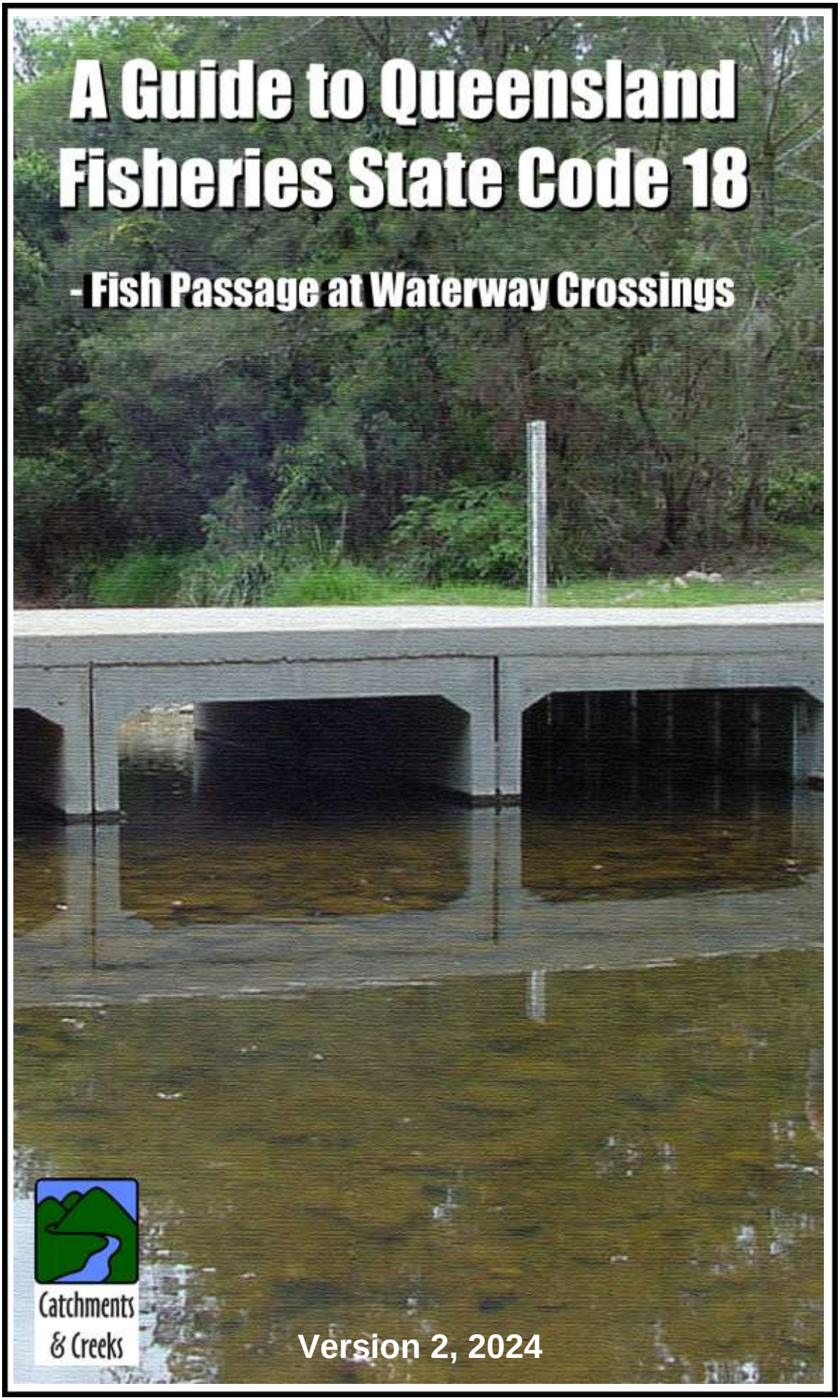
A Guide to Queensland Fisheries State Code 18
- Fish Passage at Waterway Crossings
Catchments & Creeks
Version 2, 2024

A Guide to Queensland Fisheries State Code 18

Fish Passage at Waterway Crossings

Version 2, September 2024

Prepared and illustrated by: Grant Witheridge, Catchments and Creeks

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Key words: fish passage, waterway crossings, culvert design.

Copies of this document may be downloaded from: www.catchmentsandcreeks.com.au

Cover image: Replacement Ewingar Creek culvert, Ewingar (2001).

Disclaimer

Significant effort has been taken to ensure that this document is representative of the current 2022 version of State Code 18. However, the author cannot and does not claim that the document is without error, that the author's interpretation of these codes is consistent with that of Fisheries Queensland, or that Fisheries Queensland will not alter this code from time to time rendering parts of this document obsolete.

The intent of this document is to convey the requirements of Queensland's State Code 18 for fish passage at waterway crossings. It is **not** the author's intention to convey his own design recommendations. The author cannot provide any guarantee as to the reliability or suitability of the design requirements provided within the document, or in fact by Fisheries Queensland.

The author, however, has provided personal comments (Author's Notes) on issues and complications he believes relate to various Performance Outcomes and Acceptable Outcomes. The author's alternative design recommendations for fish-friendly culverts are presented in a separate Catchments & Creeks field guide.

The author shall have no liability or responsibility to the user or any other person or entity with respect to any liability, loss, or damage caused, or alleged to be caused, directly or indirectly, by the adoption and use of any part of the document, including, but not limited to, any interruption of service, loss of business or anticipatory profits, or consequential damages resulting from the use of this document.

Specifically, the author cannot guarantee that the design procedures presented here will:

- achieve consensus with Fisheries Queensland expectations for a given site
- achieve compliance with any statutory obligations
- achieve desirable fish passage at a specific waterway crossing.

Principal reference documents and related C&C field guides

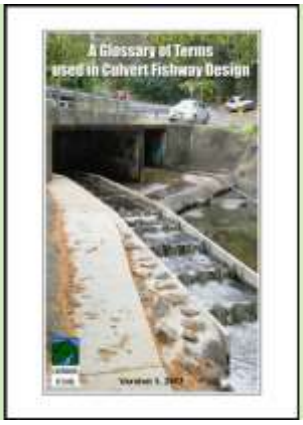
Raising Waterway Barrier Works, 2022

State Code 18

State Development Assessment Provisions (SDAP) guideline – State code 18: Constructing or raising waterway barrier works in fish habitats.

The Department of Agriculture and Fisheries.

State of Queensland, 2022.



Terms used in Culvert Fishway Design

A Glossary of Terms used in Culvert Fishway Design

Catchments & Creeks Pty Ltd, 2017, Brisbane Queensland.

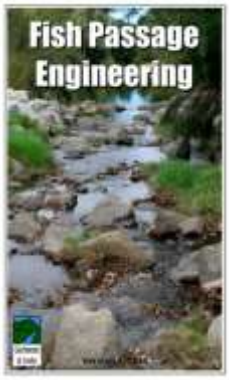
This field guide provides photos and definitions of terms commonly used by engineers and fish biologists in the fish passage industry with specific reference to culvert design.

Fish Passage Culvert Design

Fish Passage Culvert Design

Still in production as of September 2024.

Catchments & Creeks, due in 2024, Bargara Queensland.



Fish Passage Engineering

Fish Passage Engineering

Still in production as of September 2024.

Catchments & Creeks, due in 2024, Bargara Queensland.

Contents

Purpose of field guide

This field guide has been prepared specifically to:

- provide a visual aid to implementation of Queensland Fisheries' State Code 18
- provide comments on the 'Performance Outcomes' and 'Acceptable Outcomes' presented in Queensland Fisheries' State Code 18.

This field guide is **not** intended to be a detailed engineering guide, but as a 'supplement' to State Code 18.

The photos presented within this document do not necessarily represent current best practice, but are intended to represent just the current topic of discussion. It would be near impossible to obtain a 'perfect' example for each situation. No image (photo) presented in this document should be considered best practice without full knowledge of the site conditions.

About the author

Grant Witheridge is a civil engineer with both Bachelor and Masters degrees from the University of NSW (UNSW). He has over 40 years experience in the fields of hydraulics, creek engineering and erosion & sediment control, during which time he has worked for a variety of federal, state, local governments and private organisations.

