Best Management Practices for Pond Levelers and Culvert Protection Systems

A guide for using flow devices to coexist with beavers

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Attributions:

Principal author:

Jakob Shockey, Project Beaver

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Aaron Beavers, National Oceanic and Atmospheric Administration

Adrienne Averett, Oregon Department of Fish and Wildlife

Alexa Whipple, Methow Beaver Project

Andrew Schwarz, Project Beaver

Brian Bangs, US Fish and Wildlife Service

Chris Jordan, National Oceanic and Atmospheric Administration

Chuck Wheeler, National Oceanic and Atmospheric Administration

Elyssa Kerr, Beavers Northwest

Greg Apke, Oregon Department of Fish and Wildlife

Irma Lagomarsino, National Oceanic and Atmospheric Administration

Luc Lamarche, Beaver Craftworks

Mike Callahan, The Beaver Institute

Mike Conroy, Tualatin Soil and Water Conservation District

Randy Lawrence, Clean Water Services

Tom Stahl, Oregon Department of Fish and Wildlife

Layout and graphics:

Amanda Ronnquist, Fuse Consulting

Kaitlyn Philip, Fuse Consulting

Kate Broadley, Fuse Consulting

Shelagh Pyper, Fuse Consulting

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Gene Wood, Larry Woodward,

Greg Yarrow, Clemson University

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Contents

Introduction

Beavers are well known for their ability to build dams which can be found in a wide variety of habitat types including wetlands, marshes, pond and lake outlets, river side-channels, and small to medium sized streams. Beavers build dams where: (1) the flow and velocity are low enough for a dam to persist, at least seasonally, and (2) where they would benefit from increasing water depth. The deeper water created from dam building helps keep beavers safe from predation both around their den and throughout their range of activity. The beavers of North America have been building dams for millions of years, and many other plants and animals have coevolved to benefit from their ecosystem engineering. The long history of beavers managing water across the landscape means that beaver-modified floodplains have a profoundly positive impact on the habitats of these other species. Beaver-modified floodplains also contribute increased water quantity and quality, carbon sequestration and vegetative evapotranspiration, and reduced severity from floods, drought, and wildfire. However, beaver dams can also negatively impact human infrastructure and land use.

> *Flow devices are key tools for minimizing both the damage to human occupied land and the degradation of riparian and wetland ecosystems that can occur if beavers are removed completely.*

Beavers often construct dams at undersized culverts, spillways, and other human infrastructure built in the channel. Beavers are instinctively attracted to the sound of trickling water, meaning infrastructure components that concentrate flow and partially constrict the stream channel can attract dam building activity. Making use of human elements can reduce the effort and time it takes for beavers to dam the stream. Even if beavers are not damming directly on or within artificial structural elements, damming activity can reroute stream water onto historic floodplain habitats which may flood adjacent infrastructure, crops, or homes. While beaver activity often facilitates better habitat for fish and wildlife, intervention to artificially diminish the footprint of beaver activity may be required due to safety concerns for human infrastructure and negative impacts to land use.

Since beavers are territorial, they quickly recognize and colonize freshly un-occupied habitat. Removing a family of beavers from an area only serves to free it up for a new beaver family. Trapping often becomes a frustrating treadmill of reactive management that degrades the habitat and depletes the local beaver population while failing to provide a robust solution. Notching a beaver dam can temporarily alleviate flooding issues, but beavers will often fix this breach with days. Habitat modification techniques, such as pond levelers and culvert protection systems, can facilitate coexistence with beavers living near human infrastructure. These techniques are often called "flow devices" and work by either limiting the area flooded by existing dams or by modifying the ability of beavers to construct dams. Flow devices are key tools for minimizing both the damage to human occupied land and the degradation of riparian and wetland ecosystems that can occur if beavers are removed completely, and have been repeatedly shown to save money over time compared to trapping.

Flow devices are immediate and cost-effective solutions that allow beavers to remain on-site, while protecting human interests. The net benefit of these coexistence solutions makes them an important tool for facilitating more beaver-managed habitat in and around human infrastructure, homes, and crops. However, these devices are not without drawbacks. By design, these devices artificially constrain the habitat beavers are attempting to make which can also constrain the benefits beaver habitat has for fish and wildlife. Proper design and installation paired with frequent monitoring and maintenance are necessary to ensure flow device operation minimizes instream environmental impacts, especially to State sensitive, Federal Endangered Species Act listed, or Tribal culturally important native fish and wildlife species and their habitats. Flow devices are best used as an interim solution while planning for a long-term fix like culvert replacement or land use changes.

How to use this guide

The two primary categories of beaver flow device solutions are pond levelers and culvert protection systems. The following combination of design fundamentals, best management practices, and site-specific criteria form a set of standards for making, installing, monitoring, and maintaining both culvert protection systems and pond levelers as beaver coexistence solutions.

To describe these techniques, this guide uses the names pond leveler, trapezoidal culvert fence, anchor dam, pipe and fence, and pipe and dam modifications. However, various flow device designs can go by many names, including beaver bafflers, beaver deceivers, keystone fence, castor master, diversion dam, and the fence and pipe. The following best management practices (BMPs) are built on a foundation of more than 40 years of innovation*. Even so, the designs and techniques for using flow devices to coexist with beavers continue to evolve. For example, experiments in Alaska are testing a culvert protection system that acts like a maze. The maze makes it difficult for beavers to get at the culvert with damming materials while allowing large bodied fish to navigate upstream without swimming through an exclusionary mesh. As new science is conducted and innovative solutions are tested and proven effective over time, these BMPs will be revised. Additionally, the regulatory authorities in various states are working towards authorizing the rules for flow devices. As it becomes available, state-specific guidance will be published in the appendices under new versions of this guide.

This document is intended to empower the landowners, organizations, municipalities, and wildlife professionals who are interested in finding solutions to ongoing conflicts between human infrastructure and beaver habitat while still retaining the beavers and their benefits. If you would like to install a pond leveler or culvert protection system, use these standards to guide your planning, design, installation, monitoring, and maintenance. If you don't have the capacity to implement these BMPs, there are an increasing number of trained professionals who can assist in your project. To coordinate your installation with the applicable regulatory agencies, adhere to the state-specific, stepwise permitting process outlined in the document appendices.

** Jenson et. al. 1999 (Cornell Cooperative Extension), Jenson et. al. 2001 (Wildlife Society Bulletin), Lisle 2003 (Lutra), Callahan 2003 (Association of Massachusetts Wetland Scientists Newsletter), Callahan 2005 (Association of Massachusetts Wetland Scientists Newsletter), Nolte et. al. 2005 (Wildlife Damage Management), Boyles 2006 (MS Thesis, Christopher Newport University), Boyles et. al. 2008 (Proceedings of the 23rd Vertebrate Pest Conference)*

Pond levelers

When to use pond levelers

Pond levelers are a coexistence solution for conflicts between beaver-facilitated wetland habitat and human infrastructure, crops, or homes. These flow devices are applicable when the landowner is willing to allow the beaver dam and pond to remain but wants to control the maximum water height. The goal of a pond leveler is to minimize the disruption to the beaver family and their habitat, so they do not abandon the site, while establishing a maximum water height and footprint which protects the landowner's assets. Pond levelers set the water surface elevation of a beaver pond by using a plastic culvert pipe to create a leak over the crest of the dam that beavers cannot repair. The intake for the leak is hidden upstream within the beaver pond and is enclosed within a cage to keep beavers from swimming near enough to sense the flowing water. Similar to an overflow drain on a bathtub which limits the water depth, a pond leveler leaks water over the crest of the beaver dam at a desired water surface height during the low flows when beavers might otherwise increase the height of the dam (Figure 1). The outlet of this pond leveler is placed downstream of the dam.

If properly constructed, installed and maintained, the use of pond levelers limits the extent of beaver ponds, minimizing flooding and potential nuisance or damage. Pond levelers permit coexistence with beavers, and the many ecosystem benefits they provide, in areas where a human tolerance for beaver facilitated habitat is limited. Flow devices can be cost-effective solutions for controlling the height of a beaver dam and the resulting footprint of the beaver pond. They can last 5-10 years or longer if properly maintained.

