APPENDIX F: STREAM ORDER AND WATERWAY CLASSIFICATION SYSTEM

Stream Order Classification System
I&I NSW uses the Strahler stream classification system where waterways are given an 'order' according to the number of additional tributaries associated with each waterway (Strahler, 1952). This system provides a measure of system complexity and therefore the potential for fish habitat to be present.

Figure A1 indicates the Strahler stream ordering process. Numbering begins at the top of a catchment with headwater ('new') flow paths being assigned the number 1. Where two flow paths of order 1 join, the section downstream of the junction is referred to as a second order stream. Where two second order streams join, the waterway downstream of the junction is referred to as a third order stream, and so on. Where a lower order stream (e.g. first order) joins a higher order stream (e.g. third order), the area downstream of the junction will retain the higher number (i.e. it will remain a third order stream).

I&I NSW recognises 3rd order streams and above as likely to display valuable fish habitat, and hence could support viable fish populations. As a result, fish passage barriers located on 3rd order and above waterways should be considered for remediation.

Although some exceptions apply, stream order will also correspond with the waterway classification described below, with Class 4 waterways generally being 1st and 2nd order streams (and some 3rd order streams), while Class 3 will generally be 3rd order streams. Class 1 and 2 will be 3rd order or above streams.

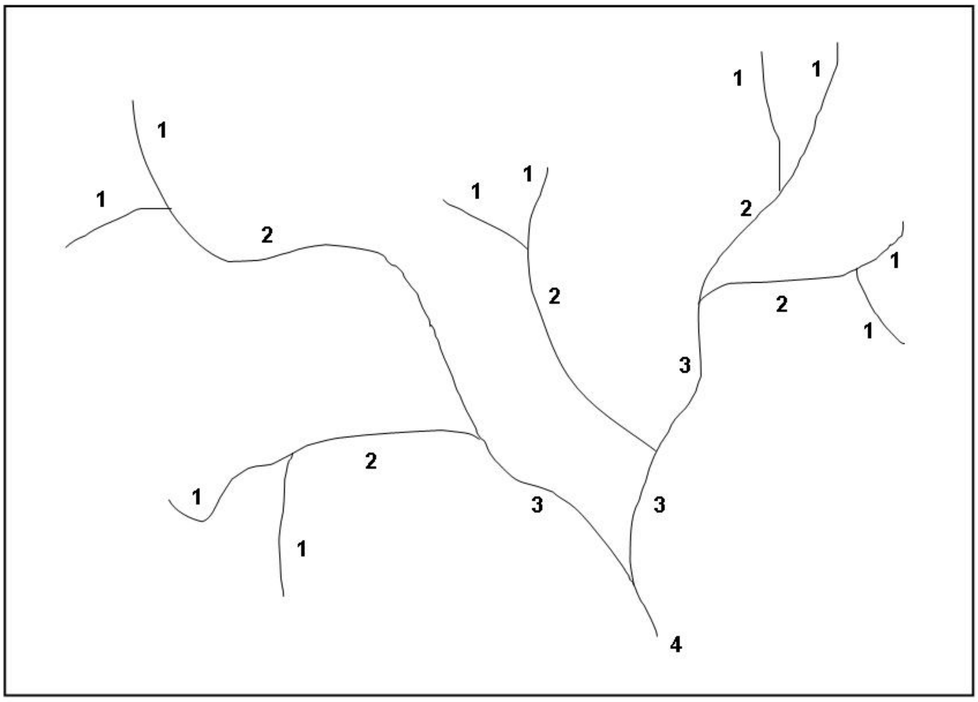


FIGURE A1. Stream ordering for a fictitious catchment using Strahler (1952) method.

Waterway Classification System

Throughout NSW, I&I NSW applies a basic 'Class' system to assign aquatic habitat values to waterways. As mentioned above, overlap exists between Class and Strahler's stream ordering system; however, specific waterway characteristics feature more prominently in Class definitions.

Table A2 outlines the characteristics of each waterway class. Waterway Class was one of the criteria used to prioritise road crossing sites in NSW as part of Bringing Back the Fish project.

TABLE A2: I&I NSW classification of fish habitat in NSW waterways and recommended crossing type. From Fairfull and Witheridge (2003).