Grant is the principal author of Brisbane City Council's: Natural Channel Design and Creek Erosion guidelines, and guidelines on the Fish Passage Requirements for Waterway Crossings.

Introduction

The first edition of this Field Guide was based on Queensland's Self-Assessable Codes for Fish Passage at Waterways Crossings, which existed in 2014.

This edition of the Field Guide is based on Queensland's State Code 18 as introduced in 2022. Table 1 provides a summary of the changes that have occurred between 2014 and 2022.

Table 1 – Changes made to codes since Version 1 (2014) of this Field Guide

Document: Accepted development requirements for operational work that is constructing or raising waterway barrier works		
Version	**Date**	**Comment**
V1	3 July 2017	Transition (including some minor changes) from previous self-assessable codes (WWBW01, WWBW02) into accepted development requirements to align with the release of the Planning Act 2016.
V1.1	14 Sept 2017	Minor change to temporarily revert to previous provisions for retro-fitting of inverts and re-sleeving of culverts under the self-assessable code until 1 July 2018 (refer to work types 4.1 and 4.2).
V1.2	15 Dec 2017	Update of departmental names due to Machinery of Government changes. Removal of link for on-line notification. Link is expected to go live in 2018 and will be included in subsequent version.
V1.3	1 Oct 2018	Revision of work types 4.1 and 4.2 and inclusion of on-line notification.
Document: State code 18: Constructing or raising waterway barrier works in fish habitats		
V1	March 2022	Release of State Development Assessment Provisions guideline

The design of fish-friendly waterway crossings requires expertise in at least three key topics, fish biology, waterway behaviour (creek engineering and river morphology), and engineering design, including: hydrology, hydraulic engineering, structural engineering, and construction.

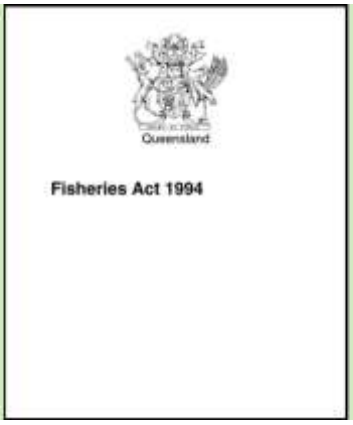
I know of nobody that has expertise in all three categories; consequently, team work is required.

Introduction

Previous version of the Field Guide

Superseded Field Guide (2014)

- In 2014 I released a *Field Guide to explain Queensland's Self-Assessable Codes for Fish Passage at Waterways Crossings*.
- However, time has aged this document, and it now appears that Queensland Fisheries has moved away from providing 'Acceptable Solutions', and has now moved towards the use of a 'Code'.



Fisheries Act 1994

Legislation

- In Queensland, the potential impacts of development on the movement of fish are managed through a fisheries development framework.
- This framework is underpinned by the:
  - *Fisheries Act 1994* working in concert with the
  - *Planning Act 2016* and
  - *Environmental Offsets Act 2014.*

Raising Waterway Barrier Works, 2022

State Code 18

State Development Assessment Provisions (SDAP) guideline – State Code 18: Constructing or raising waterway barrier works in fish habitats.

The Department of Agriculture and Fisheries.

State of Queensland, 2022.

A close inspection by the author

Author's feedback

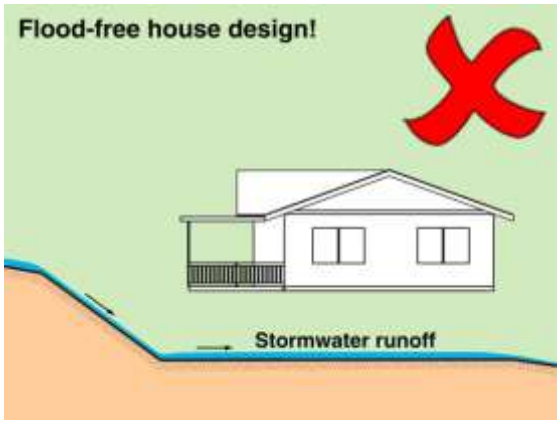
- The purpose of the C&C field guides is to pass on information to engineers that are new to the topic of the field guide.
- Some of these field guides provide a guide to the application of a specific government policy, code or guideline.
- However, in some cases I feel it necessary to provide feedback (Author's Notes) on the government policy, code or guideline, which is the case here for State Code 18.

The use of Development Codes (the author's opinion)

Codes

Introduction

- Development Codes differ from traditional government guidelines and manuals in the following ways:
  - Codes don't recommend or stipulate a particular design solution, but instead specify 'Performance Outcomes' (PO) that the design must achieve.
  - Codes can suggest 'Acceptable Outcomes' (AO) which still allow the designer a bit of freedom as to how they achieve the given outcome.



Example of an impossible outcome

Author's Note 1

- All government legislation, codes and policies must be able to satisfy the 'fair and reasonable' test.
- A code cannot specify an impossible outcome, such as: *the development does not result in adverse impacts*.
- It is not possible to build a culvert without having some impact on fish passage.
- Fish passage issues cannot be considered in isolation from other factors, and must fit into the overall aim of ecologically sustainable development.

Caution!

Author's Note 2

- Performance Outcomes and Acceptable Outcomes cannot require a developer (which includes government bodies) to achieve an outcome that:
  - is not measurable
  - is not able to be proven, or demonstrated
  - is beyond the control of the developer
  - places conditions on the developer that would apply beyond the completion of the development.

Waterway rehabilitation

Author's Note 3

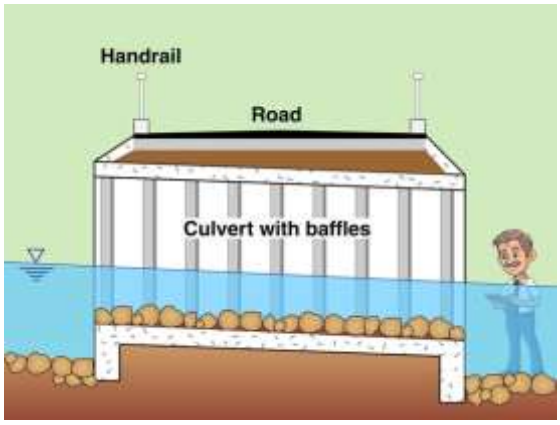
- Development codes only apply up until the specified development is completed.
- If a government department wishes to enforce an outcome beyond the completion of the development, then such an outcome must be supported (enforceable) by appropriate legislation.
- For example, in the past, developers were required to pipe creeks of a certain size; however, this does not mean that we cannot, at a later stage, go back and reverse this development condition.

The use of Development Codes (the author's opinion)

Inner-harbour fish school

Author's Note 4

- In producing a Code, government bodies cannot specify any outcome that they may wish for; instead, the outcomes must be related to a specific government objective.
- In the case of fish passage, the outcomes are likely to relate to:
  - protection of native species
  - protection of threatened species
  - protection of fish stocks
  - protection of aquatic habitats.



Inspection of a culvert without aprons

Author's Note 5

- Performance Outcomes cannot specify outcomes that are inconsistent, or in conflict, with other government legislation.
- For example, a Fisheries' code cannot specify an outcome that would:
  - unnecessarily harm terrestrial passage (environmental protection)
  - harm waterway values (waterway or natural resources protection)
  - harm human safety (work place health and safety).

No terrestrial passage features

Flood debris caught on roughness units

Author's Note 6

- Fish passage outcomes at waterway crossings must be integrated with several competing factors, including:
  - the needs of the aquatic wildlife, which may include species other than fish
  - the needs of terrestrial wildlife if these needs conflict with the fish passage needs (e.g. no provision for terrestrial passage under urban or heavy-traffic roads)
  - the needs of the waterway, with specific reference to the natural movement of bed sediments
  - the needs of the community, which includes the management of floodwaters
  - the financial constraints of the asset owner with respect to construction costs, which includes waterway crossings constructed in private property
  - the financial constraints of the asset manager with respect to ongoing maintenance costs and post-flood repairs.

