2014

The Evolution of Flow Devices Used to Reduce Flooding by Beavers: A Review

Jimmy D. Taylor II
USDA/APHIS/WS National Wildlife Research Center, jimmy.d.taylor@usda.gov

Russell D. Singleton

Wildlife Society Bulletin 38(1):127–133; 2014; DOI: 10.1002/wsb.363

Original Article

The Evolution of Flow Devices Used to Reduce Flooding by Beavers: A Review

JIMMY D. TAYLOR,[1] *United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Oregon Field Station, 321 Richardson Hall, Corvallis, OR 97331, USA*

RUSSELL D. SINGLETON, *United States Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Oregon Field Station, 321 Richardson Hall, Corvallis, OR 97331, USA*

ABSTRACT Dams created by American beavers (*Castor canadensis*) are associated with positive and negative values, and beaver management decisions are based on stakeholder perception and levels of tolerance. Lethal trapping is a widely used and accepted tool to reduce beaver damage caused by flooding; however, acceptable and efficacious non-lethal tools are increasingly desired by the public. We traced the origin of non-lethal tools used to reduce beaver flooding as far back as the early 20th century, when beavers received protective status and were reintroduced to many areas across North America. These tools focus on 2 general factors—exclusion and deception—and can be categorized as fence systems and pipe systems. We found few technological advances in tools to reduce beaver flooding until the 1980–1990s, when fence systems and pipe systems were integrated to create "flow devices." There are few studies that evaluate fence systems, pipe systems, and flow devices; however, we address their findings in chronological order. We recommend that natural resource managers avoid using fence systems or pipe systems alone, unless they can be used in areas where maintenance requirements and expected damage are extremely low. Flow devices are not intended to replace lethal control; however, we recommend use of flow devices as part of integrated management plans where beaver flooding conflicts are expected and where local conditions allow flow-device installation and maintenance. Future research should evaluate flow devices under a range of environmental conditions and include considerations for fish passage. Published 2013. This article is a U.S. Government work and is in the public domain in the USA

KEY WORDS beaver, *Castor canadensis*, culvert, dam, exclusion, fence systems, flow device, non-lethal management, pipe systems, pond leveler.

Following centuries of overharvest, the American beaver (*Castor canadensis*) now occupies much of its historical range in North America (Baker and Hill 2003). But with successful recovery brings a variety of challenges for managing the damage caused by beavers. A major source of beaver damage is attributed to flooding through dam building and plugging culverts (Baker and Hill 2003). Flooding destroys agricultural crops, trees, and residential property (Baker and Hill 2003). Sudden breaches in beaver dams affect human health and safety and are responsible for major damage to homes (Lacitis 2009, Sullivan 2012), roads (Ricker 2012), and other transportation corridors such as railroads (Associated Press 1985, Ricker 2012) and aircraft runways (McClurg 2002).

Resolving conflicts with beaver flooding requires an integrated approach that includes lethal and non-lethal techniques. Our goal here is to review the approaches used to control water levels on beaver dams while acknowledging that other control strategies (e.g., trapping and relocating and lethal control) remain important and viable options depending upon the context of the damage. A published report by Bailey (1922) suggests that efforts to manage conflicts with beavers diverged from trapping-only, to include development of non-lethal methods in the early 20th century; coinciding with periods of beaver reintroduction, population expansion, and human–wildlife conflicts (Müller-Schwarze 2011). We suggest that methods to reduce beaver flooding focus on 2 general factors: exclusion and deception. We categorize those physical devices used to exclude beavers from a point or areas as "fence systems." We categorize those devices that attempt to modify beaver behavior through deception as "pipe systems." The premise that pipe systems modify behavior is based on an axiom in beaver trapping and beaver management that suggests that beavers are attracted to sound and movement of water, which cues damming behavior (Baker and Hill 2003). We found no scientific evidence to suggest that flowing water causes a behavioral response for all beavers to dam. Nevertheless, it has been our experience that increasing water flow is commonly used to attract beavers (e.g., trapping) while diffusing flow is used to dissuade beavers. We use the term "filter" to describe a device's ability to disperse the flow of water over a large area to reduce damming stimulus (Lisle 2001).

We report the chronology in development of fence systems and pipe systems from the early 20th century to present.

