

Fishways



Fishways are constructed to pass fish around natural and man-made obstacles to migration and dispersal. Migration is the seasonal pattern of movement of adult fish to spawning grounds or juvenile fish to feeding grounds. Dispersal of juvenile fish occurs when they randomly move to feeding grounds or colonize territories in other areas of a river throughout the year. Dispersal and migration are important periods in the life cycle of fishes. Barriers to movement, such as dams and weirs, can have a significant negative impact on fish populations. Fishways can help fish negotiate around a barrier when they are properly located and designed.

Fishways have existed for almost 300 years with the earliest being built in Europe. The first notions of science-based design of fishways using the fundamentals of hydraulics was conceived in 1909 by a Belgium scientist named Denil. He developed a sloped flume with baffles that reduced the velocity of water such that fish could pass through it. His design and variations of the Denil fishway are still used today in North America.

The construction of large hydroelectric power dams in western Canada and the United States in the 1930s, such as the Bonneville Dam on the Columbia River, triggered more research and development into the design of fishways. Several types of fishways have evolved as a part of these immense dam construction projects including the pool-weir, vertical slot, fish elevators and fish locks. Learning from the inefficiencies of these fish passage projects has advanced our understanding of fish physiology, behavior, and swimming mechanics in the last fifty years of scientific research. One of the most interesting fishways is Canada's only eel ladder on the 28 metre high Robert H. Saunders Power Dam on the St. Lawrence River in Cornwall, Ontario.



The Denil fishway is a sloped flume with a series of baffles.

Fishways can be built of wood, steel or concrete and will vary in size based on the size of the river. The cost of constructing a fishway can range from a few thousand dollars to several hundred thousand dollars. Where barriers are small enough, such as in headwater areas, volunteers can build simple fishways at a low cost. In larger river systems, the design, construction and cost of fishways

are typically beyond the capabilities of volunteers. In these instances it is important that the local community help support the intent of the project.

Fisheries biologists and fishway designers must work closely as a team in determining what type of fishway to use and where to locate the structure in relation to the barrier. There are a number of preliminary pieces of information that need to be collected in advance of design. Your design team needs to know:

- What species are present in the river throughout the year
- Swimming speeds, including burst, sustained and prolonged for the target species
- When the species migrate
- How large are the migrations
- Where do the fish congregate in relation to the barrier
- How much habitat is accessible upstream
- The locations of other barriers in the watershed
- The seasonal hydrologic characteristics of the river at the location of the barrier
- How much debris and ice is carried by the river in the location of the barrier

Once this information is collected and analyzed, the design team will be better equipped to:

- Locate the fishway entrance where the fish are known to congregate below the barrier
- Provide sufficient attraction flow at the fishway entrance throughout the range of flow conditions during the year
- Provide adequate water flow and velocities, sufficient depths and resting areas through the fishway for peak migration periods
- Deflect debris away from the exit of the fishway
- Minimize maintenance and operation requirements
- Locate the exit of the fishway away from areas that would cause them to be swept downstream.

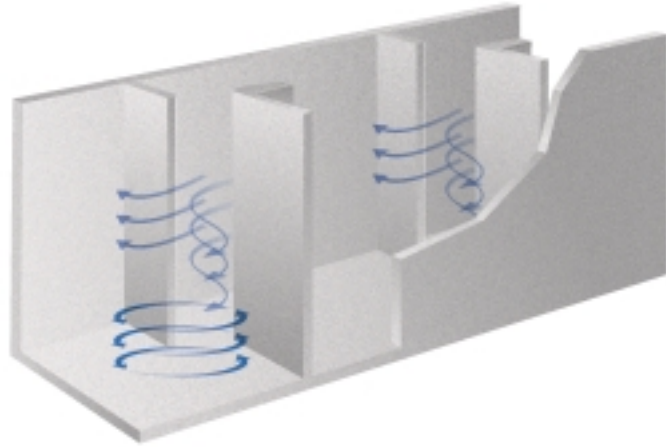
We have several varieties of fishways in Ontario that have been constructed in the last thirty years. There is only one fish elevator in this province. It was constructed on the Beaver River in Thornbury and has had difficulty in performing to its original expectations. Although they act as fishways, bypass channels and pool-riffle fishways can provide benefits to river processes and are discussed in the previous factsheet on barrier modification. The four types of fishways that have had demonstrated success in Ontario include:

- Vertical- Slot
- Pool and Weir
- Denil
- Culvert



Vertical-Slot Fishway

This type of fishway is usually constructed of concrete and conveys water down a flume of baffles and resting pools. The flume is constructed at a 10% slope or less. One or two vertical slots extend the full height of the baffle between pools and convey the water over a small drop in elevation. The speed of water passing through each slot is quickly dissipated by the standing water in the pool below. Fish will swim through the narrow slot into the next pool and rest behind the wall of the vertical baffle. It is important that the velocity of the water passing through the slot is less than the burst speed of the target fish species.



