Fish Passage

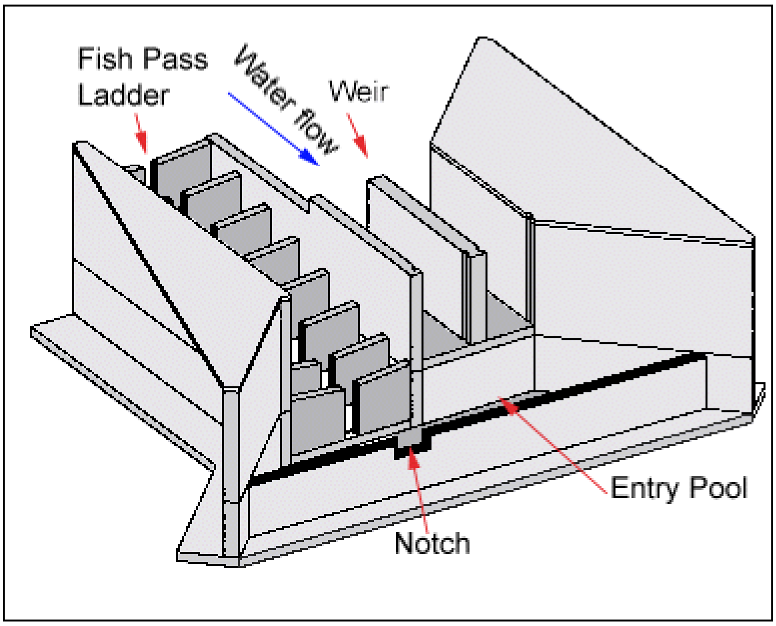
Scope

This guide provides an introduction to fish requirements when designing drainage systems for a locality. It is intended to provide an overview and planning reminder, it cannot provide detailed requirements as every water course is different and fish and amphibian species vary for location to location. A competent person should be consulted to assess the needs of your locality.

See also our guide 'Micro-Hydro Power Generation'.

Fish Ladders

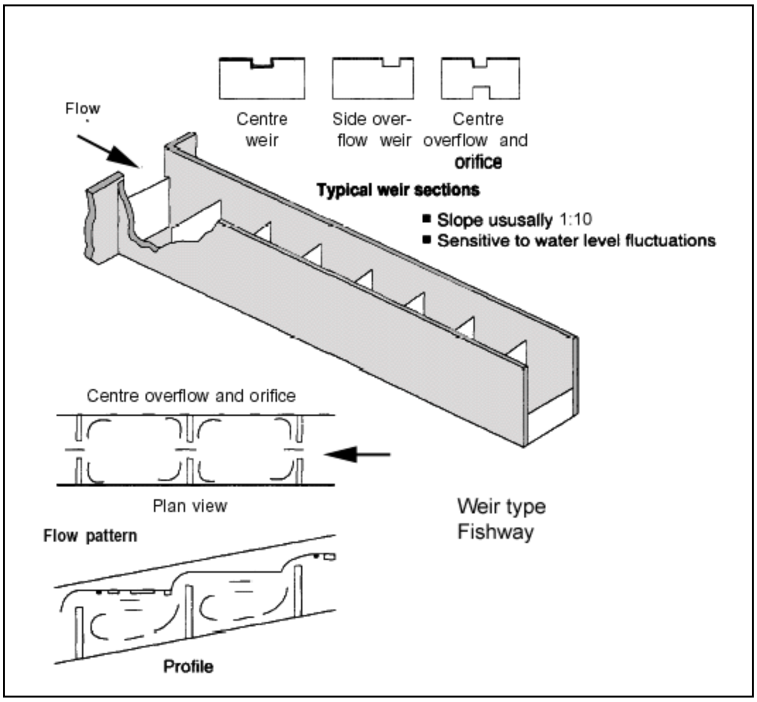
A fish ladder (or stairs, fish way, fish pass) is a structure designed to allow fish the opportunity to migrate upstream and continue their function as part of the river ecosystem. Fish ladders may be recommended when blocking structures are as low as 300-600 mm in height. Critical components to determine when a ladder is necessary are the water depth below the blockage, the water velocity, and the type of species that need to pass.



