Fish Friendly Culverts

Proper design, installation, and maintenance can protect both roadways and fish

Did you know that culverts—those large, pipes that are necessary for access over streams—can cause major problems for fish and other aquatic animals? Improperly installed or poorly maintained culverts can pose a serious threat to these animals by disrupting their habitat and spawning success. However, proper design, installation, and maintenance can protect both roadways and fish.

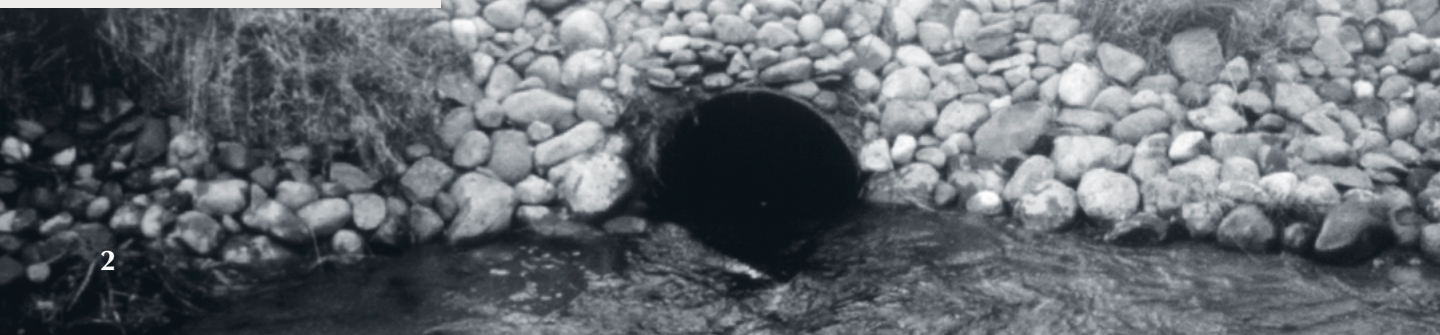
Sizing and Slope of Culverts

Spawning fish frequently begin their migration at a time of year when there is high water flow in streams. Properly sized and placed culverts are important to accommodate water velocities and flows necessary for fish to swim through the culvert. Selecting culvert diameters to match the width of the stream at an average point is a basic first step. Stream widths should be measured at the top of the banks as this may best represent the stream size during normal high water or bank-full conditions.

Several concerns should be addressed when determining the most appropriate size and position of culverts. The culvert should be sufficiently sized to allow for water depth, volume (flow) and velocity levels that will permit fish passage through the culverts. Special care is needed when installing larger culverts on streams that have low seasonal flow. Bottomless, arched culverts placed over existing stream beds are the preferred option. An alternative is to bury the bottom of the culvert at an adequate depth below the streambed, which will allow a stream channel to form within the pipe. The channel within the culvert will provide better fish passage under low-flow conditions than a culvert installed on top of the streambed. The angle or slope of the culvert should be equal to the stream grade to maintain an acceptable water velocity for fish passage.

Things to consider before you dig

- Permanent vs. seasonal road & traffic load
- Opening size required to pass the design flood
- Fish, invertebrate (insect) & wildlife migration
- Boat navigation
- Unique site conditions



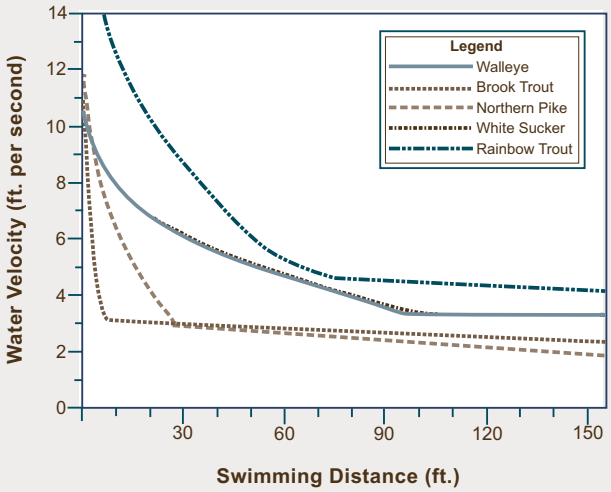
Water Velocity and Depth

While fish can swim with amazing bursts of speed, they may be unable to sustain this speed in high velocity waters throughout the entire length of a culvert. Swimming speeds vary with the species, size, and life stage of fish. Where fish are a concern, the velocity of water in the culvert (feet per second) should be based on the slowest sustained swimming speed for the fish in the stream **(see figure 1).**

Keep in mind that in situations where fish passage is not a major concern, other aquatic species may use the culvert and will need to rely on natural streambed sediments in the culvert to aid their movement. Other species of concern include vertebrates (such as mink, frogs, turtles) and invertebrates (such as insects, crayfish, snails).

