to recover.

Mandatory

While beaver trapping is widely permitted in Montana, there are exceptions and there are avenues for restricting trapping in certain areas if a reasonable and scientifically sound reason for a restriction can be demonstrated. There are currently 13 drainage-wide beaver trapping closures in Montana (Figure B9), and these areas are also closed to otter trapping. Although the reasons for these closures vary, many areas were closed to beaver trapping to prevent the accidental or purposeful trapping of otter. In other areas, particularly the far western part of the state, the closures were implemented to prevent overharvest of beavers to allow the stream systems to recover and to preserve sensitive riparian and wetland habitats that already existed in those drainages.

Since the trapping closures were implemented in the western part of the state, there has been little done to attempt to quantitatively or qualitatively evaluate if the closures have been effective at allowing beavers to occupy suitable habitats in the drainages. This is an ongoing area of research and results from a study of Montana beaver trapping closures will be provided in future versions of this document.

Special Management Areas

Most FWP Wildlife Management Areas are open to trapping, although special management regulations apply. Trappers need to apply for permission to trap, and on some WMAs only a portion is open to trapping. In these WMAs, the area, season, number of trappers, and number of beavers harvested is regulated by the area wildlife biologist. To ensure sustainable harvest, area biologists also regulate the number harvested by rotating the trapping area annually. There are currently nine Wildlife Management Areas and one Beaver Management Area (Figure B10) with special beaver trapping regulations within the state.

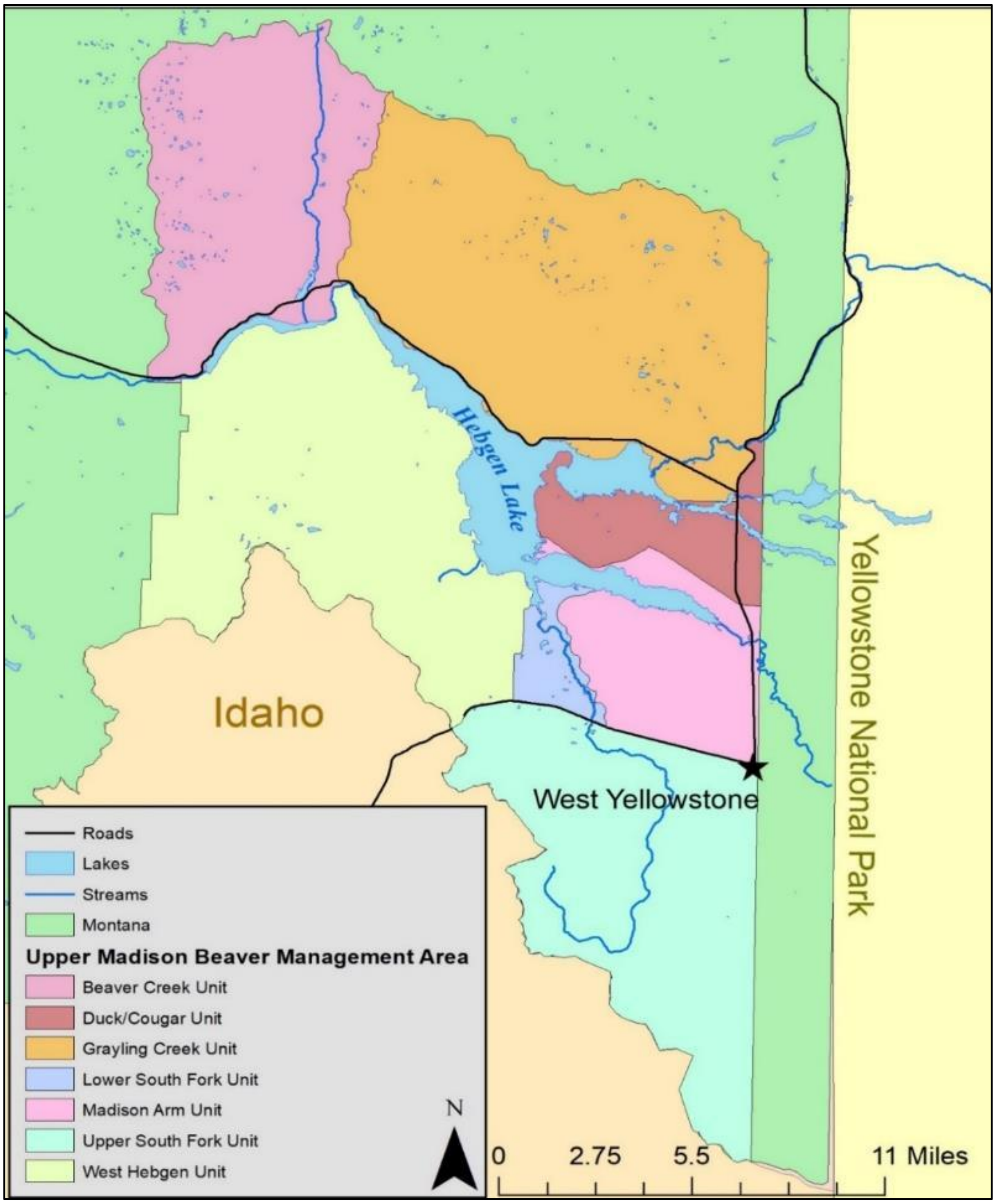


Figure B10. Example of a beaver trapping Special Management Unit known as the Upper Madison Beaver Management Area. In this area, seven trapping units are identified, and trappers must send in a written request to the FWP area biologist to trap in any of the units. Beaver trapping is limited to 5 or 10 beavers depending on the unit and depending on previous years' harvest numbers. Extensive beaver surveys conducted as part of a research project in this area (Ritter et al. 2019) indicated healthy and near-saturated populations of beavers in all areas of suitable habitat in the drainage.

Temporary

Any restriction of beaver trapping will not be successful unless the trapping community is part of the conversation from the beginning. Closing trapping on a stream removes opportunity for a user group, and regardless of how that removal affects beaver trapping, the social implications of such closures can lead to disdain for both trappers and non-trappers and may sour important relationships that FWP personnel have built in their communities. As such, any proposed trapping restriction must be carefully developed with input from FWP, the trapping community, and the general public.

Because of the sensitivity of removing opportunity for a user group on the landscape, any proposed restriction will be much better received if the restriction has a sunset date attached to it. A proposal to close trapping should have tangible goals and targets for the stream or drainage that will allow the restriction to be partially or fully lifted when goals are met. Alternatively, a stream may be closed as a trade for opening a currently closed stream to trapping, allowing rotational harvest of beavers in an area that does not diminish opportunity but also allows for some protection of beaver activity in key areas and during key time periods.

An excellent example of this type of closure is for an area undergoing intensive restoration, where allowing beavers to become well-established in the drainage will have major positive effects on the project. Once the restoration becomes self-sustaining and beavers have occupied the suitable habitat in the area, a beaver trapping restriction can be lifted. In other situations, beavers may actually be detrimental to a restoration project if they harvest or flood-out newly establishing woody plants or undermine recently constructed banks. Therefore, removal of beavers in these areas may be a benefit to the restoration project until the area is on a good trajectory for recovery, then beavers may be allowed to settle and perpetuate the restoration actions into the future.

Permitting

Several of the actions and techniques covered in this section will likely trigger a need for various forms of stream permitting. These include the construction of water gaps for livestock, development of off-stream watering systems for livestock, timber management activities that occur adjacent to stream channels, and in-stream flow leases or other major forms of water manipulation that may affect water rights.

Project managers must consult with their local Conservation District for a 310 Permit if the work will take place on private land or contact FWP for a SPA 124 Permit if the work will occur on public lands. To learn more about stream permitting, see Project Planning, Permitting, or visit DNRC's website and navigate to "Licenses and Permits," then "Stream Permitting".

Additional Information

- The Montana Beaver Working Group (BWG) – sweigand@nwf.org (head of the BWG) or torrey.ritter@mt.gov (FWP representative for the BWG)
- Low-tech, Process-based Restoration Design Manual and other LTPBR resources; https://lowtechpbr.restoration.usu.edu/
- DNRC Stream Permitting Handbook; https://dnrc.mt.gov/_docs/permits-services/StreamPermittingBinderBook2020.pdf
- FWP Trapping Regulations, BMPs, and Harvest Information; https://fwp.mt.gov/hunt/regulations/furbearer-trapping

Appendix C: Beaver Mimicry

Beaver mimicry refers to the restoration technique where practitioners use Beaver Dam Analogues (BDAs) to mimic the damming activity of beavers (Figures C1 and C2). BDAs are channel-spanning, semi-permeable structures that impound water and mimic natural beaver dams to achieve associated benefits. Practitioners using this technique may intend to initiate natural processes through introduction of structure to the stream channel, maintain the structures in the absence of beavers, and/or encourage beavers to colonize and assume maintenance.

BDAs are often used in streams where habitat conditions must improve considerably before beavers would be able to occupy the area and be successful. BDAs can help raise water tables, capture and store sediment, sub-irrigate portions of the floodplain, force meanders and other forms of channel complexity, and work to eventually reconnect streams to their floodplains in areas where that connection has been lost (Wheaton et al. 2019). BDAs have been shown to be an efficient and effective restoration technique when employed in the right areas, at an appropriate scale, and when sufficient funding and time has been allocated to maintain the structures until the restoration benefits become self-sustaining in the system, which may include natural occupancy by beavers (Pollock et al. 2007, 2017; Bouwes et al. 2018; Wheaton et al. 2019).

BDAs are also commonly used in stream systems where habitat conditions are close to a point where beavers could occupy the area, but where beavers just need a helping hand to get established and reach a self-sustaining state. These are often referred to as marginal or suboptimal habitats and are discussed in detail in Appendix D - Encouraging Natural Colonization. Beavers are highly attracted to sites that already have some infrastructure in place (e.g., dams, lodges, bank dens; Ritter et al. 2019), and so building BDAs at a restoration site can be an effective way to make that restoration site attractive as a settlement site for beavers seeking a new territory.

It is important to highlight that BDA-based restoration projects are being implemented in stream systems that either never historically supported beavers or that have shifted to a new stable state that is not conducive to beaver occupancy without substantial restoration inputs (e.g., earth-moving, deliberate vegetation planting or removal, etc.). In the latter situation, these are often systems that have shifted to a new stable state through invasion and subsequent dominance by non-native species like Russian olive, pasture grasses, or noxious weeds, or systems where severe degradation has occurred. While these other BDA efforts are still worthwhile, they are not covered under the term “beaver restoration” as defined in this document, and these are not the types of projects being referred to in this section. It would be beneficial to the beaver restoration field generally to dispel some of the confusion about what is and is not considered beaver restoration (Pilliod et al. 2018). Therefore, FWP encourages practitioners to refer to BDA-type structures by other names in situations where the long-term vision is not beaver occupancy. Examples of other names that have been used for BDA-type structures include “deformable grade structures” or “post-assisted willow structures”.

Beaver mimicry can support the goals of beaver restoration by:

- Providing the benefits of beaver damming activity in the project area without relying on beaver occupancy.

- Allowing practitioners to treat degraded stream systems that may be outside the historical range of beavers or where beaver activity is unlikely or unwanted due to limitations to their success. However, in this situation practitioners should be careful about referring to this technique as "beaver restoration," because of the perception of trying to get beavers to move into areas they never occupied historically.

- Demonstrating the effects of beaver activity at specific sites where public outreach and education is more easily accomplished.

- Providing "starter sites" that are more attractive as settlement sites for dispersing beavers to naturally colonize an area (see Appendix D - Encouraging Natural Colonization).

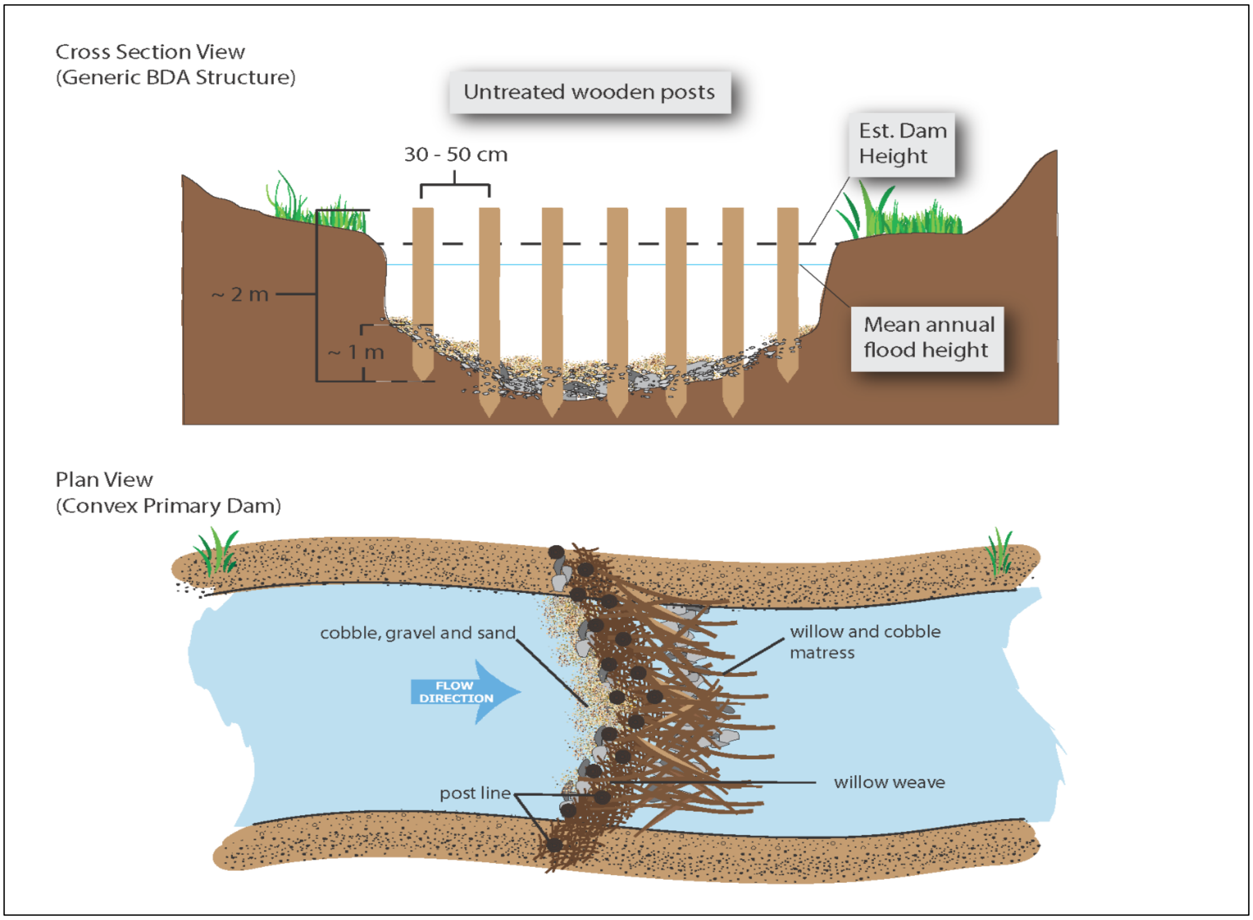


Figure C1. Schematic of a typical Beaver Dam Analogue (BDA) from Wheaton et al. 2019. Preferably, materials for the BDAs are sourced on-site other than using untreated wooden posts, though materials are often transported from elsewhere if needed. BDAs are meant to mimic the function of beaver dams by slowing water, collecting sediment, and introducing woody structure to streams. These are porous, relatively short-lived structures compared to other stream restoration techniques and therefore they often must be built in large numbers and repaired or replaced every few years to maintain functionality. BDAs are built in series to mimic natural beaver dam complexes. Fortunately, BDAs are also highly attractive to beavers who will often repair and fortify BDAs and build additional dams up- and downstream (Shahverdian et al. 2019).