Received: 22 October 2012; Accepted: 1 May 2013
Published: 26 October 2013

[1]*E-mail: jimmy.d.taylor@aphis.usda.gov*

Advances in each system are reported separately for clarity, although development occurred simultaneously. In general, fence systems discourage dam building, while pipe systems keep dams in place; however, exceptions exist. We suggest that few advances in beaver flood-control methods occurred until fence and pipe systems were combined in the 1980–1990s. This point marked a shift in non-lethal beaver management for flood control and led to a suite of current tools we refer to as "flow devices." Flow devices are designed to control water levels despite the presence of beavers, by reducing, directing, or eliminating damming behavior (Lisle 2001). The combined effects of fencing and pipes provide exclusion and deception (Simon 2006).

FENCE SYSTEMS

Fencing at large scales is generally cost-prohibitive and may not compliment other management practices. Over time, managers have developed tools that focus on excluding beavers from small areas, generally associated with culverts (Nolte et al. 2005). Regardless of culvert size or dimensions, each culvert possesses an inlet, middle, and outlet. Exclusion tools at culverts are either affixed to the culvert inlet or placed in close proximity upstream. Their purpose is to prevent beavers from plugging the culvert inlet or inside the culvert.

Culvert Guards

The origin of culvert exclusion for beaver control is unknown; however, we suggest that protecting drain tiles (i.e., a pre-1900 AD term for pipes) is likely the foundation for contemporary culvert fencing techniques. We used the search tool Google Patent (www.google.com/?tbm=pts&hl=en) and found U.S. patents for devices that protect drain pipes and culverts from debris and animals dating back to 1880 (Darst 1880). This was an exhaustive search effort and we acknowledge others may find different results depending on search criteria. Nevertheless, we identified ≥33 U.S. patents awarded for tools that address keeping cylindrical outlets (e.g., drain tiles, pipes, culverts) free-flowing. Of those, 25 patents are specific to keeping animals out. Since 1987, ≥8 of these patents were specific to preventing beaver damage and ≥2 other beaver-specific patent applications were submitted.

One of the first documented uses of culvert guards occurred when New Hampshire Fish and Game Department also was experimenting with pipe systems (Laramie 1963). After dams were removed, wire-mesh (i.e., fence) guards were placed on culverts to discourage beavers from plugging activities (Laramie 1963). This technique prevented beavers from plugging inside culverts and allowed removal of debris with less damage to culverts. However, if left unmaintained, beavers could build a large dam on the guard, completely stopping water flow through the culvert (Laramie 1963). Additionally, debris flowing downstream was more likely to accumulate on guards, thus increasing maintenance requirements (Laramie 1963). Subsequent modifications to culvert guards to decrease maintenance requirements have occurred but are not easily referenced. We have witnessed placement of a heavy metal grate to the face of culverts (Fig. 1A); leaving a small gap between the guard and the culvert to allow water to drain around the guard if it becomes clogged; and addition of a large chain affixed to the guard. A chain is secured above the culvert and utilized by heavy equipment to lift the guard for maintenance and debris removal.

Culvert extensions.—Culvert extensions were the next in progression of tools to exclude beavers from entering and plugging insides of culverts (Roblee 1984*a*; Fig. 1B), although Roblee (1984*a*) also recommended this technique for dam sites. Varieties of culvert extensions are known by common names such as Beaver Stop® (Canada Culvert, multiple locations in Canada) and Beaver Baffler (Brown et al. 2001). Whether they are ready-made or do-it-yourself, culvert extensions have the same general characteristics. They are constructed by placing a heavy-gauge wire-mesh cylinder (e.g., concrete reinforcing panels) that is the same size of the culvert being protected (Nolte et al. 2005). By attaching the wire cylinder to the end of the culvert, an extension of the culvert is created that has the capability of draining water from all sides. This increase in permeable surface area lessens the probability of beavers plugging the culvert inlet because it creates a larger surface area for beavers to dam. However, like culvert guards, culvert extensions do not dampen the sound of running water at the inlet, and it is important to keep debris from becoming entangled in the extension itself. When debris is not maintained, culvert extensions may cause flooding with or without the presence of beavers during flood events. Callahan (2003) reported a 30% failure rate using cylindrical culvert protective fences and abandoned use of this technique; however, see "Clemson pond leveler" under "Flow Devices" below.