Author's feedback on State Code 18

Trying to hold-back a moving target

Stretching your abilities to the limit

Frustration with the system

Unsatisfactory outcome

Primary objective of development codes

- Governments have the option of presenting development regulations in many different forms, including policies, guidelines, manuals and codes.
- A primary objective of a codified system is to achieve greater certainty—developers want certainty that if they invested in a project, and if they complied with the rules, their development proposal will be approved.
- In the case of a waterway crossing, the term 'developer' can include:
  - state government bodies, such as Main Roads and Queensland Rail
  - local governments, from Brisbane City Council to the smallest Queensland council
  - private land developers
  - private land owners (e.g. farmers).
- In the author's opinion, if this version of State Code 18 were to be read literally, then it would be impossible for any waterway crossing to comply with all of the Code's requirements.

Development approvals under State Code 18

- State Code 18 does not provide clear performance outcomes that can be assessed on a consistent basis.
- As a 'code', the document fails in its primary objective of providing greater certainty to developers.
- In almost all cases the code relies on the personal judgement of the reviewing fisheries officer, thus creating inconsistent and uncertain approval outcomes.

Adverse impacts on the 'designer'

- Engineers, and engineering businesses, are generally required to submit a competitive bid (fixed-fee) in order to win a design job from a potential client.
- At the stage of creating this 'bid', the engineer (designer) will have no idea if Fisheries will want all aspects of the Code addressed (at a cost of $20,000), or if Fisheries will (in the future) be willing to accept that certain data collection work, and CFD modelling, will not be required on this particular project, thus reducing the design fee to $5,000.

Waterway crossings

Wivenhoe Dam

Waterway crossings

- All of these structures are examples of waterway crossings.
- Based on this Code (as I read it), each of these structures would require the same amount of investigation, numerical modelling, and reporting.
- Obviously, fisheries officers would show appropriate discretion in the amount of information that they would expect for each structure, but it is that discretion that results in uncertainty for designers.

Weir/causeway crossings (Normanton)

Culvert crossings (Townsville)

Single lane rural property crossings

Twin pipe culvert

Sydney Harbour Bridge (NSW)

- If the Harbour Bridge were to be built in Queensland, State Code 18 would require the hydraulic modelling of a flood event that overtops (drowns-out) the structure.
- I can understand the need for a biomass survey when designing a dam or weir, but how can such time-consuming and costly survey work be justified when designing a small culvert on the driveway of a rural property that crosses a small creek.
- Only when a design is completed will the designer know the degree of investigation that will be required under this Code.

An overview of my concerns about State Code 18 (2022)

When writing any report, document, or book, one of the most important rules is to write for the benefit of the reader, and not for the benefit of the writer. When it comes to drafting technical publications, many first-time writers focus on writing the document they would want to read, rather than the document that best suites the needs of the reader.

Fortunately, State Code 18 does not suffer from most of these drafting problems. The code is easy to read, easy to follow, and it is fairly easy to understand what Queensland Fisheries are looking for within a development application. However, there is one issue that concerns me greatly. The code is not really giving designers (i.e. the reader) the information that they need. Instead, the code focus on outlining the information that designers (most likely engineers) need to supply to Queensland Fisheries (i.e. the writer).

In fact, there appears to be very little effort placed in assisting the reader to design a fish-friendly waterway crossing. That said, this problem is not a creation of Queensland Fisheries, but a creation of the code-based regulation system. Development codes have their good side, and their bad side. What is needed here is a supplementary guide, or better still, a living data bank that can slowly build a 'library' of Acceptable Outcomes that are known to satisfy the aims of Queensland Fisheries.

It is a complete waste of community money to have a designer develop, analyse, model, report, and justify a given culvert design, only to have another designer repeat the whole process for what may be exactly the same culvert design, in the same type of fish habitat.

So, here is my first question: **Is it the responsibility of Queensland Fisheries to assist designers in developing fish-friendly waterway crossings?**

Well, Queensland Fisheries is responsible for regulating the *Fisheries Act 1994*, and the stated purpose of the Act (Part 1, Division 2, Objectives) 'is to provide for the use, conservation and enhancement of the community's fisheries resources and fish habitats in a way that seeks to:

(a) apply and balance the principles of ecologically sustainable development; and

(b) promote ecologically sustainable development.'

Of course, it is not my place to tell Fisheries what their responsibilities are, the Act gives us a good indication of what their responsibilities are. The *Fisheries Act 1994* focuses on promoting the principles of ecologically sustainable development. Which means the Queensland Fisheries should consider any reasonable means of assisting in the development and promotion of fish-friendly waterway structures.

But wait, over the past 20 years of working with both Queensland and NSW Fisheries, I have been told more than once that it is not Fisheries that wants the culvert built. They say that is the engineer that wants to build the culvert, so it is up to the engineer, and the engineering profession, to determine how fish-friendly culverts can be designed.

So, here is my second question: **Is it the engineer (a person like myself) that wants the culvert built, or is it the developer, or is it someone else?**

Well, I can assure you that it is not the engineer the wants the culvert. And the developer would be more than happy not to pay for the design, approval, and construction of a culvert. So who is it that wants the culvert built?

On private property, it is the owner of the property. On a new subdivision it is the Queensland government that insists that future residents have access to the land that they have purchased and plan to build their home on. On road reserves it is the public, through various levels of government, that wants the culvert built.

So in the end, it is the users of the culvert that want the culvert built. Users which include engineers, biologists and government departments. In other words, in the 'waterway industry' we don't have the 'good guys' and the 'bad guys', just a group of professionals trying to achieve the best outcome for the community, the waterways, and the wildlife.

The government push towards the use of Development Codes is based in the idea that such codes provide greater certainty to developers, thus allowing them to have increased confidence that if they follow the 'rules', their development proposal will be approved. (This is not the author's philosophy, but instead the current aim of the Queensland Government.)

We now reach the issue that concerns me greatly about this Code. I don't see how this Code provides any certainty to developers (which includes local governments, Queensland's Main Roads and Queensland Rail), that would suggest that if they follow the rules, their development proposal will likely be approved.

The Code does not focus on providing Acceptable Outcomes. Instead, the Code focuses on outlining what information needs to be supplied to Queensland Fisheries. In other words, the Code focuses on what the 'writer' wants, not on what best suits the needs of the reader.

In reality, the current Code simply states that:

Developers shall demonstrate that their proposal prevents adverse impacts on:

- *fisheries resources and fish habitats*
- *the waterway, and*
- *the public's access to tidal land and waterways.*

This leads us to my third question: **How best can Queensland Fisheries work with the waterway industry to promote ecologically sustainable development with respect to our fisheries resources and fish habitats?**

It would appear to me, that through this Code, Queensland Fisheries are not trying to be a part of a government-wide approach to promoting the principles of ecologically sustainable development, but instead is acting as an isolated arm of the government focused on the single task of protecting the state's fisheries resources. While I admit that is a highly-valued task, it is a task that should not be conducted in isolation from the rest of the government.

The first issue is that this Code does not provide any certainty as to how much investigation, modelling, or reporting will be required on any particular development proposal. If the Code were to be taken literally (as in a legal context), then:

- the cost of completing a full report would be in excess of $20,000 (as of 2024)
- the cost of completing a full report would be the same for a small private farm driveway culvert, as it would be for constructing a major dam (waterway barrier)
- many private land owners, and small councils, would simply construct waterway crossings without seeking Fisheries approval.

Obviously, there is a 'common sense' approach to the use of the Code, but designers will have no idea if their common sense approach will match that of Queensland Fisheries. This means that when a consultancy firm is bidding on a job to design a waterway crossing, they will have no certainty as to whether the approval process will cost them $5,000 or $20,000.

The second issue is that the Code appears to abandon the previous colour-coded waterway system of purple, grey, red, amber and green fish habitats. Instead, the Code appears to require the same level of information for any type of fish habitat. This most certainly suggests that the Code has moved away from a balanced approach to ecologically sustainable development, and instead moved towards a strict approach to preventing adverse impacts on fisheries resources.