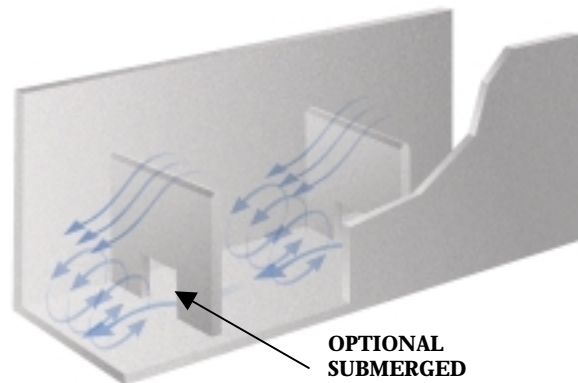
Vertical-slot fishway

The first vertical-slot fishway in Canada was built in 1946 at Hells Gate on the Fraser River in British Columbia. The arrangement of vertical-slot fishways at this location operate at flow depths ranging from 3 to 28 metres depending on the time of year. The salmon have difficulty finding the entrance to the fishways and it has been known to take three days just to pass through Hells Gate. It was designed to pass sockeye salmon on their upstream migration from the Pacific Ocean to the spawning areas in the interior of British Columbia. One of the most infamous spawning areas is the Adam's River tributary that receives a run of close to 2 million sockeye in a good year.

This type of fishway is ideal for fish species that do not jump. It is also self adjusting to flow, and functions well under a wide range of conditions. It is well suited for passing fish at barriers on large rivers. One choice example of a vertical-slot fishway can be observed passing rainbow trout in the spring on the Nine Mile River located in Port Albert, Ontario.

Pool and Weir Fishway

Like the vertical-slot fishway, the pool and weir fishway can be constructed of wood,



Pool and weir fishway

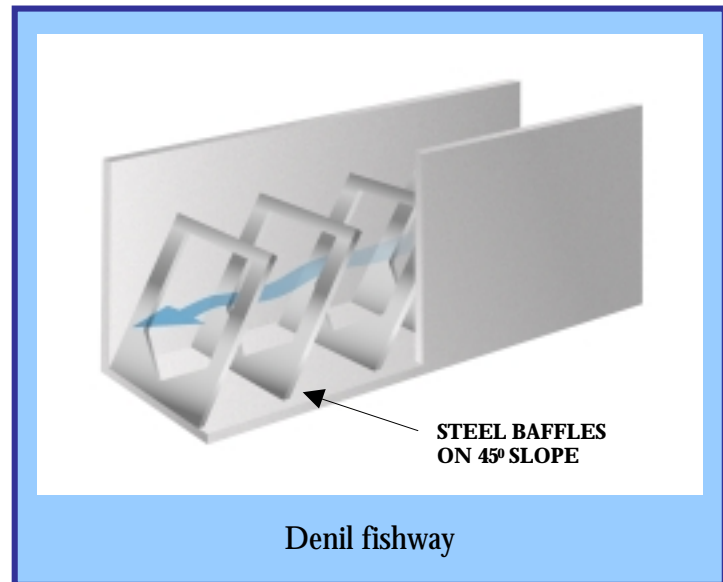


steel or concrete. It consists of a flume that is separated by low head weirs into a series of stepped resting pools. The water cascades down the series of weirs from one pool to the next. Fish ascend this fishway by jumping or swimming from one pool over the weir to the next pool. Pools provide dissipation of water velocities and also function as resting areas as fish move through the facility. The flume has a slope of 10% or less.

Pool and weir fishways are the more common type of fish passage facilities used for assisting the migration of species that are capable of jumping. This type of fishway does not work well under a variable flow regime and is best suited to situations where the flow passing through remains constant.

Denil Fishway

A Denil fishway consists of a steep flume with a series of internal baffles that are fixed to the floor and walls. The closely spaced baffles are designed to create turbulence and dissipate the energy of the water passing down the flume to velocities that permit fish movement. In fact, the design of the Denil baffles is so efficient at dissipating the energy of fast flowing water, that this type of fishway is capable of passing more volume, as compared to another type of fishway, with the same cross-sectional area. This translates into having a better attraction flow at the entrance of the fishway. For larger dams, several Denil fishways may be interconnected with intermediate pools to allow fish to rest between sections.



Denil fishways can be built with slopes ranging from 10 to 20% and prefabricated of steel or aluminum. Construction costs can range from several thousand to several hundred thousand dollars depending on the site conditions and size of the fish passage structure. With the design allowing for a steeper slope, this fishway can be constructed in a shorter area as compared to other fishways. This type of fishway can accommodate small fluctuations in the flow regime of less than 2 metres in height during the migration period.

