



Fish passage guidance for state highways

Version 1.0, August 2013

State highways have the potential to cross waterways, meaning the correct design and installation of culverts is essential for the purpose of fish passage. This guide has been designed to assist in the best practice design and retrofit of NZTA culverts for effective fish passage to meet our statutory obligations.



NZ TRANSPORT AGENCY
WAKA KOTAHI

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v1.0

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Foreword

Highways knit together the fabric of society because they are long and linear. However, threads and roads cut as well as bind. Roads have the potential to sever rivers and streams, change elevations, create small waterfalls, dry creek beds and to put open streams into drains. As a result fish passage to spawning habitats can be impaired or prevented causing potentially dramatic population declines. The NZTA recognises that managing water means more than preventing floods and scouring. Water flows need to be managed in consideration of all ecosystem aspects. Therefore NZTA developed this guide in cooperation with local authorities to ensure we minimise to the extent possible, the impact highways have on the passage of fish in streams and rivers.

Carl Reller

Environment and Urban Design Manager

November 2012

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1 Introduction

1.1 Background

The NZ Transport Agency (NZTA) holds a strong regard towards the natural environment, as demonstrated through our Environmental and Social Responsibility Policy. Through this policy the NZTA aims to continuously improve performance in the management of environmental impacts, improve its knowledge and understanding of the extent and condition of New Zealand's environment, and identify and comply with all relevant environmental legislation and regulations. This Policy along with the *State Highway Environmental Plan*⁰¹ and the *NZTA Statement of Intent*⁰² are consistent with the requirements of the *Land Transport Management Act 2003*⁰³, *Resource Management Act 1991*⁰⁴, and the *Freshwater Fisheries Regulations 1983*⁰⁵ (as demonstrated in figure 1).

01 Transit New Zealand (2008)
Environment plan, version 2.
www.nzta.govt.nz

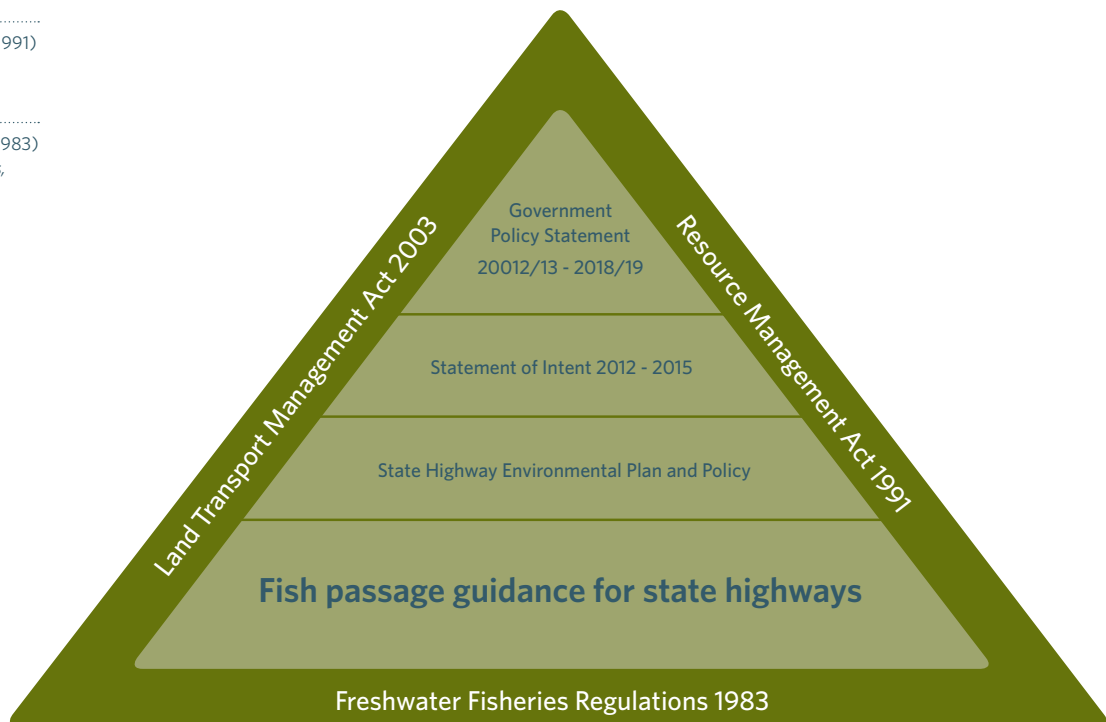
02 NZ Transport Agency (2012)
Statement of intent 2012–2015.
www.nzta.govt.nz

03 Ministry of Transport (2003)
Land Transport Management Act.
www.transport.govt.nz

04 New Zealand Legislation (1991)
Resource Management Act.
www.legislation.govt.nz

05 New Zealand Legislation (1983)
Freshwater Fisheries Regulations, Part 6 Fish Passage.
www.legislation.govt.nz

FIGURE 1 Relationship of this guide to key NZTA policy and strategy documents and other guides



The NZTA is committed to ensuring that the successful migration of fish species is not disrupted by its network, through the appropriate design of new culverts, and retrofit of existing culverts to allow for fish passage. Fish passage is required when an anthropogenic (man-made) barrier exists in the state highway network which prevents the successful migration of fish species.

There are exceptions, and in certain key native fish locations it is preferred and supported by the Department of Conservation if fish passage is not provided as this ensures upstream populations are protected from predation and competition. However, in this case authorisation must first be granted by the Director-General of the Department of Conservation.

1.2 Purpose

This guide examines the importance of fish passage and the relevant statutory context that exists and must be accounted for. The guide is primarily aimed to assist Highways asset managers, project managers and their consultants, providing basic guidance on best practice design for new culverts and fish passage solutions for existing culverts. This means that where appropriate, the most effective and efficient fish passage structures can be used. It must be noted that riparian planting is beyond the scope of this Guide, however information relevant to appropriate riparian planting can be found in the NZTA Landscape Guidelines.

FIGURE 2 An example of a perched culvert - this is not what the NZTA seeks



2 Freshwater fish and fish passage

2.1 Fish species within New Zealand

New Zealand has approximately 74 freshwater fish species, with around 51 natives (including indeterminate taxa and some marine wanderers)⁰⁶. Between one third and a half of these native fish species are diadromous. This means that they spend time in freshwater and marine environments to complete their lifecycles, and both upstream and downstream migrations are critical to access spawning and rearing habitat (with most migrations undertaken during the spring). Some species spawn in freshwater so young go to sea then return as adults, while others breed at sea and come to freshwater to mature. Native fish vary in their swimming and climbing ability with some able to climb near vertical wetted margins, while others are poor swimmers.

