Vermont Stream Crossing Handbook




Introduction

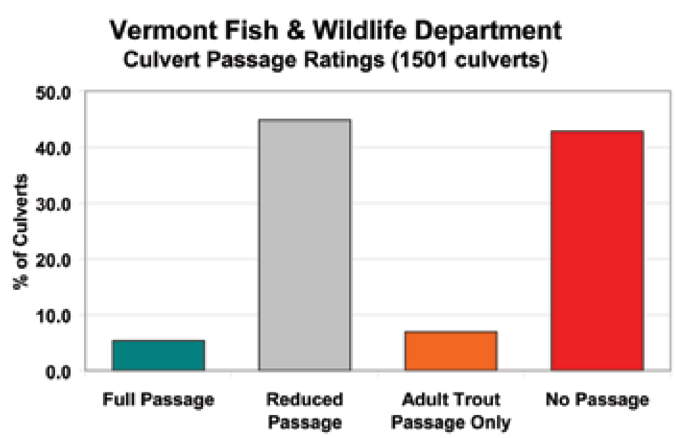
Vermonters have always strongly connected with fish and wildlife resources through their passion for fishing, hunting and other wildlife based recreation. The 2011 National Survey of Fishing, Hunting and Wildlife-Associated Recreation found Vermont second in the nation with 62 percent of our residents involved in these activities. This connection with our natural resources also provides a major economic benefit to Vermont as it has been estimated that $712 million were spent throughout the state by residents and nonresidents in pursuit of these activities during 2011.

Although public awareness of environmental issues is high in Vermont, few people consider the effects of the thousands of road crossings (bridges and culverts) on the quality of stream habitats. Stream conditions are frequently quite different upstream and downstream of a road crossing, and a crossing may look different during times of low and high stream flow. The design and condition of stream crossings determine whether a stream behaves naturally and whether fish and other aquatic animals are able to move within the stream corridor.

In the past, stream continuity was not often considered in the design and construction of stream crossings. Many of Vermont's existing stream crossings are barriers to movement of fish and wildlife. Some stream crossings that did not restrict passage when originally constructed have become barriers as the result of streambank erosion, stream channel changes or mechanical breakdown of the structure. A study conducted by the Vermont Fish & Wildlife Department (VFWD) of aquatic organism passage through culverts provided some sobering results. Of 1,501 culverts surveyed between 2004 and 2007, less than six percent were found to provide full passage of aquatic organisms.

Fortunately, advances in science and technology have revealed ways to design stream crossings that provide for passage of fish and other aquatic animals, maintain natural stream conditions, and improve protection of roads and property from some of the damaging effects of floods.

This booklet is intended to increase awareness of the values of well-designed stream crossings and provide the basic information necessary for people to evaluate existing crossings. It is hoped that town conservation commissions, highway departments, local conservation and watershed organizations as well as private landowners will use this booklet to learn about the benefits of well-designed stream crossings and help protect and restore stream continuity throughout Vermont.