Classification	Characteristics of Waterway Type	Minimum[1] Recommended Crossing Type
CLASS 1 Major fish habitat	Major permanently or intermittently flowing waterway (e.g. river or major creek); habitat of a threatened fish species or 'critical habitat'.	Bridge, arch structure or tunnel.
CLASS 2 Moderate fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks with semi-permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.	Bridge, arch structure, culvert[2] or ford.
CLASS 3 Minimal fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.	Culvert[3], or ford.
CLASS 4 Unlikely fish habitat	Named or unnamed waterway with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools after rain events (e.g. dry gullies or shallow floodplain depressions with no permanent aquatic flora present).	Culvert[4], causeway or ford.

[1] In all cases bridges are preferred to arch structures, culverts, fords and causeways (in that order).

[2] High priority is given to the "high flow design" procedures for the design of these culverts – refer to Design Considerations in Fairfull & Witheridge (2003) or engineering guidelines (Witheridge, 2002).

[3] Minimum culvert design using the "low flow design" procedures; however, "high flow design" and "medium flow design" should be given a priority where affordable (refer Witheridge, 2002).

[4] Fish friendly waterway crossing designs possibly unwarranted. Fish passage requirements should be confirmed with the local fisheries department/authority.

APPENDIX G: RECOMMENDED FISHWAY DESIGNS

Information presented here is sourced from Thorncraft and Harris (2000), and Mallen-Cooper (2000).

Rock-ramp fishways

Rock-ramp fishways were developed as a simple and relatively low-cost alternative to more formally engineered fishway designs (e.g. vertical slot and denil fishways). Rock-ramps are often used to overcome low barriers (< 3 m) such as weirs and road crossings, or at sites of significant stream channel. The structures are generally built on slopes that attempt to match the surrounding geomorphic features within the waterway, with slopes of 1:20 generally employed higher in the catchment and slopes of 1:30 recommended for estuarine sites due to smaller fish size classes.

In this style of fishway, large rocks are placed to form a series of small pools separated by rock ridges spaced at 2 m intervals. Fish ascend the fishway by darting through sections of high water velocity occurring between the large "tombstone" ridge rocks, and resting in the pools created between the rock ridges. Water flows down the fishway channels, with a head differential between 70 and 100 mm occurring across each ridged depending upon the designed slope.

Two variations of this form of this fishway are employed in Australia – the partial-width rock-ramp fishway (Figure A3), and the full-width rock-ramp fishway (Figure A4).