06 Allibone et al (2010)
Conservation status of New Zealand freshwater fish, 2009. New Zealand Journal of Marine and Freshwater Research, 44 (2), 271-278.
researchcommons.waikato.ac.nz

FIGURE 3 Inanga (*Galaxias maculatus*) and Banded Kokopu (*Galaxias fasciatus*)



Photos courtesy of Sjaan Bowie, DOC

2.2 Consequences of barriers to fish movement

In-stream barriers include both natural (e.g. waterfalls) and man-made structures (e.g. poorly designed culverts and dams). These poorly designed structures are a significant cause in the decline of freshwater fish species in New Zealand. In part, this is because fish species are at risk to injury and premature death due to issues such as increased water velocity and turbidity in poorly designed culverts. Most significantly however, the barriers have the potential to disrupt the continuity of rivers and streams, preventing freshwater fish and aquatic species from migrating upstream and downstream. Migration is essential to these species for a number of reasons including;

- diet
- reproduction
- rearing habitat and connectivity.

The barriers can also reduce the ability of some fish species to colonise and make use of suitable habitat leading to a decrease in fish numbers and potentially local extinctions, resulting in a reduction in biodiversity. Due to the linear nature of state highways, culverts can often affect many streams in a catchment and the culverts can prevent the movement of fish between the ocean and freshwater.

2.3 Fish passage purpose

The purpose of fish passage is to allow for the safe and efficient upstream and downstream passage of fish at artificial structures. The importance of fish passage is often underestimated. Significant emphasis is often placed on the disruption of flow as a result of the abstraction of water from rivers/streams, and the impact of contaminants and physical activities on these water bodies. This emphasis risks ignoring the importance of fish passage, as barriers to fish passage are a significant cause of freshwater fish population decline and extinction.

Adequate fish passage also has a significant benefit to humans due to the considerable number of freshwater fish species present in New Zealand's streams/rivers that hold an importance for their purpose as a source of food. Such fish include whitebait, eels, trout and salmon.

3 Statutory context

A number of statutory requirements apply to fish passage within New Zealand. These include the Freshwater Fisheries Regulations 1983, Resource Management Act 1991, and numerous regional policies. An understanding of these legal obligations at the design stage will ensure a reduction in expensive add-ons and continued maintenance and repairs. The relevance of these statutory requirements to fish passage is detailed below.

3.1 Freshwater Fisheries Regulation 1983

The Freshwater Fisheries Regulations (FFR) 1983⁹⁵ (see the box overleaf for Part 6 of the regulations) contains legal requirements that aim to protect New Zealand's freshwater fish and aquatic life through provisions surrounding fish passage. Authorisation is required from the Director-General of the Department of Conservation if it is intended to not meet these regulations. Part 6 of these regulations relates to the rules associated with fish passages.

Generally these requirements apply to all defined structures unless they were built prior to 1 January 1984 and were authorised under the then Water and Soil Act. However, if the culvert is pre-1983, any affordable retrofit should be undertaken if other work is being done.

For the purpose of these regulations:

Dam means any structure designed to confine, direct or control water, whether permanent or temporary; and includes weirs.

Diversion structure means any structure designed to divert or abstract natural water from its natural channel or bed whether permanent or temporary.

In summary, notwithstanding any Resource Management Act 1991 (RMA) approvals that may be held, when constructing culverts, the NZTA may not impede the passage of fish, unless written approval is obtained from the Director General of Conservation. Any culverts constructed must then be maintained so as to allow fish passage, unless specific reasons to not do so have been identified and approval is granted.

When the NZTA is constructing any diversionary structures the Director General may require the provision of a facility for fish passage, and may specify the type, general dimensions and design of such facility (including as to the required flow of water through the facility).

The RMA takes precedence meaning the Director General's ability to specify these details is expressly subject to any determination under the RMA, and any requirements cannot breach any resource consent requirements. (To avoid conflict, discussions with the Department of Conservation over the Director General's requirements should ideally be occurring before or parallel with the RMA process. If the RMA consents have already specified fish passage conditions these will take precedence).

FIGURE 4 Rock armoured on the wall behind these culverts reduces erosion, however retrofit is required to ensure the culverts are not perched



PART 6
FISH PASSAGE

Part 6 heading: substituted, on 19 October 1984, by regulation 3(2) of the Freshwater Fisheries Regulations 1983, Amendment No 1 (SR 1984/259).

41 SCOPE

1. This Part shall apply to every **dam or diversion structure** in any natural river, stream, or water.
2. For the purposes of these regulations dam or diversion structure shall not include—
 - a. any net, trap, or structure erected and used solely for the purpose of taking or holding fish in accordance with the provisions of the Act, or of these regulations:
 - b. any dam constructed on dry or swampy land or ephemeral water courses for the express purpose of watering domestic stock or providing habitat for water birds:
 - c. any water diversion not being incorporated into or with a dam, that is solely and reasonably required for domestic needs or for the purposes of watering domestic stock and that empties, without dead ends, into any viable fish habitat:
 - d. any structure authorised by a Regional Water Board not requiring a water right that in no way impedes the passage of fish.
3. For the purposes of this Part, the term **occupier** includes the owner of any land when there is no apparent occupier; and also includes any person doing any work by contract for the occupier.

42 CULVERTS AND FORDS

1. Notwithstanding regulation 41(2)(d), no person shall construct any culvert or ford in any natural river, stream, or water in such a way that the passage of fish would be impeded, without the written approval of the Director-General incorporating such conditions as the Director-General thinks appropriate.
2. The occupier of any land shall maintain any culvert or ford in any natural river, stream, or water (including the bed of any such natural river, stream, or water in the vicinity of the culvert or ford) in such a way as to allow the free passage of fish: provided that this requirement shall cease if the culvert or ford is completely removed or a written exemption has been given by the Director-General.

43 DAMS AND DIVERSION STRUCTURES

1. The Director-General may require that any dam or diversion structure proposed to be built include a fish facility: provided that this requirement shall not apply to any dam or diversion structure subject to a water right issued under the provisions of the Water and Soil Conservation Act 1967 prior to 1 January 1984.
2. Any person proposing to build such a dam or diversion structure shall notify the Director-General and forward a submission seeking the Director-General's approval or dispensation from the requirements of these regulations, shall supply to the Director-General such information as is reasonably required by the Director-General to assist him in deciding his requirements (including plans and specifications of the proposed structure and any proposed fish facility).
3. Should the Director-General consider that the information supplied is inadequate, he shall, within 28 days, advise the applicant as to what further information is required.