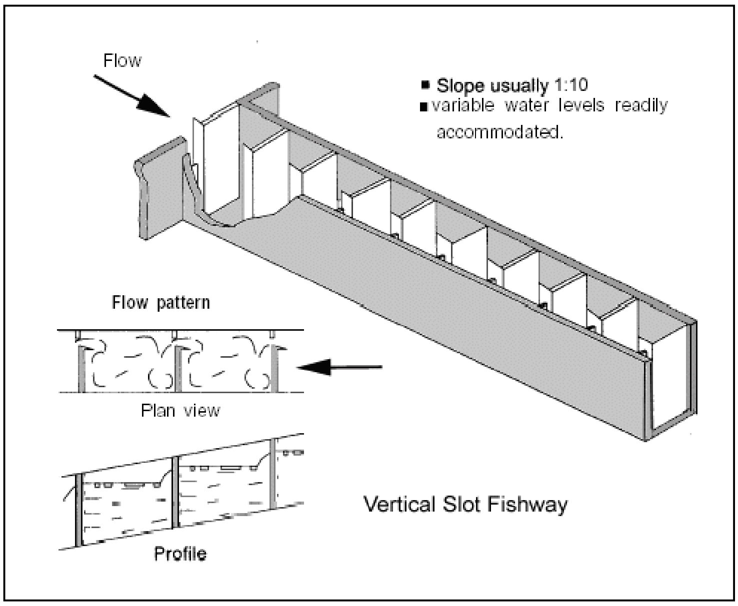
Many design factors are looked at by engineers when designing and placing a structure. Every blockage in a stream/river represents a unique situation and challenge, and each fish ladder is therefore carefully designed and placed. No one fish ladder design will accommodate most species of fish. Each species has different physical characteristics that need to be taken into consideration when designing passage facilities. Flows, energy dissipation, resting areas, drop between pools, attraction velocities, entrance eddies, and space in pools are just some of the factors that need to be considered when designing a ladder.

Types of Fish Ladders

There are four basic designs for fish ladders that are used throughout the world. These illustrations are generic and not actual designs.

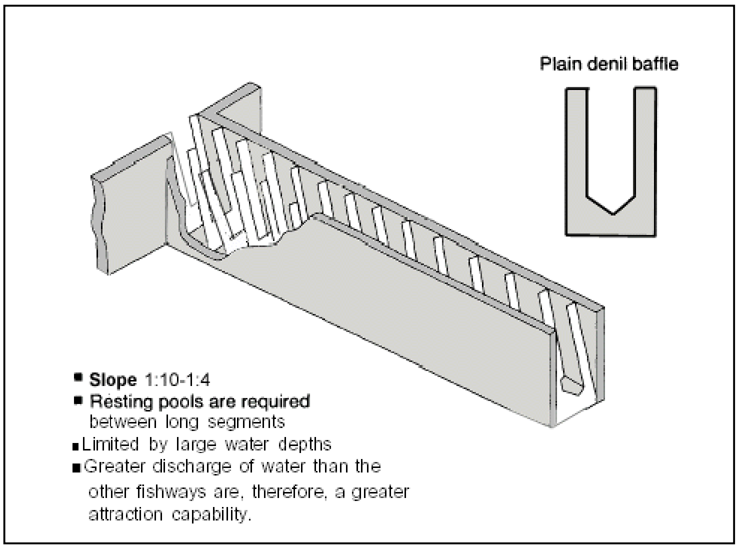


Pool-Weir: The pool and weir fish way is used at man-made structures and are the oldest of the fish way designs. In these fish ways, pools are arranged in a stepped pattern and are separated by overflow weirs between pools is for example 300 mm for most salmon and trout, which can leap from pool to pool, and in these fish ways, pools are arranged in a stepped pattern and are separated by overflow weirs.

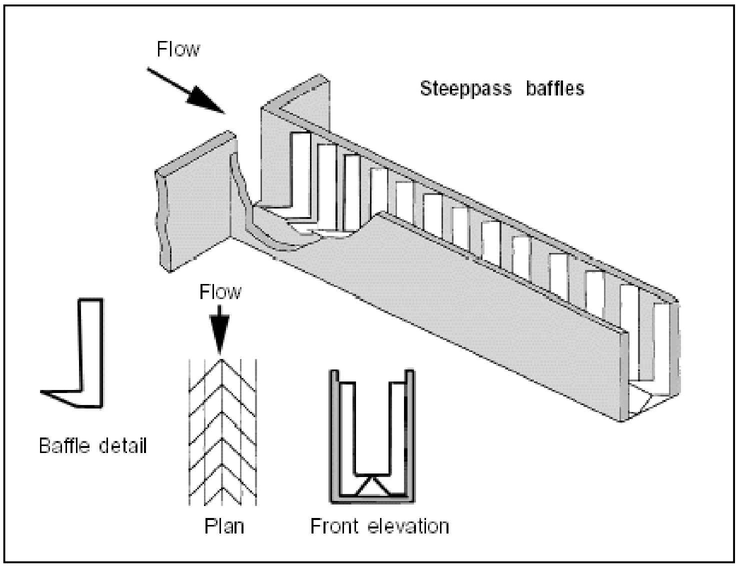


Vertical Slot/Pass: Vertical slot ladders are quite common. They repeat a constant flow pattern at all operating depths. Its design is less simple than a pool and weir design, but its advantage is that it is self regulating in terms of flow. As a rule these should not be used for more than 6 metre rise without a rest and feeding pond being available before the next rise.