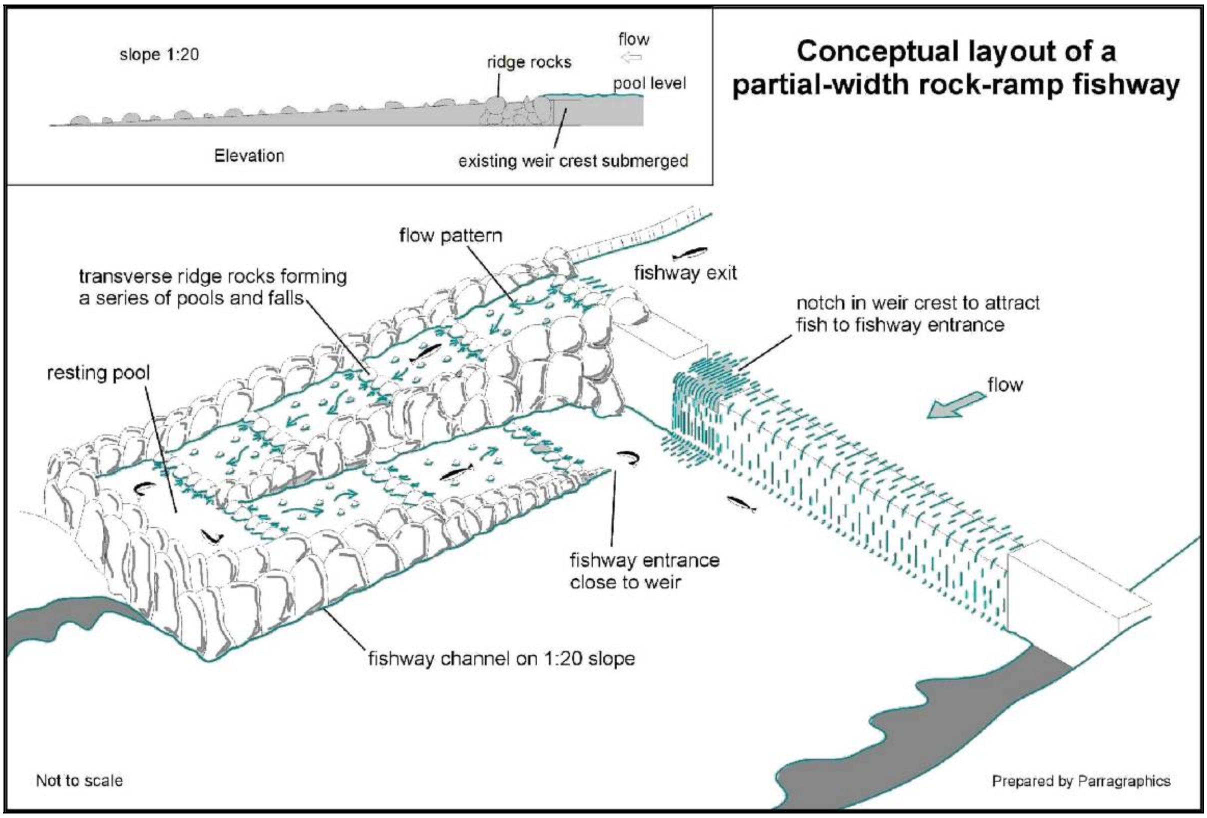


FIGURE A3: Conceptual drawing of a partial-width rock-ramp fishway.

As the name implies, the partial-width rock-ramp fishway only extends part way across the width of a waterway, with water directed down a defined channel; whereas a full-width rock-ramp fishway extends the entire width of a waterway, with low flows being directed down a defined low-flow channel.

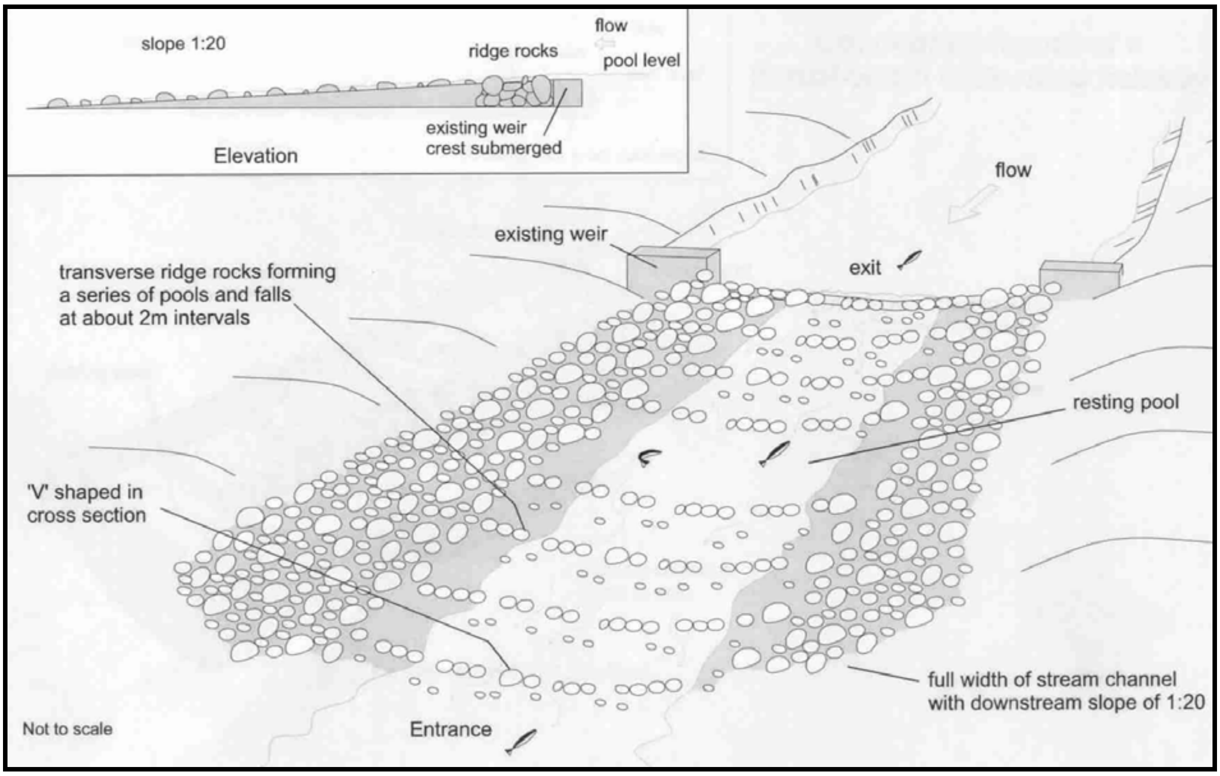


FIGURE A4: Conceptual drawing of a full-width rock-ramp fishway (plan view)

Full-width rock-ramp fishways can easily accommodate low or high flow events, and thus are considered a more effective design compared to the partial-width rock-ramp fishway which are effectively primarily during base flow periods.