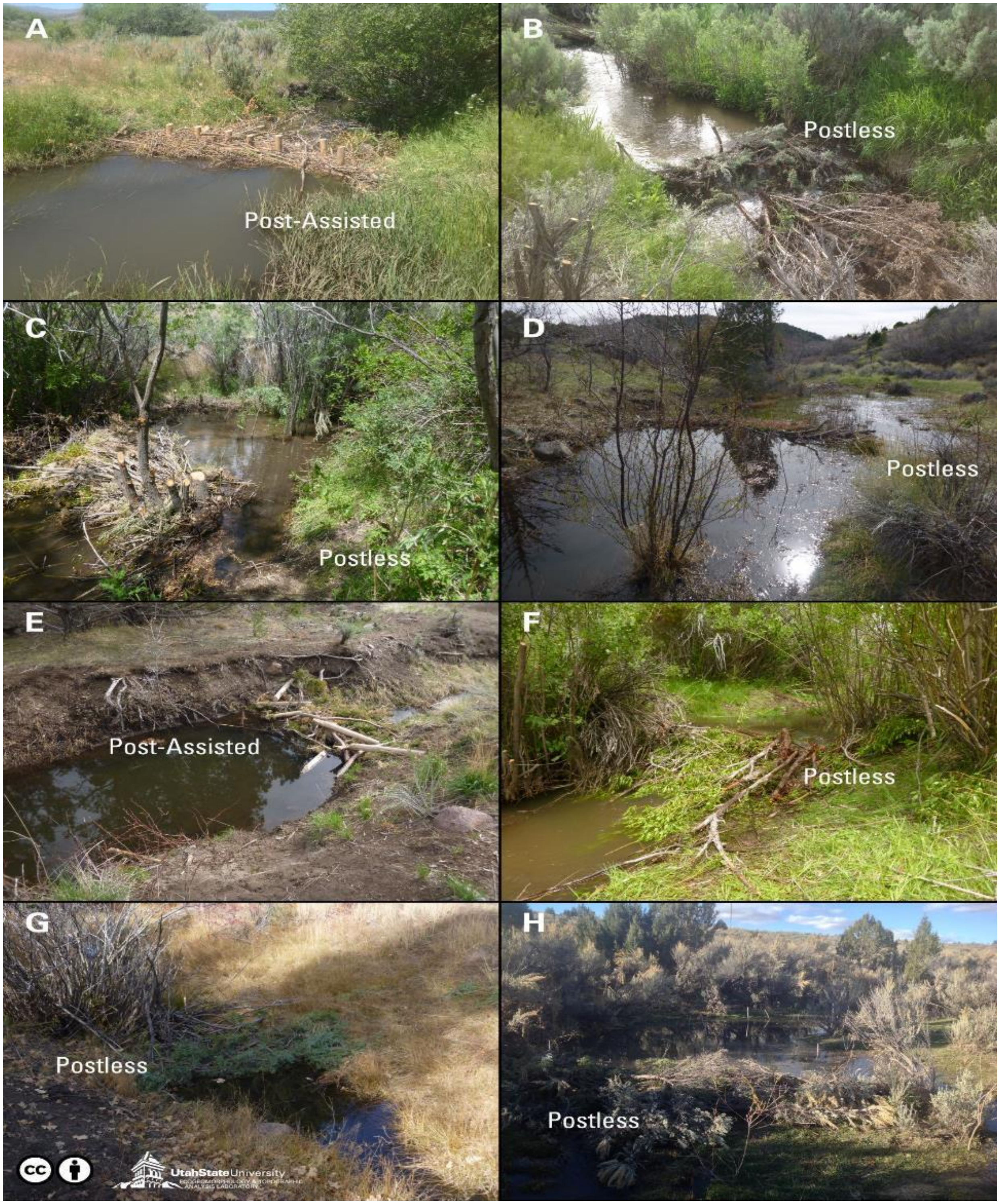


Figure C2. Photos of various sizes, shapes, and types of BDAs that may be constructed to mimic the form and function of natural beaver dams. The construction of each individual structure is not as important as building large numbers of structures in series so that they support one another and there is redundancy in the restoration actions (Wheaton et al. 2019). Post-assisted structures are more commonly used on larger streams with bigger runoff pulses whereas postless structures are used in smaller, less powerful streams and in streams where the substrate is not conducive to driving posts into the stream bed (e.g., large rock). Figure from Shahverdian et al. (2019).

The use of BDAs as a form of beaver mimicry fits under the suite of techniques referred to as "low-tech, process-based restoration" (LTPBR; Wheaton et al. 2019). LTPBR techniques and the underlying geomorphic and ecological principles are focused on restoring stream processes that naturally lead to beaver colonization and re-establishment of beavers as one of the primary sources of beneficial disturbance in stream systems (i.e., stage zero restoration: Cluer and Thorne 2014). LTPBR techniques include the use of BDAs as well as post-assisted log structures (PALSs). In LTPBR, PALSs are used to mimic and promote the processes of wood accumulation, and BDAs are used to mimic the form and function of beaver dams. Used in concert, the two structure types are meant to restore complex, active floodplains whereby the stream channel moves and changes shape over time, with associated benefits to in-channel and floodplain habitat complexity, woody riparian vegetation recruitment, and channel-floodplain connectivity. Both structure types require maintenance.

LTPBR techniques are a broad and complex topic. For additional information, reference the Low-tech Process-based Restoration of Riverscapes Design Manual by Wheaton et al. (2019), which is the most comprehensive resource on this type of stream restoration available. For this discussion, *LTPBR is referenced only in the context of how these techniques can promote the establishment of self-sustaining beaver colonies*. This can occur through supporting an existing beaver population in a stream, creating conditions conducive to beavers occupying a restoration site through natural dispersal, or through creating conditions for a beaver transplant effort that will have the highest probability of success.

Using LTPBR to support an existing beaver population

Many miles of streams in Montana exist in a degraded state (e.g., incised, simplified floodplain, low woody riparian vegetation recruitment), yet also have endemic beaver populations (Figure C3). This indicates that the existence of a beaver population in a stream does not mean that the stream does not need restoration. Instead, these types of streams may be the best opportunities when it comes to beaver restoration because there are already "restoration professionals" on-site and ready to get to work if practitioners can provide the right conditions for them.

Often the limiting factor for beavers in degraded streams is dam persistence. In incised streams, where a channel-spanning beaver dam is incapable of forcing water to flow out onto the floodplain, catastrophic dam blowouts are frequent and may prevent bed aggradation and/or floodplain widening at meaningful spatial and temporal scales to restore the stream. By constructing BDAs and PALS in areas with existing beaver populations, practitioners can provide structural and hydrologic support to existing beaver infrastructure to allow the beavers and their dams to persist through multiple runoff cycles and other high-water events.

Figure C3. Beaver colony on Ledford Creek in the Robb-Ledford Wildlife Management Area. While there are multiple beaver colonies along Ledford Creek, they rarely stay in the same place for more than a few years and are confined to the narrow, inset floodplain that has formed since the stream incised a long time ago. Natural beaver dams rarely persist long enough to raise the bed elevation of the stream, so water almost never flows out onto the larger floodplain. This may be an ideal situation for beaver mimicry because BDAs can be built and maintained to last through multiple runoff pulses and there are beavers on-site to take over maintenance of the structures once built. However, the lack of woody riparian vegetation that extends away from the stream channel would be a major issue to overcome in this area.

BDAs are the most obvious form of low-tech support for existing beaver colonies because they mimic the natural form and function of beaver dams. There are several ways in which BDAs can be used to take advantage of an existing beaver population:

1) BDAs can be built on the periphery of active beaver dams to back water up to the base of the natural beaver dams (Figure 3 in main text). This technique prevents scour from over-dam flows that can weaken existing dams, re-captures water routed around existing dams to discourage head-cutting of overbank flow channels, and prevents dramatic differences in bed elevation above and below existing dams by facilitating sediment deposition at the base of the existing dams. BDAs on the periphery of active dam complexes also effectively expand the area beavers can move around safely and harvest vegetation, potentially leading to a greater area of influence from beaver activities. In the ideal scenario, the beavers repair, enhance, and replace these supportive BDAs, incorporating them into their own infrastructure.

2) BDAs can be built in areas without natural beaver dams or where there is sign of blown-out, old beaver dams but no current occupancy. These BDA complexes can be used to attract beavers from nearby colonies to settle in the area and take over maintenance and enhancement of the BDAs. If there are existing beaver colonies in the area, then there are almost certainly dispersal-age beavers moving around looking for a place to settle down. Providing a pre-built dam complex may be all that is needed to get these dispersers to leave their natal colony and/or prevent them from leaving the restoration project area. With this technique, it is important to evaluate the likely territory boundaries of existing beaver colonies to make sure a large-enough habitat patch is treated with BDAs so that any colonizing beavers will not immediately run into territorial disputes with neighboring colonies and will have room to expand and shift the boundaries of their colony up- and downstream over time.

3) Existing beaver dams can be supported using the structural components that make up BDAs, primarily untreated wooden posts driven into the stream bed. If existing beaver dams are at high risk of blowing out during high-water periods, wooden stakes can be driven into these dams to add structural integrity and give the beavers more options for reinforcing and/or expanding their dams (Figure C4). Posts can be driven into the existing dam structure and can be extended out onto the floodplain, which may give the beavers the support they need to expand their dams beyond the stream channel. This may be especially important in incised channels where floodplain access during high-water events is rare or diminished.

Figure C4. Examples of untreated wooden posts being used to support an existing beaver dam so that it can last through high-water events (Wheaton et al. 2019).

PALSs can also support existing beaver populations, though direct effects are harder to pinpoint. Primarily, PALSs can support existing beaver populations through the reintroduction of natural processes (e.g., large wood structure and wood accumulation) that lead to stream conditions that beavers desire. However, there are some direct effects of PALSs that can provide benefits to local beavers in a restoration project area, including creation of suitable lodge sites as well as resting and feeding areas. PALS come in three primary forms: bank-attached, channel-spanning, and mid-channel (Figure C5), and their effects on beavers can differ depending on the type of PALS used:

1) Bank-attached PALSs, especially those anchored into easily excavated banks, can provide key den sites for beavers, especially as they are building up new dams and lodges in an area. Beavers are attracted to bank structure that provides scaffolding where they can excavate stable chambers in the bank. Bank structure like PALSs also provide slow-moving water along the bank that beavers prefer at their lodge entrances. Many natural beaver lodges along rivers and streams in Montana are based around large logs or log jams that have accumulated along steep banks, and PALSs mimic these accumulations of wood.

2) Channel-spanning and mid-channel PALSs can be used in a similar manner to BDAs, creating scaffolding beavers can use to construct strong dams that are resistant to blow-outs during high water. Natural beaver dams are often built on some sort of mid-stream structure, whether that is a fallen log, large rocks that stick up above the water's surface, or a small island of vegetation (Figure B2 from Appendix B). PALSs can mimic these natural, attractive dam-building sites.

Figure C5. Examples of the various forms and functions of Post-assisted Log Structures (PALSs). Figure from Shahverdian et al. (2019).

Using LTPBR to make a restoration site attractive to beavers

If there is no existing beaver population in a restoration area, and the goals of the project are to establish self-sustaining beaver colonies, then practitioners will either be looking to attract dispersers to the restoration site (see Appendix D - Encouraging Natural Colonization) or capture and move beavers to the site (see Appendix E - Beaver Transplantation). These two topics are covered in detail in the next two appendices. Even though the avenue through which beavers arrive at the restoration site is very different between encouraging natural colonization and transplantation, the underlying principles for increasing success are the same.

In both the natural colonization and transplantation scenarios, providing starter infrastructure in the form of BDAs and human-built lodges and associated deep water refugia for beavers will greatly increase the chances of successful colonization by beavers and subsequent establishment of a self-sustaining beaver population in the restoration area. Both scenarios involve determining which section or sections of stream have sufficient resources for beaver colonies and establishing BDAs and human-built lodges in those sections to retain any beavers that end up at the site, whether they get there naturally or are released there by humans.

One of the most important factors is the creation of dam *complexes* (i.e., a series of dams that back up water and sediment to the base of the next dam upstream), and not just one or two BDAs and a single human-built lodge. Practitioners should provide beavers lots of options for where the core of future beaver colonies will be, then defer the final decision to the beavers. What may appear to be ideal habitat to practitioners may not be so attractive to beavers, and there are many things we do not know about beaver habitat selection at the colony scale. So, the key will be to provide beavers multiple dams and lodges to choose from and let the beavers that do arrive decide where to spend their time establishing a colony.

Permitting

Beaver mimicry in the form of BDAs impounds water and affects the bed or banks of a stream and therefore require a 310 or Stream Protection Act (SPA) 124 permit. Project managers must consult with their local Conservation District for a 310 Permit if the work will take place on private land or contact FWP for a SPA 124 Permit if the work will occur on public lands. To learn more about stream permitting, see Project Planning, Permitting, or visit DNRC's website and navigate to "Licenses and Permits," then "Stream Permitting".

According to Montana Department of Natural Resources and Conservation (DNRC), as long as BDAs do not use control gates, culverts, headgates, ditches, or pipelines they typically do not require a water right. Human-made projects that pool or pond more than 0.1 acre-foot of water per structure or series of structures in close proximity may require a water right and a project manager should consult with their regional DNRC office.

The Army Corps of Engineers (ACOE) reviews BDAs under Nationwide Permit 27 (NWP-27) – Aquatic Habitat Restoration, Enhancement, and Establishment Activities. When reviewing an application, the following information and project details are required (J. Metzler, personal communication, September 23, 2022):

1. A delineation following the 1987 ACOE Manual and the appropriate Regional Supplement methods for the project areas as required by General Condition 32 Pre-Construction Notification (b)(5). The ACOE can perform the delineation if requested. However, it will be completed when there is availability.

2. A description, and if appropriate the location, of the ecological reference reach and why that reference reach was chosen. If the reference reach is based on a conceptual model, include the criteria used to show that your project is successful. From the NWP-27 text: “To be authorized by this NWP, the aquatic habitat restoration, enhancement, or establishment activity must be planned, designed, and implemented so that it results in aquatic habitat that resembles an ecological reference. An ecological reference may be based on the characteristics of an intact aquatic habitat or riparian area of the same type that exists in the region. An ecological reference may be based on a conceptual model developed from regional ecological knowledge of the target aquatic habitat type or riparian area".

3. Determine the criteria that will be used to define the project as successful and how those criteria will be monitored.

4. Latitude and longitude in decimal degrees (6 decimals places) to show areas where the projects starts and ends along the stream.