Stream Continuity and Natural Communities

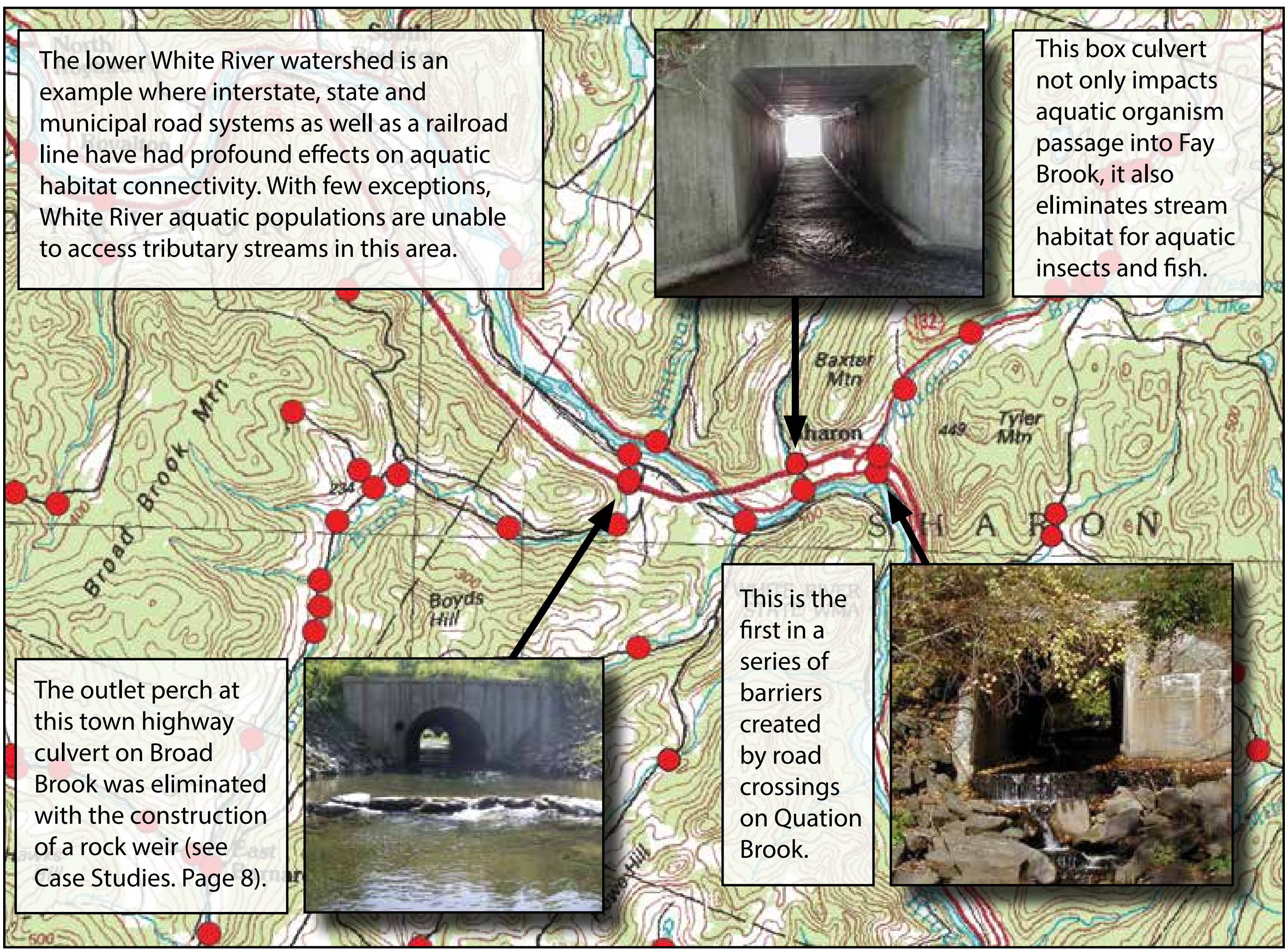
In Vermont, many species of fish and wildlife inhabit streams, wetlands and adjacent riparian lands. Effective stream protection requires that the needs of all species using the stream corridor are considered. The range of species includes everything from invertebrates such as crayfish, fish such as brook trout and suckers, amphibians such as spring salamanders, reptiles such as wood turtles, and mammals such as muskrats and mink.

Streams provide important connections within a watershed for fish and wildlife that need to move in search of food, to avoid extreme conditions or to reach habitats suitable for reproduction. Thus, free passage through stream corridors is critical to the ecology and health of the aquatic community. Some animals, such as amphibians and reptiles can also be affected when they are forced to cross roads where they become vulnerable to mortality from traffic, exposure to predators, and other dangers.

For reasons as simple as the need to escape extreme floods or as complex as maintaining genetic diversity, animals living in or along streams need to be able to move unimpeded through the watershed. Think about the roads you drive on every day. What if these roads were suddenly and permanently blocked so that you could not get to important places? This may sound absurd, but this is precisely the issue that faces species inhabiting streams throughout Vermont and elsewhere. Through the combined effects of dams and poorly designed stream crossings, we have blocked streams and forced fish and wildlife to cope with these restrictions. Many populations of stream-dependent species have been diminished or lost completely because of these barriers.

Here are a few examples of the effects of blockages:

Access to coldwater habitats: Small streams with groundwater seeps and springs provide coldwater refuge to animals during the summer when water temperatures rise. Species such as brook trout travel until they find these colder areas whenever water gets warm. If they can't get to these areas, perhaps due to a stream crossing barrier, and water temperature gets too warm - they may die.



Access to feeding areas: Different habitats provide different feeding opportunities throughout a day or season. Many species travel daily or seasonally to use these habitats.