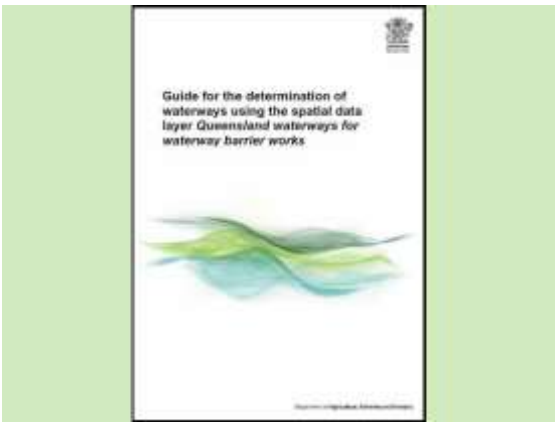
The third issue is that the Code appears to have adopted a definition of a 'waterway' that:

- includes all watercourses
- includes all parts of a watercourse up to the headwaters
- includes the full width of the left and right floodplains.

The fourth issue is that there does not appear to be any system in place to help develop a set of Acceptable Outcomes based on past studies and approvals. The Code appears to suggest that each designer has to reinvent the 'wheel' over and over again. The Code seems to suggest that it is solely up to the engineering profession to develop appropriate fish-friendly outcomes.

Performance Outcomes
PO1 to PO4

Section 2.0 – All crossings



Spatial data users guide, 2013

Spatial data layer

- The spatial data layer was developed to indicate where development within waterways may proceed in accordance with accepted development requirements.
- Available on the Queensland Globe and Development Assessment Mapping System (DAMS) mapping applications.
- The author is unsure of how these maps are integrated into State Code 18.

Mary River cod

Section 2.2 - Threatened species

- Protected species, such as:
  - Freshwater sawfish, Mary River cod, Queensland lungfish and Honey blue-eye (EPBC Act 1999)
  - Mount Elliot crayfish, Redfin blue eye, Oxleyan pygmy perch and Emerald cling goby (Nature Conservation Act)
  - Australian lungfish, Bloomfield River cod, river blackfish, freshwater gobies and Mary River cod (Fisheries Act, 94)
  - Queensland lungfish & Redfin blue eye.

Potential fish barrier at culvert exit

Section 2.4 - Waterway barriers

- The meaning of waterway barrier works is provided in the schedule dictionary of the Fisheries Act 1994, which includes:
  - dams and weirs
  - bridge and culvert crossings
  - causeways and ford crossings
  - litter booms
  - constructed riffles
  - waterway rehabilitation works
  - instream maintenance work (culverts).

Qld. Fisheries (General) Regulation, 2019

Section 3.1.1 - Accepted development requirements

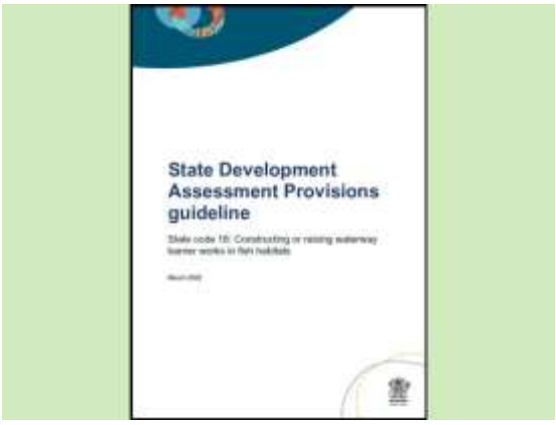
- The accepted development requirements for operational work that is constructing or raising waterway barrier works are prescribed under section 135 of the Fisheries (General) Regulation 2019.
- Constructing or raising waterway barrier works that is not accepted development is assessable development and requires development approval.

Sections 3.0 to 5.0 (PO1) – All crossings

State Development Assessment Provisions

Section 3.1.2 - Assessable development

- A development approval is required for assessable development, unless the work is accepted development.
- Assessable development that is, constructing or raising waterway barrier works, requires a development approval and is assessed against the benchmarks in *State code 18: Constructing or raising waterway barrier works in fish habitats* of the State Development Assessment Provisions (SDAP) prescribed under the Planning Regulation 2017.



Raising Waterway Barrier Works, 2022

Section 5 - SDAP State Code 18

- State Code 18 of the State Development Assessment Provisions (SDAP) sets out the assessment benchmarks that a development application for constructing or raising waterway barrier works is to be assessed against.
- Applicants must demonstrate that they have achieved the performance outcomes.
- Author's Note: this means a performance outcome must only seek outcomes that can be measured and/or demonstrated.

Box culvert with baffles (Qld)

Performance Outcome PO1

Waterway barrier works do not result in adverse impacts on waterways.

- Demonstrate no adverse impacts to waterways and fish habitats.
- Development footprint minimised.
- Minimise impacts to waterway habitats.
- Minimise change to local hydrology and hydraulics (note: the term 'hydrology' includes all aspects of hydraulics).

Unsure

Author's Note: 1.1

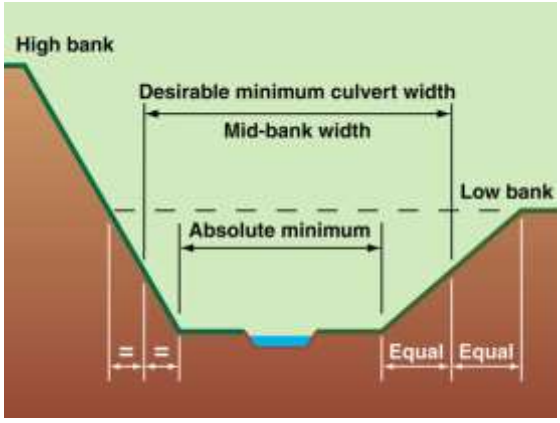
- It is not possible to:
  - design a waterway crossing that does not result in adverse impacts on the waterway and fish habitats
  - demonstrate that the proposed waterway crossing will not result in adverse impacts on the waterway and fish habitats.
- It is my understanding that such an impossible performance outcome would be considered unlawful.

Performance Outcome PO2 – All crossings

Small rural bridge crossings

De-silting operation (Qld)

Privately-owned rail bridge (Qld)



The author's suggested culvert width

Performance Outcome PO2

Development is designed, constructed and maintained to avoid and minimise impacts on matters of state environmental significance.

- Demonstrate alternative structure placement and/or construction methods and/or timing are not practical.
- Construct a bridge rather than culverts.
- Simulate the hydrological and physical characteristics of the natural waterway.
- Culvert cells span 100% of the main channel width of a waterway.

Author's Note: 2.1

- I do not believe that developers should have to, or are even able to, demonstrate that a development proposal is:
  - 'maintained to avoid and minimise impacts on matters of state environmental significance'.
- Such an outcome needs to be linked to possibly the:
  - *Fisheries Act 1994*, or the
  - *Environmental Protection Act 1994.*

Author's Note: 2.2

- It is noted that the 'developer', which is the initial owner of a new culvert, may not continue to own, or maintain the culvert.
- In many cases the developer will not be able to demonstrate what maintenance future owners will undertake.
- Examples:
  - land developers who hand-over the asset to the council
  - private road builders own and operate toll roads before hand-over to the state.

Author's Note: 2.3

- Unsure if this Outcome conflicts with Acceptable Outcome AO5.14:
  - 'The combined width of the culvert cell apertures are equal to 100 percent of the main channel width.'
- Performance Outcome AO2 appears to focus on the overall width of the culvert's cells, while Acceptable Outcome AO5.14 appears to focus on the total clear opening (width) of the culvert.

Performance Outcomes PO3 & PO4 – All crossings

Fishway bypass around a fish barrier

Performance Outcome PO3

Where development impacts on matters of state environmental significance, development mitigates impacts and provides an offset for any acceptable significant residual impact on matters of state environmental significance.

- Incorporation of fishways.
- Use of fish-friendly structures.
- Retention and/or restoration of natural vegetation.
- Off-stream access for maintenance, and fencing to control stock access.

Unusual river feature!

Performance Outcome PO4

Aspects of development are only permitted within a waterway where there is a functional requirement and the development cannot be feasibly located elsewhere.

Ancillary elements are to be located outside of the waterway.

No acceptable outcome is prescribed.