Additional Information

- The Montana Beaver Working Group (BWG) – sweigand@nwf.org (head of the BWG) or torrey.ritter@mt.gov (FWP representative for the BWG)

- Low-tech, Process-based Restoration Design Manual and other LTPBR resources; https://lowtechpbr.restoration.usu.edu/

- Chapter 6 – Beaver Dam Analogues (BDAs) in The Beaver Restoration Guidebook; https://www.fws.gov/media/beaver-restoration-guidebook

- DNRC Stream Permitting Handbook; https://dnrc.mt.gov/_docs/permits-services/StreamPermittingBinderBook2020.pdf

Appendix D: Encouraging Natural Colonization

Beaver occupancy of a project area is often the most effective and efficient form of beaver restoration because beavers can take over maintenance and expansion of damming activity after a little help from restoration practitioners. Various techniques can be used to provide the conditions needed for beavers to expand into a restoration area and create robust colonies. This can generally be done in two distinct types of sites: 1) areas that are on the periphery of established beaver colonies (marginal habitats), or 2) areas where beavers are trying to colonize suboptimal habitats and need a helping hand in becoming established and creating self-sustaining colonies.

Encouraging natural colonization can support the goals of beaver restoration by:

1) Guiding an existing beaver population into areas of suboptimal or marginal habitat to expand the area of restoration.

2) Efficiently using restoration resources by taking advantage of Montana's existing beaver populations through identifying areas where beavers can take over and perpetuate restoration investments into the future.

3) Working toward self-sustaining systems that include the suite of fish, wildlife, and plant species that make up dynamic, healthy, and resilient stream and riparian systems.

4) Working to expand areas of healthy riparian habitat from the inside out rather than targeting the worst areas first, incrementally filling in gaps in healthy stream systems and riparian habitats.

Dispersing beavers can find and colonize even remote and seemingly isolated habitats. Beavers are frequently found thriving in mountain meadows many miles from the nearest suitable habitat patch. As such, likely the greatest opportunity to promote the recolonization of historical beaver habitat lies in encouraging beavers to occupy new areas through habitat manipulation as opposed to transplantation. The most difficult aspect of this type of work is determining which areas are ready for beaver occupancy and which areas need more intensive forms of restoration before they will be ready for beavers. Additionally, practitioners must evaluate if a restoration site will be encountered by enough dispersing beavers to result in colonization within a reasonable timeframe relative to restoration actions.

Assessing the habitat potential for beavers to successfully colonize an area

Before diving into the nuances of trying to get beavers to establish dams and colonies in an area that needs restoration, it is important to get a good handle on what constitutes suitable beaver habitat. This is important because any assessment of potential restoration sites will be within the context of comparing the restoration sites to "ideal" beaver habitat and making decisions about what aspects of the site need to be restored for beavers to move in and be successful. Because beaver habitat has been described in detail in so many publications (Vore 1993, Muller-Schwarze 2011, and Pollock et al. 2017), we suggest readers consult these references to better understand beaver habitat needs before embarking on a beaver restoration project (see Table 1 in the Introduction for an overview of suitable beaver habitat).

A key feature of an area where natural colonization could be encouraged is that beavers are encountering the habitat but are not settling down. This is distinguished from areas that are suitable for beaver colonization, but dispersal barriers keep beavers from ever encountering the potential settlement site. In the latter situation, practitioners may want to consider transplantation to get beavers established (see Appendix E - Beaver Transplantation). If it is obvious, or at least very likely, that beavers are encountering the area but not settling down, then the next step is to evaluate why they are not settling down and determine if minor habitat manipulations could encourage occupancy that would lead to self-sustaining colonies, or if a more heavy-handed restoration effort is needed.

It is critical to evaluate the habitat carefully in these situations, because encouraging natural colonization often relies on artificially "propping up" beavers in an area to get them to settle long-term. This ability to choose when and where beavers settle an area is powerful, but when not used carefully can result in further degradation of habitat that may take many years, or decades, to recover. Perhaps the easiest way to articulate this is with an example.

A restoration practitioner visits an incised and degraded stream and riparian area. They notice that although the woody riparian vegetation is only growing in a narrow band right along the stream channel, the vegetation is 10 feet tall and so thick it is difficult to even see the stream. The practitioner sees this as plenty of vegetation for the beavers and knows that once the beavers build dams, they will begin to fill the incised channel with sediment. They decide to encourage beavers to colonize the area to aggrade the incised channel, raise the water table, and promote willow growth out in the floodplain. The practitioner builds BDAs and human-built lodges along the stream channel, and before long beavers show up and start building on the BDAs and using the human-built lodges. Within a year or two, the beavers have cut down a bunch of the tall willows and built up several large dams that are now collecting sediment and forcing overbank flow. It worked, right?

As the beaver impoundment grows larger, the willows along the stream upstream of the dams are inundated with water for several years, and eventually die. While some willows did start sprouting out in the floodplain, those young willows are just a few feet tall and are scattered along the periphery of the impoundments. The beavers start needing to forage further and further from the main set of dams, and given the stream is incised and simplified, they are quite vulnerable to predation outside the area of impoundment. Either due to predation or lack of forage resources near the main dams, the beavers move on and abandon the restoration site. Because the stream was incised both up and downstream of the restoration site, and the dams were not in place long enough for sediment accumulation to become a semi-permanent feature of the floodplain, the dams degrade rapidly and the stream quickly incises back through the sediment accumulations. Most of the accumulated sediment is flushed downstream and the water table drops back to its pre-beaver level. The floodplain dries out and the new willows growing far from the stream die. Because the willows that were impounded by water died as well, the stream is in worse shape than it started. This is all because the beavers were "propped up" by human intervention in an area that wasn't ready for occupancy.

How could this situation have been different? The main thing that needed to be addressed was the woody riparian vegetation. If there had been adequate vegetation away from the stream channel, the beavers could have expanded their foraging to those areas once the willows near the stream died. This would have allowed the beavers to stay longer, expand their dam complex up- and downstream, and given time for new willow growth to offset willow deaths from harvest and impoundment. Had the dam complex spread out longitudinally along enough of the stream, the dams and associated sediment accumulation could have been around long enough to "solidify," and the stream would have assumed a *new bed elevation, winding through the sediment pools behind the slowly degrading dams once the beavers left the area.*

The above example highlights the most common misuse of beaver restoration, likely because this is the most common form of degraded stream channel that practitioners seek to restore: an incised channel flowing through a dried out, perched floodplain with only a narrow strip of woody riparian vegetation along the stream channel. It is important to realize that *beavers cannot create habitat from nothing*. Beavers are very good at creating productive and ecologically rich habitats, but they need a sufficient riparian footprint to start with.

A "sufficient riparian footprint" in the context of beaver colonization refers to portions of streams and drainages where there is already some channel complexity (e.g., meanders, backwaters, side channels, tributary confluences, oxbow pools), woody riparian vegetation that extends well beyond the stream channel, and where fully built beaver dams can force at least some stream flow out onto the floodplain. It is these types of areas where beavers have the best chance of forming self-sustaining colonies.

Fortunately, these riparian footprints are generally easy to identify using aerial imagery (Figure D1). A good way to think about riparian footprints for natural colonization is that these areas are not poor habitat, but rather *suboptimal or marginal habitats*, meaning they are somewhere between wide, active floodplains with healthy riparian areas and deeply incised channels with no woody riparian vegetation.

Suboptimal Beaver Habitat = Habitats that, while not considered unsuitable for beavers, lack or have diminished resources beavers need for self-sustaining colonies. These are areas where woody riparian vegetation may be mostly (but not entirely) limited to a narrow strip right along the stream channel or where woody riparian vegetation is located away from the stream channel (i.e., > 30 m). In suboptimal habitats, there may also be a mismatch between the size of stream that must be dammed and the size of woody riparian vegetation available for construction. As a stream gets more powerful, larger diameter trees and shrubs are needed for dam building. Inadequate building materials, combined with low to moderate amounts of channel incision, may prevent natural beaver dams from lasting through high-water periods.

Marginal Beaver Habitat = Marginal habitats are generally also classified as suboptimal habitats, but are distinguished as being habitats that are on the upstream or downstream end of existing beaver-modified habitats or other areas that are generally healthy riparian areas with active, well-connected floodplains. These areas are ideal sites to encourage colonization because on at least one end of the restoration area there is suitable beaver habitat that can form the core of an active beaver colony and ideally can support robust dams and lodges. Beavers can repeatedly build dams and lodges in the marginal areas while still maintaining viable infrastructure in the main part of the colony nearby. This allows beavers to continually work on the marginal habitat while not necessarily *needing* that marginal habitat to sustain their colony and keep them in the area.

Figure D1. Examples of riparian footprints (outlined by white brackets) that were subsequently colonized by beavers in Montana. These areas are relatively easy to identify using aerial imagery and can most simply be defined as areas along a stream where the riparian vegetation extends well beyond the stream corridor and where channel complexity exists in the form of meanders, side channels, tributaries, or backwaters. Photos by Google Earth.

Figure D1. Continued. Photos by Google Earth.

Some good signs of appropriate suboptimal or marginal habitats for encouraging natural colonization by beavers are:

- Sign of attempts by beavers to occupy the area in the past, such as old dam berms, heavy clipping areas, or old lodges and bank dens. Blown-out dams are a good sign that the dams are not lasting through runoff, but that the area is otherwise suitable for beavers (see Figure B4).

- Woody riparian vegetation that extends at least 30 feet laterally from the stream channel, or at least does not consist of a single row of plants right along the stream channel that would be easily flooded by beaver damming activity (Figure D2). Alternatively, robust patches of woody riparian vegetation that, while potentially not right along the stream channel, are located within 100 feet of the channel so they are accessible to beavers for dam-building.

- An area that is not surrounded by heavily degraded sections of stream on the up- and downstream ends. A stream will almost always return to the lowest bed elevation in a given reach, so attempting to recover a small patch of incised stream within a broader incised stream channel will almost never result in self-sustaining colonies and permanent recovery of beneficial natural stream processes.

- A stream that, while it may be incised, is not so incised that even a channel-spanning dam will not allow a significant amount of water to escape the stream channel and spill out onto the floodplain. If this level of floodplain connection cannot happen, the dams are almost certain to catastrophically blow out in such a way that they do not lead to desired restoration outcomes. Beavers can be encouraged to colonize severely incised streams, but the system will still need a lot of help from restoration practitioners to reach the self-sustaining state. This situation is highly relevant to the difference between the first two bullet points on pages 41 and 42 of the main text (i.e., bed aggradation vs. forced widening), which highlights the need for practitioners to describe and plan for the process pathways through which they expect their actions to restore an incised stream channel (Nash et al. 2021).

Figure D2. An area with sufficient woody riparian vegetation for a self-sustaining beaver colony (panel A) vs. an area with insufficient woody riparian vegetation for a self-sustaining beaver colony (panel B). Note also the extensive green vegetation in the floodplain in panel A, suggesting a less severe incision issue than what is shown in panel B. It is always important to remember that woody riparian vegetation that is flooded above the root crown by beaver damming will die within a few years. So although there may appear to be plenty of woody riparian vegetation along the stream bank to start, much of that will be lost to harvest or flooding relatively quickly if beavers settle in the area. This emphasizes the importance of woody riparian vegetation that extends away from the stream channel for beaver occupancy and success in an area. Photos by Google Earth.

Assessing the potential for beaver dispersal into the project area

Once an evaluation of appropriate habitat for beavers has been completed, the next step is to evaluate the potential for beavers to find and occupy the site naturally. A variety of studies have demonstrated that beavers can disperse long distances and travel through poor or entirely unsuitable habitat to reach a settlement site (Beer 1955, Libby 1957, Hibbard 1958, Nelson and Nielsen 2010, Ritter 2018). However, shorter dispersal distances are much more common (Table D1). Beavers have been observed traveling over land on their dispersal routes, traveling through > 6 miles of unsuitable habitat, and passing through many seemingly suitable colony sites before settling down. We clearly still have much to learn about how and why beavers disperse the distances they do, and why they choose to settle down in particular areas (Ritter et al. 2019).

Table D1. Dispersal distances for beavers reported in North America, 1955−2010.

Authors	Location	Distance Type	Mean dispersal distance (miles)	Range (miles)
Ritter (2018)	Montana	Stream	6.8	1.2−26.3
Beer (1955)	Minnesota	Stream	14.1	0.3−51.0
Leege (1968)	Idaho	Straight-line	5.6	2.8−11.3
Van Deelen and Plestcher (1996)	Montana	Stream	5.2	1.8−13.8
McNew and Woolf (2005)	Illinois	Straight-line	3.7	0.6−13.0
DeStefano et al. (2006)	Massachusetts	Stream	2.9	0.3−7.1
Nelson and Nielsen (2010)	Illinois (Southern)	Straight-line	2.5	max 8.7
Nelson and Nielsen (2010)	Illinois (Northern)	Straight-line	8.7	max 154

The dynamics of beaver dispersal are complex and involve a web of interactions scientists are just barely beginning to untangle (see review in Ritter 2018). For some general guidelines based on previous studies of beaver dispersal (Table D1), if a restoration site is within approximately 4 miles straight-line distance of other active beaver colonies, it is likely dispersing beavers are frequently encountering the site and it may therefore be an appropriate site to encourage natural colonization. Multiple lines of evidence should be used to determine if beavers are dispersing through the area, including on-the-ground surveys to look for previous beaver sign and interviews with people who know the area well to see if they have memories of beavers trying to settle in the area.

It is also important to use aerial imagery or on-the-ground investigations to determine if the active colonies within 4 miles of the restoration site are seemingly healthy and likely producing dispersing beavers. If those colonies are recently abandoned, then it is unlikely they will be producing dispersers in the near-term that are willing to travel and settle in suboptimal/marginal habitats (i.e., the types of habitats where a beaver restoration project would be taking place). Another situation to watch out for is active colonies where it appears the beaver activity has contracted into a much smaller area relative to the overall beaver-modified habitats. This often happens when beaver families lose a significant number of family members, leading to an inability by the remaining beavers to keep up with maintenance of the colony infrastructure. Offspring in these situations will often stick around to “fill in” the space left by the lost family members rather than dispersing to new sites nearby.

An assessment of dispersal potential should also include identifying possible dispersal barriers between source colonies and the restoration site. Complete barriers to dispersal for beavers are rare, and more often dispersal barriers for beavers are movement impediments that are substantial enough to cause very few beavers to reach an area rather than causing no beavers to reach an area at all. An incomplete dispersal barrier can still represent a major hurdle to encouraging natural colonization because a successful beaver colony requires that a male and a female find the same spot, survive, reproduce, and continue to expand the colony boundaries while producing offspring that will likely try to settle nearby. Therefore, a potential restoration site where beavers could be encouraged to settle should be assessed to likely have a *consistent* supply of dispersing beavers and not just be technically within the dispersal range of an active colony.

In addition to obvious dispersal barriers such as waterfalls, hydroelectric dams, canyon sections, long distances of poor habitat, and dewatered streams, dispersal barriers can also come in the form of habitat sinks. These are areas where dispersing beavers may get “hung up” before reaching the restoration site. Beavers may be continually drawn into higher quality habitat along the dispersal route, may settle repeatedly in an area with heavy predator presence (both natural and human predators), or may settle in an area where they conflict with human interests and are repeatedly removed. In the latter situation, non-lethal conflict management may be a way to mitigate the effects of a dispersing beaver sink (see Appendix A - Conflict Management). In the other situations, it may be difficult to do any sort of management to keep that dispersing segment of the beaver population in the area and therefore encountering the restoration site where practitioners are trying to get them to colonize.

Aerial imagery is a powerful tool to evaluate potential dispersal routes between source colonies and a restoration site. Quality beaver restoration projects will have demonstrated that a thorough assessment of dispersal potential was completed ahead of time.