Access to spawning areas: Some species need to travel many miles to reach spawning areas in streams. For example, a study by the VFWD on the Batten Kill observed an adult brown trout that traveled over nine miles to spawn. Other species, such as rainbow smelt and suckers may travel only a few hundred feet up a tributary from a lake or pond to spawn. Regardless of the distance that has to be travelled, the presence of a barrier can greatly impact spawning success.

Natural dispersal: Juvenile trout, salmon and other fish species must move throughout the watershed to fully utilize available rearing habitat and food supplies. Some salamanders, turtles and frogs spend most of their lives near streams and travel in and along a stream's length to reproduce, seek shelter and feed. Poorly designed crossings may force these species to climb an embankment and cross roads where they are vulnerable to predators and being struck by traffic. Freshwater mussels disperse by having larvae that attach to the fins or gills of small fish. If a stream crossing blocks fish, it will prevent upstream dispersal of mussels as well. If a stream is damaged by a catastrophic event such as a toxic discharge, severe flood, or extreme drought, natural dispersal can rapidly re-establish productive aquatic communities as long as passage is not blocked.

In addition to the effects on movement of fish and wildlife, many stream crossings degrade nearby habitat by making conditions inhospitable. Poorly designed culverts can also place adjacent property and infrastructure at risk. The effects can be small but chronic, such as from excessive bank and bed scour, or catastrophic, such as massive failures which may wash out roadways and damage private properties. A well-designed and maintained stream crossing will not cause these impacts or will minimize the risk of them occurring.

White suckers spawning in a tributary of Kent Pond in Killington. Spawning runs in tributary streams of Vermont's lakes, ponds and rivers can be reduced or eliminated by poorly constructed stream crossings.

Wood Turtle, Danial Zeh

Spring Salamander, VDFW

Mink, VDFW

Northern Dusky Salamander, VT Reptile and Amphibian Atlas

Salamanders, turtles and other wildlife often must cross roads. Well designed stream crossings will give them a safer route.

Recognizing Problems

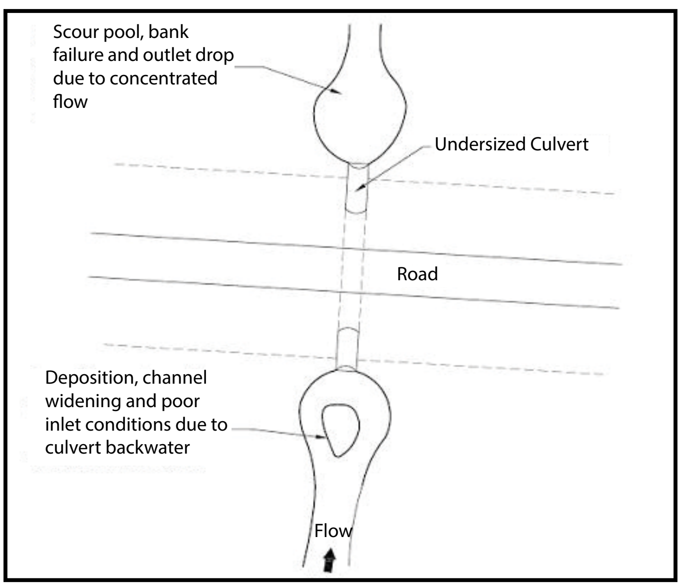
Three common stream crossing problems are undersized, shallow and perched crossings. These can be barriers which adversely impact fish and wildlife populations. Recognizing poor stream crossings and their consequences is an important step in evaluating whether crossings should be fixed or replaced.

Undersized Crossing

Undersized crossings restrict natural stream flow, particularly during floods. This results in high velocities within the structure which fish and other aquatic species cannot negotiate. Other problems involving undersized crossings include increased scouring and erosion as well as clogging and upstream ponding.

High velocities may scour the streambed in and downstream of the crossing. This can degrade habitat for fish and other wildlife. Erosion of streambanks may result in property loss as well as habitat loss. A pool is often scoured downstream of undersized culverts and may undercut the culvert and adjacent streambanks leading to bank and/or road failure.

Crossings should be large enough to pass fish, wildlife, debris and floods. The most common cause of culvert failures is when undersized culverts plug with debris during floods. When culverts plug, the culvert and road fill act as a dam, ponding water upstream. When water overtops the road, it erodes a new channel through or along the roadway.



Common problems associated with undersized stream crossings.

Perched outlet, scour pool and bank erosion.

Debris clogging.

Roadway failure.

Shallow Crossing

Shallow crossings are too high compared to the natural stream channel. The floor of the culvert is exposed and a natural streambed cannot form. As a result, water depths are commonly too shallow for many organisms to pass through them. Crossings should have a natural streambed with substrate and water depths that are similar to the surrounding stream.