44 REQUIREMENT FOR A FISH FACILITY

1. If, in the opinion of the Director-General, a fish facility is required or dispensation from such a requirement is acceptable, the Director-General shall as soon as practical but in no case longer than 6 months if a fish facility is required from the date of receiving all information required, or 3 months where a fish facility is not required from the date of receiving all information required, forward his written requirement or dispensation to whomsoever made the submission.
2. Where in the opinion of the Director-General a fish facility is required he shall specify what is required to enable fish to pass or stop the passage of fish, and while not limiting this general requirement may specify—
 - a. the type, general dimensions, and general design of any fish pass to be utilised:
 - b. the type, general dimensions, general design, and placement of any fish screen utilised.

3. Subject to the Resource Management Act 1991 and any determination under that Act, the Director-General may specify—
 - a. the type and placement of any water intake to be utilised where fish screens are not required:
 - b. the flow of water through any fish pass and the periods of the day and year when the pass must be operational:
 - c. the volume, velocity, and placement of additional water to attract migrating fish to any fish pass:
 - d. the type and scope of any remedial works in connection with any fish screen or fish pass to enable fish to approach the structure or to be returned to the normal course of the water channel:
 - e. the volume or relative proportion of water that shall remain downstream of any dam or diversion structure and the period of day or year that such water flows shall be provided.
4. Every approval given by the Director-General shall expire 3 years from the date of issue if the construction of the dam or diversion structure is not completed, or such longer time as he may allow.
5. The manager of every dam or diversion structure in connection with which a fish facility is provided shall at all times keep such fish facility in good and satisfactory repair and order, so that fish may freely pass and return at all times or are prevented from passing as specified under these regulations. Regulation 44(3): amended, on 1 October 1991, pursuant to section 361(1) of the Resource Management Act 1991 (1991 No 69).

45 ADEQUATE WATER

The manager of every dam or diversion structure in connection with which a fish facility is provided shall, subject to the Resource Management Act 1991 and any relevant determination under that Act, maintain a flow of water through or past such fish facility sufficient in quantity to allow the facility to function as specified at all times or periods specified; but no person shall be liable for a breach of this regulation due to drought, flood, or other sources beyond his control if the default is made good as soon as reasonably possible.

Regulation 45: amended, on 1 October 1991, pursuant to section 361(1) of the Resource Management Act 1991 (1991 No 69).

46 REQUIRED MAINTENANCE OR REPAIR

The Director-General may serve notice in writing to the manager of any fish facility notifying him of any defects or want of repair in such fish facility and requiring him within a reasonable time to be therein prescribed to remove any defect or make such repairs as may be required: provided that nothing in this regulation shall affect the liability of a manager under regulation 44.

47 DAMAGE

No person shall wilfully injure or damage any fish facility.

48 ALTERATIONS

No person shall, without the written consent of the Director-General, make a structural alteration in any fish facility.

49 INSPECTION OF FISH FACILITIES

Any officer may at all reasonable times enter upon any fish facility and upon any remedial works or upon the land bordering such fish facility or remedial works for the purpose of their inspection.

50 PROTECTION OF FISH

No person, other than an officer acting in his official capacity, shall take or attempt to take any fish on its passage through a fish facility, or place any obstruction therein or within a radius of 50 m of any point of a fish facility, or shall within a radius of 50 m of any point of a fish facility use any contrivance whereby fish may be impeded in any way in freely entering or passing through or passing by a fish facility except as may be provided by the Director-General in writing to the manager of the fish facility.

3.2 Resource Management Act 1991

The Resource Management Act (RMA) 1991¹⁰⁴ has a number of statutory provisions that relate to fish passages (see box below for more detail). The responsibility for implementing the RMA is with local councils who express the requirements through statutory plans. The individual councils plans will need to be considered (see section 3.3 for more guidance).

In summary (for present purposes) the Act's purpose of sustainable management set out in section 5 requires managing the use, development and protection of natural resources in a way that provides for social, economic and cultural wellbeing, health and safety, while safeguarding the life supporting capacity of water and ecosystems, and avoiding, remedying or mitigating any adverse effects on the environment,

The remaining Part 2 provisions require that certain matters of national importance be provided for by people exercising functions under the Act, including for present purposes, the preservation of the natural character of rivers and their margins, and the protection of significant indigenous flora and fauna. The provisions also require that people exercising functions under the Act, must have regard to certain other matters including relevant ecosystem values, maintenance and enhancement of environmental quality and the protection of habitat for trout and salmon.

Section 13 of the RMA is the section that imposes restrictions on works in the river bed and requires consent for such works unless they are expressly allowed in a National Environmental Standard (NES) or by a rule in a regional plan.

Section 17 of the RMA imposes a general duty on the NZTA (and its contractors) to avoid, remedy or mitigate any effects on the environment (including on fish passage).

In practice if consents under section 13 have been granted, or if there is a relevant NES or regional rule, the Part 2 matters and the section 17 duty are likely to have been considered and addressed in the conditions of the consents or in the conditions attached to the NES or rule. Complying with such conditions should ensure the obligations are addressed; however the obligations on the NZTA (and its contractors) remain.

Where consents are being sought the NZTA and its consultants will need to ensure the relevant obligations under Part 2 are addressed in the application and assessment of environmental effects.

The Department of Conservation's Director-General's requirements are subject to the RMA, and therefore his/her requirements could not include a requirement that would breach an RMA consent condition. However the Director-General can make additional requirements that are not covered in the RMA consent. To avoid potential conflict between the RMA and Freshwater Fisheries Regulations requirements, or unnecessary costs, early discussion with both the council and DOC is desirable before either permission is sought. The Director-General can refer to conditions in the resource consent in his/her approval, to ensure consistency, if he/she considers that those conditions meet the requirements of the regulations.

RESOURCE MANAGEMENT ACT
PART 2 – PURPOSE AND PRINCIPLES

SECTION 5 – PURPOSE

2.

- a. sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations;
- b. safeguarding the life-supporting capacity of air, water, soil, and ecosystems;
- c. avoiding, remedying, or mitigating any adverse effects of activities on the environment.