If the potential restoration site is > 4 miles from the nearest potential source colony, and/or major dispersal barriers have been identified, then practitioners may want to assess the possibility of transplanting beavers to the restoration site (see Appendix E - Beaver Transplantation). Regardless of how the beavers get there, habitat manipulations will likely be necessary to entice beavers to settle in the restoration site and to provide them the conditions and resources necessary to form long-term and self-sustaining colonies (Pollock et al. 2017, Brick and Woodruff 2019).

Habitat manipulation to encourage colonization (e.g., BDAs and human-built lodges)

When suitable habitat for encouraging natural colonization has been identified that is within the dispersal range of a source colony or colonies, the next step will be manipulating the habitat to encourage beavers to settle in the area. Many strategies to encourage colonization by beavers are inherent in common riparian restoration techniques. For example, using low-tech, process-based restoration techniques (Wheaton et al. 2019) to restore natural stream processes that can lead to recovery of riparian vegetation and floodplain connectivity that supports self-sustaining beaver colonies.

Other examples of supportive restoration actions include:

- Building BDAs to create attractive settlement sites for dispersing beavers or to encourage colony expansion in a direction the beavers may not have chosen naturally.

- Structurally supporting existing, natural beaver dams that are prone to blow-outs due to channel incision or other habitat issues so that those dams last long enough to achieve desired restoration benefits.

- Planting willows and other woody riparian vegetation to keep beavers from running out of forage and construction materials before their activities promote enough riparian vegetation regeneration to keep up with beaver harvest.

- Inclusion of human-built lodges or log jams to provide shelter for beavers starting out in new areas. PALSs may be an effective technique for this (see Appendix C - Beaver Mimicry), though they should not be used solely for providing beaver shelter as there is not sufficient evidence of their benefits in this context.

- Temporary or voluntary trapping closures to maintain the beaver population in an area at a level that promotes dispersal and/or colony expansion (see Appendix B - Land Management Changes, Trapping Regulations).

The most efficient and effective way to encourage natural colonization of an area is to provide "starter infrastructure" within the restoration area that dispersing beavers can discover and use to their advantage. Research on beaver dispersal and settlement strongly suggests that dispersing beavers will almost always settle in an abandoned or relic beaver colony rather than start a colony from scratch (Smith 1997, Sun et al. 2000, Ritter et al. 2019). Additionally, beaver transplant efforts in other states have universally shown that starting infrastructure greatly increases the chances of beavers remaining at the release site (Pollock et al. 2017, Brick and Woodruff 2019).

Presumably, it is much easier and safer for beavers to repair old dams and lodges than build new ones. The beavers have critical shelter in the form of old beaver infrastructure while they rebuild and the time it takes to get a fully functional colony up and running will be much less than starting from scratch. These findings suggest that the best way to encourage beavers to occupy an area of marginal or suboptimal habitat is to essentially create a human-built imitation of an abandoned colony.

Creating a human-built abandoned colony

Abandoned beaver colonies consist of old dams, lodges, channels, and bank dens that are in a state of decay. The level of decay likely has a strong influence on how attractive the site is to dispersing beavers. The level of decay is a function of the time since abandonment as well as the amount of damage previous structures sustain during severe weather and high-water periods. Restoration practitioners seeking to attract beavers to a restoration site should attempt to provide as much and as robust of infrastructure as possible to make their human-built abandoned colony the most attractive settlement site within the dispersal range of the nearest source colony or colonies.

Human-built Dams

BDAs, while a restoration technique in and of themselves (see Appendix C - Beaver Mimicry), are also ideal structures for mimicking an abandoned beaver dam that beavers will want to build on. Site placement is important. The best sites are where beavers naturally build dams, at the tail-out of pools and on riffle crests and in association with midstream structures like rocks, logs, or even the wooden posts used to create the BDAs. Practitioners should consider what will be flooded upstream of the dam site and try to position BDAs so that any bank dens, logs jams, human-built lodges, or other potential cover for beavers are not completely flooded out by the ponded water.

If stream incision is an issue in the project area and there is sign of recent or historical beaver dams that have been completely blown out, then BDAs or other dam-like structures should be made extra strong to help beavers overcome the damaging flows of high-water events. If there is sign of blown-out dams *and* existing beaver dams in the project area, then existing dams can be reinforced with posts driven into the streambed or supported by BDA construction up and/or downstream of the natural dams. All these techniques are meant to allow beaver dams to survive multiple runoff cycles and acute flood events, which provides the beavers a stable "home base" from which they can expand their existing colonies and/or colonize new areas.

Human-built lodges and dens

There are many designs for human-built beaver lodges, ranging from very simple piles of wood overlapping the stream channel, to more sophisticated “Lincoln-log” structures with covered tunnels leading to the water (Figure D3). Human-built lodge design and placement should be carefully coordinated with any BDAs and probable initial settlement site locations to make sure they will not be immediately flooded out once the BDAs back up water or are repaired by beavers.

Figure D3. Dispersing beavers are highly attracted to previous beaver infrastructure like dams and lodges when they are looking for a place to settle down. Restoration practitioners who want beavers to occupy their project site can take advantage of this by providing artificial dams and lodges that can encourage beavers to settle by providing shelter and saving the beavers time and energy in building up their colony. Panel A: Beaver dam analogues (BDAs) mimic natural beaver dams and provide a starting structure for beavers to build on. Panel B: Human-built lodges made from logs can provide shelter for transplanted beavers or can be constructed to provide shelter in a restoration area to encourage dispersing beavers to settle. Panel C: Human-built lodges can be crude and just need to have a chamber and overhead cover so the beavers feel secure, then the beavers can easily modify the rudimentary lodge to fit their needs. Panel D: Existing beaver dams that are at high risk of blowing out due to high stream power or channel incision can be strengthened by driving wooden stakes into the dam structure, making it strong enough to survive runoff and providing in-stream structure for beavers to improve or repair the dam as needed. Photos from Wheaton et al. (2019) and Brick and Woodruff (2019).

Supplemental feeding

A variety of projects, mostly centered around beaver transplants, have involved bringing in woody riparian vegetation from off-site for beavers to eat and use in the restoration area (FWP 2010, Pollock et al. 2017). This should only be done under rare circumstances where there is sufficient woody riparian vegetation at the site, but where beavers need to build up their dams and channels before they can easily access that vegetation. Supplemental feeding should never be used as a replacement for natural woody riparian vegetation, as this often represents an example of propping up beavers in an area where the habitat is not yet ready for them (see inset on page 122). If, when beavers fully dam an area, there is still not sufficient woody riparian vegetation for them to make it on their own without supplemental feeding, then that is a clear indication that other forms of restoration need to be implemented in the area before beavers can be expected to successfully colonize the site.

Permitting

There are no dedicated permits for encouraging natural colonization by beavers, but several of the associated techniques require permits. Construction of BDAs, supporting existing beaver dams, planting of woody riparian vegetation, and trapping closures all require permits that are covered in other sections of this document (see Project Planning, Permitting). Please reference those sections for specifics on permitting for these various beaver restoration activities.

Additional Information

- The Montana Beaver Working Group (BWG) – sweigand@nwf.org (head of the BWG) or torrey.ritter@mt.gov (FWP representative for the BWG)

- The Beaver Restoration Guidebook: https://www.fws.gov/media/beaver-restoration-guidebook

Starter beaver dam on a side channel of the Clark Fork River

Appendix E: Beaver Transplantation

Beaver transplants can be an effective technique for re-establishing beavers in areas of their former range. Many states in western North America have well-developed beaver transplant programs and a long history of transplanting beavers to help restore stream systems and alleviate damage complaints. However, the science of transplanting beavers is not well-developed and there is still much to learn about why some beavers settle where they are released and others leave the area entirely. In general, beaver transplants can support the goals of beaver restoration by:

- Re-establishing beavers in areas of their former range that are isolated from potential source colonies and/or are rarely encountered by dispersing beavers.

- Assuring beavers encounter a restoration site in a timely manner, which may be especially important if the restoration area is distant from source populations or if the viability of pre-transplant restoration techniques (e.g., BDAs) are time limited.

- Helping deal with beavers that have come into conflict with people by moving the beavers to an area where their efforts can be beneficial, relieving the conflict issue while promoting restoration where it is needed.

The success rate of transplanting beavers, where "success" is generally defined as beavers establishing a colony near a release site for at least one year, is often less than 50% (McKinstry and Anderson 2002, Babik and Meyer 2015, Petro et al. 2015, Brick and Woodruff 2019; review in Pollock et al. 2017). When transplanted beavers are released into areas where BDAs, human-built lodges, plantings, and other site preparations are done before the release, the success rate is higher, but still rarely exceeds 60% (Babik and Meyer 2015, Brick and Woodruff 2019). Transplanted beavers generally suffer high mortality rates (McKinstry and Anderson 2002, Petro et al. 2015), leave the area to settle in suitable habitat elsewhere (Babik and Meyer 2015, Brick and Woodruff 2019), or leave the area and settle on adjacent lands where they may come into conflict with humans. Because of this low success rate, transplants should only be used in specific situations and only after a thorough analysis of the restoration site has concluded that natural colonization is unlikely.

Beaver transplants can be a time-consuming and difficult endeavor. FWP therefore encourages practitioners to think of beaver transplants as a last-resort measure when beavers cannot be encouraged to occupy the area naturally and when all necessary restoration activities have been completed to make the site as suitable as possible, thus maximizing the probability of success.

There are three main scenarios where beaver transplants may be feasible:

1) **Dispersal Isolation:** The transplant site is isolated from source colonies by potential dispersal barriers. If it is likely dispersing beavers can reach the proposed restoration site consistently, there may be no need to transplant since the lack of beaver colonization is likely reflective of poor habitat or possibly a low beaver density in the area (see Scenario 2 below). Aerial imagery or flights can be used to conduct preliminary beaver surveys by looking for dams and associated impoundments (see Monitoring and Maintenance, Table 2). Such surveys can then be used to evaluate the potential for beavers to disperse into the

project area from nearby source colonies, mediated by estimated dispersal distances from other studies (Table D1).

2) **Low Beaver Density Relative to Habitat:** The transplant site is located in an area with a very low density of beavers relative to available, suitable habitat for colonization. In general, these areas may not need beavers for restoration, but it may be a suitable place to move beavers in conflict situations where the landowner does not want the beavers lethally removed. This definition does not encompass areas where beavers are at a low density because of natural succession of beaver-modified habitats. For example, in areas where beavers abandoned a colony due to silting in of ponds or lack of preferred vegetation from long-term occupancy. Aerial imagery surveys combined with the Beaver Restoration Assessment Tool can be used to assess how much available habitat in the area may be suitable for beavers and how much of that habitat is actually occupied by beavers. On-the-ground surveys will likely be needed to assess possible reasons for low beaver density (i.e., habitat succession or simple lack of beavers).

3) **Beavers are Needed for Restoration:** Restoration actions or structures are dependent on beaver occupancy for long-term success. For example, when beavers need to build on BDAs before they naturally degrade. Transplants may be a viable option in these situations because the beaver population needs to reach a certain density before dispersers are forced to settle in sub-optimal/marginal habitats that generally characterize restoration reaches. Beavers may be needed at the restoration site as soon as possible because their work is required for maintaining and improving BDAs or other in-stream structures before the structures naturally degrade. Often, BDA projects involve building dozens of structures at once, and a small existing beaver population may not have the numbers needed to attend to all those structures. On-the-ground beaver surveys should be used to determine more precisely the extent of existing beaver activity in the drainage to determine if supplemental beavers would be needed.

FWP Approval Process for Beaver Transplant Projects

Since beavers are a state-classified furbearer, they are considered a game animal and are under the management authority of FWP and the Fish and Wildlife Commission. An individual person or organization cannot move beavers for transplant purposes without approval of the Fish and Wildlife Commission, requiring close partnership with FWP staff. Therefore, whether a project moves forward will depend heavily on if local FWP staff have the time and latitude within their position to make such a project a priority. Agency or individual collaboration with local FWP wildlife and fisheries biologists on any proposed transplant is a required step for project approval and success.

The current FWP beaver transplant policy within the state reflects state statute and is similar in requirements used for other wildlife species. Beaver transplants require compliance with the Montana Environmental Policy Act and approval from the Fish and Wildlife Commission. In seeking approval for a beaver transplant project, practitioners must be able to demonstrate both that transplanting beavers will not cause any major, un-mitigated, negative environmental impacts and that the project area is covered under one of the three situations outlined above (i.e., dispersal isolation, low beaver density relative to habitat, beavers are needed for restoration). A beaver transplant project must include:

1) An assessment of the suitability of the release site in terms of surrounding landowner tolerance including a plan for mitigating potential conflict situations. The Beaver Restoration Assessment Tool can provide an overview of potential conflict issues in the area (see BRAT inset in Introduction).

2) A thorough assessment of habitat suitability at the release site demonstrating appropriate habitat for beaver colony establishment and persistence (see Project Planning). Practitioners must be able to demonstrate that beavers will be able to establish a colony at or near the release site and remain in the area for at least several years. Fairly simple evaluation forms can be used to assess potential release sites for habitat suitability (Figure E1). Release sites should be treated like areas where practitioners want to encourage natural colonization (see Appendix D - Encouraging Natural Colonization), and therefore should be supplemented with BDAs and rudimentary lodges if such structures are not already available in the project area.

3) An adequate timeframe to determine an appropriate source site for beavers. A source of beavers to transplant must be available within the same watershed (HUC 8 level) to minimize potential disease transmission, lessen the risk of spreading Aquatic Invasive Species to new areas, and avoid unnatural genetic mixing. Plans should also address how many beavers would be moved into an area, over what timeframe, and contingencies for transplanted beavers doing exceptionally well (potential conflicts develop) or poorly (beavers do not colonize the site).

4) An established protocol for trapping and transporting beavers to the release site (see Protocol for Transplanting Beavers in Montana below).

5) Preparation of an Environmental Assessment (EA) that speaks directly to the breadth of considerations outlined in the main body of this document. The EA process must include an appropriate public comment period and culminate with the issuance of a Record of Decision (ROD). Then, the project will need to be presented to, and vetted by, the Montana Fish and Wildlife Commission, who have the authority to approve or deny the project.

Statute 87-5-702* – *Definitions
(11) Transplantation is defined as the release of or attempt to release, intentional or otherwise, wildlife from one place within the state into another part of the state.

Statute 87-5-711* – *Control of importation for introduction and transplantation or introduction of wildlife.
(1) Except as otherwise provided, the importation for introduction or the transplantation or introduction of any wildlife is prohibited unless the commission determines, based upon scientific investigation and after public hearing, that a species of wildlife poses no threat of harm to native wildlife and plants or to agricultural production and that the transplantation or introduction of a species has significant public benefits.*

Statute 87-5-714 – **Wildlife species authorized for introduction or transplantation**
*(2) The commission may by rule and subject to the provisions of **87-5-711** authorize the department to transplant or introduce species of wildlife not listed in subsection (1)*.*

*Beavers are a state classified game animal (furbearer) and are not included in the list (87-5-714) of species allowed to be transplanted. Therefore, they require Fish and Wildlife Commission approval with an associated EA and ROD.