Perched Crossing

Perched crossings have outlets that are elevated above the level of the downstream channel. Perching can result from improper design and/or installation or from years of downstream bed erosion. Crossings should be large enough that downstream scour is prevented.

A good crossing ...

- Spans the stream and banks
- Does not change the velocity
- Has a natural streambed
- Creates no noticeable change in the river

Effective crossings include

- Bridges
- Open bottom arches
- Culverts that span and remain buried in the streambed

Stream Crossing Design Concepts and Considerations for Aquatic Organism Passage (AOP)

Safe and stable stream crossings can accommodate aquatic populations and protect stream health while reducing expensive erosion and structural damage. Key concepts and considerations for effective stream crossing designs are listed below. More detailed technical guidance is available in the *Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont* published by the Vermont Fish & Wildlife Department. The Guidelines are available through the Department's website in the Fish and Wildlife Library (Learn More » Fish and Wildlife Library » Reports and Documents » Aquatic Organism Passage at Stream Crossings).

Structure Type: Open bottom structures such as arches or bridges are preferred as they maintain a natural streambed and have less risk of developing passage problems. In many cases, closed stream crossing structures (with bottoms) are an acceptable alternative if properly designed and constructed.

Structure Width: The crossing should not constrict the stream channel bankfull width. As described previously, undersized crossings often result in a host of problems including impacts to fish and wildlife passage, stream stability and structure performance. The bankfull width is defined as the stream channel width when water just begins to overflow into the active floodplain. (Diagram 1)

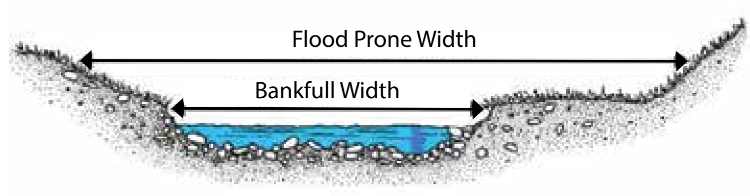


Diagram 1. Stream channel bankfull and flood prone width.

Structure Length: Longer structures disrupt more stream habitat and are often more difficult to provide passage. The use of wide structures and headwalls can reduce structure length and minimize stream impacts. (Diagram 2)

Stream Channel Alignment: Alignment of the crossing structure to the stream is an essential part of the design. When the culvert is not properly aligned with the upstream and downstream channel, the hydraulic capacity is reduced and the likelihood of debris clogging is increased. (Diagram 2)

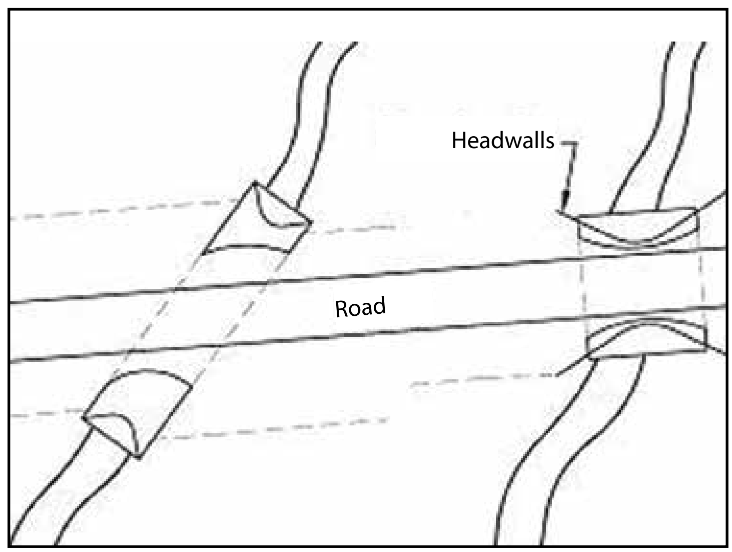


Diagram 2. Examples of stream crossings which are aligned with the stream channel.

Vertical Alignment: The streambed profile within the crossing should match, as closely as possible, the natural stream channel profile. This profile should be determined outside of the influence of the existing structure. (Diagram 3)

Culvert Embedment and Natural Streambed: Stream substrate should closely match natural substrates found in the stream channel above and below the crossing. The culvert should remain embedded, creating an invisible transition between the natural stream channel and the crossing structure. (Diagram 3)

Depth and Velocity: Crossings should be essentially "invisible" to fish and wildlife—they should be designed to maintain appropriate flow and substrate through the crossing. At high or low flows, water depths and water velocities should be the same as they are in the natural stream channel above and below the crossing.