SECTION 6 – MATTERS OF NATIONAL IMPORTANCE

(a) the preservation of the natural character of the coastal environment (including the coastal marine area), wetlands, and lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use, and development: (c) the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna:

SECTION 7 – OTHER MATTERS

- d. intrinsic values of ecosystems:
- f. maintenance and enhancement of the quality of the environment:
- h. the protection of the habitat of trout and salmon:

PART 3 – DUTIES AND RESTRICTIONS UNDER THIS ACT

SECTION 13 – RESTRICTIONS ON CERTAIN USES OF BEDS OF LAKES AND RIVERS

1. No person may, in relation to the bed of any lake or river,

- a. Use, erect, reconstruct, place, alter, extend, remove, or demolish any structure or part of any structure in, on, under, or over the bed;
unless expressly allowed by a national environmental standard, a rule in a regional plan ... or a resource consent.

2. No person may do an activity described in subsection (2A) in a manner that contravenes a national environmental standard or a regional rule unless the activity

- a. is expressly allowed by a resource consent; or
- b. is an activity allowed by section 20A.

2A. The activities are

- d. to damage, destroy, disturb, or remove the habitats of animals in, on, or under the bed of a lake or river.

SECTION 17 – ADVERSE EFFECTS - DUTY TO AVOID, REMEDY, OR MITIGATE ADVERSE EFFECTS

(1) Every person has a duty to avoid, remedy, or mitigate any adverse effect on the environment arising from an activity carried on by or on behalf of that person, whether or not the activity is in accordance with a rule in a plan, a resource consent, a designation, section 10, section 10A, or section 20A.

3.3 Regional policies

In recent years more regional policies, plans and rules are reflecting the requirements of the RMA by requiring the provision of fish passage (refer to the Tasman District Council case study below). The rules in these plans are specific to the boundaries of that region; generally they are designed to meet the same requirements of the Freshwater Fisheries Regulations. The implications of these regional policies (when an existing use right does not apply) is that options to provide for fish passage may need to be retrofitted. The number of culverts on the state highway network within the region is usually significant, so it is best for each network to work alongside the regulators to develop a medium term programme of identifying appropriate barriers to then retrofit for fish passage either through a targeted retrofitting programme or as part of routine maintenance work.

Case study – Tasman District Council

Tasman District Council formed the Tasman Resource Management Plan which was prepared in accordance with the RMA, with the aim to assist the Council in carrying out its functions to achieve the purpose of the Act. Included in this Plan are the provisions surrounding fish passage which fall under Chapter 28:

28.1.2.1 – Permitted Activities (General)

This rule states the conditions which activities in, on or under a lake or river must comply with, to be classified as a permitted activity under the Plan. The condition relevant to fish passage is under (q) and states:

(q) The design, placement, and maintenance of any structure does not impede the passage of fish, except that in respect of culverts, fords, and tidal flood gates existing as at 27 February 2010, and except where permitted by condition 28.1.6.1(c)(x), this condition does not have legal effect until five years from now.

Most culverts and fords are permitted activities, although are subject to some performance standards to reduce adverse effects. Adverse effects of culverts can be accounted for through correct design methods, and new culverts must allow fish passage to be properly constructed to avoid erosion/scouring. Existing culverts that do not cater for flood flow or fish passage may require improvements. However, the rules for existing culverts/fords will not apply until five years after the operative date of the provisions in the Plan, allowing Council and other landowners to manage and plan for any works that may be necessary to meet the conditions.

FIGURE 5 Perched projected culvert presents a complete fish passage barrier to upstream migrants



4 Design practice

Culverts have often been designed with a focus on hydraulic capability, and little regard given to requirements regarding fish passage. Through increased awareness of the barriers to fish passage the NZTA seeks to achieve fish passage being designed into culvert works.

The use of best practice design can lead to more effective and efficient construction of fish passage structures. Best practice design can be used for the installation of a new culvert, and additional solutions are also possible to provide fish passage in existing culverts. When considering the installation or retrofit of a culvert, an ecologist is best employed to assess the necessity of fish passage, any design considerations, and aid with choosing the most appropriate solution.

Different culvert designs and fish passage solutions are detailed below, with the inclusion of tables to easily identify the advantages and disadvantages of each option. For a more comprehensive summary of fish passage design practices refer to the key guideline document provided by the Department of Conservation & NIWA⁰⁷.

4.1 Necessity for fish passage

An important aspect that must be considered before undertaking the installation of a new culvert or retrofit of an existing culvert is to consider the priority/necessity of doing this. The following list identifies the factors that need to be considered by an ecologist and discussed with the local authority when assessing whether fish passage is required for a culvert⁰⁸:

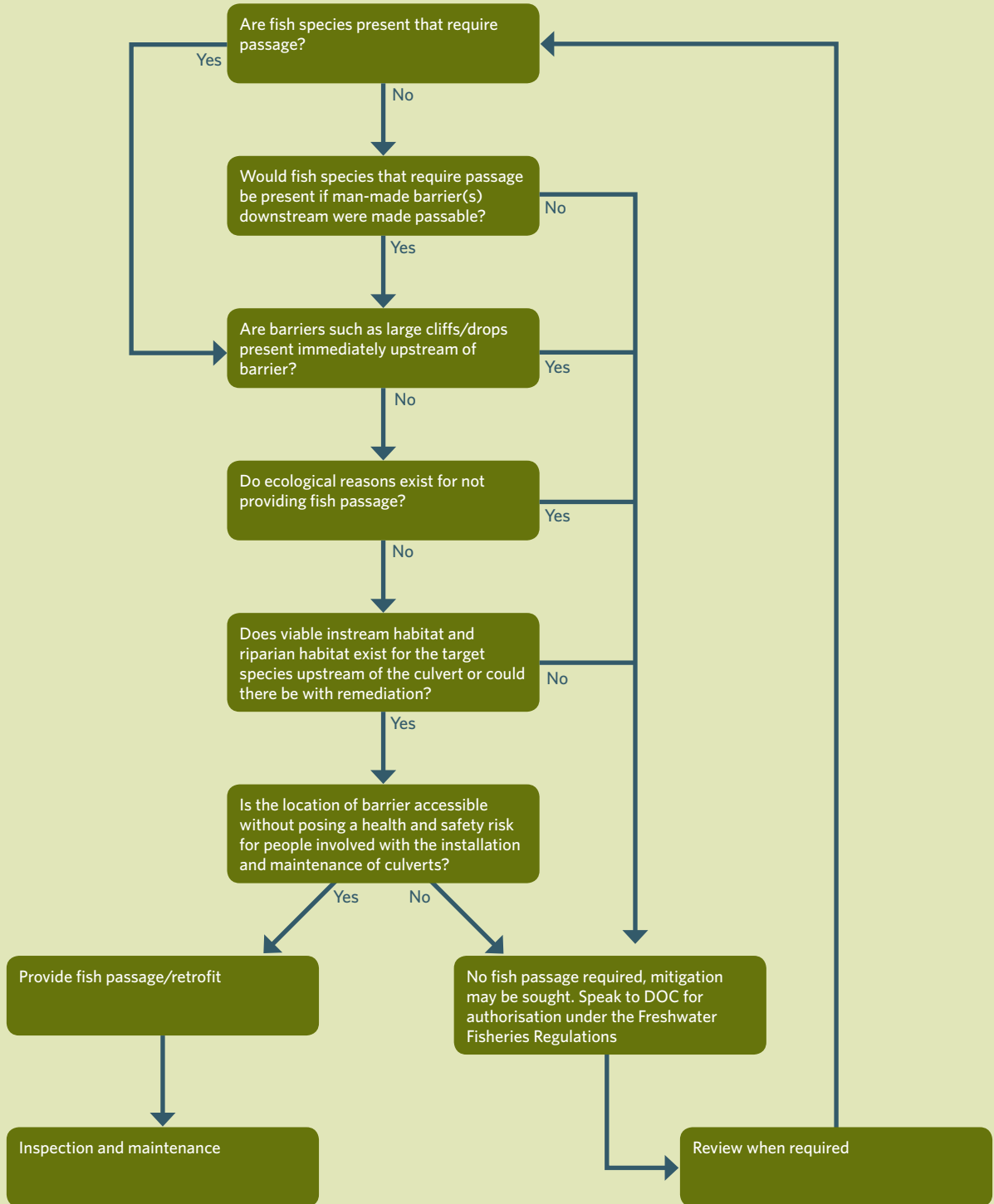
- **Presence of other migration barriers both upstream and downstream of the culvert:** It may be unnecessary to ensure passage through a culvert if there are barriers (natural or anthropogenic) just below or above which cannot be overcome by any fish species. This requires an ecological survey of the stream, just above and below the culvert location and if any of the barriers can be made passable then a fish passage structure should be fitted or the existing culvert should be retrofitted.
- **Species and distribution of fish within the catchment:** Distinguishing the distribution of fish to determine if migrants do actually pass through a reach to access higher waters. This requires fish resource information such as site-specific data on species and distribution gained through electric-fishing, trapping or spotlighting.
The current barrier could be useful for purposes such as stopping the spread of unwanted aquatic pests and the protection of key threatened resident species.
- **Size and type of habitat available upstream:** If habitat upstream is not suitable or extensive enough to support a population of a particular species, it may not be necessary to provide passage. This includes in-stream and riparian habitat for the species present. However an investigation must first be undertaken by an ecologist to determine if restoration is possible.
- **Timing of fish migrations, duration, and flow requirements of the species concerned:** The timing of migrations can be used to determine the passage flow for target species, and to schedule culvert construction to minimise disruption to fish migration.
- **Altitude and distance from the sea:** Only a few diadromous species are found at high elevations (>200m) and they are relatively good climbers, negotiating sections of river impassable to lowland species. Fish passage at these elevations may not need to be as stringent as it is at lower elevations. However, it is therefore essential to determine what species, if any, are present and at what densities.
- **Practical considerations:** When undertaking the retrofit of culverts, practical considerations must be taken into account. This includes factors such as the ease of access to the site. If the culvert is situated down a steep embankment then accessing the site may pose a health and safety risk for people involved with installation and maintenance. If the site is situated in an isolated area, to reduce the cost of contractors that could spend a high proportion of the budget in travel time, it is best to include the retrofit in a package of works.

07 Department of Conservation & NIWA (1999) *Fish passage at culverts: A review, with possible solutions for New Zealand indigenous species.*
www.doc.govt.nz

08 Auckland Council (2000) *Fish passage guidelines for the Auckland region.*
www.aucklandcouncil.govt.nz

The following flow chart is an easy to follow visual tool to assess whether or not fish passage/ retrofit is required. An ecologist must be used to help in this decision making process.

FIGURE 8 Assessment of an in-stream barrier



Adapted from Auckland Regional Council⁰⁸

Case study - Coach Stream, Porters Pass

As previously described there are certain cases where it is beneficial to prevent fish passage. The construction of a barrier to fish passage can reduce the spread of unwanted aquatic species to higher waters which have the potential to compromise the survival of rare/endangered species.

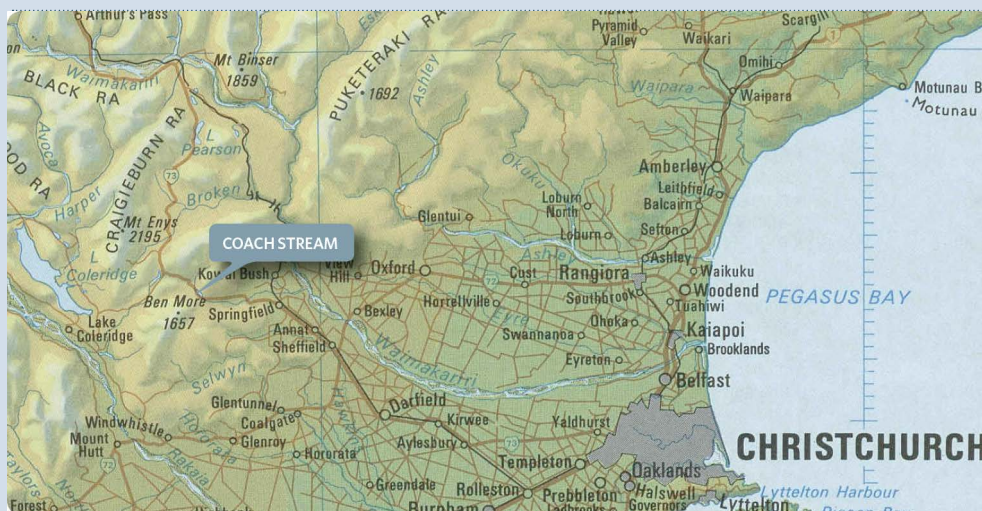
Coach Stream in Porters Pass is one such example where Environment Canterbury, the Department of Conservation and the University of Canterbury are interested in restricting trout passage through the Coach Stream culvert to protect native Canterbury galaxias (*Galaxius vulgaris*) above the culvert. Consultation with and authorisation is required from the Department of Conservation whenever fish passage is to be restricted.