On the Gloucester River (Hunter/Central Rivers CMA), modified versions of the partial-width rock-ramp fishway were employed at causeway road crossings, with the upstream exit of the fishway meeting the downstream edge of the road cap at a ‘V’ depression in the road surface. Alternatively, at The River Road, Currowan Creek (Southern Rivers CMA), a full width rock ramp fishway was installed. These modified fishways provide a means for fish to reach the road surface, but fish passage remains limited to rising flows when water depth across the road surface is increased. The full-width rock-ramp fishway at Skewes Crossing on the Orara River bypassed this issue with water flow and fish passage occurring beneath the road deck through a single large box culvert.

Vertical slot fishways

Vertical slot fishways comprise a more engineered and controlled version of a rock-ramp fishway where resting pools are essentially concrete cells, with the entrance/exit to/from each of the pools being a vertical slot at either end (Figure A5). The maximum water velocity occurs as water falls through each slot, with the downstream pool acting to slow water down and provide resting areas for ascending fish. The slope of the channel and the width of each slot controls the water velocity (generally < 1.4 ms^{-1}) through each slot, thus the fishway can be designed to suit the swimming ability of particular ascending fish.

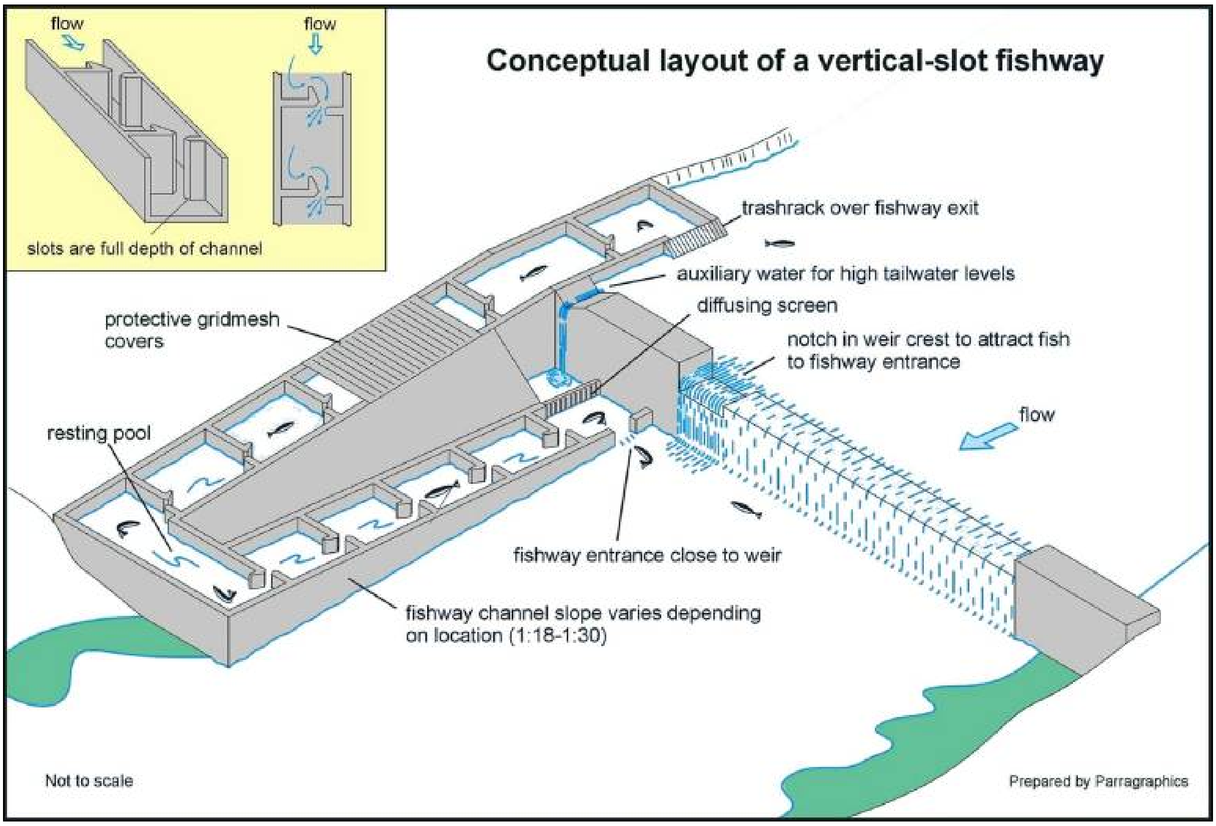


FIGURE A5: Conceptual drawing of a vertical slot fishway. Baffles act to control water direction and speed within the fishway, allowing fish to ascend.

Vertical slot fishways have flexibility of operation over varying headwater and tailwater levels, as well as allowing fish to pass through the fishway at any depth. As a result, vertical slot fishways are considered one of the most effective fishways designs for passing a range of fish species and size classes. Vertical slot fishways are generally more expensive than a rock-ramp structures, and requires larger volumes of water to operate.

Denil fishways

Denil fishways comprise a straight channel set with a series of near vertical “U” shaped baffles along the entire length (Figure A6). The main advantage of Denil fishways is that they can be built on steeper slopes (1:12) than rock-ramp or vertical slot fishways. This feature enables Denil fishways to be installed in their own right or as a retrofitting technique for older design fishways (such as chute or submerged orifice designs which were designed for Northern Hemisphere fish species) that have a slope that is too steep for most native fish to ascend.

Fish passage is possible for smaller species or size classes near the base of the denil inserts where water velocities are reduced. Better swimming species or larger size classes will use the remainder of the fishway to ascend.

Design concessions for the Denil fishway include the requirement for high water volumes to pass through the fishway for effective operation, and functioning over a limited headwater range compared to vertical slot fishways.