Appendix B

Methow Beaver Project

Release Site Score Card Date___________________

Site ID_________________________ Observer____________________

GPS Coordinates_UTM (NAD 83)__________________________ Subwatershed_________________________

Lat Long_____________________________ Location Description_________________________________

Stream Gradient of the defined habitat unit

_______ **5.** ≤3% **3.** 4-6% **1.** 7-9% **0.** ≥9%

Stream Flow **Min (fall)**

____

	garden hose	fire hose	30" culvert	un-wadeable
garden hose	1			
fire hose	3	4		
30" culvert	4	5	5	
un-wadeable	1	2	1	0

Max (spring)

Habitat Unit Size (stream length)

_______ **5.** Extensive stretch of the stream **1.** Small isolated pocket

Woody Food

a. **3.** Aspen, willow **2.** Alder **1.** Other hardwoods

b. **3.** Within 10 meters **2.** Within 30 meters **1.** Within 100 meters

c. **3.** Large amount (thousands of stems) **2.** Some (hundreds of stems) **1.** Little (dozens)

_______ **Woody food score = multiply a x b x c**

Herbaceous Food

_______ **3.**Grass/Forbs Present **0.** No Grass/Forbs Present

Floodplain Width

_______ **5.** Wide stream bottom **0.** Narrow V Channel

Dominant Stream Substrate

_______ **5.** Silt/Clay/Mud **2.**Sand **1.** Gravel **0.** Cobble **-1.** Boulders **-3.** Bedrock

Historic Beaver use

_______ **10.** Old structures present **0.** No indication of previous occupancy

Lodge and dam building materials

_______ **5.** A variety of 1-6" diameter woody vegetation avail. **-10.** no building material present

Browsing / Grazing impacts

_______ **5.** No Impact or obvious presence of browsers / grazers **(-10).** Heavy browsing / grazing impact.

_______ Bonus: (5 points each) 1. Easy Access. 2. Recent fire. 3. No conflict with human values. 4. Existing aquatic escape cover. 5. Landowner / user enthusiastic

_______ Total Score

Narrative description of site and notes/ Photo ID# / sketch on back:

Figure E1. Beaver transplant site evaluation form from the Methow Valley Beaver Project (Brick and Woodruff 2019). This form is fairly simple, and a more in-depth analysis of the site will be required during formulation of an Environmental Assessment. However, this is a good form for gathering initial data on potential release sites and comparing multiple sites in a drainage or region prior to a formal proposal.

FWP understands and is supportive of the conservation benefits beavers provide. Several beaver transplant efforts to date include the Upper Missouri Watershed Beaver Relocation Project (FWP 2010) and Reservoir Creek Beaver Restoration Project (FWP 2018). In these projects, FWP biologists worked with private landowners to assess the viability of the project, established specific projects goals, and conducted a comprehensive EA that was presented to the Fish and Wildlife Commission. As with most wildlife species, moving beavers is a complex process and can bring unintended consequences. Therefore, transplants will only be used as a management tool when ideal circumstances are presented.

Montana Beaver Transplant Policy

While FWP does not have an official policy in place for transplanting beavers, a Proposed Policy was included in the 2018 EA for the Reservoir Creek Beaver Restoration Project, which was approved by the Fish and Wildlife Commission. This Proposed Policy outlines the procedures used in FWP-initiated projects. The Proposed Policy outlined below has been updated from the original version published in the EA for the Reservoir Creek Beaver Restoration Project to provide more detail and to better outline appropriate conditions for beaver transplants in Montana.

<u>BEAVER POLICY (PROPOSED)</u> (1) The following procedure will be used in transplanting beaver (*Castor canadensis*) in Montana:

(a) Beavers, for all transplants in Montana, shall be wild-trapped from existing populations as approved by the Fish and Wildlife Commission. Source populations should be large and expansive so that removal of beavers for a transplant effort will not cause a measurable change in the local population at the source colony or colonies. Alternatively, and preferably, transplanted beavers will be captured from areas where they conflict with human infrastructure, in which case removal of as many beavers as possible will most often be the goal.

(b) Proposed beaver transplants will be investigated by a local FWP wildlife biologist (area game biologist or regional nongame biologist). An evaluation of the proposed release site will be conducted that includes a biological reconnaissance indicating suitability of the area with reference to habitat requirements of beavers. The evaluation shall be reviewed by the local fisheries biologist to provide recommendations concerning the proposed transplant. This may include a recommendation of non-viability if the proposed project threatens conservation populations of fish or other aquatic life.

(c) A signed statement of landowner concurrence from the proposed beaver removal area and the transplant site. Signed statement documents are the responsibility of the party requesting the beaver transplant. The project lead will contact neighboring landowners within 4 miles up- and downstream of the release site to notify them of the project and address concerns. Practitioners are encouraged to reach out to landowners in immediately adjacent drainages as well if they are within reasonable dispersal distance for beavers.

(d) An environmental assessment (EA) is required to evaluate any impacts of the proposed transplant and to notify and solicit comments from the public, municipalities, and government agencies. The EA and comments will be developed and evaluated by FWP staff, and a Record of Decision (ROD) will be issued by the Regional Supervisor in the FWP Region where the work will take place. The EA, public comment, and ROD will be provided to the Fish and Wildlife Commission for their decision-making process and final action.

(e) Beavers will not be transplanted into areas where beavers already occur except under specific circumstances:

   a. Transplants may be used in areas where BDAs are constructed *with the explicit goal of encouraging beaver occupancy*. In these situations, the project may be more successful if beavers take over maintenance of the structures before they naturally degrade. Evidence for this type of situation would be when beaver activity surveys in the project area show that the existing beaver population is small and therefore may be incapable of producing enough dispersal-age beavers to fill in the habitat created by the BDAs within the lifespan of the BDAs. Careful attention must be paid to habitat conditions, and suitable woody riparian vegetation should be established in the project area before any transplants are undertaken in these circumstances.

   b. Transplants may be used as a method to alleviate beaver conflict issues when the conflict beavers can be moved to an area with plenty of unoccupied, suitable habitat and minimal chances of conflict situations developing. Alternatively, this type of transplant can be done if a landowner or set of landowners have requested beavers on their property and they are willing to take on the responsibility of dealing with any resulting beaver conflicts that may arise.

   c. Transplants may be used to augment an existing beaver population that has experienced dramatic declines due to trapping, predation, disease, or some other impact. Beavers shall not be transplanted into populations where disease is confirmed or highly suspected to be the cause of a die-off.

   d. Transplants may be used by landowners whose ownership encompasses an entire stream length or whose ownership of a stream corridor is only shared with: a) public land management agencies that have also signed off on the transplants, or b) other private landowners who have signed off on the transplants.

(f) Transplants shall be conducted from July through October. A record of all transplants, including date captured and date released, number planted, sex, age, weight, tag types and ID numbers, locations of release site and source of stock, and any health screenings will be maintained by FWP. Genetic material may be collected and archived for future evaluations of transplant success including dispersals.

(g) Only beavers that appear healthy and are from healthy populations will be transplanted. Captured beavers will undergo a health screening whereby they are examined for evidence of illness or disease. If possible, blood samples will be taken to test for tularemia, and no beavers will be transplanted if they are seropositive for the bacteria. Beavers that are seropositive for tularemia will be euthanized if they are symptomatic or can released back at the point of capture if they are asymptomatic.

Protocol for Transplanting Beavers in Montana

In addition to the proposed policy above, the following protocols outline more detailed aspects of beaver transplants that are required in Montana. If practitioners are at this point, it is assumed they have done the necessary background work to:

- Identify a release site or release sites that are biologically and socially suitable for beavers.

- Identify healthy source colonies where beavers can be removed without causing significant environmental harm (i.e., very large colonies or conflict situations).

- Demonstrate that natural colonization is unlikely or is unlikely to occur within the needed timeframe for the project.

- Identify neighboring landowners that may be affected by released beavers and conduct outreach to determine project palatability among neighbors.

There are several resources available for comprehensive guidance on capturing, holding, and transporting beavers for transplant efforts. The following protocols are specific to efforts in Montana, but do not cover the breadth of methods and considerations involved with beaver transplants. We recommend practitioners review “Chapter 5 - Relocating Beaver” in the Beaver Restoration Guidebook (pp 64-84 in Pollock et al. 2017) for a complete overview of all aspects of beaver transplants. The protocols in Chapter 5 were developed to facilitate successful beaver transplants. While deviation from some of these protocols may be required under certain circumstances, adhering to these protocols, when possible, will improve the chance of successful transplants. Successful transplants can help garner support for beaver transplants and pave the way for future projects within the state.

Trapping Period

Beavers live-trapped for transplant purposes will only be trapped outside of the reproductive season:

- Breeding = November - March
- Gestation = approximately 100 - 130 days
- Birth = March - July

Given these dates, a conservative live-trapping period for beaver colonies in Montana would run from approximately July 1 through October 31. If it can be demonstrated that the target beaver is a lone beaver or a beaver pair that are not yet raising young, then the timing of trapping is less of a concern, and the beaver(s) could be trapped and transplanted any time of year outside the heart of winter. In most years, the “heart of winter” is approximately December 1 through February 28. It may be difficult to determine if a beaver or beaver pair is without young unless it is known when the beavers established the colony. If the colony was established in the same year as when the beavers would be trapped and relocated, it can then be assumed there are no young in the colony. As a conservative approach, beavers should only be live-trapped and relocated outside of the July 1 – October 31 season if it is a conflict situation.

Live trapping of beavers will only occur under the authority of FWP, either by FWP personnel or by trappers permitted by FWP for such activities. Trapping conducted outside the Montana furbearer trapping season will require approval by the Fish and Wildlife Commission as part of the EA process. Any trapping operation outside the furbearer trapping season will require thorough signing of the area to warn the public of the presence of traps. Signs must be at least 8” x 11,” printed on bright orange or red paper that will be resilient to weather, and posted every 150-300 feet (depending on site distances and the presence of trails) in a perimeter around the area where traps are placed.

Traps and Trappers

Those conducting live-trapping operations shall have experience live-trapping beavers or will be under the guidance of an experienced trapper. Suitable live traps include suitcase-style traps (Hancock), cage traps (Tomahawk, Hav-a-Hart), or modified cable snares (McNew and Woolf 2005, Ritter 2018).

Trap Checks

Live traps will be set as late in the afternoon/evening as possible and checked as early as possible the following morning to reduce non-target captures and to minimize stress and predation risk for captured beavers. Live traps shall not be set unless the trapper can monitor the traps under this schedule. Traps will be closed during the day to avoid non-target captures. Beavers should not be confined by traps in extreme cold (< 20° F) or extreme heat (> 80° F) (Petro et al. 2015). Captured beavers at rest can start to shiver at 32° F (MacArthur 1989), so if beavers are kept from being active (e.g., in a cage trap), then trapping should not occur at temperatures less than approximately 30° F. Live trapping beavers in areas within the known range of grizzly bears requires consultation with, and approval from, the regional FWP bear biologist. This may require a written plan for minimizing the potential for negative interactions with bears.

Animal Transfer and Transport

Captured beavers will be transferred from the live trap to a transport cage that is large enough for the beavers to turn around. Beavers should not be placed together in a transport cage or the eventual holding facility unless they can be monitored closely to make sure they tolerate one another’s presence. Even beavers from the same colony can become aggressive towards one another under the stress of captivity. Catch poles or “beaver bags” (Beaver Restoration Guidebook, pp 73-74) may be needed to move and manipulate beavers for transport and transfer to a holding facility.

Once captured, beavers need to be kept cool and calm. Cover the transport cage with a cloth to keep beavers calmer. Practitioners should be aware of the potential for over-heating with a covered cage. The transport cage should have ventilation to allow air flow and prevent trapping body heat inside. Secure bags of ice to the tops and/or sides of the transport cage to keep the beavers cool. Holes should be poked in the bags to allow water to drip onto the animals. Alternatively, the animal(s) can be sprayed with water to keep them wet if overheating is a concern. In hot temperatures (i.e., > 80° F), a fan might be warranted to improve evaporative cooling. Beavers should always have access to shade.

People involved with the capture and transport process should work quickly and quietly to minimize stress. Personal Protective Equipment (PPE) is required when handling and working with beavers, their excrement, and their housing to avoid disease/parasite transmission.

Quarantine

Once captured, beavers need to be kept in a holding facility for at least 24 hours, but beavers can be held for up to several weeks if needed and if holding facilities are not causing significant stress or injury. Beavers must be held temporarily for several reasons:

- To allow time to capture the desired number of beavers for the transplant or, if an entire beaver family is to be moved, allow enough time to capture all the individuals in the colony.
- To allow time for any potential Aquatic Invasive Species (AIS) to be removed via drying, defecation, and grooming (see AIS protocols below).
- To allow for sample collection and subsequent disease screening by the state wildlife veterinarian.

In addition to these reasons for holding beavers, there is some evidence that temporarily housing beavers results in a greater probability that they will colonize the release site or at least remain close to the release site (Tippie 2010, Petro et al. 2015). Similarly, moving beavers as mated pairs or entire family units also seems to increase success of transplants (Pollock et al. 2017). Housing beavers allows them to be absent from their home colony long enough to disassociate from their original territory and remain safe from predation risk.

Holding Facilities

Holding facilities (see inset below) should be constructed in consultation with the FWP wildlife veterinarian and should be developed using best management practices (Pollock et al. 2017). Holding facilities should consist of materials that can be easily replaced or thoroughly disinfected. Beavers should have access to cover (e.g., a kennel or other enclosed environment), water (e.g., small swimming pool or pond), and food at all times.

Food for captured beavers should consist of fresh aspen and willow cuttings supplemented with rodent pellets. Apples and carrots can be used to induce foraging but should not be a large part of the beavers' diet during captivity. For more recommendations on food for captured beavers, consult the Beaver Restoration Guidebook (pp 79).

Practitioners have noted that one of the major health issues beavers seem to develop during captivity is related to the gastrointestinal tract, particularly colic from abrupt changes in diet and stress from the capture, handling, and housing process. To reduce these issues, it is recommended that people holding beavers in captivity do so only for as long as is absolutely necessary to prepare the beavers and the release site for the transplant. Additionally, practitioners should do everything they can to reduce stress and to mimic a natural diet for the beavers while they are being held. If more permanent holding facilities are constructed, such as those shown below, they should be located in areas away from foot and vehicle traffic and in as quiet of an area as possible.

Holding facility design for beavers from Idaho Department of Fish and Game and Utah State University

The Idaho Department of Fish and Game has constructed several beaver holding facilities in consultation with Utah State University to help with housing beavers that are scheduled for transplant (Figure E2). These facilities are designed to be easily cleaned and disinfected between beaver cohorts and are meant to keep beavers for up to three weeks.

Figure E2. Examples of beaver holding facilities used by Utah State University (panel A) and Idaho Fish and Game (Panel B). The main structures consist of prefabricated metal dog cages that are then covered in metal flashing to reduce stress and thwart climbing by the beavers. The roofs can be raised or lowered to allow for greater air flow, though other practitioners have had beavers climb out of the holding facility via the gap between the roof and the top of the cages. The cages were installed on top of a concrete pad that was poured specifically for this purpose.

Materials

1) Prefabricated metal dog kennels.

2) Metal flashing for sides of kennels to prevent climbing.

3) Watering troughs to be filled with water for swimming and defecating (Figure E3).

4) Wooden plank for a ramp into and out of water trough.

5) Watering troughs to be turned upside down and used as a lodge. A semi-circle should be cut out of the troughs as an entryway for the beavers, but be cautious of sharp metal edges that could injure beavers (Figure E3).

6) Large dog bowls for rodent pellets and other supplemental foods (carrots, apples, etc.; Figure E3).

7) Straw for flooring (Figure E3).

8) Misting system if heat management is going to be an issue (holding pen should be kept at less than 90 degrees).