GPT located at limit of fish habitat (Qld)

Example development proposals that 'are not acceptable within waterways because they can be located elsewhere and still provide their intended function':

- 'storm water treatment systems such as detention basins, water sensitive urban design structures, gross pollutant traps or water treatment facilities proposed in a waterway, when they should be treating the water quality outside of the waterway to protect the aquatic ecosystem values'

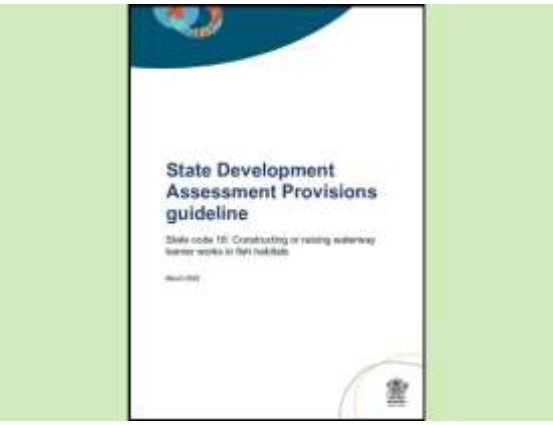
Floating litter boom (NSW)

Author's Note: 4.1

- Given that the Code's definition of a waterway includes all watercourses (which extend to the headwaters of the catchment) such an exclusion of stormwater systems is inappropriate.
- In addition, floating litter and oil booms (a form of GPT) in waterways should continue to be used.
- I assume this clause means that Queensland Fisheries has now banned the construction of all on-stream lakes.

Performance Outcome PO5

Performance Outcome PO5 – All crossings



Raising Waterway Barrier Works, 2022

State Code 18

Performance Outcome PO5 is a complex objective with several Acceptable Outcomes (AO5.1 to AO5.22) presented.

Performance Outcome PO5 also has an extensive list of information that is to be submitted with any development application.

The author's comments on this information request are provided below each listed Acceptable Outcome.

Box culvert with experimental baffles

Performance Outcome PO5

For the life of the barrier, adequate fish passage must be provided and maintained at all waterway barrier works through:

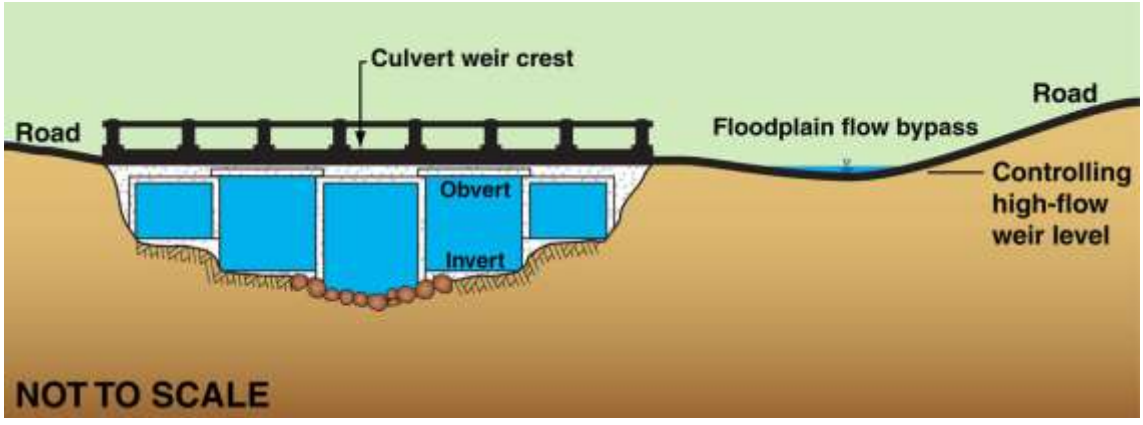
1. fishway(s) that adequately provide for the movement of fish; or
2. the movement of fish is adequately provided for in another way.

Drowned-out culvert structure (Qld)

Acceptable Outcome: AO5.1

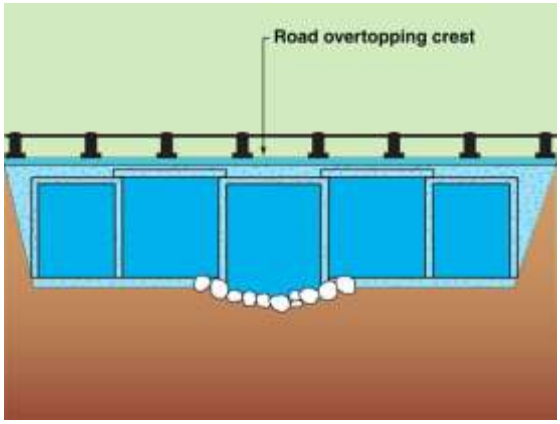
FOR ALL CROSSINGS

Hydraulic conditions (depth, velocities and turbulence) from the downstream to the upstream limit of the structure allow for fish passage of all fish attempting to move through the crossing at all flows up to the drownout of the structure.



Road culvert with adjacent floodplain lower than the culvert crest elevation

Acceptable Outcome AO5.1 – All crossings



Floodwater spills across the roadway

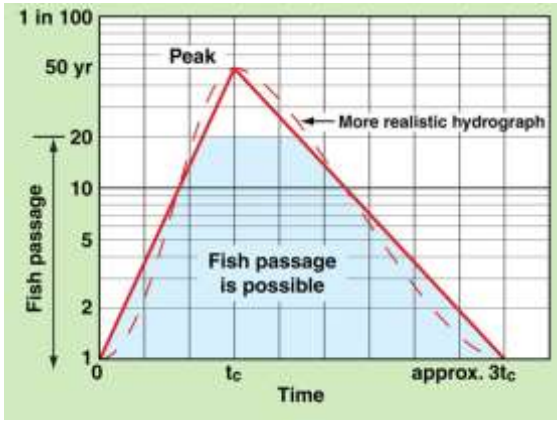
Author's Note: 5.1.1

- Readers should refer to Acceptable Outcomes AO5.22 for culvert crossings designed with a flood immunity ARI greater than 50 years.
- The drowning out of a structure occurs when the actual crossing is overtopped.
- If the approach roads are lower than the crest of the crossing (i.e. floodwaters first pass around the crossing rather than over the crossing), then this should be taken as the point of structure overtopping.

A very high bridge (Qld)

Author's Note: 5.1.2

- Given that this Outcome applies to 'all crossings', it would apply to those designed to be flood free for the 1% (1 in 100) flood.
- If we include the usual freeboard, this would mean the structure would only be drowned-out during events greater than 1 in 200 year flood.
- If the future of fish stocks relies on fish migration for a few hours during a 1 in 200 year event, then we are in real trouble!



Simplified flood hydrograph

Author's Note: 5.1.3

- If a crossing is designed to be fish friendly for all events up to say the 1 in 20 year event, then this does not mean fish passage will not occur during larger events; instead:
  - during a 1 in 50 year event, fish passage should be possible for approximately **90%** of flood duration.
- Table 2 provides an estimate of the duration of likely fish passage during a flood event (presented as a percentage of the flood duration).

Table 2 – Estimation of the percentage of the total flood duration in which fish passage should be possible

Fish passage design storm for the crossing	Actual flood event (1 in X years)					
	1 in 5 yr	1 in 10 yr	1 in 20 yr	1 in 50 yr	1 in 100 yr	1 in 200 yr
1 in 5 years	100	95	90	85	80	75
1 in 10 years	100	100	95	85	85	80
1 in 20 years	100	100	100	90%	90	85
1 in 50 years	100	100	100	100	95	90
1 in 100 years	100	100	100	100	100	95

Acceptable Outcomes AO5.2 & AO5.3 – All crossings

Repair work to flood-damaged bridge (Qld)

Acceptable Outcome: AO5.2

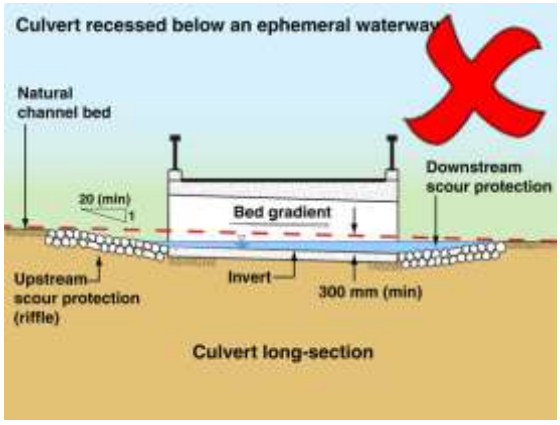
For the life of the crossing, the relative levels of:

1. a bed level crossing or a culvert invert
2. bed erosion protection
3. apron scour protection; and
4. the waterway bed, are maintained to avoid drops in elevation at their joins.