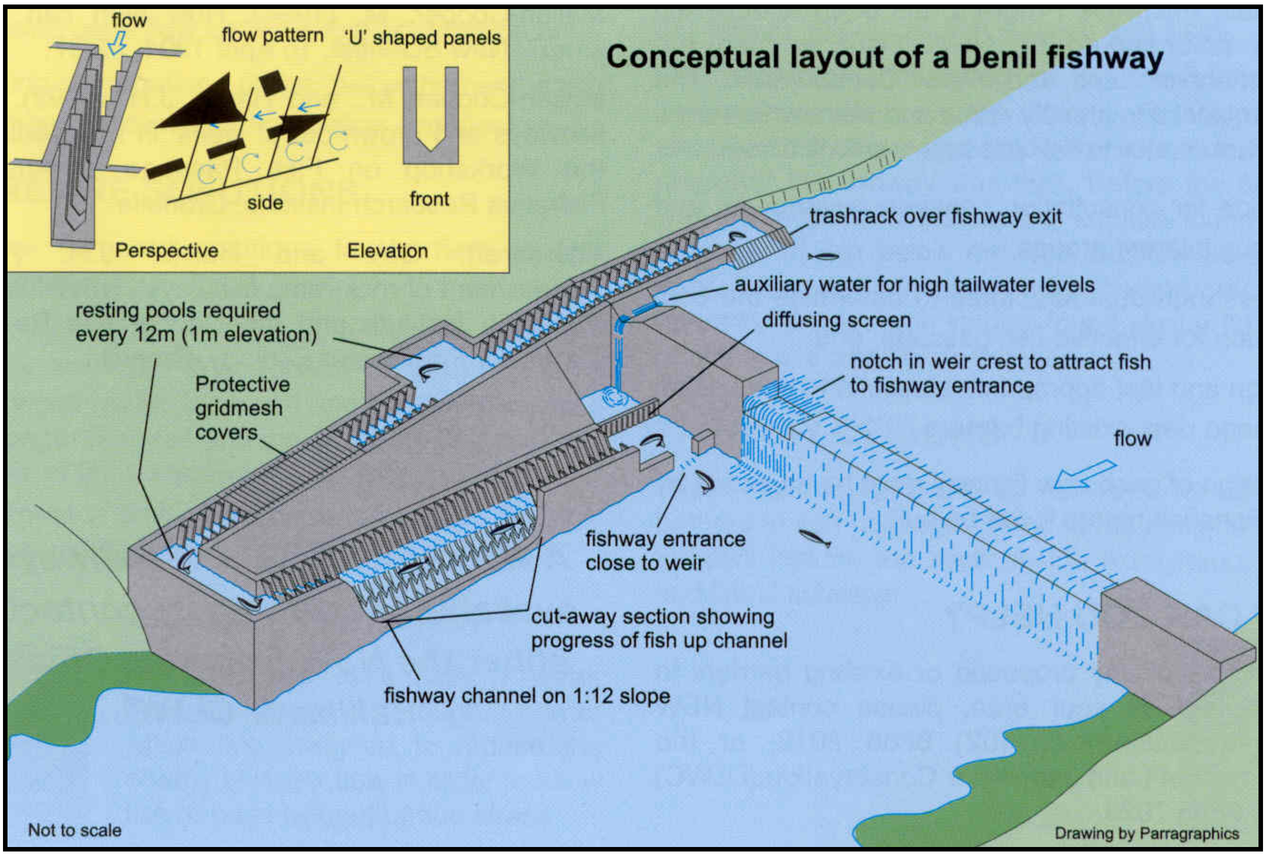


FIGURE A6: Conceptual layout of baffle and water movement within a Denil fishway.

APPENDIX H: ACTIVE FLOODGATE MANAGEMENT OPTIONS

The benefits associated with active floodgate management are largely related to the frequency and duration of gate opening, and predominantly include:

- Improved fish passage and connectivity between estuarine and drainage habitats;
- Improved habitat condition, including the control of aquatic weeds;
- Enhanced water quality through the controlled exchange of water, which reduces acidity, iron and aluminium flocs; increased stable dissolved oxygen levels, and decreased nutrients and algal blooms; and
- Enhanced wetland habitats upstream (Johnston et al., 2003).

When planning to actively manage floodgates and implement a modification or opening program, it is important to consult with local and state authorities, as well as adjacent landholders that may be affected, to gain the relevant approvals and avoid the potential risks associated with opening floodgates. Risks can include flooding, which can result from operator or mechanical failure, and increased salt levels from overtopping of saline water or lateral salt seepage, both of which can impact agricultural productivity and are affected by the hydrology of the surrounding environment (Johnston et al., 2003). These potential risks however, can be avoided by undertaking a detailed assessment of the hydraulic conditions of the drainage area prior to active management and then commencing a regular maintenance and inspection routine during management actions.

Four options of active floodgate management are available to allow for fish passage and improvements in water quality upstream of the floodgates. These four options are shown in Figure A7 and include auto tidal floodgates, (1a), the 'Smart Gate' design (1b), sluice gates (1c), and various forms of winch gates (1d).