Another consideration is minimum water depth during low-flow dry periods. The depth must be adequate for fish to be completely immersed and not scraping bottom. Depending on the stream, fish may migrate during summer heat in search of cooler waters with higher oxygen levels. Improper culvert design and placement can impact downstream migration as well. Shallow culvert water can create a bottleneck, affecting an entire section of stream. A six-inch minimum water depth is recommended.

Figure 1. Limiting flow velocity for fish



Fish, similar to human runners, can log higher speeds over short distances easier than they can in a long distance marathon.

Figure 1 shows a relationship between water speed (velocity) and fish swimming distance. As water velocity increases, fish are only able to swim for short distances. In a 50-to-100-foot culvert, for example, the limiting flow velocity for walleye and northern pike drops to less than 3.3 ft/sec.

This fact sheet outlines issues to consider when installing culverts in streams. For additional site-specific information, such as species of fish present, locations of spawning areas, and design considerations, consult a Department of Natural Resources Transportation Liaison in your area.

A stream is considered navigable under Wisconsin law if it has a defined bed & banks and regularly recurring periods when it is possible to float a canoe or small recreational craft. Wisconsin requires that culvert installation (new or replacement) on navigable streams be approved under a state Department of Transportation administrative code (Trans 207). Your local DNR Transportation Liaison can assist you with this approval process.

Timing Culvert Installation

In order to minimize stream sedimentation, flow interruption, and disturbance of fish during sensitive seasons, carefully consider the time and duration of culvert installation or repair. Scheduling projects so that they don't coincide with fish migrations, spawning, and egg incubation periods minimizes negative impacts on fish and avoids installation problems associated with high-water seasons. **Figure 2** is a generalized time frame for fish spawning and development in Wisconsin, although these spawning times do not necessarily include migration times. It is important for regulatory and project sponsors to consult with local fish or water resources biologists in order to plan for the best times to avoid fish mating and migration activities in a particular stream.

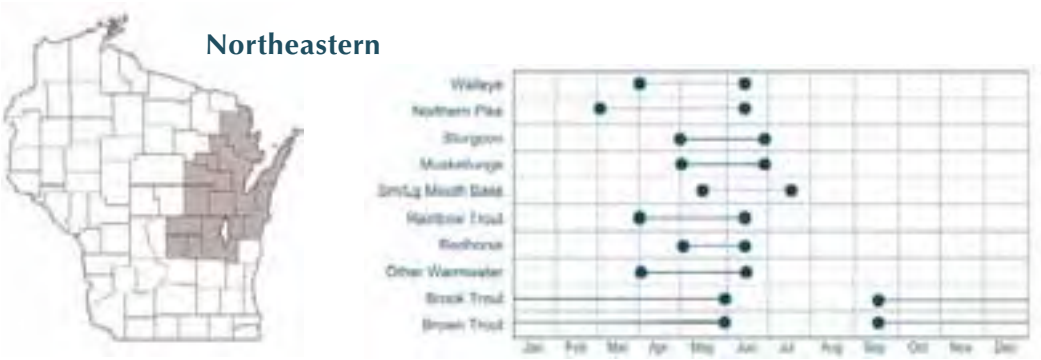
Adequate site preparation is important for avoiding delays and preventing erosion once the site is exposed. Prompt installation and immediate attention to soil stabilization avoids prolonged stream disturbance and continuous maintenance problems. Installing appropriate erosion and sediment controls on disturbed soils before site work is finished can reduce long-term costs. Preventing erosion, by vegetating the site with seed and mulch, is often easier than trying to control moving soil.