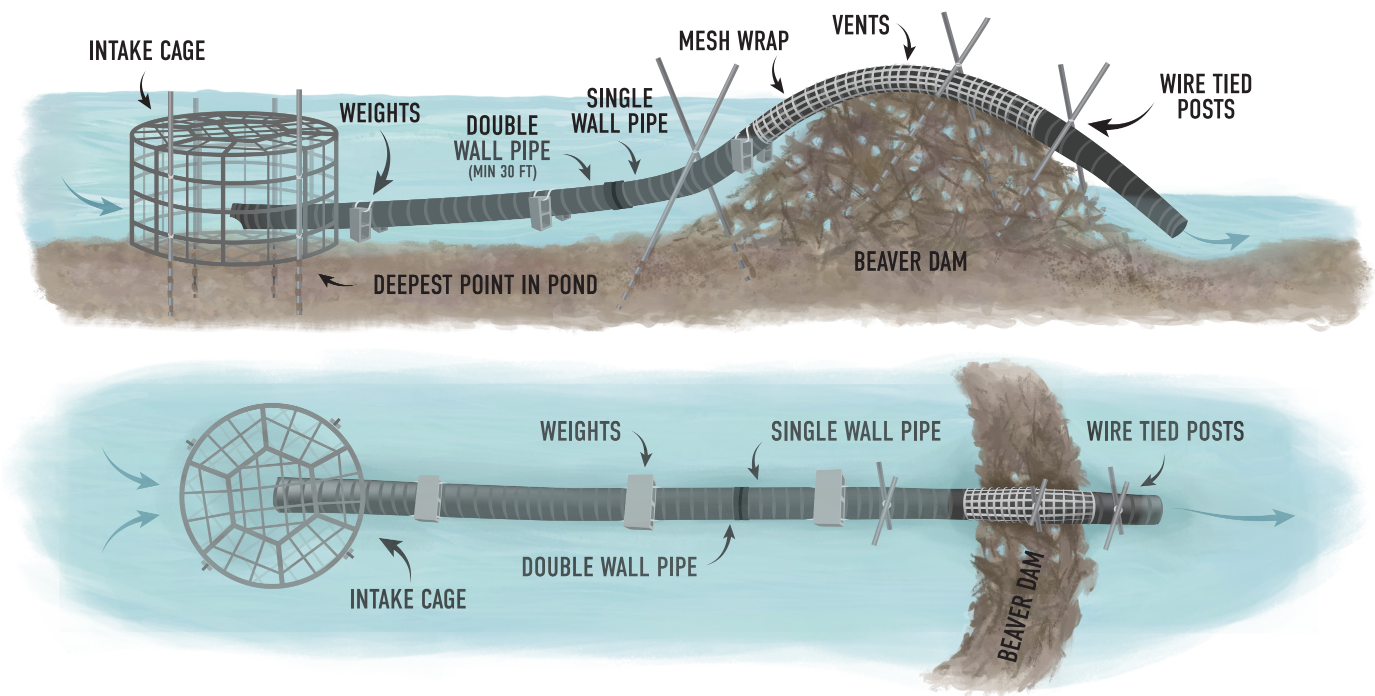


Figure 1. Standard pond leveler with no modifications.

Design fundamentals

Pond leveling devices control the height of a beaver dam by using a plastic culvert pipe and a caged intake located upstream within the beaver pond to hide a leak at the dam. Beavers will be unable to regulate the impoundment depth by adding height to the dam, and since they generally won't raise the dam height unless water is running over the top, the physical height of the dam will be constrained along with the water level. Artificially constraining the extent of beaver-facilitated habitat can impact the fish and wildlife that rely on beaver-managed ecosystems. As such, pond levelers should only be installed after careful consideration and every effort should be made to maintain the maximum possible extent of the beaver pond.

Essential design components of pond leveling systems

- **Minimize adverse impacts to habitat:** The installation of a pond leveler will decrease habitat for beavers and other native fish and wildlife. In order to minimize adverse impacts to habitat:
    - Maximize the footprint of the beaver pond by lowering the dam crest elevation only as much as is required to alleviate human flooding concerns. Maintaining maximum water depth over the openings to the beaver den or lodge is vital to prevent abandonment and/or the construction of new dams upstream or downstream of the flow devices.
    - Minimize fish and wildlife interaction with the pond-leveling system, particularly regarding impairing or preventing fish passage and the entrapment of other species such as turtles, waterfowl, or even larger mammals. Sharp edges that fish and wildlife could come into contact with should be smoothed, beveled, or tucked away and there should be no artificial protrusions into the flow path of the pond leveler. Pond levelers should not dewater the stream or otherwise artificially restrict instream flows. Fish passage design components may be required for the device. Reference the Appendices for state-specific criteria.
    - Consider the long-term plan for the site. Infrastructure changes like upgrading culverts or moving critical infrastructure away to give the aquatic and riparian ecosystems more room are the best long-term coexistence solutions.
- **An upstream intake:** While beavers will quickly fix any leak in the upstream surface of their dam, hiding the intake of the pond leveler 30' to 60' upstream removes it from the proximity of the dam where beavers tend to search for the leak.
- **A caged intake:** The intake must be caged to prevent beavers from swimming close enough to the pipe to feel or hear running water. If this exclusionary cage is too small and beavers sense the leak, they will mobilize enough debris to encapsulate the entire intake cage in days. The cage must have openings small enough that a beaver cannot fit through. The size of the cage must correspond with the size of the pipe used, so that when fully flowing there is no discernible flow through the fence.

- **Eliminated "trickling" sound and feel:** Beavers can detect leaks by hearing and feeling them. It is essential to eliminate the sensations of flowing water within the pond leveling system upstream of the beaver dam. Beavers are adapted to cascading water on the downstream side of their dam and will generally not attempt to repair leaks from this side. This outlet can be further protected with a domed lattice of sticks or mesh.

- **Dispersed intake flow:** The uniform, circular lip of the intake pipe must be disrupted to prevent the intake flow coupling with the pond surface (a whirlpool) if the intake cage is positioned in less than 4' of water. One effective method is to cut a half-circle of pipe material out of the bottom lip of this opening (Figure 2).

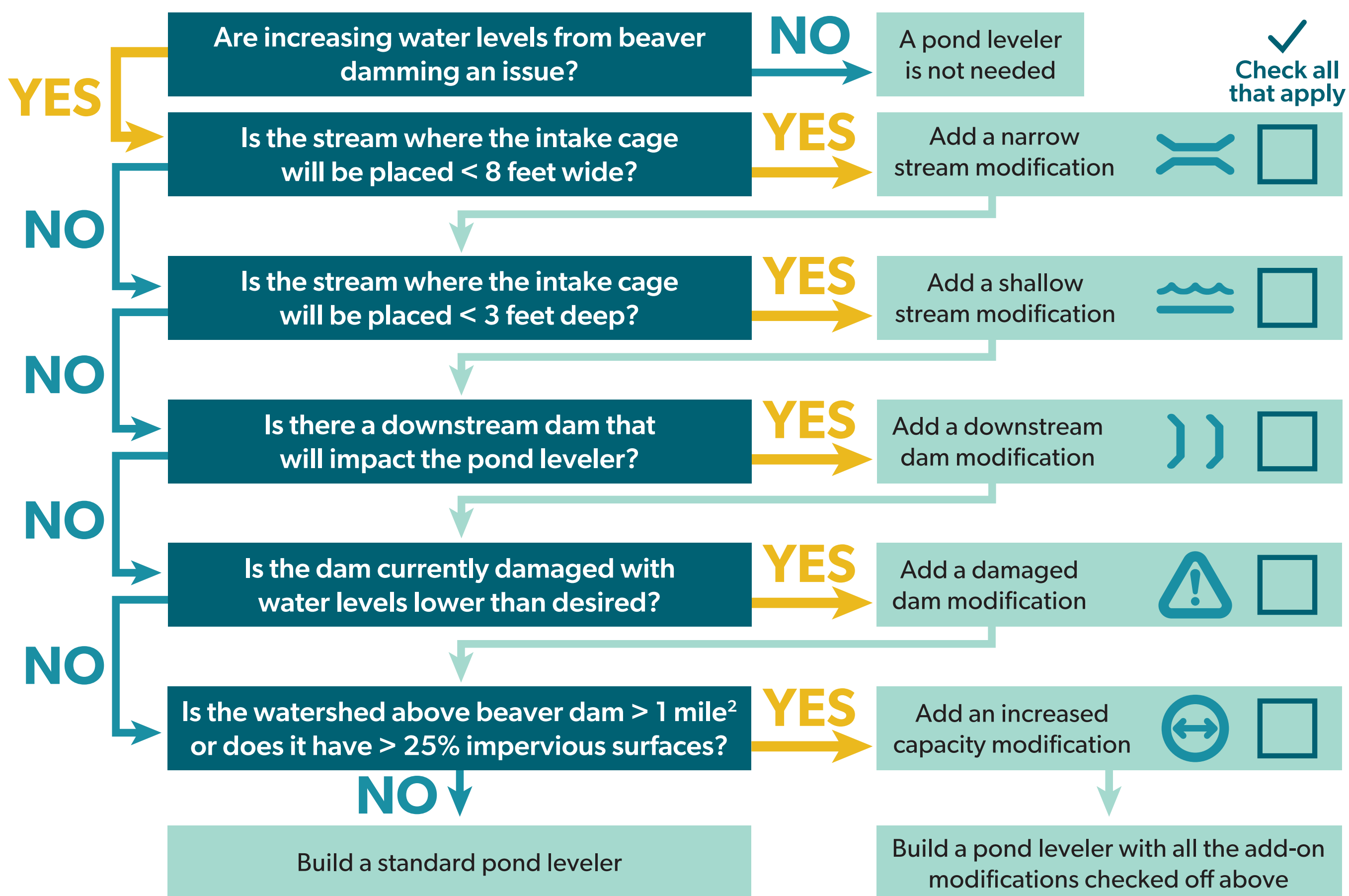
- **Stabilized flow device:** Staking the intake cage is only necessary where the intake cage is subjected to discernible flows. At these sites, firmly stabilize the intake cage and pipe to keep beavers from moving it and to minimize the need for adjustment after high-flow events. The pipe can be held in place at the dam using steel posts and the intake cage and pipe can be held in place with either steel posts or weights (Figure 1).

- **Vented pipe:** Small vent holes or slits must be cut into the top surface of the submerged pipe to release gas trapped in the pipe or within the pipe wall. These holes are essential to minimize air entrapment and keep the pipe from floating. The size of holes must be kept to a minimum to avoid attracting the attention of a beaver and to avoid potentially trapping fish, amphibians, or other wildlife.

- **Rugged construction:** It is important to construct a pond leveling system with high quality materials that can withstand normal environmental forces over time. For the pipe, use High Density Polyethylene, which is often called HDPE, and henceforth "plastic culvert pipe" in this guide. This pipe is available as single wall or double wall construction. Double wall is more robust and its smooth interior is quieter, but it lacks flexibility. Single wall is flexible, but not as quiet. Metal products like wire mesh, tie wire, screws and steel posts should all be heavy duty products that will last for a reasonably long period while being exposed to the elements.