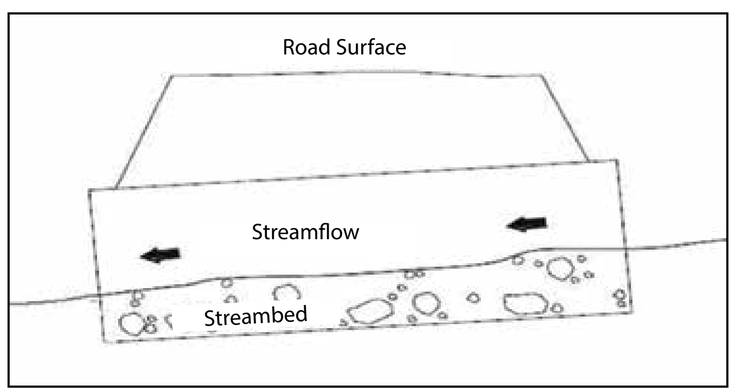


Diagram 3. An embedded stream crossing aligned vertically with the stream channel.

Replacing or Retrofitting Culverts

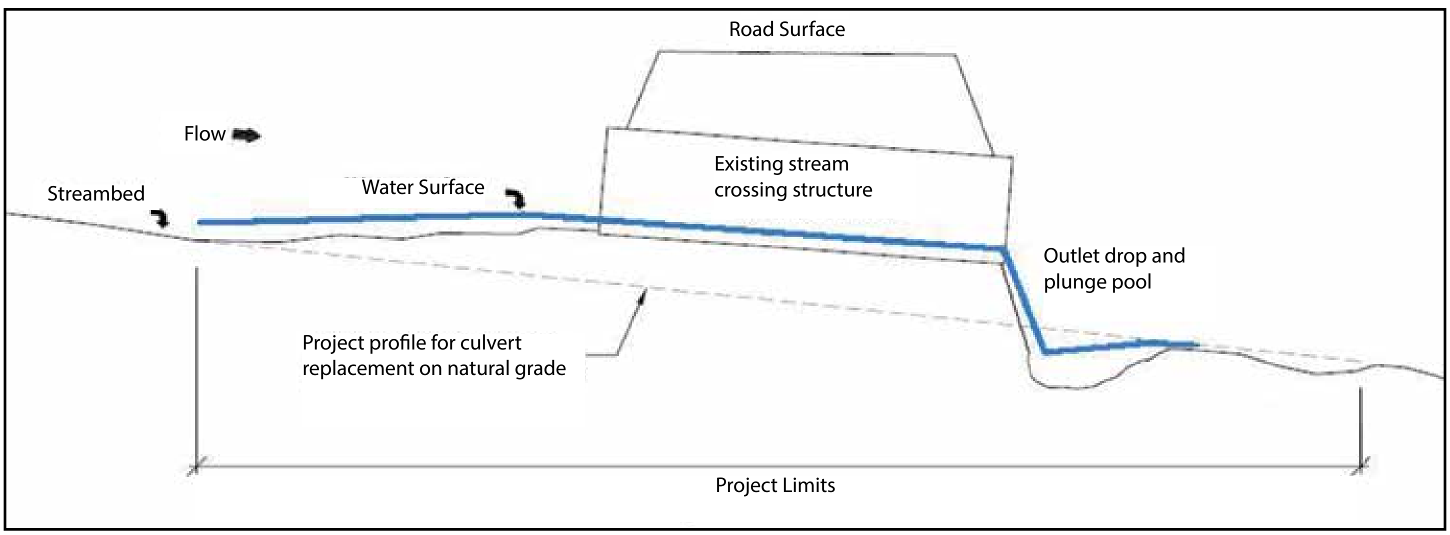
Most stream crossings in Vermont were designed and installed at a time when the environmental impacts of such crossings were not understood. Even effective, but aged crossings, may need to be upgraded or replaced because they have weathered decades of floods and wear. Periodic upgrading of bridges, culverts, and roads is often required to keep crossings safe and effective. Repairing or replacing deteriorated culverts is not always as straightforward as installing a larger pipe. Streams may naturally adapt to the problems caused by poorly designed or degraded crossings. The benefits of retrofitting or replacing a crossing should be weighed against the costs of the project and the environmental consequences. If feasible, a culvert should be replaced. Careful analysis, drawing on the expertise of engineers, river scientists, biologists and construction professionals, should consider the following:

- Potential for upstream and downstream flooding
- Effect on upstream, downstream, and riparian habitat
- Potential for erosion, including headcutting (progressive channel erosion upstream of culvert)
- Overall effect on stream stability
- Potential benefit to aquatic resources

When replacement is desirable, crossings should be designed with the concepts and considerations discussed above in mind. In some cases a retrofit may be more appropriate, leaving the current culvert in place and adjusting the streambed to eliminate perching, or adding bed material inside the culvert to create a more natural streambed.

For a replacement culvert, a longitudinal profile of the streambed, both upstream and downstream of the culvert, should be completed to determine how well the up and downstream slopes and elevations match. If there is a significant difference, there is a potential for significant erosion of the streambed, particularly if the new culvert is larger, and additional considerations will have to be taken in the design.

Replace…	**Retrofit…**
If a structure is in poor condition.	If a structure is in good condition.
If the crossing is undersized for flood flows and debris.	If the crossing is adequate for flood flows and debris.
If structure cannot be modified to achieve conservation goals considering species of concern and habitat gained.	If retrofit design can achieve conservation goals considering species of concern and habitat gained.
If replacement will not impact critical wetlands.	If replacement will impact critical wetlands.
If replacement is financially practical.	If replacement is financially impractical.



Replacement culverts should consider the natural streambed profile (outside of the influence of the existing structure) when defining the new project profile.

Case Study

Town: Sharon, VT
Stream: Broad Brook
Responsible Agencies/Partners: White River Partnership, U.S. Fish and Wildlife Service, Trout Unlimited, Vermont Fish & Wildlife Department, Vermont Department of Environmental Conservation, U.S. Forest Service, Town of Sharon

Broad Brook is a tributary of the lower White River and supports wild, self-sustaining populations of brook trout, rainbow trout and a variety of nongame fish species. In addition to supporting resident fish populations, Broad Brook serves as a spawning and nursery stream for a variety of species residing in the White River. In times of thermal stress, tributaries like Broad Brook can also provide an important coolwater refuge.

The first culvert above the mouth of Broad Brook is a concrete arch located only a few hundred feet above the confluence with the White River.

During its initial construction over two decades ago, the VDFW worked with the town to add a series of wooden baffles in hopes of providing some reduction of velocities at higher flows. The undersized culvert ultimately developed a perch of nearly one foot under low flow conditions, limiting aquatic organism passage.

A group of partners (listed above) recognized the problem and decided to retrofit this culvert to enhance passage. To eliminate the outlet perch, a rock weir was constructed downstream of the outlet pool in 2007, raising its elevation above the base of the culvert. The rock weir was designed like a natural stream feature and provides multiple passage pathways which change with stream flow levels. Fish and other aquatic organisms can now freely enter the culvert at a variety of flows.

Broad Brook culvert with outlet perch.

Constructed rock weir eliminates outlet perch.

A wild Vermont rainbow trout.

Original corrugated metal culvert.

Case Study

Town: Readsboro, VT
Stream: Heartwellville Brook
Responsible Agency: Vermont Agency of Transportation

Heartwellville Brook is a tributary to the Deerfield River and supports wild, self-sustaining populations of brook trout and brown trout. The previous culvert was an 8'10" X 6'1" corrugated metal pipe arch that constricted flows and limited aquatic organism passage. In 2007, the Vermont Agency of Transportation replaced the aging structure with a 12' X 8' reinforced concrete box and included design features to accommodate aquatic organism passage. These features included an embedded culvert with concrete bed retention sills, a constructed streambed with banklines, and a grade control feature below the culvert outlet.

The result is a stream crossing that is essentially "invisible" to fish and other aquatic organisms as they move through the stream system. This was confirmed with studies by VDFW, which found that a variety of sizes of brook trout and brown trout had successfully moved through the structure and that fish were also residing within the culvert!

Looking upstream at the new concrete box culvert. Note the rock grade control weir constructed downstream of the project to maintain the streambed elevation at the outlet.

Stream substrate within the culvert was constructed to mimic natural stream conditions and withstand the forces of high flows.

Wild brook trout collected from Heartwellville Brook.