Predicting the future

Author's Note: 5.2

- This Outcome cannot be demonstrated at the development approval phase because it requires the developer to predict future works and activities.
- This Outcome is best achieved through legislation (Fisheries Act) or 'conditions' attached to the development approval.



Fishways steeper than the bed gradient!

Acceptable Outcome: AO5.3

The crossing and associated erosion protection structures are installed at no steeper gradient than the waterway bed gradient.

Riffle upstream of a recessed culvert

Author's Note: 5.3

- All recessed culverts (i.e. culverts that function as a 'pool' during low flows) would literally fail this outcome!
- This Outcome would:
  - prevent erosion protection measures from being designed as a fishway
  - prevent the use of an upstream riffle to allow the culvert to be recessed into the bed!
- This Outcome needs to be reworded.

Acceptable Outcomes AO5.4 & AO5.5 – All crossings

Artificial culvert-bed roughness (NSW)

Acceptable Outcome: AO5.4

The crossing and associated erosion protection structures are roughened throughout to approximately simulate natural bed conditions.

Smooth bed of a sand-based creek (Qld)

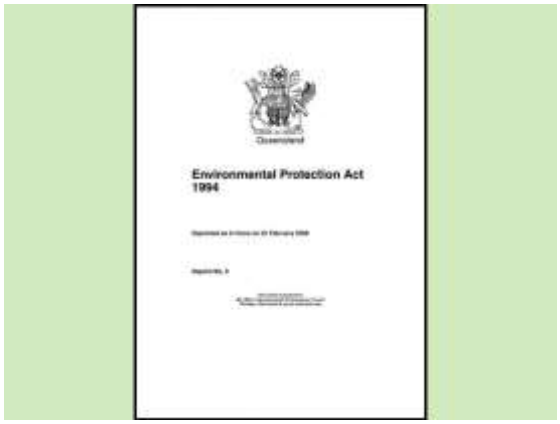
Author's Note: 5.4

- The 'roughness' of waterway beds varies from smooth clay-based beds to rough gravel-based beds.
- 'Roughness' can exist in two forms:
  - surface roughness (i.e. particle size)
  - form roughness linked to irregularities in the bed, which includes bed vegetation, which is the primary roughness of many clay-based beds.
- However, the roughness in a culvert may need to be greater than 'smooth clay'.

Flood debris blockage of a culvert (Qld)

Acceptable Outcome: AO5.5

Design and maintenance measures are in place for the life of the crossing to keep crossings clear of blockages through a regular inspection program in order to retain fish passage through the crossing.



Environmental Protection Act 1994

Author's Note: 5.5

- Again, this is a 'development outcome' that is asking the 'developer' to demonstrate what works will occur in the future, potentially by a third party (i.e. the future owner of the crossing).
- This is best achieved through legislation linked to possibly:
  - *Fisheries Act 1994*
  - *Planning Act 2016, or*
  - *Environmental Protection Act 1994.*

Acceptable Outcomes AO5.6 & AO5.7 – Causeway and ford crossings

Ford crossing of a sand-based creek

Acceptable Outcome: AO5.6

The crossing is built at or below bed level so that the surface of the crossing is no higher than the stream bed at the site.

(It is noted that this Outcome applies only to causeway and ford crossings)

Causeway crossing of a clay-based creek

Author's Note: 5.6

- This outcome effectively bans the use of causeways within fish habitat streams.
- This will be difficult for many private land owners that would like to use a causeway to cross a waterway in their property: BUT, if we are serious about protecting fish habitats, then this needs to be done.
- Designers must be very careful before designing a recessed ford crossing in country dominated by cracking clays (not that anyone would want a recessed ford crossing).

Ford crossing over a rock riffle (Qld)

Acceptable Outcome: AO5.7

The lowest point of the crossing is installed at the level of the lowest point of the natural waterway bed (pre-construction), within the footprint of the proposed crossing.

(It is noted that this Outcome applies only to causeway and ford crossings)

Ford crossing of a sand-based creek (Qld)

Author's Note: 5.7

- If we are banning all causeway crossings within fish habitat waterways, and if a ford crossing, by definition, followed the bed level of the waterway, then this outcome seems inevitable.

Acceptable Outcomes AO5.8 & AO5.9 – Causeway and ford crossings

Ford crossing of a clay-based creek

Acceptable Outcome: AO5.8

There is a height difference between the lowest point of the crossing and the edges of the low-flow section of the crossing so that water is channelled into the low-flow section of the crossing.

(It is noted that this Outcome applies only to causeway and ford crossings)

Ford crossing of a gravel-based creek

Author's Note: 5.8

- Ford crossings traditionally only exist on sand-based and gravel-based waterways, which either don't have a low-flow channel, or if one does form from time to time, its location is highly variable.
- A ford crossing of a rock-based waterway is simply the rock bed.
- If the intention is to replace causeway crossings of clay-based creeks with a sealed (i.e. concrete) ford crossing, then the practicalities of this outcome will be questionable.

Ford crossing of a rock outcrop (Qld)

Acceptable Outcome: AO5.9

The level of the remainder of the crossing is no higher than the lowest point of the natural waterway bed outside of the low-flow channel.

(It is noted that this Outcome applies only to causeway and ford crossings)

Concrete crossing of sand-based creek

Author's Note: 5.9

- In sand-based and gravel-based waterways, the base of the crossings is the natural bed—it must never be sealed (e.g. concrete) because this would interfere with substrate migration.
- In clay-based creeks, this outcome does not appear to be practical.
- I am unsure what this Outcome is trying to achieve (which does not mean the clause is wrong—just that I do not understand it).

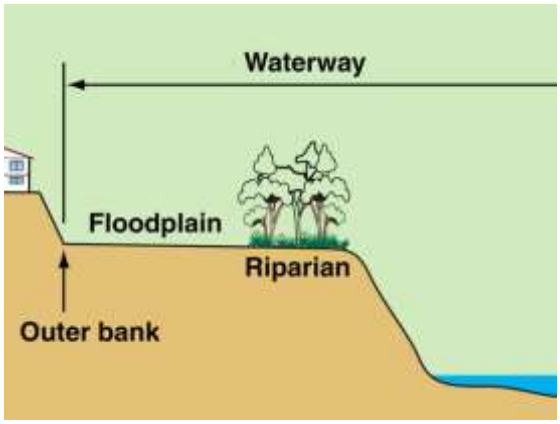
Acceptable Outcome AO5.10 – For bridges only

Rail bridge (Qld)

Acceptable Outcome: AO5.10 for bridges

Bridge support piles are not constructed within the low-flow channel and do not constrict the edges of the low-flow channel, and the number of piles within the waterway are minimised.

(This Outcome only applies to bridge crossings)



Definition of a 'waterway'

Author's Note: 5.10.1

- Section 2.1 of State Code 18 states that a waterway, as defined in the *Fisheries Act 1994*, includes any watercourse.
- The 'Dictionary' in the *Fisheries Act 1994* refers to the *Water Act 2000* for the definition of a 'watercourse'.
- The *Water Act 2000* defines a 'watercourse' in Chapter 1, Part 2, Section 5, which is reproduced and discussed over the following three pages.

Bridge over a wide river

Author's Note: 5.10.2

- The author could not find a definition of a 'low-flow channel' in State Code 18, *Fisheries Act 1994,* or the *Water Act 2000.*
- In the case of coastal 'rivers', the low-flow channel is normally the full width of the channel bed.
- In such a case, the task of not constructing bridge piers in the low-flow channel would be problematic—bridges such as shown (left) would not meet this outcome.

Wide floodplain near Longreach (Qld)

Author's Note: 5.10.3

- In the case of some western Queensland 'rivers', the width of the waterway (if the literal definition of a waterway is accepted) can be as much as 100 km.
- If this Outcome were taken literally, it would mean:
  - raised (earth fill) road embankments would not be allowed across floodplains
  - some bridges in western Queensland could be as much as 100 km long, with minimal piers over that 100 km.