- **Appropriately sized pipe:** Determining the appropriate pipe size for your site can be tricky, and requires considering the size of the watershed, its land-use, the percentage of impervious surface, and the permeability of the beaver dam itself. The porosity of the beaver dam depends on the materials used in the dam and can fluctuate seasonally, or even daily, as beaver add fresh mud and other materials to maintain the dam. Except where there are concerns with fish passage, use a pipe size that will carry the majority of flows moving over the beaver dam. Pipe size, material and gradient will change how much water (usually measured in cubic feet per second) can flow through your pond leveler. Look up the flow calculations for your pipe (usually available from the manufacturer) and estimate based on a 1% gradient. For reference, at 1% slope a 12" double wall pipe will move 3.8 cubic feet per second (CFS), while a 12" single wall pipe will move 2.7 CFS. A 15" double wall pipe will move 7.0 CFS, while a 15" single wall pipe will move 4.2 CFS.

Choosing pond leveler modifications



Best management practices

Pond leveling systems can successfully facilitate human/beaver coexistence for many years provided they are planned, installed, and maintained correctly. Adhering to the following Best Management Practices and modifications applicable to your site will provide the highest chance of long-term success.

Site planning

1. Prepare and submit a project plan to the applicable local, state, and/or federal permitting authority. Follow your state-specific project plan review process outlined in the document appendices.

2. Determine the new water height of the pond. If the pond contains a beaver den or lodge, find the elevation of the entrance tunnel. The water surface elevation of the pond must not drop below the top of the underwater entrance tunnel. This elevation marks the lowest possible pond elevation that can be used in the design. If the water level is lowered below the top of the burrow entrance, beavers may relocate

to adjacent stream reaches or build a new dam (often downstream), or freeze to death in cold winter climates. If beavers abandon the dam, the investment in designing and installing a pond leveler is lost. If the target dam does not contain a lodge or den, it is still important to only lower the water height the minimum amount needed to meet the coexistence objectives.

3. Develop a site plan by creating rough sketches of installation based on site layout, including expected impact up and downstream of target dam. Create two sketches with one viewing the site from above and the second viewing the site from one side.

4. Determine pipe size needed at your site. The two most common sizes are either 12" or 15" diameter. The standard design for these best management practices assume a 12" pipe is appropriate. The increased capacity modification (pg. 15) accounts for sites where a 15" pipe is needed. Generally, a 15" pipe should be used if the watershed above the beaver dam is over one square mile or has over 25% impervious surfaces. If the site has very little tolerance for natural pond level fluctuation, it is better to opt for an oversized pipe.

    » The online USGS tool StreamStats can be used to determine relevant attributes. Select the point that represents the beaver dam location, then select parameters including the area that drains to that stream point (DRNAREA) and the area percentage of impervious surfaces (LC11IMP).

5. Refer to the Design Fundamentals when designing the pond leveler and determine if the site requires any of the listed modifications.

6. Develop adaptive management plans for beaver or environmental disturbance to the site. These may include excessive debris accumulation, streamflow dropping below the intake cage, beaver modification of intake cage area, and construction of additional beaver dams up or down stream.

7. Collect the materials and tools that will be required for the installation day. Plan to use hand tools only. The use of heavy equipment can trigger additional permitting requirements. Hand tools can include rakes, shovels and saws to modify the beaver dam, a post pounder or sledge hammer for installing posts, and a small boat, kayak, or paddle board if the pond is too deep for chest waders.

8. Plan to conduct the entire installation within a single day during an appropriate in-water work window.

Installation

1. Minimize on-site micro-plastic contamination by cutting vent holes in plastic culvert pipes in an area where debris can be contained and properly disposed.

2. Select the upstream location for the intake cage. Prioritize maximum water depth, pond width, and the distance from the dam (in that order). Install the intake cage at the deepest point in the upstream pond as far from the beaver dam as the site allows (Figure 1). If possible, place in a sheltered area (like the inside bend of a stream channel slightly outside the thalweg) to minimize debris accumulation during high flow events.

3. Incrementally remove material from the beaver dam to the desired height before installing the pipe through the dam at this elevation.

4. Float the intake cage into place using pontoons. Simple pontoons can be made with 6-8' lengths of capped 6" or 8" PVC pipe and temporarily fastened under the intake cage with rope and a quick-release knot. Orienting the pontoons perpendicular to the pipe will increase stability during installation.

5. Stake the pipe and intake cage in place where possible with steel posts. Where the water is too deep or substrate is too hard (or soft), weigh pipe and intake cage down with concrete blocks or steel weights (Figure 1).

6. Wrap any exposed single wall pipe on the crest of the beaver dam with a wire mesh wrap, typically hardware cloth, to dissuade beavers from chewing into the pipe (Figure 1). Double wall pipe does not need to be wrapped.

7. Cover the exposed pipe with woody debris and mud to help camouflage it, and to help prevent beavers from chewing on the exposed pipe. Notch a small leak in the dam away from the pond leveler to give the beavers something to fix after the disruption of installation and lowering the water.

Maintenance

Check the pond leveling system regularly (minimum yearly) for any weather or beaver related damage. Before and after the typical peak-flow seasons are good periods to conduct maintenance. In many regions, these periods are in the fall before the winter precipitation and in spring after the last of the high-flows. Use only hand-tools for maintenance. Maintenance activities should include:

- Removing any accumulated debris from the intake cage. Some pond levelers, like those submerged deep in a pond or lake, may accumulate little or no debris and require minimal maintenance. Other pond levelers, like those installed in three feet of water within an active stream channel, may accumulate floating debris quickly and require monthly maintenance during certain times of the year.

- Making adjustments to the pipe outlet as necessary to meet original design criteria.

- Monitor the water level over the entrance tunnel to the beavers' den and look for potential new damming activity upstream and downstream of the device. Adaptively managing for changing site conditions. If necessary, modify the pond leveler to meet the initial objective while remaining within the construction guidelines.

- Additional maintenance and reporting requirements may be required. Reference the Appendices for state-specific criteria.

Site-specific criteria

Every site with beaver activity is unique. The stream morphology, hydrology, native fish and wildlife presence, beaver use, and objectives of the flow device installation can all vary between sites. It is essential to modify the design of a pond leveler to meet site-specific conditions.

The standard design criteria are broadly applicable to most sites. Site specific modifications can be added to the standard design depending on site features. In all cases, the application of the design criteria are meant to keep beavers actively using the dam and pond. The core goal of the design is not to install a pond leveler. The goal of the design is to maximize beaver habitat by keeping beavers at the site and minimize disruption to human infrastructure, without impairing passage for all the species and life stages of anadromous and resident fish using the aquatic resource.

Site features for a standard design

- An active and intact beaver dam is the direct source of the problematic water surface elevation.
- There is a suitable location within the upstream pond for the intake cage that is 30'-60' from the beaver dam with a width of 8' or more and depth of 3' or more during low flow periods at the target elevation.
- There are no downstream beaver dams that impact the ability for a pond-leveling system to lower the water surface elevation to the desired level.
- Site is appropriate for 12" pipe size (see Site Planning).

Design criteria

1. Use 12" diameter plastic culvert pipe.
2. Use at least 10' of double wall plastic culvert pipe at the intake cage.
3. Install pipe intake in the center of an intake cage, at least 12" above its wire floor. The diameter of this intake cage must be a minimum of 6' wide. The pipe should be secured in place using 9-gauge (or heavier) corrosion-resistant wire. Products with zinc or copper should be avoided as these are toxic to aquatic life.
4. Cut a half-circle out of the bottom lip of the intake pipe at its mouth approximately 6" deep and 8" wide (Figure 2).
5. The cage must be constructed with 6-gauge welded wire (or heavier) and should have a maximum of 6" by 6" openings (a beaver can pass through larger mesh sizes). When passage of fish species is a concern, mesh openings or migration pathways within the structure must be large enough to accommodate passage of the target species and life stages. Reference the Appendices for fish specific and state-specific criteria.

6. Use double wall plastic culvert pipe where possible. Single wall can be substituted if double wall is not available.

7. Use single wall plastic culvert pipe where flexibility is needed. If single wall pipe is not available, coupling 10' lengths of double wall pipe can provide some flexibility.

8. Maximize the distance between the beaver dam and intake, with a minimum of 30' and ideal range of 40'-60'. Install intake cage in the deepest part of the upstream pond and a minimum of 4' away from either bank. Maximize the distance between the stream banks and the cage to allow for passage of fish and wildlife.

9. Connect segments of plastic culvert pipe with split couplers secured with zip-ties and ceramic coated or stainless screws (no longer than necessary so as not to protrude into the interior of the pipe).

10. Cut small holes or slits (1/8 inch) at the crest of every rib in the single wall culvert pipe at 11, 12 and 1 o'clock in orientation (Figure 2). Running a portable circular saw down the length of the pipe with the blade set at an appropriate depth is a quick and efficient technique. Capture and dispose of the plastic debris.

11. Cut small holes or slits (1/8 inch) at the crest of every rib in the double wall culvert pipe at 4, 8, 11, 12 and 1 o'clock in orientation (Figure 2). Cut through only the outer wall to allow air trapped between the ribbed exterior layer and smooth interior layer of plastic to escape. Capture and dispose of the plastic debris.

12. Secure the pipe in place with weights and/or steel posts every 10'-20', using 9-gauge (or heavier) corrosion-resistant wire. Products with zinc or copper should be avoided as these are toxic to aquatic life.