Figure E3. Example of the inside of a beaver holding facility from the Idaho Department of Fish and Game. The watering trough on the left side of the image is used for beavers to swim, drink, and defecate. The up-turned trough in the back has a semi-circle cut out of it and is used as a beaver lodge. Fresh willows and rodent pellets are provided for food and straw is used for bedding.

Construction

1) Roof of enclosure needs to be secure so beavers do not climb up and out of pens.

2) Concrete pad should include channels on both sides of each pen to allow for drainage of water used to clean pens and for water being emptied from swimming troughs. Alternatively, the concrete pad can

be poured in such a way as to provide a swimming trough at the back of the kennel with a draining mechanism installed (Figure E4).

3) All materials beavers have access to should be made of metal to prevent chewing. Any plastic, wood, or thin metal used in the pen will likely be chewed on heavily by beavers.

4) Straw flooring should primarily be concentrated within and around the lodge. Wood chips and other materials from the trap site or natal colony can be mixed in to help the beavers feel more “at home”.


Figure E4. Concrete pads designed specifically for beaver holding facilities. The pads are poured to provide a swimming trough at the back end of the caged area and includes a gentle slope into the swimming area for beavers to easily climb in and out. Drainpipes are fitted into the structure to allow for easy draining and cleaning of the holding facilities between beaver cohorts.

Maintenance

1) Water in the swimming trough should be replaced every day. This helps with removal of potential parasites and AIS and keeps the water cool, which helps the beaver thermoregulate and reduces stress. If water in the swimming troughs is heating up throughout the day, blocks of ice can be placed in the troughs to keep the water cool until the next drain and refill.

2) Fresh food should be added daily, including both rodent pellets and woody riparian vegetation Woody riparian vegetation should consist of willow, aspen, and/or cottonwood only. Some alder may be mixed in but should not be the main vegetation provided to the beavers. Any soggy or old food should be removed and the bowl it was placed in should be rinsed and dried before adding new food.

3) Straw should be replaced as needed to keep the beavers' environment clean. However, straw should not be replaced more frequently than needed as beavers may be more comfortable in the environment as it starts to take on more of the beavers' scent.

4) Pens should be checked daily for wear and tear, paying particular attention to areas beavers may be chewing or climbing. Adjustments should be made to prevent chewing and climbing that may lead to injury.

5) Large logs or branches should also be provided in the pens for general chewing/gnawing by captive beavers.

Cleaning and disinfecting
1) The entire pen needs to be cleaned and disinfected between beavers or beaver groups.

2) All straw should be removed, and the water trough and food bowls emptied and sanitized with a 10% bleach solution.

3) The entire pen should be hosed down and either left in the sun for 24 hours or scrubbed with a stiff brush and 10% bleach solution. The entire pen should be rinsed and drained again after use of bleach solution.

Health Screening

All captured beavers will undergo a health screening (Figure E5) to check for common signs of illness, disease, or parasites. Detection of a potential health issue may warrant longer quarantine times, treatment with medications, possible re-release back into the source colony, or, if symptoms are severe, euthanasia. Beavers should be examined upon capture and again after the quarantine period so that capture-related stress or minor injury are not misinterpreted as illness or disease. If any of the boxes on the form shown in Figure E5 are marked "yes", the beaver shall not be transplanted, and the Wildlife Health Lab should be consulted for next steps. Any beaver that is euthanized or dies during trapping/quarantine will be necropsied to attempt to determine cause of death, and the carcass must be incinerated if drugs were used for euthanasia.

Aquatic Invasive Species (AIS) Concerns

The transfer of AIS (e.g., whirling disease, New Zealand mud snails, Driesenid mussels) because of transplanting beavers is a concern. To minimize the transfer of AIS, beavers from waterways containing AIS will only be transplanted to other approved waterways containing the same AIS (contaminated to contaminated). Coordination with local fisheries biologists and the FWP AIS program will be required for beaver transplants.

In waterways where the AIS status is not known, beavers will be quarantined in a holding facility for at least 24 hours prior to transplant, or as long as it takes for beavers to dry completely, pass multiple rounds of feces, and show any signs of disease or illness. Beavers should first be allowed to dry completely after capture, then should be periodically rinsed with clean fresh water during the quarantine period. Holding facilities will be kept as clean as possible so that beavers are not re-infecting themselves with potential AIS as they move around in the holding pens.

Personnel and volunteers involved in live-trapping and transplant efforts will follow the gear decontamination protocol (see below).

MONTANA FISH, WILDLIFE & PARKS

Beaver Transplantation Health Screening Form

FILL OUT ONE FORM FOR EACH BEAVER CAPTURED AS PART OF THE TRANSPLANTATION EFFORT

MFWP Project Lead: ______________________________ Regional office: _________________

E-mail: ____________________ Phone number: ____________________ Date: ___________

Signature of MFWP Project Lead: ____

Date captured: _________________________ Date released: ___________________________

Capture location: Latitude: ______________________ Longitude: _______________________

Release location: Latitude: ______________________ Longitude: _______________________

Beaver ID - Ear tag: _________________ Transmitter frequency: _________________________

Sex (M or F): ______ Weight (lbs): ______ Number: ___ out of ___total

Anesthetized (Y or N, if yes then list type of drug): ______________________________________

Health Symptom	Yes	No
Lethargic (not attributable to capture-related exhaustion)		
Compromised from injury (broken bones, major laceration, etc.)		
Emaciated or very poor body condition		
Obviously blind with missing eye(s), sclerosis, or cataracts		
Exhibiting excessive hair loss		
Severe lumps, swelling, or draining abscesses		
Heavy external parasite load		
Heavy nasal discharge (suggesting upper respiratory infection)		
Audible respiratory sounds indicating distress caused by potential infection		
Anal discharge indicating diarrhea or intestinal mucosal bleeding (very dark – black)		
Neurological signs *(e.g., head tilted to one side, aimless walking or circling, not responsive to stimuli, no response when touched or handled, excessive threatening sounds or actions)*		
Excessive drooling or salivation		
Abnormal anatomical features (mutations, additional appendages)		
Missing incisors		
Other (describe): ______________________________________		

IF YOU CHECKED YES TO ANY OF THE "HEALTH SYMPTOMS" DO NOT TRANSPLANT THIS BEAVER!

Contact the MFWP Wildlife Health Lab for further instruction

Figure E5. Health screening form for beavers captured for transplant in Montana (Adapted from Oregon Department of Fish and Wildlife).

Sample Collection and Disease Testing

Ideally, all beavers captured as part of a transplant will have blood drawn and be screened for at least tularemia. If disease testing shows they are positive for tularemia, the beavers shall not be used for transplants and may need to be euthanized using protocols approved by the state wildlife veterinarian. Disease-testing of captured beavers may vary depending upon clinical history, test availability, and the type of release site (e.g., existing beaver population or isolated). If there is no reason to suspect that tularemia may be present in the source population, or if the beavers will be transplanted into an area with no existing beaver population, then blood-drawing and disease testing may not be needed. Some potential signs of tularemia in a beaver population that may trigger a need for testing include:

- An abnormally low amount of active beaver sign relative to the number of intact dams and lodges in the source colony or colonies, indicating a potential recent or on-going die-off. Note that this is also one of the situations where beavers can be transplanted (i.e., Low Beaver Density Relative to Habitat), so an investigation of the site to look for evidence of a disease-related die-off is highly recommended.

- Beaver carcasses found in or around the source colony with no clear sign of the cause of death.

- Captured beavers that are abnormally sluggish, excessively salivating, have abnormal stools, show neurological symptoms such as lack of balance/coordination, or are exhibiting other strange behavior.

Before undertaking any beaver transplant project, consultation with the FWP wildlife veterinarian is required for instructions on biological sample collection and processing. If practitioners can collect a fresh fecal sample from captured individuals, pellets should be placed in a sealed bag and sent to the Wildlife Health Lab for fecal analysis. Fecal analysis should be done even if blood is not drawn for additional disease testing to broaden our understanding of parasites found in Montana beavers. However, the presence of common parasites such as those listed below will not preclude beavers from being transplanted.

General disease screening of beavers may include:

<u>Serology:</u>
Francisella tularensis
Yersinia pestis
Leptospira sp.
Toxoplasma gondii

<u>Fecal analysis</u>:
Giardia
Coccidia
Various helminths

Blood should be collected from the ventral tail vein using a 21-gauge needle. No more than 3 ml of blood should be collected from an individual animal. With the animal in dorsal recumbency, the vein can be found in a small depression on the midline of the tail, approximately 0.5-1 cm caudal to the hairline on the ventral aspect of the tail. Blood can usually be collected within 1 cm of the hairline on the tail.

Sedation

Anesthesia will be used if painful procedures will be implemented (e.g., applying tail transmitter), or may be used to aid in handling/collection of biological samples and sexing. Anesthesia may not be needed on every beaver transplant project and should only be done when absolutely necessary. If the only reason to sedate a beaver or beavers is for sexing or ease of handling, then it should not be done.

Drug combinations used successfully in beavers include the following:

- 10 mg/kg ketamine plus 1 mg/kg xylazine intramuscularly.
- Telazol 5 mg/kg intramuscularly.
- BAM (0.1 cc per 10 lbs), antagonized with atipamezole (5 mg per mg Medetomidine) and naltrexone (1 mg per mg Medetomidine). Supplemental oxygen should be provided.

Sexing

Sexing beavers is useful for making sure potential breeding pairs are released together and for general tracking of project success. The most reliable and least intrusive method for determining the sex of captured beavers is by examining the color and scent of anal gland secretions. Males have yellowish brown or caramel brown and viscous secretions that smell like oil or diesel fuel. Females have whitish or creamy tan and more runny secretions that smell like bleu cheese (Figure E6; Pollock et al. 2017). The anal glands are slightly craniolateral to the opening of the cloaca. To collect secretions, push the anal gland sack toward the cloacal opening until the papilla is exposed. Then gently squeeze the anal gland to collect the secretion. See pp 76-78 in the Beaver Restoration Guidebook for detailed instructions.

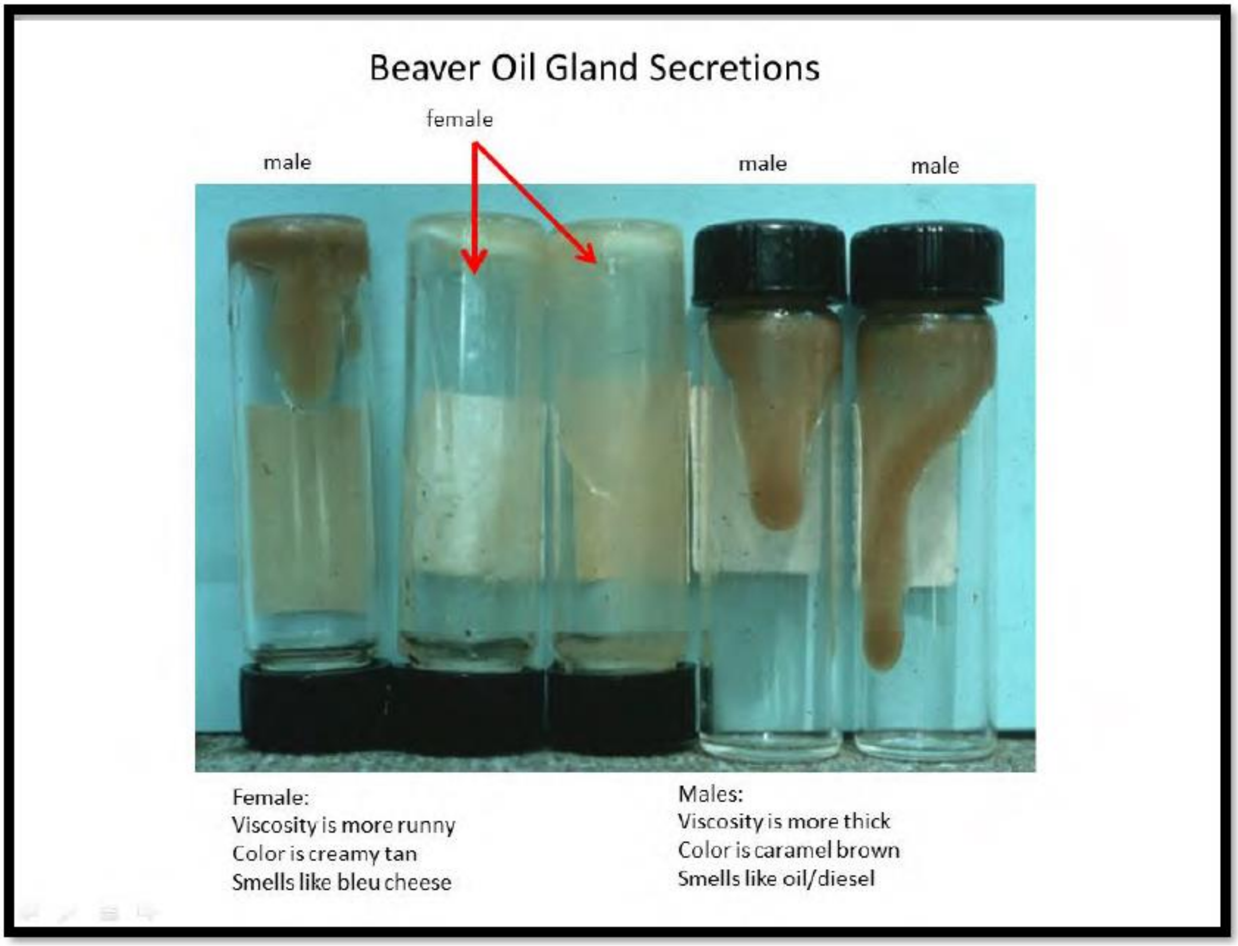


Figure E6. Examples of an anal gland secretions used to determine sex of live-captured beavers (Pollock et al. 2017, Photo courtesy of Dr. Lixing Sun).

Ear tagging and transmitters

Depending on the goals and stipulations of the transplant project, individually marking beavers may be desired or required. Individually marking beavers allows for some determination of the transplant success, as marked beavers may be spotted during evening/morning visual surveys, recaptured in other areas, removed due to conflict issues, monitored with game cameras, or tracked using GPS or VHF transmitters if there is funding available for such equipment. The simplest form of marking beavers is metal or plastic ear tags of appropriate size for beavers that should be employed for every transplanted beaver. Beaver bags are useful for safely restraining beavers while attaching ear tags and transmitters and collecting samples. If beavers are sedated for sample collection and sexing, this can facilitate installing ear tags or transmitters.

Transplant Timing

The timing for releasing beavers into the pre-approved release site will almost always depend on when the beavers are captured, which will depend on a variety of factors. It is generally thought that releasing beavers in the fall (mid-September through late October) will maximize the probability of them remaining at or near the release site (Vore 1993, Cramer 2012). The stated reasoning for this is that beavers will naturally feel some urgency to get dams and lodges built up and sealed in preparation for winter, and so will be less likely to leave in search of a new settlement site. However, this has not been rigorously tested, and many beaver transplant efforts have seen similar levels of success or failure regardless of when beavers are released (see review in Pollock et al. 2017).