Auto-tidal Modification

Auto tidal designs use a float and reverse hinge system to open an aperture within the floodgate, allowing for the exchange of water as the tide falls and rises (Fig. A7; Plate A). This modification has the advantage of being automatic in operation and allows for excellent water level control, with the float able to be adjusted at preferred water levels (Johnston et al., 2003).

"Smart Gate" Modification

The 'Smart Gate' design (Fig. A7; Plate B) is also automatically operated by a motor driven winch which opens and closes an aperture when specific water quality parameters are met (Johnston et al., 2003). This modification is a more complex design that doesn't necessarily improve fish passage due to the fluctuations of water quality variables at a structure, which can result in the aperture opening and closing numerous times in a short period or remaining closed over a longer duration.

A.

B.

C.

D.

FIGURE A7: Examples of floodgate modification designs including a) tidal floodgate, b) ‘Smart Gate’, c) sluice gates, and d) winch gates.

Sluice Gate Modification

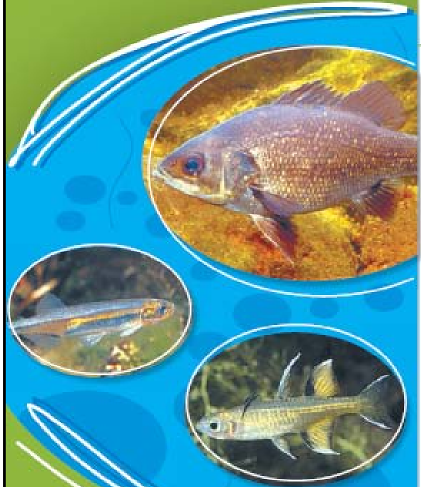
Sluice gate modifications consist of a sliding plate cover that can be opened and closed either vertically or horizontally over an aperture within the floodgate (Fig. A7; Plate C). This design provides excellent water level control during non-flood periods, with a variable aperture size making them adaptable to most systems. However, sluice gates require manual operation to open and close the aperture, which can impact on the effectiveness of active management.