13. Run the pipe downstream of the dam a minimum of 4' or into the downstream pool (Figure 1). The location of this outlet will impact fish movement. Coordinate with your state-specific fish and wildlife agency on the outlet design and fish movement considerations. Reference the Appendices for fish specific and state-specific criteria.

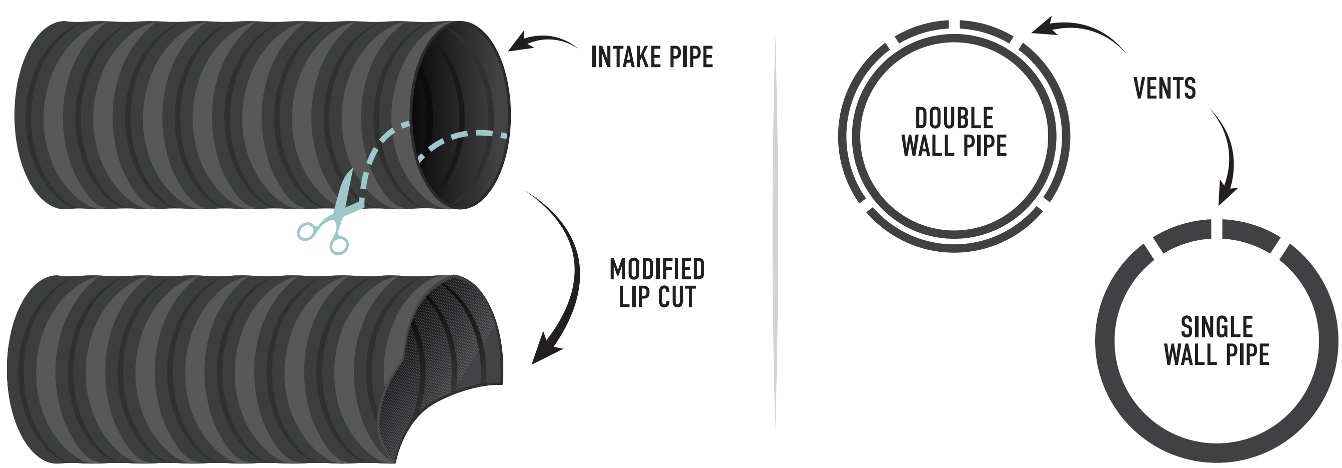


Figure 2. Modification to intake pipe and locations for pipe vent cuts.

Narrow channel modification

Narrow channels, such as severely incised streams, present an extra challenge to pond leveling systems. Pond levelers work because the cage around the intake excludes beavers from swimming near the intake of the pipe where they can sense the moving water. If the intake cage isn't adequately sized, beavers will discover and plug the device. However, if a 6' standard design intake cage takes up most of a narrow stream and there isn't adequate space for beavers to maneuver around it, they are likely to use the cage as a dam anchor and begin building directly on the intake structure. The closest intake cage must be a minimum of 30' from the beaver dam.

In streams with potential beaver habitat, these narrow, deep characteristics often represent a temporary degraded state. Beaver dams will begin the process of restoring habitat to a more functional state, through collecting sediment and reconnecting the floodplain. This natural, process-based restoration can contribute to more active floodplain habitat in the future and the intake cages may be more prone to sedimentation. Plan accordingly.

When pond levelers are deployed in areas with an active channel of less than 8' in width, the following design criteria aim to:

- Distribute intake flow over two or more points to reduce potential beaver attraction.
- Minimize the profile of the intake cage and maximize the area of unobstructed channel, without sacrificing the buffer the cage provides.

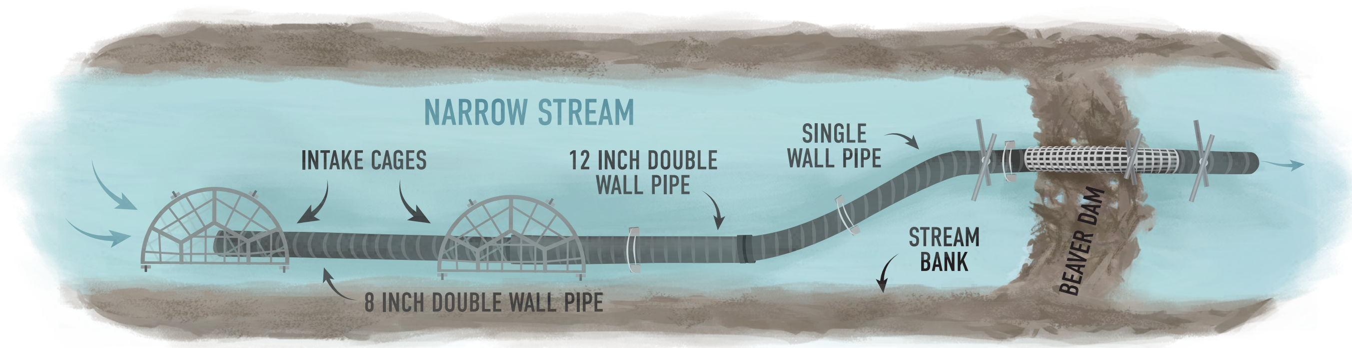


Figure 3. Overhead view of dual intake pond leveler modification for narrow streams using half-circle intake cages.

Narrow channel design criteria

Follow design criteria #5-13 from the standard design.

14. Construct a dual intake pond-leveling system with the intake flow distributed over two cages, spaced at a minimum of 20' from each-other (Figure 3).

15. Construct two half-circle intake cages with a radius of 4' each using a minimum 6-gauge wire thickness.

16. Split the intake flow between the two intake cages by nesting an 8" double wall pipe into the mouth of a 12" double wall pipe (Figure 4).

17. Cut a half-circle out of the bottom lip of the mouth of an 8" intake pipe and install with the intake positioned at the midpoint along the flat side of the cage (Figure 2).

18. Cut a half-circle out of the bottom lip of both the 8" and 12" intake pipes and secure the smaller pipe within the larger one, such that the opening area is roughly the same as the other intake (Figure 4). Use ceramic coated or stainless screws (no longer than necessary so as not to protrude into the interior of the pipe) and/or 9-gauge corrosion resistant wire. Products with zinc or copper should be avoided as these are toxic to aquatic life.

19. Install the opening of the nested pipes in the second cage at the midpoint along the flat side (Figure 3).

20. Install both intake cages with their flat sides tight along the stream bank to prevent beavers from swimming between the bank and the intake cages. Maximize the distance between the opposite stream bank and the intake cages to allow beaver (and other fish and wildlife) passage. Sometimes this requires using a shovel to shape the shore so the cage rests snugly against the bank.

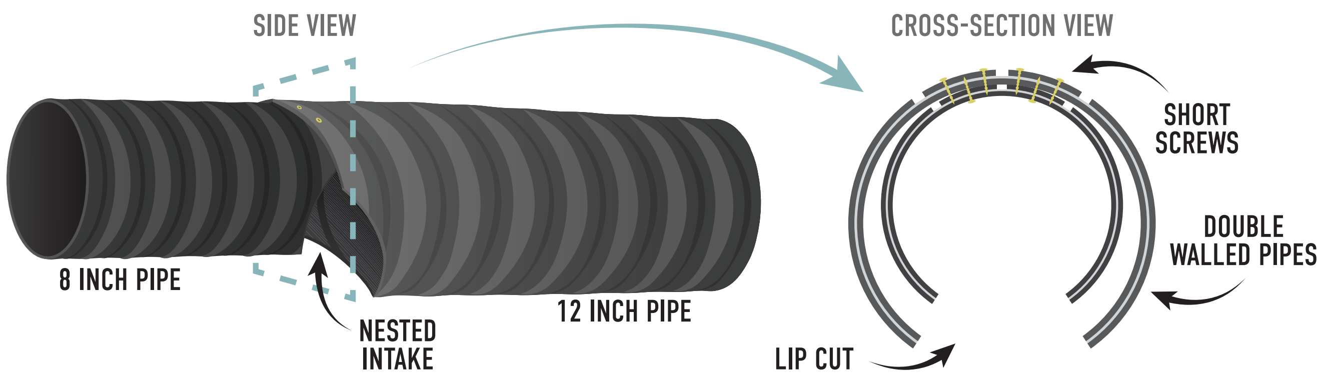


Figure 4. Nested pipe configuration used when constructing a dual-intake pond leveler.

Shallow channel modification

Pond leveler systems work because the cage around the intake excludes beavers from swimming close enough to the intake pipe to sense moving water. In shallow channels or if water around the cage drops, the flow per area into the cage is concentrated, increasing the chances that beavers will discover the intake pipe. When pond leveling devices are deployed in areas with a water depth of 1-2', the flow per area into the intake cage(s) must be minimized to diminish potential beaver attraction. The closest intake cage must be a minimum of 30' from the beaver dam.