T-Culverts

Shortly after culvert extensions were first reported, T-culverts were used to alleviate beaver flooding conflicts along roadsides (Roblee 1987). These devices were constructed by cutting a hole in the side of a piece of large-diameter culvert suitable to connect a smaller diameter piece of culvert to the side. The resulting "T"-shaped culvert combination was then affixed to the existing culvert on site. It was recommended that the "T" portion of the culvert be 1.2 m diameter when attaching to a 15–46 cm existing culvert and 1.5–1.8 m diameter when used to accommodate an existing culvert larger than 46 cm (Roblee 1987). When attached, the installed T-culvert was lower than the existing road culvert, so the entire culvert slopes downward from the road. When constructed correctly, the end of the culvert drained water over a larger surface area and produce less audible cues to beavers. Roblee (1987) found this technique successful in New York, USA, but only under certain conditions: 1) stream flow was moderate with normal flow of the culvert approximately one-fourth of the culvert's diameter; 2) both ends of the T-culvert rested in calm water that was 1.2–1.8 m deep; and 3) substrate was solid.

Culvert fencing.—Descriptions of fencing to manage beavers can be traced to the early 20th century (Bailey 1922); however, these methods were untested and were proposed to contain beavers to small areas rather than

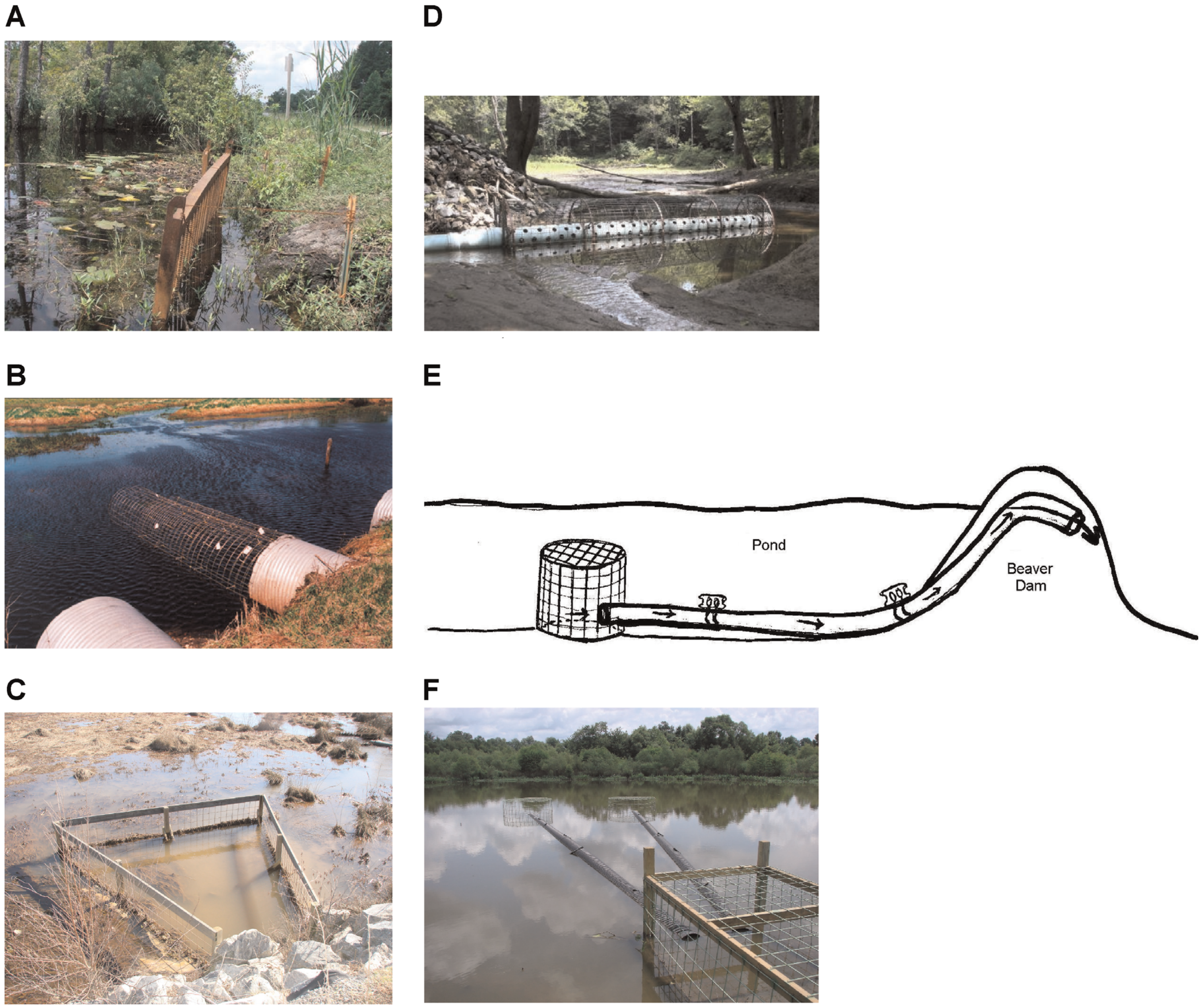

Figure 1. Examples of non-lethal devices used to reduce flooding by beavers. (A) A culvert guard in North Carolina, USA. Photo credit—National Wildlife Research Center. (B) A culvert extension. Photo credit—canadaculvert.com. (C) A trapezoidal beaver fence (in this case a Beaver Deceiver^{TM}) located in Virginia, USA. Photo credit—National Wildlife Research Center. (D) A Clemson pond leveler. Photo credit—martinezbeavers.org. (E) Drawing of a Flexible Pond Leveler^{TM} provided by M. Callahan, demonstrating the exclusion at the intake, the distance separating intake and exit from the pipe, and maintenance of preferred water level by the "hump" in the pipe going through the dam. (F) A double pipe system located in Virginia, USA, demonstrating the use of culvert fencing (lower right corner), flexible pipe, and round fencing. Photo credit—National Wildlife Research Center.

exclude them. Culvert fencing is a system in which a fence is constructed upstream of the culvert inlet to exclude beavers. It comes in many shapes (e.g., crescent, rectangular, semi-circular, square, and trapezoidal) and also is referred to as beaver fencing, deep-water fencing, and pre-dams (Brown et al. 2001). Culvert fencing is usually constructed of heavy-gauge wire mesh supported with metal or wooden posts. The wire mesh openings allow some stream debris to flow through the system while still preventing beavers from getting to the culvert inlet.