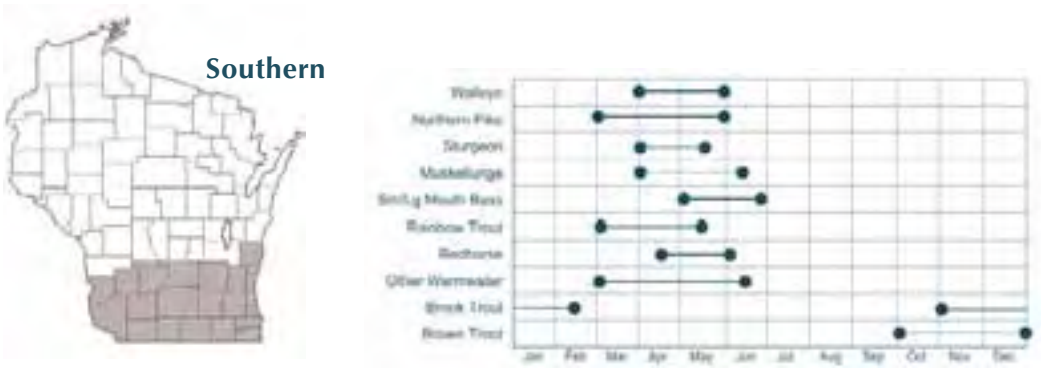
Completing work prior to mid-September generally allows time for seed to germinate and stabilize disturbed soils. Avoid leaving soils exposed over the winter months, as melting snow and heavy spring rains can easily erode unprotected soil. When soil enters streams, the suspended soil particles can negatively impact fish feeding, create abrasions on fish gills (leading to infection), and ultimately fill in the gravel areas needed for spawning. Eroded soils can also contribute to lower dissolved oxygen levels, smother aquatic plants, increase water temperature and even change the shape of the stream channel. In the end, it is much better to prevent erosion than try to repair the damage after it has occurred.

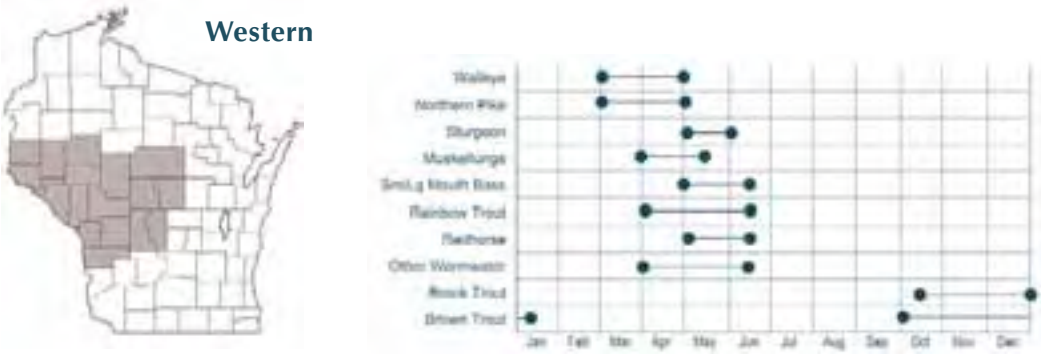
Single vs. Multiple Culverts

In many cases either one large culvert or several smaller culverts can be used to channel stream flow under a road. One large culvert is generally preferred on most stream crossings, but may not be the best choice on a stream with a wide range of stream flows. Single large culverts aid in reducing debris blockage, provide for better fish and wildlife passage, and reduce flow velocities for better fish passage. Burying larger culverts deeper in the streambed can also allow for fish passage because a smaller, low-flow channel will become established within the culvert. If multiple culverts are used, one should be placed lower than the others to hold low-flow water to provide adequate fish passage during low-flow periods.

Figure 2. Average time for fish spawning







Culvert Placement

Installing a culvert on top of the existing streambed or installing undersized culverts can cause problems for fish as well as for the culvert itself. In these situations, water often begins to flow below the culvert and cause piping. Piping simply means that flowing water will carry away the soil from below and around the culvert, increasing the chance of a washout. Another problem from this type of installation results when the outlet becomes perched above the level of the stream. Perched culverts are a serious barrier to fish and wildlife movement **(see Figure 3).**