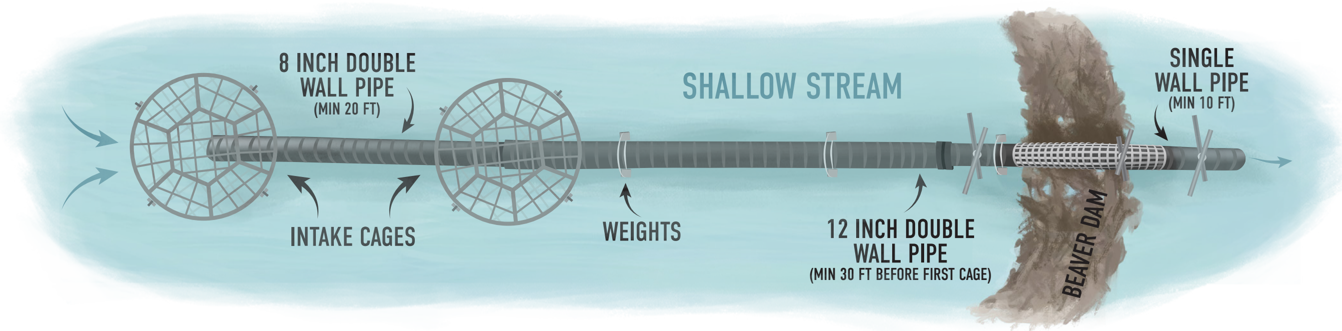


Figure 5. Dual intake pond leveler modification for shallow streams.

Shallow channel design criteria

There are two options for a shallow site:

- A single intake system with a larger cage
- A dual intake system (Figure 5)

For a single intake system

Follow design criteria #1, and #3-13 from the standard design.

14. Install pipe intake in the center of an 8' diameter intake cage.
15. Install intake cage in the deepest part of the upstream pond and a minimum of 4' away from either bank. Maximize the distance between the stream banks and the cage to allow for passage of fish and wildlife.

For a dual intake system

Follow design criteria #5-13 for a standard design, and #20, 22 and 24 from the narrow channel modification.

25. Construct two round, 6' intake cages using a minimum wire thickness of 6-gauge.
26. Cut half-circle out of the bottom lip of an 8" intake pipe at its mouth and install in the center of upstream cage (Figure 2).
27. Install cages in the deepest part of the upstream pond and a minimum of 4' away from either bank. Maximize the distance between the stream banks and the intake cages to allow for passage of fish and wildlife.

Downstream dam modification

Sometimes beavers will build an additional dam downstream of a pond-leveling system which can flood the original dam and flow device. Large downstream dams have the potential to increase water levels above the maximum set by the pond leveler. The risk of downstream dam construction can be minimized through adherence to the best management practices during installation, particularly by retaining an adequate pond depth for the beavers. However, if an additional dam is constructed less than 50' away, the downstream pond can be controlled by extending the pipe from the outlet of the existing pond leveling system across the downstream dam (Figure 6).

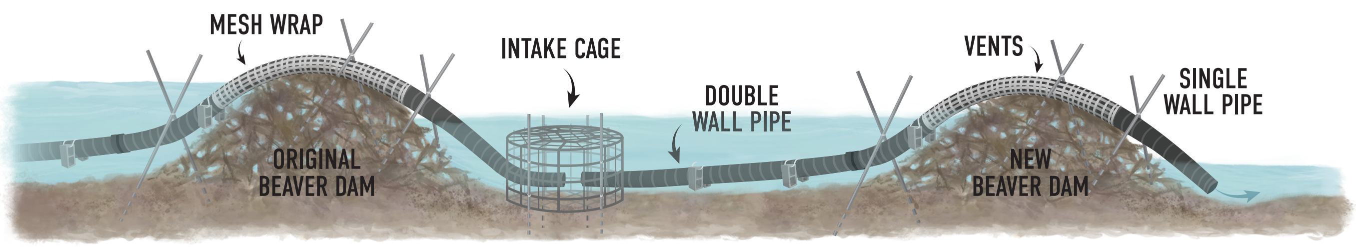


Figure 6. Pond leveler extension to accommodate additional downstream beaver dams.

Downstream dam design criteria

Follow design criteria #9-13 from the standard design.

14. Extend the pipe from the original pond leveler into an exclusion cage at the toe of the original dam and then through and over the new dam downstream. Build the new cage using criteria #3-5. Extend a new pipe from the downstream side of this cage, leaving either 6" between the two pipe ends within the cage.

15. Use flexible single wall plastic culvert pipe to extend the existing pipe into the new cage downstream of the original beaver dam, and over the new beaver dam. Use double wall plastic culvert pipe to extend between the beaver dams along the flat stream bottom.

16. Install the pond leveler through the downstream beaver dam at least 6" lower in elevation than the original dam.

Damaged dam modification

Sometimes a dam has been removed or reduced below the desired crest elevation prior to the planned installation of a pond leveler. If an immediate need to reduce flooding is required, reducing the beaver dam height will provide a temporary solution while assessing the options for beaver coexistence at a site. If the dam is still below the desired crest elevation when you are ready to install the pond leveler, either: (1) wait for the beavers to increase the dam's height to the target elevation or (2) install the pond leveler above the dam at the desired elevation (it will not flow until the beaver dam is built back to that point).

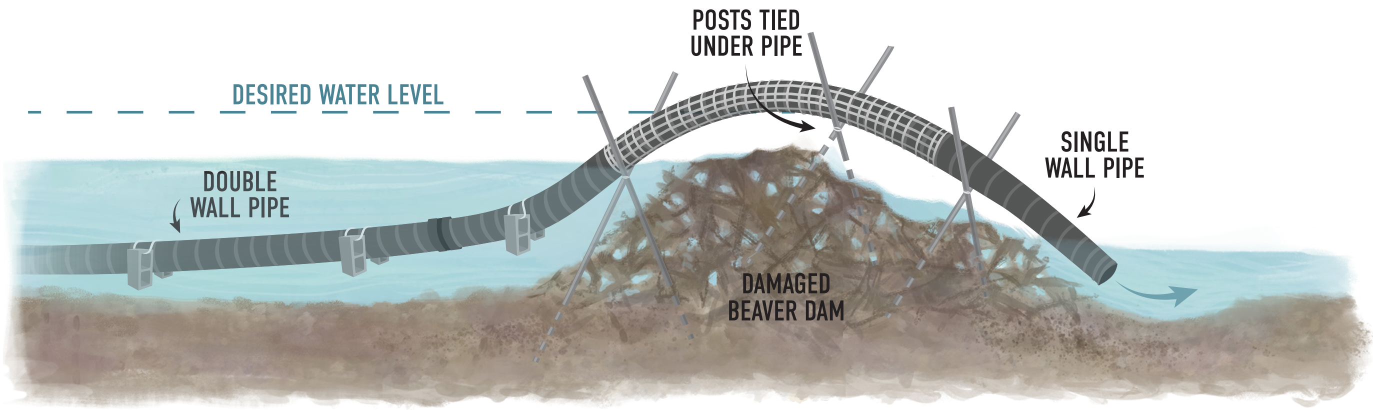


Figure 7. Installing or adjusting pond leveler to account for dam damage.

Damaged dam design criteria

Follow design criteria #1-12 from the standard design.

13. Position the single wall plastic culvert pipe at the desired maximum dam elevation and secure suspended in place with steel posts directly over the dam crest (Figure 7). Fasten the pipe to the steel posts using a minimum wire thickness of 9-gauge.

14. Wrap exposed pipe with a corrosion-resistant wire mesh wrap, typically hardware cloth, securing with hog-rings or wire. Products with zinc or copper should be avoided as these are toxic to aquatic life.

Increased capacity modification

A 12" pipe is generally sufficient for most sites. However, in special cases where the watershed above the beaver dam is over one square mile or has over 25% impervious surfaces, additional capacity may be required.

Increased capacity design criteria:

Follow design criteria #1, 3, and 5-13 from the standard design.

14. Install pipe intake in the center of a 7' diameter intake cage.

15. Use 15" plastic culvert pipe. This pipe can convey almost 2x the flow rate of a 12" pipe.

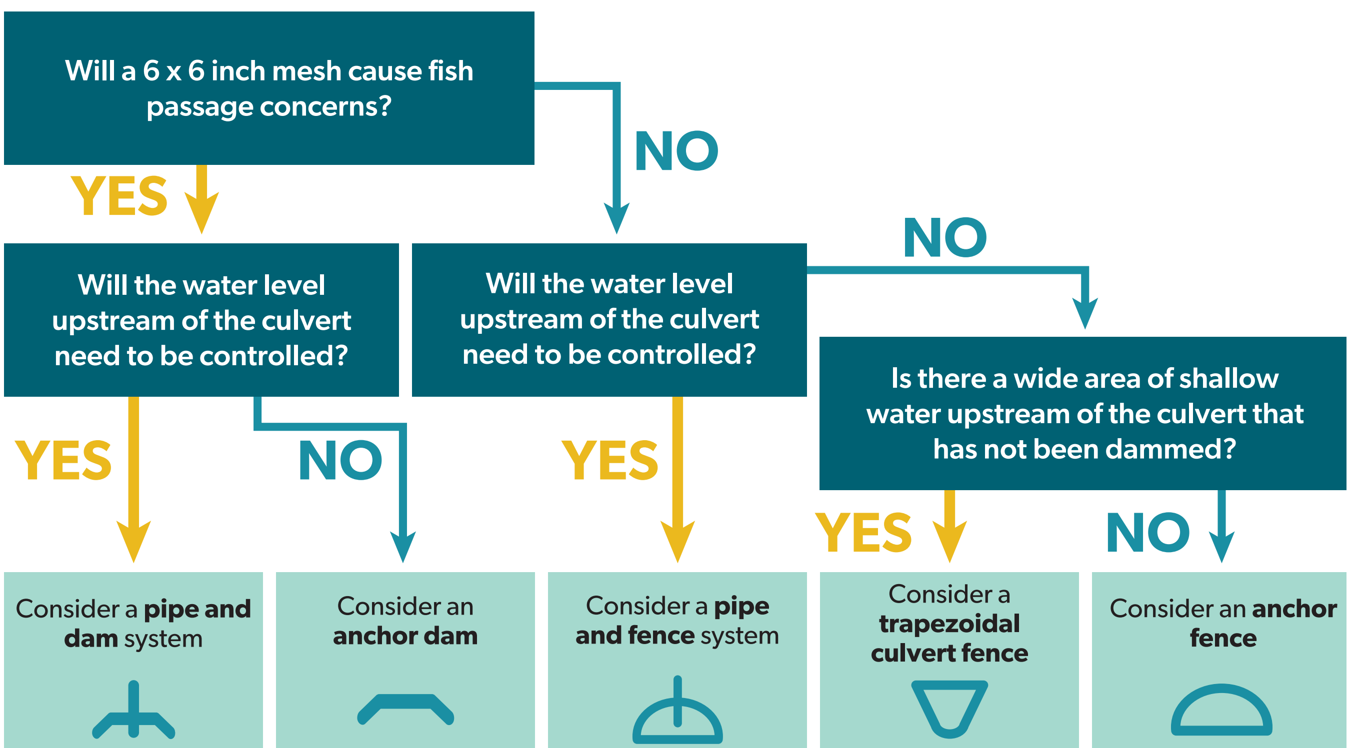
Culvert protection systems

When to use a culvert protection system

Culverts, spillways and similar human infrastructure can be protected from beaver damming while preserving their function. Many of the culverts where beaver damming occurs are undersized and may present fish passage issues. If possible, replace the culvert with a structure that is properly sized and designed.