Technical Concerns

This document presents concepts and considerations for the design of stream crossings to provide aquatic organism passage. Stream crossing designs should also meet or exceed other applicable local, state, or federal standards for hydraulic capacity, headwater depth, as well as structural and safety design parameters. Qualified consultants can provide technical assistance on all of these issues.

Conclusion

Vermont citizens generally agree that protecting the environment, while accommodating a growing population and sustaining the economy is a priority. The transportation infrastructure is essential to our way of life, and because that infrastructure cuts across natural ecosystems, it is imperative that we find ways to minimize adverse effects on habitats and wildlife.

Stream crossing designs have improved in recent years through the collaborative efforts of engineers, construction professionals and environmental scientists. Safe and stable stream crossings can accommodate aquatic resources and protect stream health while reducing expensive erosion and structural damage.

This booklet is intended to raise awareness about stream crossings and watershed continuity, and to introduce design concepts and considerations for new and replacement crossings. Additional resources and technical assistance are described below.

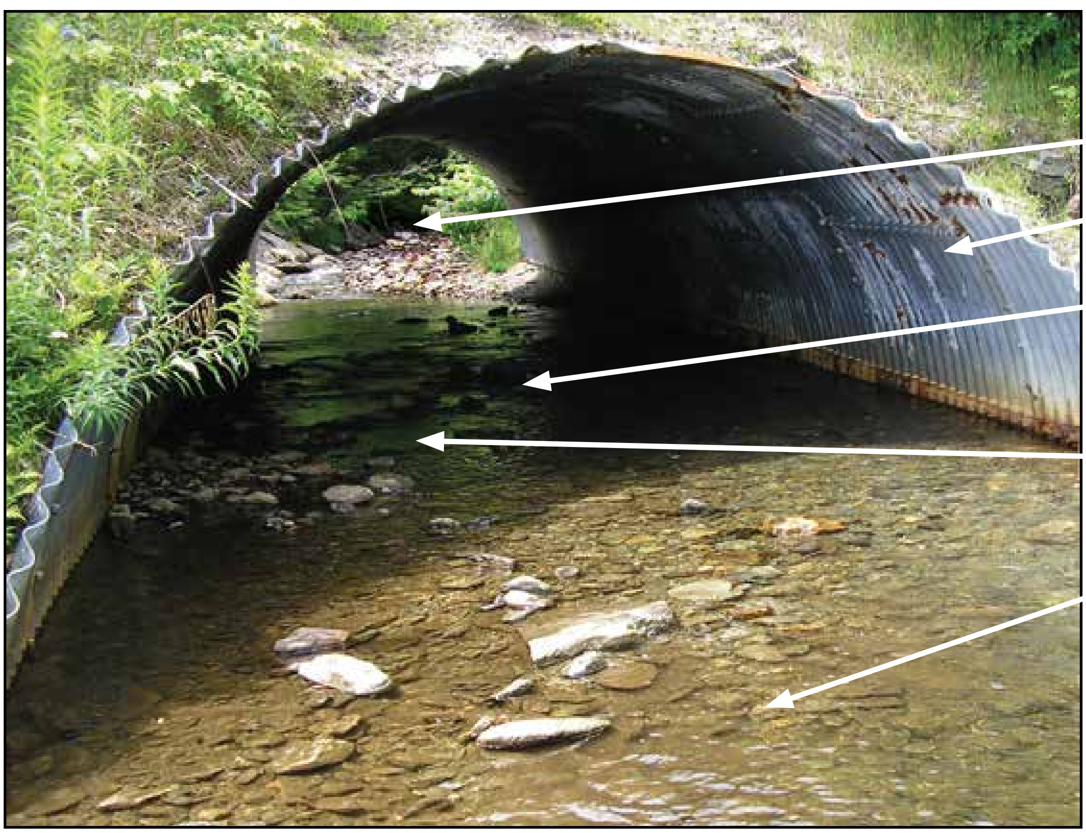
Getting More Information:

Technical Guidance and Project Assistance

For current information on stream crossings from the Vermont Department of Environmental Conservation (VDEC), including specific regulation requirements, permit applications, and Stream Alteration Engineer contacts. Visit VDEC River Management website (http://dec.vermont.gov/watershed/rivers/river-management) or call (802) 490-6195.

Stream Alteration Engineers should be contacted in the early stages of developing a stream crossing project. They can assist with bankfull width determinations, design criteria, and permit requirements.