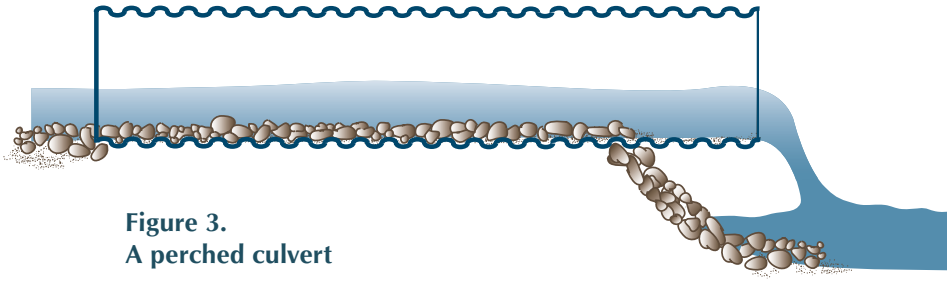


Figure 3.
A perched culvert

Setting the culvert bottom at least 6 inches (or 10-20% of the culvert diameter, whichever is greater) below the stream bed elevation will allow for better fish passage and help reduce the risk of piping. Deeper placement may be necessary on certain high-gradient streams to allow sediment to reach equilibrium inside the pipe and establish a more "natural" slope.

A "normal" streambed, **(see Figure 4)**, has a slope of 0.5% or less (<6 inch vertical drop in 100 feet distance), fine substrate materials (eg. clay-sand), and a meandering pathway. Water in a stream with a minimal slope would appear calm with no surface ripples. Streams that do not meet these criteria will likely need an engineering analysis to determine correct culvert placement.

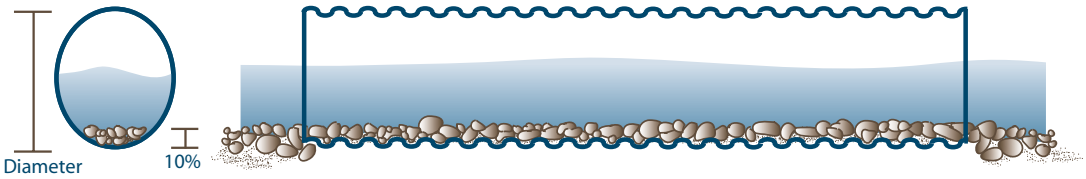


Figure 4.
Normal culvert installation

Other Options

In most fish passage situations, corrugated metal culverts are preferred over smooth bottom culverts with shallow water conditions. In addition to providing structural strength to the culvert, the corrugated surface slows down water velocity, making it more fish-friendly. However, there are other options.

When fish and wildlife are major concerns, biologists prefer structures that pose the least risk to migration. Open-bottom culverts preserve the natural creek substrate and do not disturb the streambed **(see Figure 5).** Common shapes include semicircular arch, elliptical arch, and concrete box culverts. These types of structures must be supported on footings located on both sides of the crossings. On gravel roads, footings may be a simple steel plate, but on paved surfaces, a concrete footing may be required. However, open bottom pipes have their own problems. Installation requires the creation of a bypass or similar arrangement during construction of footings. In addition, bottomless structures are 30% to 50% more expensive than a round or oval pipe. On certain high-value streams, bridges are the preferred option. Depending on the size of existing culverts, Department of Transportation (DOT) funding may be available to help pay for replacement bridges.

Figure 5.
An open-bottom culvert

Keep in mind that many other types of wildlife travel through culverts as well. The state of Wisconsin requires that the habitat needs of endangered species are considered during culvert installation and replacement. Your DNR Transportation Liaison can help you with meet these requirements.

A Final Thought

Do not underestimate the effect of a culvert crossing. While culverts only cover small sections of any stream, their influence on fish and other aquatic species can be immense, especially when you consider the cumulative effects of many road crossings. Proper planning, design, and installation can protect roads while providing year-round fish passage and preserving healthy streams.

Sources of Assistance

Sizing and placing culverts correctly can be complicated. Understanding local stream history, watershed conditions, storm intensity and frequency, and the life cycle requirements of fish often require the assistance of engineers and biologists. Human safety issues such as backwater elevations, maximum velocities, and road overtopping frequency also must be weighed at the design stage. Hiring a professional engineer to coordinate the design may be money well spent. Determine local sources of assistance and do not hesitate to ask for help. Consider contacting the following:

- County Land and Water Conservation Department
- County Highway Department
- Department of Natural Resources Transportation Liaison
- Department of Transportation
- U.S. Army Corps of Engineers (if wetlands are affected)
- U.S.D.A National Forest Service
- U.S.D.A. Natural Resources Conservation Service

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