If financial, logistical, and time critical responses prevent immediate culvert replacement, a properly constructed, installed and maintained culvert protection system can provide a cost-effective solution that can last 5-10 years or longer if properly maintained. A culvert protection system is designed to protect infrastructure while allowing beavers to remain in their habitat. It is vital that the addition of a culvert protection system does not further impact the passage of target fish species or life stages of concern.

Choosing a culvert protection system



Design fundamentals

Culvert protection designs work by either physically excluding beavers from the culvert or spillway or by altering the cues that promote dam building activity. Primary tactics include:

A **trapezoidal culvert fence** (Figure 8) protects the culvert by physically excluding beavers from the area around the culvert inlet using wire fencing. The shape of the fence also alters the physical and auditory cues that promote dam building. Beavers will often start to construct a dam along the two sides of the fence exclosure nearest to the culvert, but generally abandon the dam building as the angle of the fencing pushes them out into still water where they no longer detect the sensations of flowing water. As a result, a majority of the fence remains unobstructed.

An **anchor fence** (Figure 9) directly protects the culvert's mouth with a semi-circle of fencing. Beaver damming activity is still allowed at the culvert mouth, but the location of the dam is controlled by the fence structure. By relocating the damming activity upstream, flow through the culvert is unimpeded. This design can be modified to accommodate a pond leveler through the anchor fence if the elevation or extent of the upstream beaver pond must be limited. The modification of adding a pond leveler to an anchor fence is often called a **pipe and fence** culvert protector (Figure 10).

An **anchor dam** (Figure 11) is a similar strategy used to protect culverts at sites where fencing should not be used in the stream. This tactic includes construction of a Beaver Dam Analog (BDA) reinforced with steel posts—just upstream of the culvert mouth. While this tactic does not exclude the beavers from the infrastructure, it can divert them into investing and improving upon the reinforced BDA as their new dam, leaving the culvert open. This design can be modified to accommodate a pond leveler through the reinforced BDA if the extent of the upstream beaver pond must be limited. The modification of adding a pond leveler to an anchor dam is often called a **pipe and dam** culvert protector (Figure 12).

Create a long-term plan for site that includes infrastructure changes such as upgrading culverts or moving critical infrastructure away from riparian habitat. The best long-term coexistence solution for beaver-human conflicts is to give the aquatic and riparian ecosystems more room to facilitate natural processes and build ecosystem resilience.

Essential design components of culvert protection systems

- Beaver exclusion from the culvert: Unless constructing an anchor dam or pipe and dam, beavers should be excluded from the area around the culvert using heavy gauge wire that is small enough that both adult and sub-adult beaver cannot pass through.
- Provide fish passage: It is essential that designs minimize passage obstruction or delay of fish species and life stages of concern. When passage of fish species is a concern, mesh openings or migration pathways within the structure must be large enough to accommodate passage of the target species and life stages. Reference the Appendices for fish specific criteria.
- Start with a clean culvert: During the appropriate time of year, remove all the aggregated damming materials from within the culvert and upstream area of work. Take appropriate safety precautions when

removing dams that are retaining large quantities of water. This activity can be quite dangerous since the force behind the flowing water increases exponentially as the dam is lowered, the risk of a sudden dam collapse increases, and a person could be swept into the culvert and drowned.

- Stabilize flow device in place: It is important to stabilize the anchor fence in place with steel posts and/or untreated cedar lumber (as needed), to minimize the need for major readjustment after high flows.
- Rugged construction: It is important to construct the culvert protection system with high quality materials that can withstand the forces of nature in a streambed. Metal products like wire mesh, tie wire, screws, and steel posts should all be of quality construction that will hold up over time and exposure.
- Facilitate wildlife passage: Leave an opening in the exclusionary fence that runs up onto dry land to provide an exit for other wildlife that may use the culvert to move up and down the stream (Figure 8).
- Minimize adverse impacts to habitat by:
    - Minimizing sediment mobilization and turbidity when removing damming material from the culvert and during installation and maintenance
    - Reduce the footprint of the beaver pond only as much as is necessary to address human concerns.

Best management practices

It is vital that culvert protection systems be planned, installed, and maintained correctly to successfully facilitate human-beaver coexistence for many years. The following Best Management Practices should be adhered to when implementing these coexistence methods:

Site planning

1. Contact your state fish and wildlife agency to determine if the site must consider passage of target fish species and life stages in the design. Discuss any concerns using the recommended 6" by 6" mesh spacing may cause for fish passage related to mesh size, distance between the culvert and anchor fencing, or distance between the culvert and anchor dam. Note that beavers will dam against the mesh of the anchor fence design while the mesh of a trapezoidal culvert fence will remain relatively unobstructed. Follow the specific guidelines in the Appendices for developing and submitting your project plan to the appropriate state agencies.
2. Determine the footprint of the wetted stream channel upstream of the culvert or spillway during low flow in the absence of beaver damming. If there is a wide area of shallow water upstream of the culvert (without the influence of a beaver dam), consider a trapezoidal culvert fence. If there is not an adequate, shallow, upstream wetted area adjacent to the culvert's inlet, then consider an anchor fence or an anchor dam.

3. Determine the human infrastructure tolerance for upstream impoundment. If the culvert capacity remains open, how high can a beaver dam be built? If the beavers can be allowed to naturally set the height of their dam, consider an anchor fence or anchor dam. If there is a maximum dam height that must be enforced, consider installing a pipe and fence or a pipe and dam flow device.

4. Develop a site plan by creating rough sketches of installation based on site layout, including the expected up and down stream impact. Create two sketches with one viewing the site from above and the second viewing the site from one side.

5. Develop maintenance and adaptive management plans for beaver or environmental disturbance to the site. Disturbances can include, but are not limited to, excessive debris accumulation, intake cage stranding due to low flow (when the water around the intake cage decreases below 2' deep), beaver modification of intake cage area, construction of additional beaver dams upstream, downstream, or within the culvert.

6. Adhere to the Design Fundamentals in designing the culvert protection solution.

Installation

- Remove all the aggregated damming materials from within the culvert and the upstream area of work immediately before flow device installation. Remember to take appropriate safety precautions when removing dams that are retaining large quantities of water.

- Use only hand-tools for culvert system installation and conduct within a day if possible.

- Stabilize with heavy duty steel posts firmly driven into the streambed and spaced close enough to resist damming and flooding.

- Reinforce with steel or untreated wood. Do not use treated wood.

Maintenance

- Check the fence system regularly (minimum quarterly) for weather or beaver related damage.

- Remove any accumulation of debris from the fencing of a trapezoidal culvert fence and from the intake cage for a pipe and fence flow device.

- Adjust the fence, pipe, or outflow as necessary to meet original design criteria or to adaptively manage for changing site conditions.

- Adaptively manage for changing site conditions. If necessary, modify the installation to meet the initial objective while remaining within the construction guidelines.

- Use only hand-tools for maintenance.

Site-specific criteria

Every site with beaver activity is unique, making it essential to modify the design of a culvert protection system to the site specific conditions. The following standard design criteria are broadly applicable, and the subsequent examples provide site specific modifications to the standard design in response to variations in site features. In all cases, the design criteria are intended to allow beaver to actively use adjacent stream reaches while allowing the protected culvert to function normally.

Trapezoidal culvert fence — standard site

Site features

- Active beaver damming within infrastructure that creates a flow constriction point, such as inside a culvert or spillway.
- Shallow stream channel upstream of the culvert mouth (assessed during low flow without beaver activity) with open water that is less than 3' deep, greater than 3 times the width of the culvert, and longer than 16'. A trapezoidal culvert fence needs to accommodate at least 2' (laterally) of open water on all sides between the fence and the bank.