Circumstances may also exist where it is necessary to create access for some fish species, while excluding undesirable species. Selective, purpose-designed barriers that prevent some species but allow access for other species can be obtained. Authorisation must also be granted by the Department of Conservation in this instance.

FIGURE 6 The culvert in Coach Stream where it is beneficial to prevent fish passage for the protection of native fish populations from trout



FIGURE 7 Location of Coach Stream



Sourced from the LINZ Data Service <http://data.linz.govt.nz/>. Crown Copyright Reserved

4.2 Design consideration for fish passage

Before considering which appropriate fish passage design or fish passage solution is required, it is important to understand the design considerations for the ecological requirements of fish species present:

Water velocity

Fish can only migrate upstream if water velocity is equal to or less than the fish's swimming ability. Therefore fish passage should ensure the water velocity is not greater than the natural stream velocity. It is also important to provide fish with different options of flow-velocities and depths to emulate the natural characteristics of streams.

At normal flow this means the water velocity should be maintained at less than 0.3m/s to allow for the passage of fish. This can be achieved by ensuring the culvert diameter is large enough to accommodate the full normal flow bed width of the waterway. This can be achieved if the culvert diameter is larger than the stream width at average flow, and a rule of thumb for determining appropriate barrel diameter is $1.2 \times \text{channel} + 0.5\text{m}^{09}$.

Positioning of the culvert

It is important to ensure the entrance of the culvert is located where fish can access it. To ensure that fish can easily find their way, fish passage should be designed to maximise the waterway area providing a wider path for the fish (this also aids in maintaining natural stream velocity).

Another significant design consideration is ensuring that the invert level of the culvert is below the natural bed level of the waterway. This allows the bottom of the culvert to be filled with streambed material which increases bed roughness and imitates the natural stream bed. The distance between the invert of the culvert pipe and the waterway bed level should be approximately 20% of the culvert diameter⁰⁹.

Flow turbulence

If a culvert has excessively turbulent flow it can make the culvert impassable and create downstream erosion. This can be overcome by including irregular channel roughness, which reduces fast flows; however it must be ensured that the turbulence is not excessive. This can be achieved through maintaining the natural stream bed, or if retrofitting through the use of baffles.

Light requirements

As some fish species can be affected by the amount of light available and may not enter a completely dark culvert, it is important to consider increasing the amount of light within a culvert. This can be achieved through reducing the culvert length, and increasing the diameter of the culvert.

Water depth and wetted margin

Low water depths and lack of a wetted margin can significantly reduce fish passage. To maintain an adequate water depth and wetted margin, the natural bed and waterway depth should be retained, however if this is not possible, arch and circular culverts are preferred over options such as box culverts. Water depth can also be increased through creating weirs or maximising roughness through the use of baffles.

It is also important that the passage has a sufficient flow at all times (except in ephemeral waterways) when required in the fish life cycle to allow access of fish.

Gradient and length of culvert

Culvert length can create an issue if it is greater than the distance fish can travel at any one time, or if it results in fish exerting high energy levels to make their way through. Monitoring of culverts by Boffa Miskell in the Alpur highway since 2007 has looked at length of the culverts and the types and numbers of fish sampled above the culverts. The monitoring of these low gradient culverts which were fitted with low flow baffles, suggests that 120m culverts were passed by all species present in this area, but culverts over 200m restricted Inanga, reduced banded kokopu but had no effect on eel and koura.

Gradient is also an issue if the culvert is placed at a steeper gradient than the natural stream bed, as it can create increased velocities making upstream migration for fish difficult. It is therefore preferable to locate the fish passage where the channel gradient is lowest, and limiting slope between 0% to 5%, however maintaining the gradient as close to the natural stream bed is preferable⁰⁷.

Timing and undertaking of works

When possible, it is best if in-stream works (such as installing and retrofitting culverts for fish passage) are avoided during the period when most fish migrate upstream (which is generally spring and early summer). However for complete details of migration timing contact an ecologist.

When undertaking works for the installation and retrofit of fish passage, protection of the stream is also important. Works should be undertaken with appropriate sediment control measures, and waterways may need to be diverted if concrete is to be used in works.

FIGURE 9 Long fin Eel (*Anguilla dieffenbachia*) - fish species with good climbing ability



Photo courtesy of Philippe Gerbeaux, DOC

4.3 Culvert types

The installation of a new culvert allows the best design practice to be incorporated from the start, with increased emphasis placed on the design of a culvert for the purpose of fish passage. The different culvert types are detailed below.

Single pipe culvert

Single pipe culverts are one of the most common types of culvert. A disadvantage of a single pipe culvert is that it cannot usually encompass the full width of the natural waterway bed. A higher water velocity can also result if culverts are not oversized, as the waterway area is reduced, increasing velocity.

FIGURE 10 An example of a single culvert



Arch culvert

Arch culverts are effectively a half culvert and are considered advantageous to fish passage due to the natural river/stream bed and gradient they leave in place. Arch culverts are generally recommended as one of the best culvert designs for this reason. However, they tend to be more suited to low water depth and levels, and are therefore not usually suitable in high water flow environments.

FIGURE 11 An arch culvert that maintains stream bed and has also a low flow channel



Box culvert

Box culverts can be used in larger streams/streams, and can be placed next to each other limiting the effect on the natural stream channel. However, box culverts are seen as undesirable due to the spreading of flows resulting in shallow depths across their wide, flat cross-sections, and because of this are not recommended. If box culverts are installed the base of the culvert should be modified by haunching the sides so that wetted margins are always present at average flows. A low flow channel can also be created to maintain a channel that fish can utilise during dry periods⁰⁹.

FIGURE 12 Double box culverts



Multi-barrel system of culverts

Generally one large culvert is better than several smaller ones, as a multi-barrel system can cause debris blockage and higher flow velocities.

However, when a multi-barrel system of culverts must be used it is advantageous to fish passage when at least one barrel is situated lower than the others, providing a passage in times of low flow. At times several smaller barrels may also fit better in low fill than a single larger one, which can avoid the need to increase the elevation of the road⁰⁷.

Multi-barrel systems must in no way restrict stream conveyance, which means the combined volume of the culvert should at least be larger than the existing channel area.