The Beaver Deceiver^{TM} (Beaver Deceivers International, Grafton, VT) is a specific example of a culvert fence, whose use was first documented at the Penobscot Indian Nation in Maine, USA (Lisle 2001). Lisle (2001) preferred using a trapezoidal design where the base was the approximate width of the culvert inlet and remaining sides are near equilateral (Fig. 1C); however, the device did not block the stream channel, else it became a beaver dam. Similarly, CulverClear^{TM} Trapezoid Culvert Protective Fences (Beaver Solutions LLC, Southampton, MA) used the same design, yet were constructed with metal posts rather than wooden posts (Callahan 2003). Other quadrilateral shapes and configurations can be as effective as the equilateral design and are dictated by the site. Culvert fences contain a wire floor to prevent beaver entrance from underneath. They are not enclosed on top, as this could create maintenance problems. Tippie and O'Brien (2010) provided a material list, building instructions, and images of 4 Beaver Deceiver^{TM} configurations.

Culvert fences in general are not filters alone and in the authors' opinion, should not be referred to as flow devices. They should be used at low-risk areas such as quiet culverts with little water flow or where site conditions prohibit a pipe

system (Lisle 2001). Culvert fencing can be effective in reducing frequency of culvert plugging by beavers, but as with other types of fence systems, maintenance is required to prevent debris accumulation in front of the culvert. In an observational study in the northeastern United States, Callahan (2003) reported a high success rate utilizing the trapezoidal fence and contributed failures to 1) the fence getting dammed, 2) no maintenance being performed, and 3) formation of a new downstream dam. When culvert fences are combined with a pipe system, they can become effective flow devices (see "Flow Devices" section below).

PIPE SYSTEMS

In many circumstances, it is acceptable or desirable to have beavers, their dams, and the pools they create in streams. However, as with plugged culverts, when flooding exceeds stakeholder acceptance levels, natural resource managers must intercede. Unlike fencing systems that prevent damming, pipe systems allow managers to control water levels while keeping dams in place. As with fencing, the true origin of the use of pipes as a flow device is unknown; however, it is most likely that they coevolved around the turn of the 20th century as beavers were restocked into areas throughout their native range (Bailey 1922).