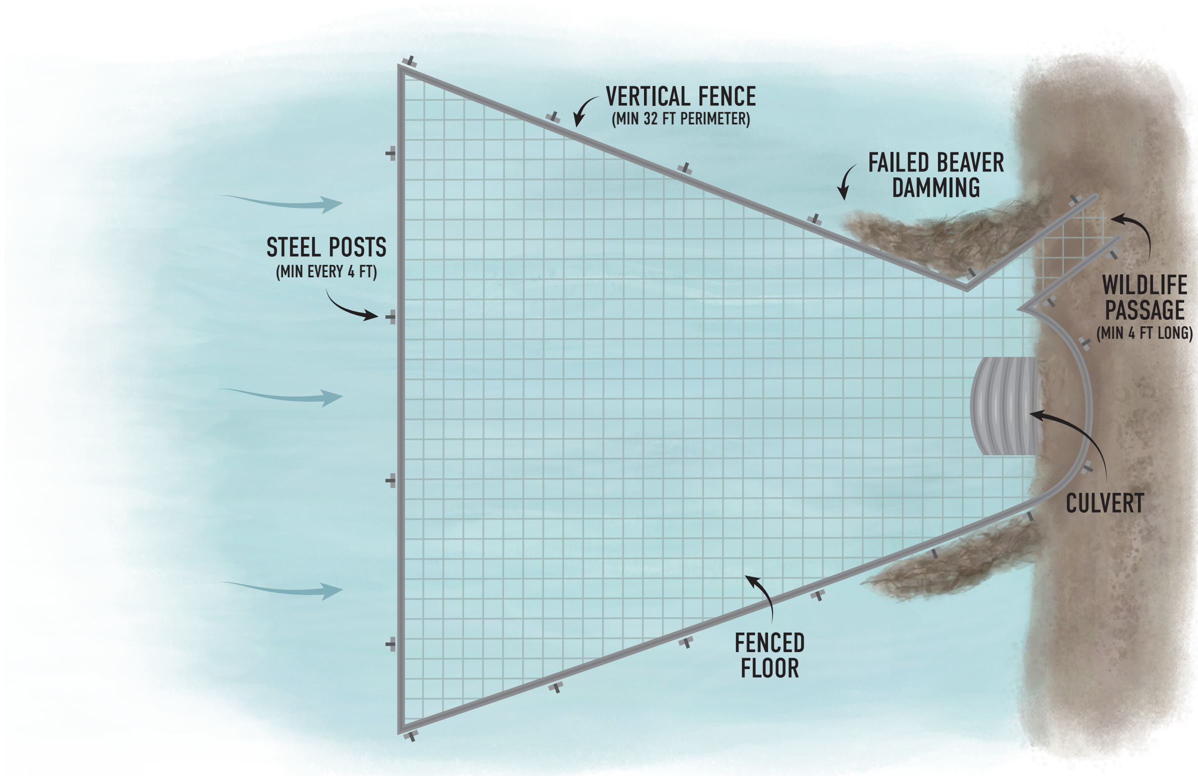


Figure 8. Trapezoidal culvert fence.

Trapezoidal culvert fence design criteria

1. Design the trapezoid with a minimum perimeter length of 32' and at least 2' of open water around all sides between the fence and the bank. The typical length of the trapezoid's sidewalls should be 12' and its face should be at least double the width of the culvert's opening (i.e. 12' for a 6' culvert). These measurements are flexible per site requirements as long as minimum surrounding water and perimeter length are maintained. If the perimeter length is too short, beavers may treat the structure like an anchor fence and dam around the perimeter.

2. Construct the fence using welded wire with a minimum thickness of 6-gauge.

3. The fencing should be constructed using 6" by 6" openings between wires. Do not construct an opening size less than 4" by 4" to avoid accumulating too much floating debris. When passage of fish species is a concern, mesh openings or migration pathways within the structure must be large enough to accommodate passage of the target species and life stages. Reference the Appendices for fish specific criteria.

4. Attach wire panels together with a minimum overlap of one cell and fasten with one hog ring on each of the parallel overlapping wires.

5. Create a fenced floor using a mesh resting horizontally on the streambed. The mesh must run all the way to the culvert's mouth, allowing no place for beavers to tunnel underneath.

6. Extend fencing a minimum of 18" (ideally 24") above the water surface elevation at low flow conditions. In general, the total height of the wall should equal the stream depth plus 2 feet.

7. Extend fencing, including the floor, onto the road bank to completely surround the culvert.

8. Construct one opening with side walls in the trapezoid's perimeter that extends a minimum of 4' long across dry ground onto the road bank. Extend a floor in this terrestrial wildlife passage from the floor of the flow device to the end of the passageway (Figure 8) and infill with small rocks and other on-site materials to provide solid footing. Build this passage minimum of 16" wide and minimize exposed sharp wire ends for both wildlife and human safety.

9. Stabilize with heavy-duty steel posts at least every 4 feet and firmly driven into the streambed. Angle bracing the upright posts with additional steel posts is recommended for streams with heavy flows (see bracing in Figure 9). Untreated 2" by 6" timber can be used for additional bracing around the entire top of the fence. Use heavy gauge wood staples to secure the wire mesh to the wood and heavy duty lag bolts to attach the cross bracing at the corners.

10. Fasten the trapezoidal culvert fence to steel posts using a minimum wire thickness of 9-gauge.

Anchor fence — standard site

Site features

- Beavers can be allowed to manage upstream habitat and the extent of upstream beaver impoundment does not require control.

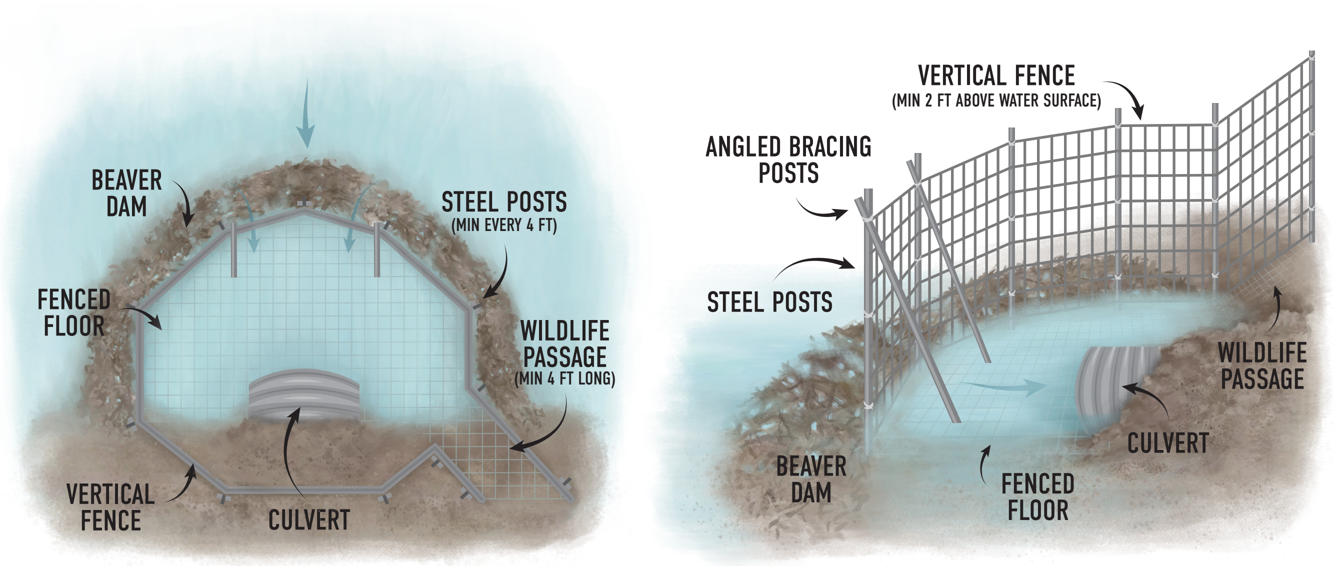


Figure 9. Standard anchor fence shown from above (left) and side (right).

Anchor fence design criteria

1. Construct a half-circle of fencing to protect the culvert or spillway, with the top of the arc facing upstream (Figure 9). Allow for 6-8 feet of radial space between the fencing and the culvert.

2. Construct the fence using welded wire with a minimum thickness of 6-gauge.

3. The fence should be constructed to have a maximum of 6" by 6" openings between wires.

4. Attach wire panels together with a minimum overlap of one cell and fasten with one hog ring on each of the parallel overlapping wires.

5. Fenced floor must run all the way to the culvert's mouth, allowing no place for beavers to tunnel underneath.

6. Extend fencing a minimum of 18" (ideally 24") above the water surface elevation at low flow conditions. In general, the total height of the wall should equal the stream depth plus 2 feet.

7. Extend fencing onto the road bank to completely surround the culvert (unless there are concrete walls that surround the culvert, or another such surface, that you can run the fencing up against so that beavers cannot dig around the fencing).

8. Construct one opening in the exclusion fence perimeter adjacent to one side of the culvert mouth that extends to the dry bank with side walls for a minimum of 4' long across dry ground. Extend a floor in this terrestrial wildlife passage from the floor of the flow device to the end of the passageway (Figure 9) and infill with small rocks and other on-site materials to provide solid footing. Build this passage minimum of 16" wide and minimize exposed sharp wire ends for both wildlife and human safety.

9. Stabilize with heavy-duty steel posts at least every 4 feet and firmly driven into the streambed. Angle bracing the upright posts with additional steel posts is recommended for streams with heavy flows.

10. Secure the anchor fence to steel posts using a minimum wire thickness of 9-gauge.

Anchor fence — pipe and fence modification

Site features

- Beavers cannot be allowed to freely control upstream habitat and its water surface elevation. The extent of upstream beaver impoundment requires control, and a maximum elevation must be set for the beaver dam at the exclusion fence using a pond leveler.

Pipe and fence design criteria

Construct an anchor fence in accordance with the standard design #1-10.

11. Construct and install a pond leveler in accordance with the standard pond leveler Design Fundamentals, Best Management Practices, and Site specific Criteria.