Denil: fish ladders are rectangular chutes or flumes created by the baffling controls flow. These relatively narrow chutes have baffles extending from both sides and bottom which point upstream. Not suitable for deep water. Resting pools should be included at intervals.



Steep Pass: these are a variation on the Denil design. The steep-pass has a more complex configuration of baffles than the standard Denil, is more efficient in controlling water velocity, and is operable at steeper slopes (up to about 1:3 for salmon and steelhead). The maximum slope, and therefore the water velocity within the fish way, is a design criteria dependent on species and size of fish to be passed. Less flow is required for successful passage. However, due to its smaller open dimensions, the steep-pass has a more limited operating range and is more susceptible to debris problems than the plain Denil.



Need for Fish Ladders ; It was recognised long ago that obstructions in rivers such as dams fragment aquatic ecosystems and affect fish populations. France developed fishway laws during the 1660's requiring passage be built into new dam structures. Fragmentation of rivers can and has resulted in the decline and in some cases a complete extinction of fish species. It is important that the fish types local sedentary and more robust migratory are catered for when selecting the water flow rates. This is to ensure that the more sedentary and weaker swimmers can use the way.

In recent years piped fish by-passes have been constructed at major hydroelectric dams these combine a ladder with large bore pipe sections. These have proved more successful for less capable fish in high rise conditions but can cause deaths for a percentage of fish.

Construction Phase Culverts

Following use on temporary routes, these can be carefully removed to minimise soil and stream bed disturbance. It is important that these culverts be of adequate diameter to handle above-normal water flows, long enough to extend slightly upstream and downstream from the crossing. They should be installed with a 1:50 to 1:25 downstream angle to aid in flushing out debris and minimising flow rates for fish movement. A single culvert, sized to handle the water flow, is less likely to clog than several smaller stacked culverts and provides more opportunity for fish passage.

Remember 300 to 600 mm diameter pipes pose a trapping danger to children and dogs sized animals and should not be used where these groups may become stuck.

Fish Habitat

Protection of fish habitat is necessary for stream crossings where fisheries exist. The choice of crossing location is important in terms of both sedimentation effects and fish passage. For fish passage, preferred locations are those that do not cause large increases in velocity and have no abrupt changes in gradient or alignment of the channel. Sections of a stream with uniform alignment, good bank stability, and uniform gentle gradients are easier to cross with provisions for fish passage.

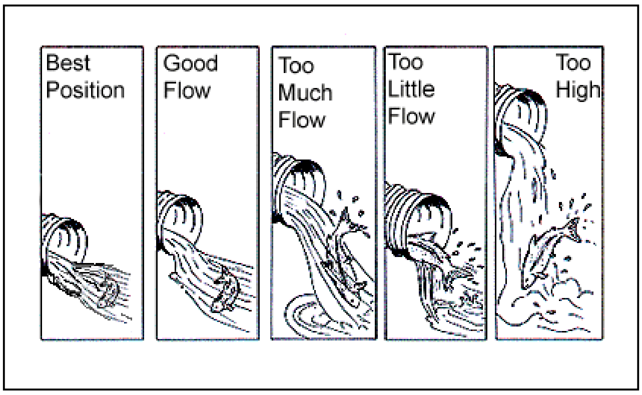
Determine the type and extent of fish habitat before selecting drainage structure design. The incorporation of fish-passage facilities at stream crossings should be based on assessments of the life-cycle requirements of fish species, of habitat quality, and of the accessibility of sites to fish. Natural barriers downstream or immediately upstream from the site may eliminate the need to provide fish-passage facilities. Usually, a fisheries biologist must be consulted to assess the habitat.

Bridges and arch culverts are preferred for crossing streams with migratory fish. Bridges are preferred because they usually cause less modification of the stream than do culverts, and are often the best way to ensure fish passage. Culverts are by far the most common type of crossing device and the most likely to cause barriers to fish migration.

Culvert crossings have been installed in thousands of streams with little or no thought to their effects on fish populations. A single, poorly installed culvert can eliminate the fish population of an entire stream system.