Culvert Fishways

There are a variety of different types of culverts used in road, highway and railway construction projects. There are concrete, corrugated steel and wooden culverts that can be rectangular, open footing, arch or round in shape. Culverts can vary in length, from several metres under a road, to hundreds of metres of pipe under an urban subdivision. The benefit of a culvert in comparison to a

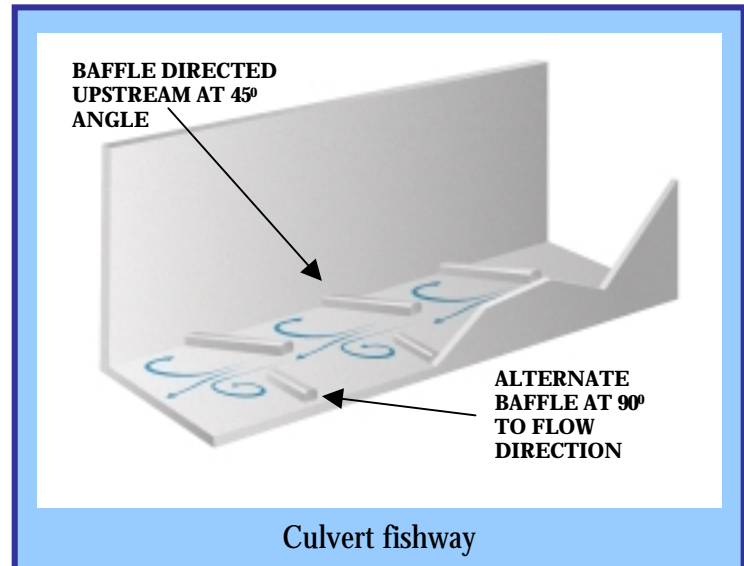


bridge is that it is cheaper and more efficient at conveying water as compared to a meandering natural channel. This is because culverts are straight and smooth and this allows them to move water faster.

Unfortunately, culverts that are inadequately designed or improperly located in streams can lead to the creation of barriers to fish migration. Perched culverts are a typical barrier to fish passage on headwater streams. A vertical drop at the end of the culvert, as a result of excessive scouring of the stream bed over several years, makes it difficult for fish to pass. Culverts that are built on steep slopes produce problems for fish migration where the velocity of the water passing through the barrel is greater than what fish can swim through. This is known as a velocity barrier. Also, the

depth of the water in the culvert is important. Sufficient depth must be present to allow for fish movement. There is a collection of design and placement qualifications to consider prior to installing a new culvert:

- The hydrology of the watercourse
- The species of fish present throughout the year
- The slope of the channel through the reach
- Bottomless culverts are preferred.
- Culvert alignment should be the same as the stream.
- Keep the proposed slope as close to 0.5% as possible.
- Maintain a water velocity of 1.0m/s or less throughout the length of the culvert under low flow and bankfull stages.
- A series of internal baffles will be needed where the culvert is greater than 25 metres long and the proposed slope is greater than 1.0% or where the velocity of water exceeds 1.0 m/s.
- Maintain a minimum depth of 0.25 metres in the culvert under low flow conditions.
- Install such that 10% of the culvert barrel is below the bottom of the natural stream bed. Back fill the bottom of the culvert with appropriately sized river stone where possible.
- Construct a plunge pool at the downstream outlet of the culvert that is at least 0.6 metres deep and twice as long and as wide as the width or diameter of the culvert.
- Likewise, the upstream inlet of the culvert should allow sufficient resting areas for fish after passing through the culvert.



- Where multiple culverts are proposed, one should be located at least 0.25 metres below the other(s) and designed with fish passage qualifications.

For existing culverts that act as barriers to fish migration, there are two alternatives that can be considered in developing a solution. Creating a backwater into the barrel of the culvert, with one or a series of rocky ramps and pools downstream of the outlet, will remove a vertical drop and reduce the velocity of water passing through the culvert. Care should be taken as to not exceed 0.25m of the depth of culvert with the backwater effect. Another method is to install baffles inside the barrel of the culvert. There are a variety of different styles of baffles including: boulders, weirs, slotted weirs, offset baffles and spoiler baffles. Offset or alternating baffles are considered the best type. They are constructed of wood or concrete, secured to the base of the culvert and provide up to 0.25 m of depth. Slower pool areas between baffles allow fish to rest as they move through the culvert. Both of these alternatives can be designed and implemented by volunteers, under proper guidance from MNR or conservation authority staff.

Demonstrations

Fishways have been constructed in the following demonstration projects:

Pool and Weir Fishway

- Project #4, Quance Dam Fish Ladder
- Project #7, North Creek
- Project #97, Boyne River Rehabilitation Project
- Project #109, Morningside Tributary Aquatic Habitat Rehabilitation Project
- Project #118, Rouge River Headwaters Rehabilitation Project

Denil Fishway

- Project #83, Bluevale Dam Fishway

Culvert Fishway

- Project #66, Purpleville Creek Rehabilitation Project
- Project #109, Morningside Tributary Aquatic Habitat Rehabilitation Project

For More Information

Please refer to the following authors and their respective publications located in the bibliography:

- Design of Fishways and Other Fish Facilities (Clay, 1995)
- Introduction to Fishway Design (Katapodis, 1992)
- Culvert Guidelines: Recommendations for the Design and Installation of Culverts in British Columbia to Avoid Conflict with Anadromous Fish (Dane, 1978)