Three-Log Drains

The original three-log drain (Bailey 1922) was constructed by notching a beaver dam and laying ≥3 straight hardwood logs on a board or piece of sheet iron in the opening. Two hardwood logs or poles were placed perpendicularly through the dam with their upstream ends slightly apart. A third log was placed on top and then covered with the spoil dam material. The resulting triangle allowed water flow between the poles and took advantage of a beaver's general distaste for chewing through submerged hardwood logs (Arner 1963). This method was later modified using uneven green or water-logged logs, sheet metal, and green sticks between the logs to improve drainage (Arner 1963; see Nolte et al. 2005 for drawing).

Three-log drains are inexpensive tools to reduce flooding at dams in certain situations; however, they are not a favorable alternative where high flows are a concern because they likely will not drain water fast enough. Nevertheless, we surmise the basic premise behind three-log drains involves keeping beavers, their dams, and their positive benefits in place while reducing probability of damage. Also, the dampening of flowing water is thought to minimize additional damming by resident beavers (Bailey 1922). These concepts are cornerstone in the evolution of flow devices.

Metal Pipe Drains

Concomitant to reports of three-log drains, Bailey (1922:11–12) stated "One or several pipes of sufficient size to carry the normal water flow should be laid through the dam with the outlet at the level at which the water is to be held, the other end terminating in a wire strainer, reaching down into deep water and covered with stones or logs." He went on to say that the intake end of the pipe must be deep enough that it does not create current or water draft at the surface when water is at the desired level (Bailey 1922). Bailey (1922) also recommended the outlet extend a few feet beyond the lower face of the dam to prevent plugging by beavers, and the pipes be sufficiently weighted to prevent beavers from moving them. Interestingly, concerns over beaver plugging from downstream outlets seem to be dismissed in subsequent literature describing beaver pipe systems. Bailey (1922) made no mention of protecting pipe intakes or of using metal pipe drains with culverts. Nevertheless, we believe metal pipe drains were the genesis for what would become "flow devices" 7 decades later.

Perforated Fiber Pipes

Extending the concept of metal pipes, New Hampshire Game and Fish used wood-fiber pipes to control beaver-pond water levels for waterfowl management (Leighton and Lee 1952). Holes were drilled into lower pipes to allow water to enter pipes at multiple points, thus creating a filter (Leighton and Lee 1952). A modification of the perforated pipe design called "beaver pipes" was later implemented in New Hampshire, USA (Laramie 1963). Beaver pipes, also called wooden pipes, were longer and larger in diameter than fiber pipes, yet used the same general concept. They were installed perpendicularly through a beaver dam with the downstream end of the pipe open and the upstream end plugged. The upstream plugged end was perforated to allow water to slowly drain from impounded water without the creation of audible cues of running water to stimulate beaver behavior (Laramie 1963). Like its predecessors (the metal pipe and three-log drain), this method was designed to slowly drain water from an impounded area. In the case of a flood event, water was simply allowed to flow over the dam until water levels became stable.

Flexible Pipe

Extending flow technology further, corrugated tubing has been placed through beaver dams and culverts, and is generally easier to transport and install at problem sites than wood or metal pipes (Roblee 1984*b*). Holes drilled into tubing aided in sinking the device and increased drainage. A notch cut on the bottom side of the pipe, near the cap, allowed water to enter the pipe from underneath and aided in dampening water noise. Concrete blocks and rope were used to anchor the system in place. Periodic maintenance is required to clear mud and debris from openings in the tubes, and to check anchor posts. The most common error when using this technique is failing to calculate the correct diameter-to-tubing ratio to account for the flow rate of the water body being drained (Roblee 1984*b*). Approximate discharge rates are available for various tube diameters (Roblee 1984*b*, Nolte et al. 2005). Although this technique does filter some water, it is not recommended for use without ≥1 fence filters (see "Flexible pipe and fence systems" below).

FLOW DEVICES

While the principles used to control beaver flooding may have originated near the same time (Bailey 1922), our review of the literature suggests these principles were not

incorporated until the 1980–1990s. Furthermore, we suggest that this period marks a notable shift in beaver management and that advances within the past 25 years have integrated fence and pipe technologies to improve efficacy.