Water Act 2000*, Chapter 1, Part 2, Section 5 – Meaning of *watercourse

5 Meaning of *watercourse* (as at 2000)

(1) A ***watercourse*** is a river, creek or other stream, including a stream in the form of an anabranch or a tributary, in which water flows permanently or intermittently, regardless of the frequency of flow events—

(a) in a natural channel, whether artificially modified or not;

or

(b) in an artificial channel that has changed the course of the stream.

(2) A ***watercourse*** includes any of the following located in it—

(a) in-stream islands;

(b) benches;

(c) bars.

(3) However, a ***watercourse*** does not include a drainage feature.

(4) Further—

(a) unless there is a contrary intention, a reference to a ***watercourse*** in this Act, other than in this part or in the definitions in schedule 4 to the extent they support the operation of this part, is a reference to anywhere that is—

(i) upstream of the downstream limit of the ***watercourse***; and

(ii) between the lateral limits of the ***watercourse***; and

(b) a reference in this Act to, or to a circumstance that involves, land adjoining a watercourse, is a reference to, or to a circumstance that involves, land effectively adjoining a ***watercourse***.

Note for paragraph (b)—

Generally, the non-tidal boundary (***watercourse***) of land bounded by a watercourse, as provided for under the *Survey and Mapping Infrastructure Act 2003*, would not correspond precisely with the line of the outer bank of a watercourse under this Act.

(5) In this section—

adjoining includes being bounded by, being adjacent to, or abutting.

lateral limits, of a watercourse, are the outer bank on one side of the watercourse and the outer bank on the other side of the watercourse.

Water Act 2000*, Chapter 1, Part 2, Section 5A – Meaning of *outer bank

5A Meaning of *outer bank* (as at 2000)

(1) The ***outer bank***, at any location on one side of a watercourse, is—

(a) if there is a floodplain on that side of the watercourse—the edge of the floodplain that is on the same side of the floodplain as the watercourse; or

(b) if there is not a floodplain on that side of the watercourse—the place on the bank of the watercourse marked by—

(i) a scour mark; or

(ii) a depositional feature; or

(iii) if there are 2 or more scour marks, 2 or more depositional features or 1 or more scour marks and 1 or more depositional features—whichever scour mark or depositional feature is highest.

(2) However, subsection (3) applies if, at a particular location in the watercourse—

(a) there is a floodplain on one side of the watercourse; and

(b) the other side of the watercourse is confined by a valley margin.

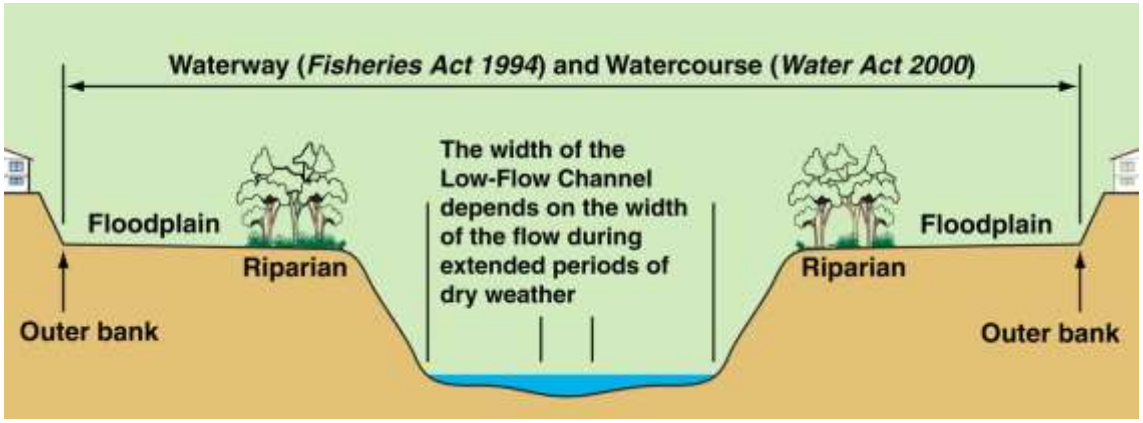
(3) Despite subsection (1)(b), the ***outer bank*** on the valley margin side of the watercourse is the line on the valley margin that is at the same level as the outer bank on the other side of the watercourse.

(4) Despite subsections (1) to (3), if under this part the chief executive has declared an outer bank on a side of a watercourse for any length of the watercourse, the ***outer bank*** on that side of the watercourse for that length is the outer bank as declared by the chief executive.

(5) To remove any doubt, it is declared that an ***outer bank*** of a watercourse—

(a) can not be, or be a part of, an in-stream island, bench or bar located in the watercourse; and

(b) can not be generally closer to the middle of the watercourse than any part of an in-stream island, bench or bar located in the watercourse.

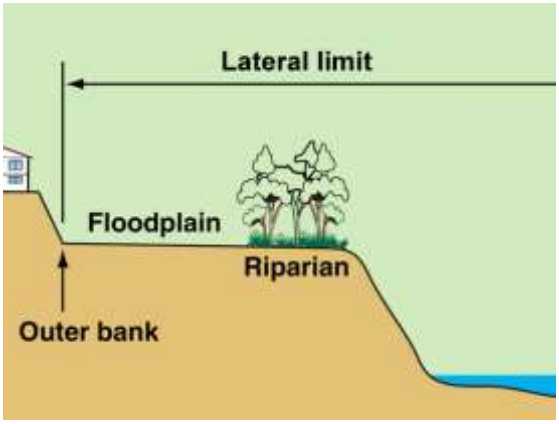


Defining the limits of a 'waterway' and a 'watercourse'

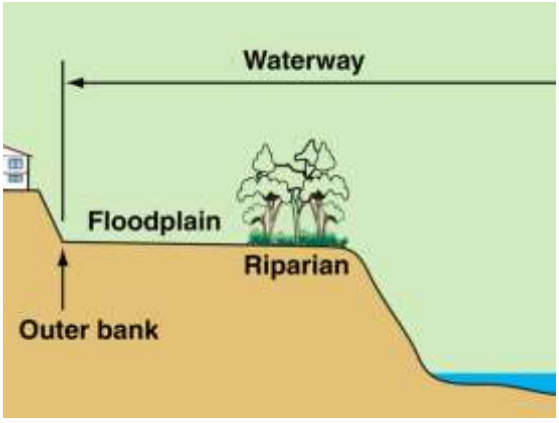
An overview of the *Water Act 2000* definition of a *watercourse*

Fisheries Act 1994

Water Act 2000



Lateral limit



Outer bank

State Code 18 and *Fisheries Act 1994*

Note; the following discussion represents only the author's opinion.

- **State Code 18** refers to the ***Fisheries Act 1994*** for a definition of a waterway, which includes any watercourse.
- The 'Dictionary' in the ***Fisheries Act 1994*** refers to the ***Water Act 2000*** for a definition of a 'watercourse'.

***Water Act 2000* – Watercourse**

- Chapter 1, Part 2, Section 5 of the ***Water Act 2000*** refers to a 'watercourse' as including:
  - anywhere that is upstream of the downstream limit of the watercourse, which would take it to the top of the catchment; and
  - between the lateral limits of the watercourse (see below).
- Note: Part 4b in this definition only applies to the *Water Act 2000.*

***Water Act 2000* – Lateral limits**

- Chapter 1, Part 2, Section 5 of the ***Water Act 2000*** also defines the 'lateral limits' of a watercourse as being between:
  - 'the outer bank on one side of the watercourse and the outer bank on the other side of the watercourse.'

***Water Act 2000* – Outer bank**

- Chapter 1, Part 2, Section 5A of the ***Water Act 2000*** defines the 'outer bank':
  - if there is a floodplain on that side of the watercourse [then the outer bank is] the edge of the floodplain that is on the same side of the floodplain as the watercourse; or
  - if there is not a floodplain on that side of the watercourse, then it is defined by the same level as the outer bank on the other side of the watercourse.

Author's Note: 5.10.4

- State Code 18 appears to adopt a definition of a 'waterway' which includes the full width of the floodplains.
- This issue can be resolved by the Code adopting its own definition of a waterway.

Acceptable Outcomes AO5.11 & AO5.12 – For bridges only

Smooth, non-fish-friendly abutments

Acceptable Outcome: AO5.11 for bridges

Bridge abutments and bank revetment works do not extend into the waterway beyond the toes of the banks.