Beaver life history suggests the rising and climax phases of spring runoff are the primary dispersal period and the falling phase and end of runoff are the primary settlement periods for beavers in Montana (Ritter 2018). Therefore, releasing beavers during the waning phase of runoff may correspond to greater transplant success as it more closely mimics natural settlement. Summer and fall months are spent building up dams, lodges, and caches in preparation for winter, so transplanting beavers during this time might also anchor the beavers to their new site. However, releasing beavers in the fall may cause the beavers to feel they do not have enough time to build up their infrastructure, which may cause them to leave the release site in search of their natal colony. Based on these uncertainties, beaver transplants have the potential to be successful any time of year but must be done outside the breeding period. Careful monitoring of project success should be done to increase our understanding of the most appropriate timing for transplanting beavers.

Release Protocol

After beaver holding and processing, it is suggested that beavers are transplanted in at least a male-female pair, if not an entire family unit. Of course, the number of beavers and the family structure will often depend on the source of the beavers (i.e., conflict situation or well-established beaver colony). Beavers should be transported to the release site in separate transport cages, wooden boxes, or pet kennels, and released as a group. Release sites should be prepared ahead of time with starter dams and rudimentary lodges (Figure E7) to provide shelter and deep water for the released beavers (see Appendix D - Encouraging Natural Colonization, Creating a Human-built Abandoned Colony). After beavers have been released, the holding facility and all equipment must be thoroughly cleaned and then disinfected using Virkon disinfectant or other similar disinfectant that is both bactericidal and virucidal (e.g., 10% bleach solution).

Figure E7. Example of a rudimentary lodge constructed of materials found on-site at a beaver release location. The lodge should have a chamber roughly the size of a large kennel or overturned bathtub and the floor should be dry. Practitioners recommend creating an awning of branches connecting the lodge entrance to the water to increase safety for transplanted beavers (photo and recommendations from Brick and Woodruff 2019).

Monitoring and reporting for transplanted beavers

Areas where beavers have been released should be monitored frequently (every two weeks) to look for sign of beavers building on provided starter dams and lodges. If it appears the released beavers left the release site, practitioners should walk up- and downstream from the release site as far as possible within suitable beaver habitat to check for signs of colonization elsewhere. If the beavers do leave the site, practitioners should check in with neighboring landowners so they can keep an eye out for potential conflict situations developing. The use of VHF or GPS transmitters on released beavers is a good idea if there is funding and staff time available to better keep tabs on released beavers and to contribute to the broader knowledge base around transplant outcomes.

If released beavers do not remain at the release site, it is not an indication the site is unsuitable, and additional beaver releases may be required (Pollock et al. 2017). However, any plan for multiple releases must be outlined in the original EA process for vetting by FWP biologists, the public, and the Fish and Wildlife Commission.

When possible, beavers that die after transplant will be collected for necropsy to determine the cause of death, though retrieving transplanted beavers will be difficult if not impossible without tracking devices on individual beavers.

Decontamination Protocol

All capture equipment, transport cages, and holding facilities for transplanted beavers need to be cleaned and disinfected between beaver cohorts. This includes waders, boots, gloves, and other personal equipment used during the capture and holding process. Decontamination is important and must be done to minimize the chances of spreading disease or parasites between groups of beavers and to avoid any unnecessary infections or other sanitation issues. Decontamination is also an important part of preventing the spread of AIS between waterways where beaver captures and releases are taking place.

The following protocols have been adopted directly from the 2017 Utah Beaver Live Trapping and Transplant Protocol, supplemented with additional information from the FWP AIS program. These protocols are necessary to control the spread of AIS during beaver transplant projects.

Equipment to be decontaminated includes, but is not limited to:

- Footwear, waders, and gloves.
- Boats, trailers, and vehicles.
- Capture/release equipment, including traps, live cages, beaver bags, holding boxes, and scales.
- Any part or component of the quarantine facility that the beavers contact.
- Any other equipment having contact with the water, riparian area immediately adjacent to the water, or aquatic animals.

When possible, stage recreation or work operations sufficiently away from the water body to minimize unnecessary contact by equipment with potentially AIS affected areas, avoiding inadvertent contamination of equipment. New Zealand mudsnails have been found in riparian areas more than 40 feet from the water's edge.

Decontamination should occur before arrival at a project site, so AIS are not transferred from the last visited area. Decontamination will occur onsite at the last area. DO NOT ARRIVE OR MOVE ABOUT IN MONTANA WITH DIRTY OR WET EQUIPMENT! Decontamination should again occur before leaving a project site, so AIS are not transferred to the next site.

Decontaminations must be done on a site-by-site basis not drainage-by-drainage, since many AIS are found within one stream segment or body of water but may not yet occur either upstream or downstream.

Desiccation, either by drying or high temperature wash, is very effective at killing AIS. And, in limited situations, some chemicals are helpful.

Accepted methods for Montana follow the mantra of Clean, Drain, and Dry:

1. CLEAN (remove) all attached mud, debris, plants, or animals from the aforementioned equipment. Scrub with a stiff-bristled brush, then visually inspect, since AIS (seeds, spores, plant shards, or the animal itself) frequently collect in seams, crevices, or cracks on equipment, including tires, or between the laces and tongue of wading boots (felt-soled wading boots should not be used for beaver transplant projects). Follow the cleaning and inspection with a tap water rinse, where possible, or rinse with clear raw water. Additionally, some chemical treatments can aid in the cleaning step for footwear and capture/transport equipment. Footwear and small capture equipment (not boats or vehicles that have been in contact with the water) can be sprayed with Clorox Formula 409 to kill New Zealand mudsnail and whirling disease spores. Wetted contact time should be at least 30 minutes, then allow the gear to dry in the sun prior to reuse. The correct Clorox Formula 409 product will list dimethyl benzyl ammonium chloride as 0.3%. Copper sulfate solutions having a concentration of 252 mg/l of copper are known to kill New Zealand mudsnails. Wetted contact time using copper sulfate should be more than 5 minutes, then allow the gear to dry in the sun prior to reuse. If decontaminating large pieces of equipment (not boats or vehicles that have been in contact with the water or riparian area), use Hyamine or Sparquat, which can be purchased in bulk. Quat 128 mixed as 6.4oz/gallon of water is reported to kill chytrid fungus, whirling disease spores, and New Zealand mudsnails. As an alternative to these chemicals, a 20% commercial bleach solution applied for at least 10 minutes can also kill AIS but may be hard on some types of equipment. A 5% bleach solution can also be used but must be applied for at least 60 minutes.

2. DRAIN all raw water from the aforementioned equipment to prepare it for drying. If a boat is used, make sure any raw water circulation systems or containers (coolers and sample containers) are drained, including cooling systems, livewells, ballasts, bilge, and motors (let the lower unit down, so water drains, then run the engine out of the water for 2-3 minutes to raise the temperature to 140 degrees F, etc.).

3. DRY the aforementioned equipment to kill AIS. Temperature and humidity affect drying time, so in Montana dry for 7 days in summer (June, July, and August); 18 days in spring (March, April, and May) and fall (September, October, and November); or 30 days in winter (December, January, and February). Due to extended freezing temperatures in winter, properly winterized equipment can be exposed for 72 consecutive hours of subfreezing temperature to kill AIS.

Conflict Considerations

The possibility of beaver coming into conflict with people at the proposed transplant site must be thoroughly evaluated as part of the EA process. Beavers will not be transplanted to areas where conflict concerns are present unless all cooperating parties agree to accept the risk and manage around the possibility of future conflicts.

Permitting

There are no dedicated permits for translocating beavers when it comes to potential impacts to the bed and banks of a stream. However, many of the techniques suggested for encouraging beavers to stay at a release site will require permits, such as constructing BDAs or doing other forms of restoration to prepare the site for beavers.

Live-capturing, transporting, and releasing beavers can only be conducted by FWP personnel or those authorized and subsequently supervised by FWP. An FWP biologist must work with a landowner, agency, or group to identify and evaluate a release site. If the FWP biologist determines, based on the criteria laid out in this document, that the project has a good chance of success, then the FWP biologist can begin the process to get approval for the transplant. "Success" needs to be defined for the project ahead of time and will often be measured through establishment of self-sustaining beaver colonies at the project site and/or at nearby sites over time.

The FWP biologist will develop an Environmental Assessment (EA) in accordance with the Montana Environmental Policy Act. The EA will outline the project and describe all potential positive and negative effects of the project on the physical and social environment of the area affected. The EA will go out to the public for a review period where the public will have a chance to provide comments. FWP will then review those comments, make any necessary adjustments to the EA based on those comments, and then issue a Record of Decision (ROD). In the ROD, the Regional Supervisor will recommend the project be approved or denied.

In the next step, the EA and ROD are reviewed by the Fish and Wildlife Commission. The Fish and Wildlife Commission will then vote to approve or deny the project at one of their regularly scheduled meetings. Once the project is approved by the Commission, the beaver transplant can proceed under the guidance and supervision of the project lead from FWP.

While much of this process is done by the FWP biologist, their time is limited. The landowner, group, or agency that is seeking to transplant beavers will be asked to provide much of the detailed information that will go into the EA. As with all projects under the umbrella of "beaver restoration", the transplant project needs to be thoroughly evaluated and well-thought-out ahead of time to have a chance of being approved and implemented.

Additional Information

- Chapter 5 – Relocating Beaver in The Beaver Restoration Guidebook; https://www.fws.gov/media/beaver-restoration-guidebook

- Methow Valley Beaver Project (one of the largest and most successful beaver transplant projects in North America); https://methowbeaverproject.org/

- The Beaver Restoration Assessment Tool (BRAT) for Montana, which includes the beaver-human conflict potential model; https://www.arcgis.com/apps/webappviewer/index.html?id=f26958e584384ea89e6c5fc0d3775d1b

References

Agouridis, C., D. R. Edwards, S. R. Workman, J. Bicudo, B. K. Koostra, E. Vanzant, and J. Taraba. 2005. Stream bank erosion associated with grazing practices in the humid region. Transactions of the American Society of Agricultural Engineers 48(1):181-190.

Andréassian, V. 2004. Waters and forests: From historical controversy to scientific debate. Journal of Hydrology 291:1–27.

Babik, M., and W. Meyer. 2015. Yakima Basin Beaver Reintroduction Project 2011-2015 progress report. Washington Department of Fish and Wildlife, Ellensburg, USA.

Baker, B. W. 2003. Beaver (Castor canadensis) in heavily browsed environments. Lutra 46(2):173-181.

Bartel, R. A., N. M. Haddad, and J. P. Wright. 2010. Ecosystem engineers maintain a rare species of butterfly and increase plant diversity. Oikos 119:883-890.

Beer, J. R. 1955. Movements of tagged beaver. The Journal of Wildlife Management 19:492-493.

Bennett, K. E., T. J. Bohn, K. Solander, N. G. McDowell, C. Xu, E. Vivoni, and R. S. Middleton. 2018. Climate driven disturbances in the San Juan River sub-basin of the Colorado River. Hydrology and Earth System Sciences 22(1):709–725.

Bewley, D., Y. Alila, and A. Varhola. 2010. Variability of snow water equivalent and snow energetics across a large catchment subject to Mountain Pine Beetle infestation and rapid salvage logging. Journal of Hydrology 388(3–4):464–479.

Biederman, J. A., A. J. Somor, A. A. Harpold, E. D. Gutmann, D. D. Breshears, P. A. Troch, D. J. Gochis, R. L. Scott, A. J. Meddens, and P. D. Brooks. 2015. Recent tree dieoff has little effect on streamflow in contrast to expected increases from historical studies. Water Resources Research 51(12):9775–9789.

Boyce, M. S. 1981. Beaver life-history responses to exploitation. Journal of Applied Ecology 18(3):749–753.

Bouwes, N., N. Weber, C. E. Jordan, W. C. Saunders, I. A. Tattam, C. Volk, J. M. Wheaton, and M. M. Pollock. 2016. Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead. Scientific Reports 6.

Brick, P., and K. Woodruff. 2019. The Methow Beaver Project: The challenges of an ecosystem services experiment. Case Studies in the Environment. 3(1):1-14.

Burton, T. 1997. Effects of basin-scale timber harvest on water yield and peak streamflow. Journal of American Water Resources Association 33(6):1187–1196.

Busher, P. E., and P. J. Lyons. 1999. Long-term population dynamics of the North American beaver (Castor canadensis) on Quabbin Reservation, Massachusetts, and Sagehen Creek, California. In: Busher, P. E., Dzięciołowski, R. M. (eds) Beaver Protection, Management, and Utilization in Europe and North America. Springer, Boston, Massachusetts, USA.

Chaney, E., W. Elmore, and W. S. Platts. 1990. Livestock grazing on western riparian areas. U.S. Environmental Protection Agency, Washington, D.C., USA.

Cluer, B., and C. R. Thorne. 2014. A stream evolution model integrating habitat and ecosystem benefits. River and Research Applications 30(2):135-154.

Collen, P., and R. J. Gibson. 2001. The general ecology of beavers, as related to their influence on stream ecosystems and riparian habitats, and the subsequent effects on fish – a review. Fish Biology and Fisheries 10:439-461.

Cooke, H. A., and S. Zack. 2008. Influence of beaver dam density on riparian areas and riparian birds in shrubsteppe Wyoming. Western North American Naturalist 68:365-373.

Cramer, M. L. 2012. Stream habitat restoration guidelines. Co-published by the Washington Departments of Fish and Wildlife, Natural Resources, Transportation and Ecology, Washington State Recreation and Conservation Office, Puget Sound Partnership, and the U.S. Fish and Wildlife Service. Olympia, Washington, USA.

Cutting K. A., J. M. Ferguson, M. L. Anderson, K. Cook, S. C. Davis, and R. Levine. 2018. Linking beaver dam affected flow dynamics to upstream passage of Arctic grayling. Ecology and Evolution 8(24):12905-12917.

Demmer, R., and R. L. Beschta. 2008. Recent history (1988 – 2004) of beaver dams along Bridge Creek in Central Oregon. Northwest Science 82(4):309-318.

DeStefano, S., K. K. G. Koenen, C. M. Henner, and J. Strules. 2006. Transition to independence by subadult beavers in an unexploited, exponentially growing population. Journal of Zoology 269:434-441.

Dittbrenner, B. J., M. M. Pollock, J. W. Schilling, J. D. Olden, J. J. Lawler, and C. E. Torgersen. 2018. Modeling intrinsic potential for beaver (Castor canadensis) habitat to inform restoration and climate change adaptation. PLoS ONE 13(2):e0192538.

Dupont, J., R. S. Brown, and D. R. Geist. 2007. Unique allacustrine migration patterns of a bull trout population in the Pend Oreille River drainage, Idaho. North American Journal of Fisheries Management 27:1268–1275.

Fairfax, E., and E. E. Small. 2018. Using remote sensing to assess the impact of beaver damming on riparian evapotranspiration in an arid landscape. Ecohydrology 11(7):e1993.

Fairfax, E., and A. Whittle. 2020. Smokey the Beaver: beaver-dammed riparian corridors stay green during wildfire throughout the western United States. Ecological Applications 30(8):e02225.

Fesenmeyer, K. A., D. C. Dauwalter, C. Evans, and T. Allai. 2018. Livestock management, beaver, and climate influences on riparian vegetation in a semi-arid landscape. PLoS ONE 13(12):e0208928.

Frantisek, J., S. Baker, and V. Kostkan. 2010. Habitat selection of an expanding beaver (Castor fiber) population in central and upper Morava River basin. European Journal of Wildlife Research 56:663–671.

Goeking, S. A. and D. G. Tarboton. 2020. Forests and water yield: A synthesis of disturbance effects on streamflow and snowpack in western coniferous forests. 2020. Journal of Forestry 118(2):172-192.