Clemson Pond Leveler

Wood and Woodward (1992) united lessons learned from previous technology and revealed the Clemson pond leveler (Fig. 1D). Major developments included the improved modifications of the intake end of the pipe, which acts as a filter and is protected by fencing, and an optional water-level control elbow on the outlet end of the pipe. The intake end of the pipe was modified by joining a perforated 3-m section of 25-cm-diameter polyvinyl chloride (PVC) pipe to the end of the upstream side. The end of the intake was capped while the other was fitted with a 25–20-cm diameter reducer sleeve and joined to the section of pipe extending through the dam, thus creating a filter. The intake pipe (filter) was then suspended inside a portion of 5 × 10-cm galvanized welded wire (exclusion fencing). The wire was closed on the capped end of the pipe and necked down to fit snuggly at the reducer sleeve. The resulting enclosure excluded beavers from trying to plug holes or investigate water loss (Wood and Woodward 1992). The other before-mentioned adaptation was at the outlet end of the pipe and consisted of an optional elbow that allowed managers to maintain a certain water level (Wood and Woodward 1992). Various lengths have been used to produce the desired depth. This has been particularly useful when a pond is desired but water levels are a concern. Since its creation, there have been additional design modifications to the Clemson pond leveler including an adaptation for fish passage (Close 2003).

The Clemson leveler is considered a viable non-lethal management option under many circumstances; however, sites require post-installation maintenance to remain effective (Nolte et al. 2000). In a survey of landowner satisfaction in the southeastern United States, Nolte et al. (2000) reported that Clemson levelers installed to manage water levels for waterfowl habitat were generally considered successful, while levelers installed to provide a perpetual flow of water were less successful. Although considered widely as a tool for use at beaver dams, we have observed Clemson levelers used as an improved culvert extension to prevent plugging of culvert inlets. In either situation (dam or culvert), managers should be reminded of the potential size limitations of the 20-cm PVC pipe, because these devices are best utilized in very low-flow situations. Additionally, managers in areas with cold winter climates should be aware that PVC standpipes may crack when water freezes.

Flexible Pipe and Fence System

Flexible pipe and fence systems utilize the deception of pipe technology (i.e., the filtering of water and the separation of inlets from outlets) and the exclusion properties of fencing to create a tool that can be utilized at culverts or dams. These systems are known by several common names, including but not limited to Castor Master™, Double Filters, or Flexible Pond Leveler™. These systems generally use black, corrugated single- or double-walled polyethylene pipe to move water (Lisle 2001). Pipes are flexible, generally available in 6.1-m sections, and can be joined with couplers to extend length as needed. The majority of the length of pipe required is placed beneath the surface of the water on the upstream side of the dam or culvert. Fabrication and installation of the flexible pipe portion of these systems generally follows the descriptions in the "Flexible Pipe" subsection under "Pipe Systems" above. Fence filters and exclusion added to the inlet and outlet sections of pipe improve the methodology described by Roblee (1984*b*).

All flexible pipe and fence systems contain some sort of small fence (i.e., filter) to protect the upstream end of the flexible pipe (i.e., inlet). The Round Fence™ is a vertical cylinder built with a floor and a roof placed over the capped (upstream) end of the pipe (Lisle 2001, 2003). This design allows water to be drained in both shallow and deep-water situations. A standard-sized Round Fence™ is built of heavy-gauge welded wire with a diameter of 1.8 m and typically 0.9 m tall. However, the same effect can be gained from a square of rectangular wire fence as long as it limits beavers' ability to plug the inlet and feel the movement of water into the pipe. The caged portion of the system excludes beavers from altering the inflow portion of the pipe. Addition of an inlet on the underside of the fenced portion of pipe aids in dampening water sound and movement in shallow-water situations. When used at a dam, an upward bend or "hump" is formed where the pipe goes through or over the dam (Lisle 2001). The height of the hump sets the water level and further aids in reducing the sound of water flowing through the pipe (Fig. 1E). When used with culverts, a culvert fence is required to receive the flexible pipe and prevent beavers from entering the culvert (Fig. 1F). In high animal movement areas, a turtle door may be added to systems. A turtle door is a small opening in a fence designed to allow the passage of beavers, turtles, and other animals wanting to reach the downstream side of a system. Turtle doors are also equipped with sharp turns called wings to prevent beavers from moving damming material inside the fence (Lisle 2001). Lisle (2003) also demonstrated using a T-shaped culvert at the culvert fence to allow passage of wildlife. The T-shape prevents beavers from passing sticks through the opening (Lisle 2003).

Size of the wetland and expected water volume during flow events dictate the required number of pipes and filters per culvert fence. Tippie and O'Brien (2010) provided material lists, building instructions, and images for building 2 types of flexible pipe and fence systems.

WHAT WORKS AND WHAT IS NEXT?