FIGURE 13 An example of a multi-barrel system of culverts



Concrete aprons

A concrete apron is a smooth, horizontal concrete slab which is placed at the outlet of a culvert during installation. The apron disperses water flow to reduce erosion at the outlet of the culvert. This method can result in shallow water depths across the apron, making it unsuitable for larger fish species. To mitigate this, during low flows aprons should have a method of channelising water. This can be achieved through the use of iron fixed on a diagonal across the apron which will push the water to one side.

Aprons can create a significant vertical drop that may cause difficulty for the passage of swimming fish species, and result in erosion of the stream bed where the concrete apron finishes. Concrete aprons can be of particular use for the passage of indigenous climbing species; however species reliant on swimming only may be hindered.

FIGURE 14 A concrete apron which has created a significant vertical drop, reducing the passage of fish

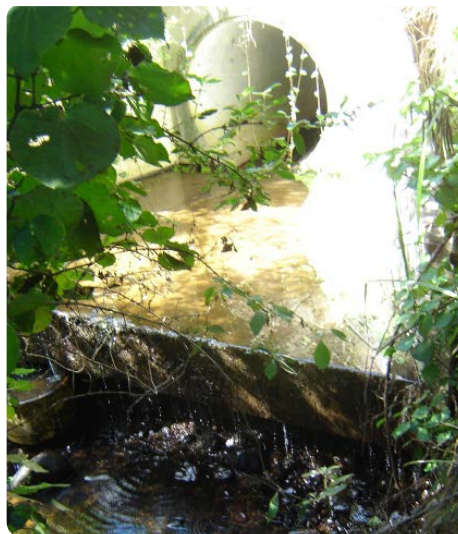


TABLE 1 Advantages and disadvantages of different culvert types

Culvert type	Advantages	Disadvantages
Single pipe culvert	<ul style="list-style-type: none"> Concentrates low flows to its centre maintaining a minimum water depth 	<ul style="list-style-type: none"> Difficult to encompass full width of natural waterway bed Can increase water velocity
Arch culvert	<ul style="list-style-type: none"> Keeps natural stream bed intact Generally a highly recommended culvert design 	<ul style="list-style-type: none"> Not usually suitable in high water flow environments
Box culvert	<ul style="list-style-type: none"> Can accommodate the full natural width of waterways More useful in larger waterways 	<ul style="list-style-type: none"> Not suitable for low flows Spreads water flows resulting in very shallow depth
Multiple-barrel system of culverts	<ul style="list-style-type: none"> One barrel situated lower than the others can provide passage during low flow Fits better in a low cross-section profile (compared to one large barrel) without having to raise road level 	<ul style="list-style-type: none"> Risk of debris blockage Can create higher water velocities
Concrete aprons	<ul style="list-style-type: none"> Reduces [initial] erosion of the stream bed at the culvert outlet Provides a useful passage for indigenous climbing species 	<ul style="list-style-type: none"> Shallow water depth over the apron makes it unsuitable for larger fish species Vertical drop of the apron can be hard to traverse for some species, and can create erosion of the stream bed at the end of the apron

4.4 Fish passage solutions

Best practice design is strongly encouraged when installing culverts and constructing fish passage. However, for culverts that have been previously installed without best practice, solutions to retrofit may be required to provide for successful fish passage.

The following information details the different options that can provide solutions for fish passage.

Baffles

Baffles are a series of precisely positioned plates/baffles throughout a culvert. Baffles can have several advantages to fish passage. They can aid fish passage by reducing strong water velocity, which makes it easier for fish to swim through the passage, particularly small indigenous species. The baffles also provide resting areas for fish.

However baffles do create disadvantages. They can increase turbulence which can make the trip difficult for small fish and can result in the accumulation of debris. If not designed correctly they can interrupt the path for small fish species and therefore they must not cross the entire floor of the culvert. Baffles are generally not suitable for culverts with a diameter smaller than 0.8m, due to blockage concerns and installation problems⁰⁸. Compared to other retrofit options, the installation and maintenance of baffles may be expensive; however current research into the use of different materials could reduce costs.

FIGURE 15 Baffles inside a culvert



Rope installation

Rope installation involves attaching rope to a point inside the culvert and securing the other end of the rope to the streambed through waratah posts and "D-rings" or similar concepts. The rope can be used to aid juvenile climbing species such as juvenile banded kokopu, koaro, eels and shortjaw kokopu, with recent research proving this. For example a study on the use of ropes and juvenile banded kokopu (a native whitebait species) has shown they can climb up a special type of polypropylene rope. The installation of ropes is seen to be advantageous for a number of reasons. Rope is relatively quick to install and is more economic than many other methods¹⁰. So far ropes have also proven to be an effective means of passage at long, high gradient culverts.

A significant downfall of rope installation is that it is only a suitable method to overcome physical barriers for climbing species. If the upstream habitat is suitable just for climbing species then rope installation can be a viable option. A detailed survey must be carried out to determine which species are present.

The NZTA has been trialling the use of ropes (figure 16) on SH35 in the Bay of Plenty (see case study) to assess the long term maintenance requirements. After one winter and numerous storm events the rope has held in place in all except one location where theft is believed to be the reason the rope is no longer in place.

FIGURE 16 Rope has been installed in this culvert to aid fish passage



Rock armouring

Rock armouring can provide an excellent, cost-effective solution for perched culverts. Rock or gravel material is placed at the outlet to build up the stream bed, bringing the water level to the height of the culvert (as shown in figure 17). Precaution must be taken with this method as built up gravel or rock has the potential to prevent fish passage, particularly during low summer flows, where flows course through rather than over the consolidated material. This means ensuring the rock is placed in such a way that flows continue over rather than through the placed material. The use of rock armouring at either end of the culvert can reduce erosion of the surrounding bank and reduce damage caused to the culvert as a result of this.

When rock armouring is used in exposed applications such as around culvert approaches, establishment of vegetation over the rock matrix and down to the water's edge should be encouraged. The establishment of vegetation is encouraged as bare rocks can create a barren zone where vegetation would normally provide cover for upstream migrants.

FIGURE 17 The effective use of rock armouring at a culvert outlet



Notched weir

The construction of a notched weir at the outlet of a culvert results in the toe of the culvert being flooded as well as increasing the water level inside the culvert. This can be of particular use for the retrofit of perched culverts, where the culvert sits above the water level. Ensuring the weir is notched means that a distinct pathway is available during all flows. Notched weirs can also act in moderating velocity by creating impoundments inside culverts, and are particularly effective as they provide a fish passage solution for both climbing and non-climbing species.