Winch Modification

As with sluice gates, winch modifications require manual operation (Fig. A7; Plate D), and as their name implies, floodgate opening occurs via a winch and cable system. Gates can be opened either vertically or horizontally, and although these designs provide excellent fish passage, as the whole floodgate is opened, active management at the site requires regular attention and a significant amount of manual labour which can hinder the implementation of management actions.

APPENDIX I: BRINGING BACK THE FISH PROJECT BROCHURE

Bringing Back the Fish



What you can do to return native fish to our rivers and creeks…naturally.

What do fish need?

Native fish need:

- **Healthy habitat** - this means clean water, plants along the riverbank, and sites for feeding, shelter, and spawning
- **Free access to this habitat** – fish need to be able to move easily between flowing creeks, floodplains, wetlands, and estuaries.

When is habitat not fish friendly?

When native trees are cleared

Removing native trees and plants, especially along creek and river banks, means less habitat and food for fish, and more sediment and pollution runoff into the water.

When fish can't move

Weirs, floodgates, and poorly designed road crossings prevent fish from moving upstream and downstream for food, shelter, and spawning.

When wetlands are drained

Wetlands are valuable nursery grounds for fish, and also act to filter the water that drains into our rivers and estuaries.

Bringing Back the Fish

Bringing Back the Fish is a Natural Heritage Trust (NHT) funded project managed across the five coastal NSW Catchment Management Authority (CMA) regions. The NSW Department of Primary Industries is helping to deliver the program, which aims to:

- Improve fish migration at key weir, road crossing, and floodgate barriers.
- Restore fish habitat
- Engage fishers to identify key barriers and important fish habitat
- Monitor and assess restored sites.

Ornate Rainbowfish

What can you do to help?

- Protect healthy habitat from damage
- Install fish friendly waterway crossings
- Grow native vegetation on streambanks
- Retain logs in your stream
- Manage floodgates to allow tidal flushing
- Return water to wetlands
- Control livestock access to waterways
- Provide off-stream water and shade for livestock.

How can we bring back the fish…naturally?

Remove obsolete barriers

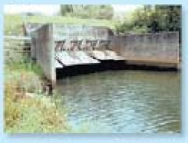
Removing weirs and causeways opens up hundreds of kilometres of habitat for fish.

Build fishways

Fishways allow fish to swim up and over barriers such as weirs. This rock ramp fishway is one of several designs used in NSW.

Tandan Catfish

Open floodgates



Open floodgates allow tidal flushing and fish movement, and improve downstream water quality.

Plant trees and control weeds

Native trees stabilise streambanks which reduces sediment and pollution in our waterways. Their foliage and leaf litter also attract insects that provide food for fish.

Empire Gudgeon

Provide off-stream water for livestock

Troughs provide stock with clean, reliable water, and are a fish friendly alternative to stock trampling and grazing streambanks and polluting waterways.

Restore and protect wetlands

Wetlands are important breeding grounds for native fish, frogs, and birds, and provide grazing opportunities in drought.

More information

Technical information on improving habitat in rivers and creeks and along their banks is available from your nearest NSW DPI office and on the internet.

NSW DPI Key Publications:

- **Barriers to fish passage**
- **Policy and guidelines for fish friendly waterway crossings**
- **Wetlands and floodplains**
- **Removal of large woody debris from NSW rivers and streams**
- **Degradation of native riparian vegetation along NSW water courses**

See also

www.dpi.nsw.gov.au/fisheries

NSW DPI contacts

Northern Rivers and Hunter-Central Rivers
Conservation Manager (AHR) 1243 Bruxner Highway, WOLLONGBAR NSW 2477 T: 02 6626 1395, F: 02 6626 1377

Sydney, Hawkesbury-Nepean, Southern Rivers
Conservation Manager (AHR) 12 Shirley Road, WOLLSTONECRAFT NSW 2065 T: 02 8437 4909, F: 02 9966 0650

NSW Department of Primary Industries · Australian Government · Catchment Management Authorities

Cover fish: from top: Australian Bass, Australian Smelt and Pacific Blue Eye

APPENDIX J: BRINGING BACK THE FISH PROJECT POSTER

aquatic habitat rehabilitation

making more fish

...naturally