Reports by Callahan (2003, 2005), although descriptive, provide the most information to date on use of flow devices in the field, and were reprinted with the author's permission in Simon (2006). Callahan (2003) reported high success using flow devices and attributed most failures to beavers constructing new dams downstream from the flow device. Given beavers' propensity for moving their dam building activities, and potentially moving damage to another landowner's property, land managers should monitor upstream

and downstream after installing flow devices. To lessen the probability of new dams, Callahan (2003) recommended lowering the pond level only as much as necessary to prevent property damage. Boyles and Savitzky (2008) concluded that 40 flow devices installed at 21 sites were more cost-effective than trapping and clearing culverts at those sites for the Virginia Department of Transportation; however, future research is needed to investigate cost–benefit analyses of flow devices over longer periods of time and larger spatial scales.

Flow devices are not intended to replace trapping, and trapping must remain a viable option for managers to use appropriately when beaver damage exceeds stakeholder acceptance (Simon 2006). Callahan (2005) used trapping to remove beavers and resolve problems at 69 (16%) sites in the northeastern United States where 1) site characteristics (e.g., topography, development) were not conducive to installation of flow devices, 2) landowners had no tolerance for beavers, or 3) landowners had no tolerance for changes in water levels. He also used trapping to reduce beaver density prior to installing flow devices at 8 sites where water levels needed to be lowered more than one vertical foot (0.3 m; Callahan 2005). Several sites where flow devices were installed and monitored in Virginia, USA, were on sites where trapping was previously conducted (Boyles and Savitzky 2008). Given beavers' ability to rapidly recolonize suitable habitat, single trapping events are not intended to solve long-term conflict; however, trapping provides timely conflict resolution and may be integrated with management strategies where stakeholders desire maintaining beaver ponds.

As beaver and human populations continue to share the same space, human–wildlife conflicts will continue and are likely to increase in some areas (Taylor et al. 2008). Values and attitudes toward beavers are likely to differ based on experience, distance from cities, resources at jeopardy, and a myriad of other factors. Nevertheless, tools and techniques are currently available to integrate non-lethal beaver management into landscape-scale management plans spanning urban, suburban, rural, and wilderness areas. In our opinion, management strategies that use fence or pipe systems alone will likely require more maintenance and be less effective than modern flow-device systems that combine fence and pipe technologies. However, research is needed to evaluate the effects of flow devices in a wide range of habitats and environment conditions, including more research with fish passage. We recommend that future research in evaluating flow devices include collaborative efforts with social and wildlife scientists. Management options should include lethal and non-lethal forms of control and not take an either–or approach. Additionally, a firm understanding of the basic biology of beavers and hydrology must be considered in designing studies and evaluating success of conflict resolution.

ACKNOWLEDGMENTS

Funding for the authors was provided by U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services' National Wildlife Research Center. We thank D. Dwyer, A. Lavelle, and D. Sphar for assistance with literature review. We also thank S. Breck, M. Callahan, H. Perryman, M. Tobin, and 2 anonymous reviewers for comments on a previous version of this manuscript. Mention of commercial companies, commercial products, patents, or trademarks does not imply the recommendation or endorsement by the U.S. Department of Agriculture. We mentioned product names solely to report factually on available data and to provide specific information.

LITERATURE CITED

Arner, D. H. 1963. Production of duck food in beaver ponds. Journal of Wildlife Management 27:76–81.

Associated Press. 1985. Amtrak accident laid to beavers. New York Times. 14 December 1985; < http://www.nytimes.com/1985/12/14/us/amtrak-accident-laid-to-beavers.html?n=Top%2fNews%2fScience%2fTopics%2fAnimals >. Accessed 30 Sep 2013.

Bailey, V. 1922. Beaver habits, beaver control, and possibilities in beaver farming. U.S. Department of Agriculture Bulletin 107, Washington, D.C., USA.

Baker, B. W., and E. P. Hill. 2003. Beaver (*Castor canadensis*). Pages 288–310 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. The Johns Hopkins University Press, Baltimore, Maryland, USA.

Boyles, S. L., and B. A. Savitzky. 2008. An analysis of the efficacy and comparative costs of flow devices to resolve conflicts with North American beavers along roadways in the coastal plain of Virginia. Proceedings of Vertebrate Pest Conference 23:47–52.

Brown, S., D. Shafer, and S. Anderson. 2001. Control of beaver flooding at restoration projects. Wetlands Regulatory Assistance Program (WRAP) Technical Notes Collection (ERDC TN-WRAP-01-01). U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi, USA.