12. Install the overflow pipe through the fencing of the anchor fence (Figure 10) at the desired maximum dam crest elevation and secure in place with corrosion-resistant wire (minimum of 9-gauge or heavier) and heavy-duty steel posts. Products with zinc or copper should be avoided as these are toxic to aquatic life.

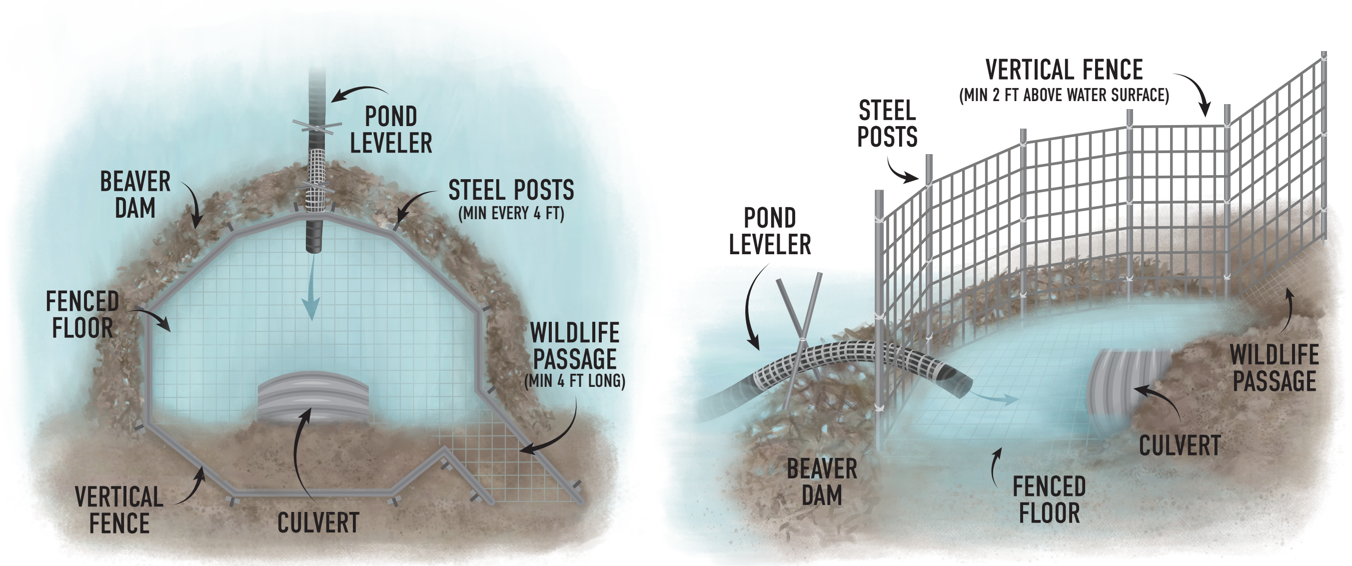


Figure 10. The combination of an anchor fence and pond leveler to create a pipe and fence culvert protection system shown from above (left) and side (right).

Anchor dam — standard site

Site features

- Beavers can be allowed to manage upstream habitat. The extent of upstream beaver impoundment does not require control.
- Stream is less than 1.5' deep 6-8' upstream of the spillway.
- A fence with 6" by 6" openings is not appropriate for the site.

Anchor dam design criteria

1. Construct a Beaver Dam Analogue (BDA) 6-8 feet upstream of the culvert or spillway. Adhere to the best management practices for a "post-less BDA" in Chapter 4, Appendix E of the Low-Tech Process-based Restoration of Riverscapes: Design Manual (Wheaton et al. 2019).
2. Stabilize with heavy-duty steel posts, firmly driven into the streambed no less than 12" apart (Figure 11).

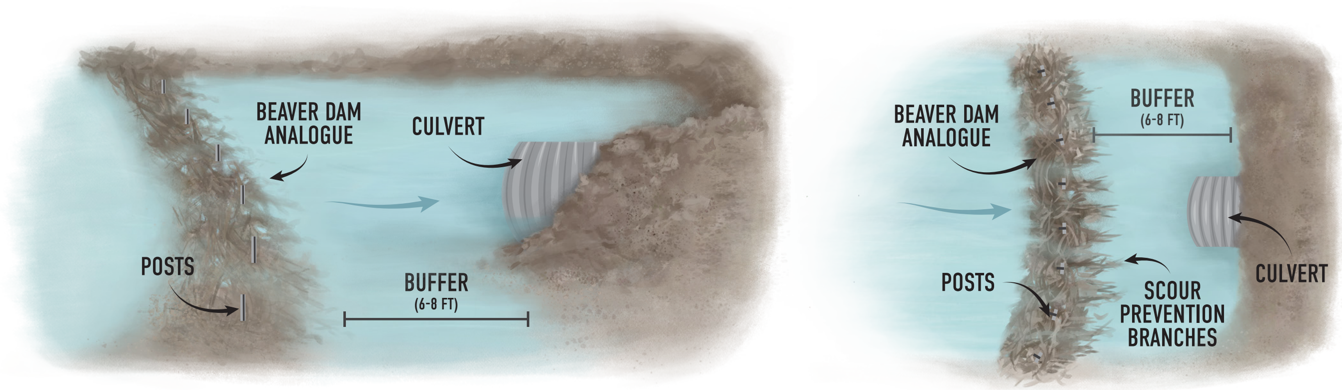


Figure 11. Anchor dam using a post-less BDA that is reinforced with steel posts.

Anchor dam — pipe and dam modification

Site features

- Beavers cannot be allowed to freely control upstream habitat. The extent of upstream beaver impoundment requires control, and a maximum elevation must be set for the beaver dam using a pond leveler.
- A fence with 6" by 6" openings is not appropriate for the site.

Pipe and dam design criteria

Construct an anchor dam in accordance with design criteria for a standard design #1-2.

3. Construct and install a pond leveler in accordance with the standard pond leveler Design Fundamentals, Best Management Practices and Site specific Criteria.

4. Position the overflow pipe over the anchor dam, using the same procedure outlined for a natural beaver dam (Figure 12).

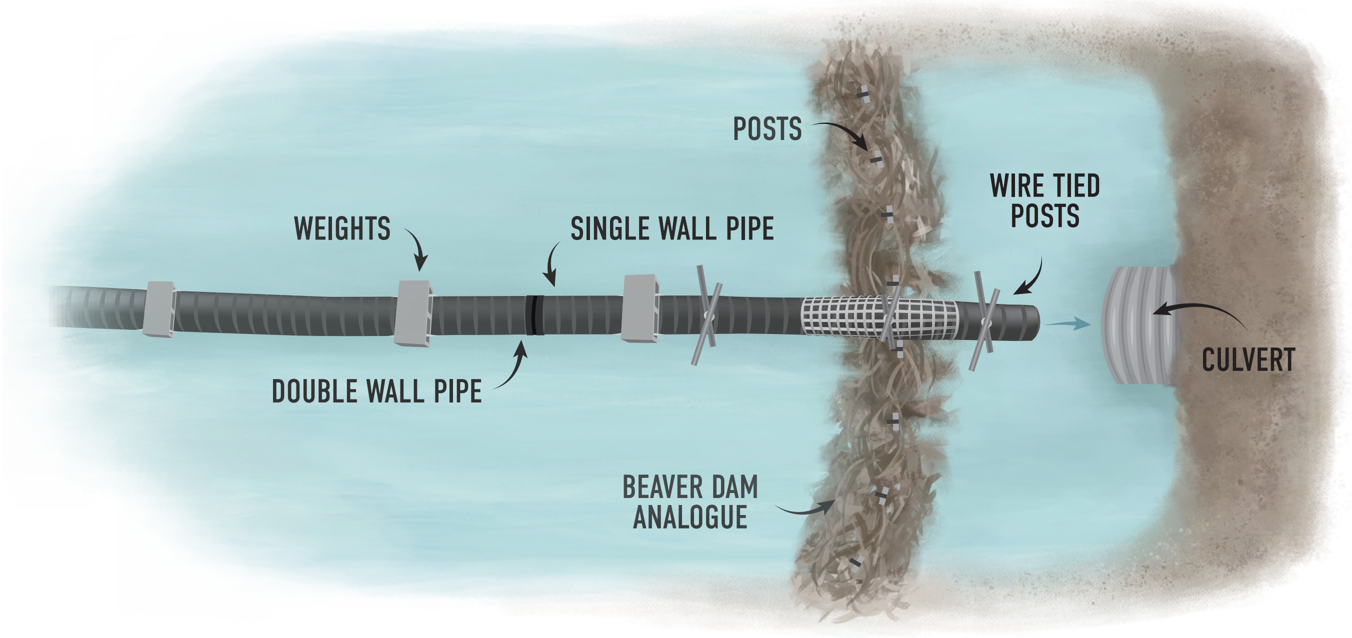


Figure 12. Combination of an anchor dam and pond leveler to create a pipe and dam culvert protection system.

Appendix

> *Note: We are working with the applicable regulatory authorities in varies states in the USA to green-light the permitting process for flow devices. Country and state specific guidance will be published here as we finalize those appendices. If you would like to support this effort, please contact Project Beaver.*

Version History:

Version 1.0 — Original document

Version 1.1 — Minor text edits and additions to the title page, attributions section, and pages 3, 11, & 19.

Version 1.2 — Rebrand; new logo, updated cover picture and minor text edits to page 28.

Version 1.3 — Increased minimum diameter for a standard pond leveler intake cage from 5' to 6' (pages 10 & 12).

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