VDFW District Fish Biologists can also be contacted early during the planning of projects to identify aquatic resource issues associated with a specific stream crossing project. Visit the Vermont Fish & Wildlife website (Vermont Fish and Wildlife » Learn More » Fish and Wildlife Library » Maps » Fisheries Districts) or call (802) 828-1000.



A Well Designed Crossing

State and Federal Regulations

The importance of aquatic organism passage is recognized in several state and federal regulations and programs. This section provides a current list of regulations which relate to stream crossing structures and aquatic organism passage in Vermont. Other local municipal regulations may also apply. More detailed information for these regulations is available from the provided links.

U.S. Army Corps of Engineers, Vermont General Permit.
www.nae.usace.army.mil/

Vermont Stream Alteration Rules and Permits.
http://dec.vermont.gov/watershed/rivers/river-management#rules

10 V.S.A. Chapter 151. State and Land Use Development Plans (Act 250).
http://www.nrb.state.vt.us/

Vermont Water Quality Standards. http://dec.vermont.gov/watershed

10 V.S.A. Chapter 111 § 4607. Obstructing streams.
http://legislature.vermont.gov/statutes/chapter/10/111

Additional Resources

Aquatic Organism Passage Design and Stream Assessments:
Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont. Bates, K. K. and R. Kirn. 2009. Vermont Fish & Wildlife Department
www.vtfishandwildlife.com/common/pages/DisplayFile.aspx?itemId=111510
(Vermont Fish and Wildlife » Learn More » Fish and Wildlife Library » Reports and Documents » Aquatic Organism Passage at Stream Crossings)

Vermont Stream Geomorphic Assessment Protocols. Vermont Agency of Natural Resources. http://dec.vermont.gov/watershed/rivers/river-corridor-and-floodplain-protection/geomorphic-assessment

FishXing. Software and Learning Systems for Fish Passage Through Culverts. This comprehensive website provides technical presentations, case studies, software, reference library and links on fish passage and stream assessment.
www.stream.fs.fed.us/fishxing/

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings. U.S. Forest Service. 2009.
www.stream.fs.fed.us/fishxing/aop_pdfs.html

Fish and Wildlife Conservation
Conserving Vermont's Natural Heritage. A Guide to Community-Based Planning for the Conservation of Vermont's Fish, Wildlife and Biodiversity. Vermont Fish & Wildlife Department. (Vermont Fish and Wildlife » Get Involved » Partner in Conservation » Community Wildlife Program)

Vermont's Wildlife Action Plan. Vermont Fish & Wildlife Department.
www.vtfishandwildlife.com/cms/One.aspx?portalId=73163&pageId=480706
(Vermont Fish and Wildlife » About Us » Budget and Planning)

More Passage Friendly Stream Crossings

Here are some recent examples of town and private stream crossing projects which provide aquatic organism passage.

Tabor Branch, Topsham

Chase Brook, Berlin

Clay Brook tributary, Warren

Great Brook tributary, Middlesex

Acknowledgements

Special thanks to Patrick Ross and Shayne Jaquith of the Vermont Department of Environmental Conservation, River Management Program and Kozmo Ken Bates, consulting fish passage engineer, Kozmo, Inc., Olympia, WA.

The concept of this brochure, its layout and much of the text is taken from the Massachusetts Stream Crossing Handbook published in 2005 by the Riverways Program in conjunction with biodrawversity (www.biodrawversity.com). The Riverways Program is within the Division of Ecological Restoration, Massachusetts Department of Fish and Game (www.mass.gov/eea/agencies/dfg/der/aquatic-habitat-restoration/).

Emily Minck and Lilla Lumbra produced the graphic design of this document.

Funding

Funding of this project was provided by the Vermont Fish & Wildlife Department under the State Wildlife Grant Program and by fishing license sales and matching Dingell-Johnson/Wallop-Breaux funds, available through the Federal Aid in Sport Fish Restoration Act. The Lake Champlain Basin Program also provided funding for the reprinting of this document.

The MISSION of the Vermont Fish & Wildlife Department is the conservation of fish, wildlife and plants and their habitats for the people of Vermont. In order to accomplish this mission, the integrity, diversity and vitality of all natural systems must be protected.

The Agency of Natural Resources is an equal opportunity agency and offers all persons the benefit of participation in each of its programs and competing in all areas of employment regardless of race, color, religion, sex, national origin, age, disability, sexual preference, or other non-merit factors.

Lake Champlain Basin Program

Revised July 2016

Cover images: spring salamander and brook trout - Michael Humling / wood turtle-Lilla Lumbra

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