The following are some important considerations for culvert installation (Furniss et al. 1991, Yee and Roelofs 1980):

- **The two most important considerations for fish passage through culverts are maximum acceptable water depth for the migrating species, and outfall. Squashed pipe unless semi-submerged are likely to be prone to drying out. Corrugated pipes which are commonly used for culverts are not suitable for fish passages.**
- **The culvert should be placed at or below the original streambed elevation, and water depth and velocity at low and high flows should be integrated into the design. Fish jumping pools can be used to help flow control and outlet design**
- **the water flow is important, too low or sediment build up and the fish cannot swim. Too high a flow and poorer swimmers cannot move against the flow. Where it is necessary for the outfall to be positioned higher than the stream level (flood levels in high water season) the outfall should be no more than the jump height local sedentary fish can handle. The best solution has the outlet below the surface of he lower stream.**



- **Control scouring at culvert outlets with energy dissipators such as heavy rock riprap consistent with fish passage considerations.**
- **At stream crossings, avoid channel width changes and protect embankments with riprap.**
- **Align culverts with the natural course and gradient of the stream. Locate valley-bottom paths/roads to provide a buffer strip of natural vegetation between the road and stream.**
- **Select periods of low flows for construction to limit disturbance. Design and construct a stream crossing so that if the culvert should fail, the stream flow will not be diverted out of the original channel**
- **Ensure erosion-control measures are completed before the wet season in your area. Locate fuel storage areas away from the stream.**
- **Construct dikes to contain the largest possible spill.**
- **If gravel removal operations are permitted in the streams, co-ordinate the removal with a fisheries biologist who can give beneficial information to protect your fisheries.**
- **The diameter of culverts must be adequate to allow maximum flows and the expected debris to pass. Washing out of culverts and**

their earth fills damages the path and is a source of sedimentation. Channel bank stability upstream and downstream of culverts should be provided for. Road and path crossings alter the hydraulics of streams above and below the crossings for considerable distances, sometimes making stream banks more susceptible to erosion. Severe erosion can alter the configuration of the stream and crossing, and can eliminate the design components that provide for fish passage.

- A single large culvert is better than several small ones because it is less likely to become plugged, and carries water at low velocities.
- Where culverts are installed in stream sections with steep gradients, it is important to create or improve resting pools, cover, and bank protection along the stream above and below the culverts. Maintaining a stable stream bottom through the culvert-influenced area is essential.

Resting Places

Resting areas immediately downstream of and upstream of the culvert (or ford) are desirable with the requirements being:

- an area of water of adequate depth (e.g. at least 300 mm for trout, 450 mm for salmon);
- an area of deeper water with adequate cover for resting;
- rocks or overhanging vegetation; and
- moderate flow conditions (well within the cruising speed of the fish – see table).
- Resting pools within the culvert are not recommended as they are likely to collect silt and debris and would be difficult to maintain

Several North American reports present guidelines for the design of low stone weir installations intended to raise tailwater height. It is recommended that weirs should be a minimum of 6 metres apart and have a maximum fall of 300 mm between successive weir crests, and that the most downstream structure should have its crest level with the stream bed to act as an erosion control mechanism. This is suitable for salmon and trout but may be too high for more sedentary species.

There are many other potential effects arising from poor planning and design which include the following:

1. The loss of genetic diversity in an upstream reach for resident fish as fish can go downstream but not back upstream.
2. The loss of range for juvenile (anadronmous) and resident fish that may migrate upstream at certain times of the year.

3. The loss of nutrients (from the anadromous spawning adults) to reaches upstream of passage blockages.
4. Changes in fish genetics or community assemblages upstream of fish passage impediments because certain stronger swimming fish species or life stages can pass upstream while the weaker swimming fish can not.
5. The loss of resident fish on small streams after extreme flood of drought events that evacuates fish from the reach and fish are not able return.

Table 1 Design Criteria for Salmonids

	Notes	Brown Trout 150 mm	Sea Trout 250 mm to 500 mm	Salmon > 550 mm
Maximum Water Velocity:	a,b,c			
Culvert Length <20m		1.25m/s	1.6m/s	2.5m/s
Culvert Length 20-30m		1.0m/s	1.5m/s	2.0m/s
Culvert Length >30m		0.8m/s	1.25m/s	1.75m/s
Minimum Diameter of Pipes		0.3m	0.3m	0.5m
Minimum Depth of Water	d	0.1m	0.15m	0.3m
Maximum Water Level Drop	e	0.2m	0.3m	0.3m
Trash Screen (minimum gap)	f	0.05m	0.1m	0.2m
(From Scottish guidance on river crossings migratory fish passage – Note: it relates to adult migratory fish and not the needs of juveniles or local sedentary fish)				

Notes

a) Mean velocity of cross-section (there will be areas of lower and higher velocity).

b) The velocities for the shorter culverts approximate to the burst speed achievable by each species at 5°C, and the velocities for culverts > 30m approximate to the cruising speed.

c) These velocities should not be exceeded at any flow within the passage design flow range.

d) Minimum depth acceptable at the lower end of the passage design flow range.

e) Maximum drop at either intake or outlet.

f) The minimum gap a fish can pass through will depend upon the size of the fish - these gaps are for typical large adults. Trash screens should be avoided whenever possible but if this is not possible a grid of sufficient size to allow fish passage should be used.