Callahan, M. 2003. Beaver management study. Association of Massachusetts Wetlands Scientists Newsletter 44:12–15.

Callahan, M. 2005. Best management practices for beaver problems. Association of Massachusetts Wetlands Scientists Newsletter 53:12–14.

Close, T. L. 2003. Modifications of the Clemson pond leveler to facilitate brook trout passage. Minnesota Department of Natural Resources, Special Publication 158, St. Paul, USA.

Darst, F., inventor. 1880. Drain-tile gate. U.S. patent 231,544. 24 August 1880.

Lacitis, E. 2009. Beaver-built dam bursts on Whidbey Island, 8 homes struck by flood. Seattle Times. 4 April 2009; < http://seattletimes.com/html/localnews/2008983204_mudslide04m.html >. Accessed 30 Sep 2010.

Laramie, H. A. 1963. A device for the control of problem beavers. Journal of Wildlife Management 27:471–477.

Leighton, R. S., and J. A. Lee. 1952. A progress report on a technique to control water levels in beaver impoundments. Proceedings of the Northeastern Wildlife Conference 8:1–4.

Lisle, S. 2001. Beaver management at the Penobscot nation, USA: using flow devices to protect property and create wetlands. Proceedings of the European Beaver Symposium 2:147–156.

Lisle, S. 2003. The use and potential of flow devices in beaver management. Lutra 46:211–216.

McClurg, D. 2002. Beaver dams a constant threat to Bellingham International Airport. Whatcom Watch Online, September 2002 cover story; < http://www.whatcomwatch.org/php/WW_open.php?id=162 >. Accessed 30 Sep 2013.

Müller-Schwarze, D. 2011. The beaver: its life and impact. Second edition. Cornell University Press, Ithaca, New York, USA.

Nolte, D., D. H. Arner, J. Paulson, J. C. Jones, and A. Trent. 2005. How to keep beavers from plugging culverts. U.S. Department of Agriculture Forest Service, Technical Report 0571-2830-MTDC, Missoula Technology and Development Center, Missoula, Montana, USA.

Nolte, D., S. R. Swafford, and C. A. Sloan. 2000. Survey of factors affecting the success of Clemson beaver pond levelers installed in Mississippi by Wildlife Services. Proceedings of Wildlife Damage Management Conference 9:120–125.

Ricker, N. 2012. Receding beaver dam flood waters leave extensive road damage in Orrington. Bangor Daily News. 24 March 2012; < http://bangordailynews.com/2012/03/24/news/bangor/receding-beaver-dam-flood-waters-leave-extensive-road-damage-in-orrington >. Accessed 30 Sep 2013.

Roblee, K. J. 1984*a*. A wire mesh culvert for use in controlling water levels at nuisance beaver sites. Proceedings of the Eastern Wildlife Damage Control Conference 1:167–168.

Roblee, K. J. 1984*b*. Use of corrugated plastic drainage tubing for controlling water levels at nuisance beaver sites. New York Fish and Game Journal 31:63–80.

Roblee, K. J. 1987. The use of T-culvert guard to protect road culverts from plugging damage by beavers. Proceedings of the Eastern Wildlife Damage Control Conference 9:25–33.

Simon, L. J. 2006. Solving beaver flooding problems through the use of water flow control devices. Proceedings of Vertebrate Pest Conference 22:174–180.

Sullivan, J. 2012. Broken beaver dam unleashes flood near Duvall. Seattle Times, 5 November 2012; < http://seattletimes.com/html/localnews/2019614155_beaverdam06m.html. >. Accessed 30 Sep 2013.

Taylor, J. D., D. L. Bergman, and D. L. Nolte. 2008. If you build it, they will come—management planning for a suburban beaver population in Arizona. Proceedings of the Vertebrate Pest Conference 23:43–46.

Tippie, S., and M. O'Brien. 2010. Working with beaver for better habitat naturally. Other publications in wildlife management. Paper 63. University of Nebraska, Lincoln, USA. < http://digitalcommons.unl.edu/icwdmother/63 >. Accessed 30 Sep 2013.

Wood, G. W., and L. A. Woodward. 1992. The Clemson beaver pond leveler. Proceedings of Annual Conference of Southeastern Association of Fish and Wildlife Agencies 46:179–187.

Associate Editor: Breck.