Goldfarb, B. 2018. Eager: The Surprising, Secret Lives of Beavers and Why They Matter. Chelsea Green Publishing, White River Junction, Vermont, USA.

Grasse, J. E., and E. F. Putnam. 1955. Beaver management and ecology in Wyoming. Wyoming Game and Fish Communication Bulletin 6, Cheyenne, USA.

Harris, H. T. 1991. Habitat use by dispersing and transplanted beavers in western Montana. Thesis, University of Montana, Missoula, USA.

Hibbard, E. A. 1958. Movements of beaver transplanted in North Dakota. The Journal of Wildlife Management 22:209-211.

Howard, R. J., and J. S. Larson. 1985. A stream habitat classification for beavers. The Journal of Wildlife Management 49:19-25.

Jakober, M. J., T.E. Mcmahon, F. T. Russell, and C. G. Clancy. 1998. Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams. Transactions of the American Fisheries Society 127(2):223-235.

Jin, L., D. I. Siegel, L. K. Lautz, and M. H. Otz. 2009. Transient storage and downstream solute transport in nested stream reaches affected by beaver dams. Hydrological Processes 23:2438-2449.

Kauffman, J. B., and W. C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications... A review. Journal of Range Management 37(5):430-438.

Kebbe, C. E. 1960. Oregon's beaver story. Oregon State Game Commission Bulletin 15(2):3-6.

Kemp, P. S., T. A. Worthington, T. E. Langford, A. R. Tree, and M. J. Gaywood. 2012. Qualitative and quantitative effects of reintroduced beavers on stream fish. Fish and Fisheries 13(2):158-181.

Kennedy, B., D. Peterson, and K. Fausch. 2003. Different life histories of brook trout populations invading mid-elevation and high-elevation cutthroat trout streams in Colorado. Western North American Naturalist 63(2):215-223.

Kivinen, S., P. Nummi, and T. Kumpula. 2020. Beaver-induced spatiotemporal patch dynamics affect landscape-level environmental heterogeneity. Environmental Research Letters. 15(9):e094065.

Larsen, A., J. R. Larsen, and S. N. Lane. 2021. Dam builders and their works: Beaver influences on the structure and function of river corridor hydrology, geomorphology, biogeochemistry and ecosystems. Earth-Science Reviews 218:e103623.

Lautz, L., C. Kelleher, P. Vidon, J. Coffman, C. Riginos, and H. Copeland. 2018. Restoring stream ecosystem function with beaver dam analogues: Let's not make the same mistake twice. Hydrological Processes. 33(1):174-177.

Leege, T. A. 1968. Natural movements of beavers in southeastern Idaho. The Journal of Wildlife Management 32:973-976

Libby, W. L. 1957. Observations on beaver movements in Alaska. Journal of Mammalogy 38:269.

MacArthur, R. A. 1989. Energy metabolism and thermoregulation of beaver (*Castor canadensis*). Canadian Journal of Zoology 67:651-657.

Macfarlane, W. W., J. M. Wheaton, N. Bouwes, M. L. Jensen, J. T. Gilbert, N. Hough-Snee, and J. A. Shivik. 2015. Modeling the capacity of riverscapes to support beaver dams. Geomorphology 277:72-99.

Majerova, M., B. T. Neilson, N. M. Schmadel, J. M. Wheaton, and C. J. Snow. 2015. Impacts of beaver dams on hydrologic and temperature regimes in a mountain stream. Hydrology and Earth System Sciences Discussions 12:839-878.

Majerova, M., B. T. Neilson, and B. B. Roper. 2020. Beaver dam influences on streamflow hydraulic properties and thermal regimes. Sciences of the Total Environment 718: e134853.

McCall, T. C., T. P. Hodgman, D. R. Diefenbach, and R. B. Owen, Jr. 1996. Beaver populations and their relation to wetland habitat and breeding waterfowl in Maine. Wetlands 16(2):163-172.

McKinstry, M. C., and S. H. Anderson. 2002. Survival, fates, and success of transplanted beavers, Castor canadensis, in Wyoming. The Canadian Field-Naturalist 116:60-68.

McNew, L. B. J., and A. Woolf. 2005. Dispersal and survival of juvenile beavers in southern Illinois. American Midland Naturalist 154:217-228.

McNew, L. B. J., C. K. Nielson, and C. K. Bloomquist. 2007. Use of snares to live-capture beavers. Human-Wildlife Interactions 1:106-111.

Montana Department of Fish, Wildlife and Parks (FWP). 2010. Upper Missouri Watershed Beaver Relocation Project Environmental Assessment. Helena, USA.

Montana Department of Fish, Wildlife and Parks (FWP). 2015. Montana’s State Wildlife Action Plan. Helena, USA.

Montana Department of Fish, Wildlife and Parks (FWP). 2018. Reservoir Creek Beaver Transplant Environmental Assessment. Helena, USA.

Montana Department of Fish, Wildlife and Parks (FWP). 2019. Montana Statewide Fisheries Management 2019. Helena, USA.

Montana Department of Fish, Wildlife and Parks (FWP). 2022. 2022 Wolf and Furbearer Trapping Regulations. Helena, USA.

Montana Department of Natural Resources and Conservation. 2020. Montana Stream Permitting: A Guide for Conservation District Supervisors and Others. Helena, USA.

Muller-Schwarze, D. 2011. The beaver: Its life and impact. 2nd edition. Cornell University, Ithaca, New York.

Munir, T. M. and C. J. Westbrook. 2021. Thermal Characteristics of a Beaver Dam Analogues Equipped Spring-Fed Creek in the Canadian Rockies. Water 13(7):990.

Munther, G. L. 1983. Integration of beaver into forest management. Proceedings of the Eighteenth Annual Meeting of the American Fisheries Society, Laramie, Woming, USA.

Naiman, R. J., J. M. Melillo, and J. E. Hobbie. 1986. Ecosystem alteration of boreal forest streams by beaver (Castor canadensis). Ecology 67:1254-1269.

Naiman, R. J., C. A. Johnston, and J. C. Kelley. 1988. Alteration of North American streams by beaver. BioScience 38:753-762.

Nash, C. S., G. E. Grant, S. Charnley, J. B. Dunham, H. Gosnell, M. B. Hausner, D. S. Pilliod, and J. D. Taylor. 2021. Great expectations: Deconstructing the process pathways underlying beaver-related restoration. BioScience 71(3):249–267.

Nelson, T. A., and C. K. Nielsen. 2010. Population ecology of beavers in Illinois. Southern Illinois University, Carbondale, Illinois.

Nyssen, J., P. Pontzeele, and P. Billi. 2011. Effect of beaver dams on the hydrology of small mountain streams: example from the Chevral in the Ourthe Orientale Basin, Ardennes, Belgium. Journal of Hydrology 402:92-102.

Parson, G. R. 1975. Effect of a 4-year closure of the trapping season for beaver in eastern Warren County, New York. New York Fish and Game Journal 22(1):57-61.

Parsons, G. P., and M. K. Brown. 1978. An assessment of aerial photograph interpretation for recognizing potential beaver colony sites. New York Fish and Game Journal 25:175–177.

Payne, N. F. 1984. Mortality rates of beaver in Newfoundland. The Journal of Wildlife Management 48(1):117–126.

Petro, V. M., J. D. Taylor, and D. M. Sanchez 2015. Evaluating landowner-based beaver relocation as a tool to restore salmon habitat. Global Ecology and Conservation 3:477-486.

Pilliod, D. S., A. T. Rohde, S. Charnley, R. R. Davee, J. B. Dunham, H. Gosnell, G. E. Grant, M. B. Hausner, J. L. Huntington, and C. Nash. 2018. Survey of beaver-related restoration practices in rangeland streams of the western USA. Environmental Management 61(1):58-68.

Pollock, M. M., M. Heim, and D. Werner. 2003. Hydrologic and geomorphic effects of beaver dams and their influence on fishes. American Fisheries Society Symposium 37:1-21.

Pollock, M. M., T. J. Beechie, and C. E. Jordan. 2007. Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. Earth Surface Processes and Landforms 32:1174-1185.

Pollock, M. M., J. M. Wheaton, N. Bouwes, and C. E. Jordan. 2011. Working with beaver to restore salmon habitat in the Bridge Creek Intensively Monitored Watershed. Nation Oceanic and Atmospheric Administration, Seattle, WA, USA.

Pollock, M. M., T. J. Beechie, J. M. Wheaton, C. E. Jordan, N. Bouwes, N. Weber, and C. Volk. 2014. Using beaver dams to restore incised stream ecosystems. BioScience 64:279-290.

Pollock, M. M., G. M. Lewallen, K. Woodruff, C. E. Jordan, and J. M. Castro. 2017. The beaver restoration guidebook: working with beaver to restore streams, wetlands, and floodplains. Version 2.0. United States Fish and Wildlife Service, Portland, Oregon, USA.

Polvi, L. E., and E. Wohl. 2012. The beaver meadow complex revisited - the role of beavers in post-glacial floodplain development. Earth Surface Processes and Landforms 37:332-346.

Polvi, L. E., and E. Wohl. 2013. Biotic drivers of stream planform: implications for understanding the past and restoring the future. BioScience 63:439-452.

Pomeroy, J., X. Fang, and C. Ellis. 2012. Sensitivity of snowmelt hydrology in Marmot Creek, Alberta, to forest cover disturbance. Hydrological Processes 26(12):1892–1905.

Potts, D. 1984. Hydrologic impacts of a large-scale mountain pine beetle (Dendroctonus ponderosae Hopkins) epidemic. Journal of American Water Resources Association 20:373–377.

Pugh, E., and E. Gordon. 2013. A conceptual model of water yield effects from beetle-induced tree death in snow-dominated lodgepole pine forests. Hydrologic Processes 27:2048–2060.

Puttock, A., H. A. Graham, J. Ashe, D. J. Luscombe, and R. E. Brazier. 2020. Beaver dams attenuate flow: A multi-site study. Hydrological Processes 35(2):e14017.

Ritter, T. 2018. Ecosystem pioneers: beaver dispersal and settlement site selection in the context of habitat restoration. Thesis, Montana State University, Bozeman, USA.

Ritter, T., C. N. Gower, and L. B. McNew. 2019. Habitat conditions at beaver settlement sites: Implications for beaver restoration projects. Restoration Ecology 28(1):196-205.

Roper, B. 2022. Effects of beaver dams on stream and riparian conditions on public lands in the United States' Inland Northwest. Western North American Naturalist 82(4):638-659.

Rosell, F. and R. Campbell-Palmer. 2022. Beavers: Ecology, Behaviour, Conservation, and Management. Oxford University Press, Oxford, United Kingdom.

Rosell, F., O. Bozser, P. Collen, and H. Parker. 2005. Ecological impact of beavers (Castor fiber and Castor canadensis) and their ability to modify ecosystems. Mammal Review 35(3-4):248-276.

Russell, K. R., C. E. Moorman, K. J. Edwards, B. S. Metts, and D. C. J. Guynn. 1999. Amphibian and reptile communities associated with beaver (Castor canadensis) ponds and unimpounded streams in the piedmont of South Carolina. Journal of Freshwater Ecology 14:149-158.

Scarmardo, J., and E. Wohl. 2020. Sediment storage and shallow groundwater response to beaver dam analogues in the Colorado Front Range, USA. River Research and Applications 36(3):398-409.

Scrafford, M. A., D. B. Tyers, D. T. Patten, and B. F. Sowell. 2018. Beaver habitat selection for 24 years since reintroduction north of Yellowstone National Park. Rangeland Ecology & Management 71:266-273.

Shahverdian, S. M., Wheaton, J. M., Bennett, S. N., Bouwes, N., Camp, R., Jordan, C. E., Portugal, E. and N. Weber. 2019. Chapter 4 – Mimicking and Promoting Wood Accumulation and Beaver Dam Activity with Post-Assisted Log Structures and Beaver Dam Analogues In: J. M. Wheaton, S. N. Bennett, N. Bouwes, J. D. Maestas, and S.M. Shahverdian (Editors), Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Utah State University Restoration Consortium, Logan, Utah.

Shepard, B. B. 2004. Factors that may be influencing nonnative brook trout invasion and their displacement of native westslope cutthroat trout in three adjacent southwestern Montana streams. North American Journal of Fisheries Management 24(3):1088-1100.

Siemer, W., S. Jonker, and J. Organ. 2013. Toward an understanding of beaver management as human and beaver densities increase. Human-Wildlife Interactions 7(1):114-131.

Silverman, N. L., B. W. Allred, J. P. Donnelly, T. B. Chapman, J. D. Maestas, J. M. Wheaton, J. White, and D. E. Naugle. 2018. Low-tech riparian and wet meadow restoration increases vegetation productivity and resilience across semiarid rangelands. Restoration Ecology 27(2):269-278.

Smith, D. W. 1997. Dispersal strategies and cooperative breeding in beavers. Dissertation, University of Nevada, Reno, USA.

Sun, L., D. Muller-Schwarze, and B. A. Schulte. 2000. Dispersal pattern and effective population size of the beaver. Canadian Journal of Zoology 78:393-398.

Tippie, S., and M. O'Brien. 2010. Working with beaver for better habitat naturally. Other Publications in Wildlife Management 63.

Trimble, S., and A. Mendel. 1995. The cow as a geomorphic agent – A critical review. Geomorphology 13:233-253.

United States Fish and Wildlife Service. 1973. Endangered Species Act of 1973. U.S. Department of the Interior, Washington D. C., USA.

Van Deelen, T. R., and D. H. Plestcher. 1996. Dispersal characteristics of two-year-old beavers in western Montana. The Canadian Field-Naturalist 110:318-321.

Vore, J. 1993. Guidelines for the reintroduction of beaver into southwest Montana streams. Montana Department of Fish, Wildlife, and Parks, Helena, MT, USA.

Wathen, G., J. Allgeier, N. Bouwes, M. M. Pollock, D. Schindler, and C. Jordan. 2018. Beaver activity increases habitat complexity and spatial partitioning by steelhead trout. Canadian Journal of Fisheries and Aquatic Sciences. 76(7):1086-1095.

Weber, N., N. Bouwes, M. M. Pollock, C. Volk, J. M. Wheaton, G. Wathen, J. Wirtz, and C. E. Jordan. 2017. Alteration of stream temperature by natural and artificial beaver dams. PLoS ONE 12(5): e0176313.

Westbrook, C. J., D. J. Cooper, and B. W. Baker. 2006. Beaver dams and overbank floods influence groundwater-surface water interactions of a Rocky Mountain riparian area. Water Resources Research 42:1-12.

Wheaton J. M., S. N. Bennett, N. Bouwes, J. D. Maestas, and S. M. Shahverdian (Editors). 2019. Low-Tech Process-Based Restoration of Riverscapes: Design Manual. Version 1.0. Utah State University Restoration Consortium. Logan, UT.

Winward, A. H. 2000. Monitoring the vegetation resources in riparian areas. General Technical Report RMRS-GTR-47. U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT.

Wohl, E. 2019. Saving the Dammed: Why We Need Beaver-modified Ecosystems. Oxford University Press, New York, USA.

Wohl, E. 2021. Legacy effects of loss of beavers in the continental United States. Environmental Research Letters 16(2):e025010.

Wright, J., C. Jones, and A. Flecker. 2002. An ecosystem engineer, the beaver, increases species richness at the landscape scale. Oecologia 132:96-101.

Beaver dam, food cache, and lodge on Little Wapiti Creek in the Gallatin River drainage