Weirs can be formed through the arrangement of large rocks. These provide a more aesthetically pleasing look due to their natural appearance, compared to a man-made concrete structure. However, rocks can be difficult to secure in place at times due to the difficulty in anchoring them to the river/stream bed. Rocks can be positioned to lean against each other increasing stability. It is important to ensure that the notched weir does not form a barrier itself.

FIGURE 18 Notched weir

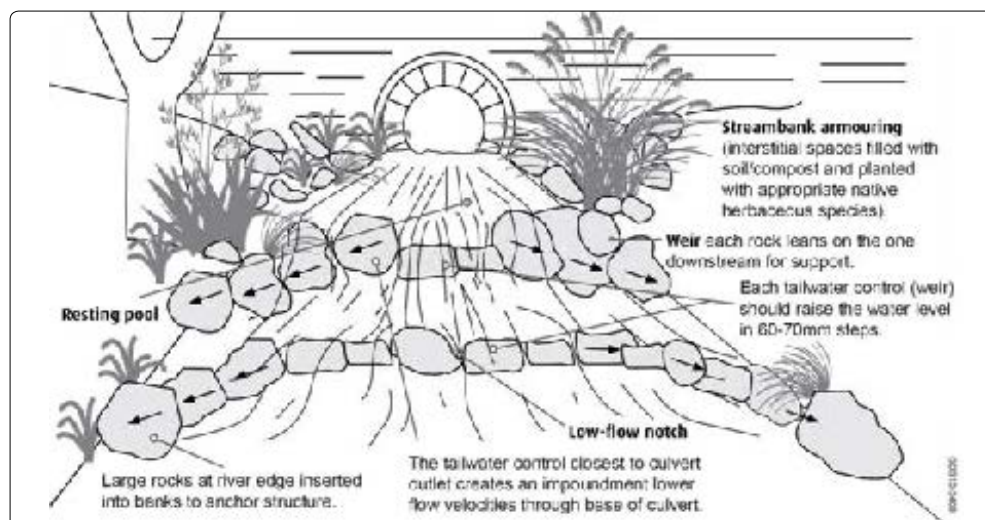


Diagram courtesy of Bay of Plenty Regional Council

Ramp fishways

Ramp fishways consist of boulder/cobble or artificial substrate ramps that cover the whole width or a section of the barrier⁰⁸. They are a suitable fish passage solution particularly for perched culverts, and can also be used below a notched weir.

Rock-ramps are one such type of ramp fishway, and can be used for barriers where the difference between water level and barrier is less than 1m. A rock-ramp is constructed of larger boulders and smaller rocks cemented into place (to avoid water seepage), which aids in back-filling the outlet to promote fish passage. This fish passage solution is also advantageous due to the natural look it provides.

Concrete ramps are another type of ramp fishway, which have a concrete ramp embedded with cobble attached at the culvert base, or at the base of a receiving pool. This ramp method can be used when a greater head height exists (between 1-1.5m). It is essential that the width of the ramp provides a wetted margin in both high and low flows, and that the ramp has rounded edges with no sharp margins that may be impassable to climbing fish.

FIGURE 19 A concrete ramp which has been embedded with cobbles to air fish passage



Case study – Bay of Plenty retrofit

A significant retrofit operation of culverts was carried out along State Highway 35 between Opotiki and Lottie Point, at the tip of East Cape. This was an initiative by the NZTA in conjunction with the Bay of Plenty Regional Council (BOPRC) and Opus. The retrofit of culverts was particularly important in this area as the majority of the State Highway 35 alignment is adjacent to the coast.

The retrofit process involved a number of steps. Initially information and data was gathered to give a starting point from which culverts could be assessed. In March 2010 site inspections were then carried out at every site to identify key characteristics. From this an assessment of the appropriate design was then carried out, firstly considering if the culvert actually did pose a barrier to fish passage and if so, then identify the best possible fish passage retrofit options.

Twenty six sites were selected for retrofit in this area. The installation of ropes was found to be the most effective retrofit method for the culverts in this area taking into consideration the ecological benefits, as well as time and funding constraints.

This initiative from the NZTA has resulted in retrofits at these sites that should allow for successful fish passage. Continued research into the operation of these culverts for fish passage will allow results to be gathered about just how successful the use of rope as a retrofit method proves to be¹⁰.

TABLE 2 Advantages and disadvantages of different fish passage solutions

Culvert type	Advantages	Disadvantages
Baffles	<ul style="list-style-type: none"> Can aid in reducing strong water velocity Provides resting areas for fish 	<ul style="list-style-type: none"> Roughness can reduce upstream movement of small fish Can result in the accumulation of debris Can interrupt path for small fish species (must ensure baffles do not cross entire floor of culvert) Can be expensive Physical access to pipes is required to fix structures, with many culverts too long and narrow for use of baffles
Rope installation	<ul style="list-style-type: none"> Quick to install More economical method than most Relatively durable Less consenting issues than other methods Useful passage for juvenile climbing species* 	<ul style="list-style-type: none"> Prone to theft (good quality rope, ease of take) Not suitable for all swimming species Maintaining passage for all life-stages/lifecycle requirements more problematic
Rock armouring	<ul style="list-style-type: none"> Relatively low costs Good solution for perched culverts Aids in bank protection Protects integrity of culvert 	<ul style="list-style-type: none"> Incorrectly placed rocks can create a dam which will act as a barrier to fish passage
Notched Weir	<ul style="list-style-type: none"> Very useful for retrofit of existing perched culverts, as will increase water level/depth Effective for both climbing and non-climbing species Aesthetically pleasing natural appearance 	<ul style="list-style-type: none"> Poorly designed weirs can restrict passage (hence it is vital that the weir is notched) and even still can at times still create barrier for fish
Ramp fishways	<ul style="list-style-type: none"> Rock ramps provide a natural looking solution Ramps are a good solution for remedying perched culverts 	<ul style="list-style-type: none"> Correct construction of ramp is critical. Must ensure the width allows for wetted margins and there are no sharp edges

Glossary

DOC	Department of Conservation
FFR	Freshwater Fisheries Regulations 1983
NZTA	NZ Transport Agency
RMA	Resource Management Act 1991
SH	State Highway

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FIGURE 20 Double culvert with the installation of rope



Further information

NZ Transport Agency Environmental Management Website

<http://www.nzta.govt.nz/network/operating/sustainably/environment.html>

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