(This Outcome only applies to bridge crossings)

Typical bridge abutment conditions

Author's Note: 5.11

- Clarification is required to confirm that the term 'banks' refers to the lower banks (channel banks) adjacent the channel, and not the upper banks (outer banks) at the edge of the floodplain.
- Otherwise, refer to comments as per Acceptable Outcome AO5.10.

Single span bridge (NSW)

Acceptable Outcome: AO5.12 for bridges

Suitable fish habitats are maintained within the low-flow channel.

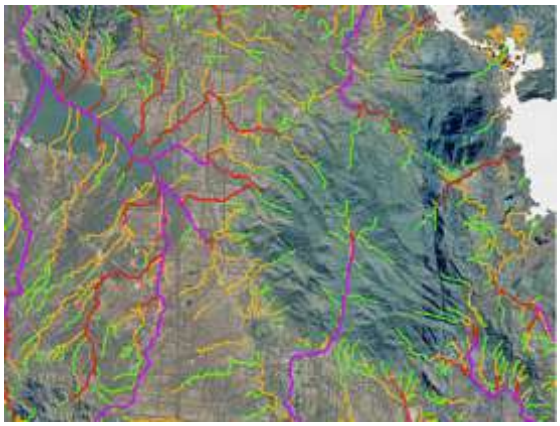
(This Outcome only applies to bridge crossings)

Single span bridge (Qld)

Author's Note: 5.12

- This Outcome should be easy to achieve for bridge crossings.
- The author expects that most fish will be able to squeeze under this bridge (left)—this is what can happen when you try to avoid central piers!

Acceptable Outcomes AO5.13 & AO5.14 – For culverts only



Spatial Data Layer

Acceptable Outcome: AO5.13

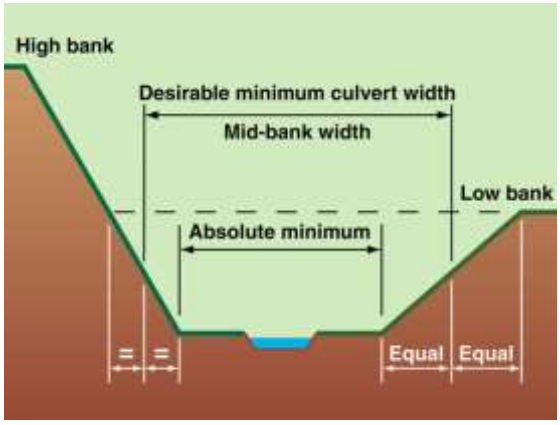
Culverts are only installed where the site conditions do not allow for a bridge.

(This Outcome only applies to culverts)

Small timber bridge (NSW)

Author's Note: 5.13

- I struggle to think of any site condition that would allow a culvert, but not allow a bridge.
- I believe this Outcome effectively ends the use of culverts at any fish habitat waterway.
- This clause does not appear to take into account the waterway grading system presented in the Spatial Data Layer.



Desirable minimum culvert bed width

Acceptable Outcome: AO5.14

The combined width of the culvert cell apertures are equal to 100 percent of the main channel width.

(This Outcome only applies to culverts)

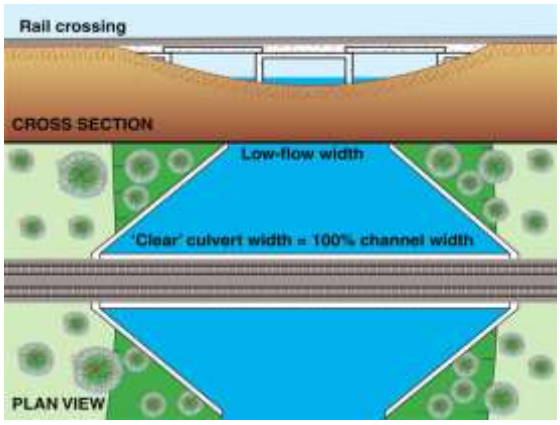
Pipe culvert (Qld)

Author's Note: 5.14

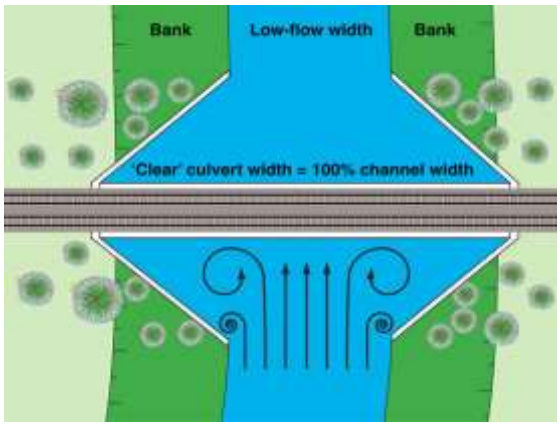
- This Outcome refers to the clear width of the culvert, which would exclude the legs (vertical sides) of box culvert cells).
- Unsure how this Outcome would apply to a pipe culvert (what is the 'clear width'?).
- If taken literally, this Outcome excludes culverts that have a combined width greater than 100 percent of the main channel width.
- I believe appropriate fish passage can be achieved without such an outcome.

Author's Note: 5.14 (continued)

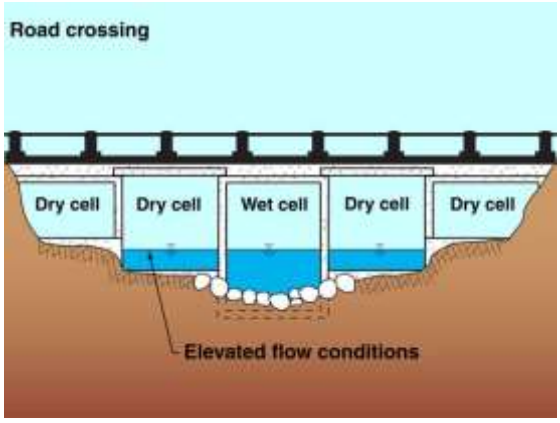
Define the channel width in this case?



Plan view of a 100% width box culvert



Potential large-scale turbulence



Variable-invert multi-cell box culvert

Possible 'negative' consequence of this Outcome

- Queensland Fisheries should think carefully about the possible negative consequences of this Acceptable Outcome.
- These consequences could include:
  - increased risk of bank erosion
  - increase disturbance to the waterway banks
  - road designers may begin to locate crossings at waterway 'chokes'.

Potential non-fish-friendly outcomes

- The author could not find a definition of a 'channel width' in State Code 18, *Fisheries Act 1994,* or the *Water Act 2000.*
- If it is assumed that the channel width is defined by the width of the channel at the elevation of the channel's low bank, then:
  - this would require excavation into the protected riparian vegetation
  - increased hard engineering to stabilise the excavated banks
  - increased large-scale turbulence.

Increased disturbance to the waterway banks

- In many channels, the top width of the channel can be much greater than the width of the channel bed.
- This means the channel width can be more than three times the bed width.
- That means this outcome could double, or even triple, the cost of the culvert.
- Rapid flow expansion and contraction through a flat-bed culvert would be significant.

Stepped box culverts

- A potential solution would be stepped or staggered box culverts where the floor of each culvert cell matches the local bank height.
- The foundations of such culverts can be expensive.

Acceptable Outcomes AO5.15 & AO5.16 – For culverts only

Introduced bed roughness (NSW)

Deposition of bed material (NT)

Sidewall baffles (NSW)

Small pipe culvert on a fish habitat creek

Acceptable Outcome: AO5.15

The base of the culvert incorporates a low flow channel consistent with the natural low flow channel and:

1. is buried a minimum of 300 mm to allow bed material to deposit and reform the natural bed on top of the culvert base; or
2. the base of the culvert is the waterway bed; or
3. the base of the culvert cell and any scour protection within the waterway is roughened throughout to approximately simulate natural bed conditions.

Author's Note: 5.15

- This outcome appears to be a repeat of Acceptable Outcome: AO5.4.
  - *'The crossing and associated erosion protection structures are roughened throughout to approximately simulate natural bed conditions.'*
- If *'the base of the culvert is the waterway bed'*, then it is not a culvert!
- Unsure what is expected here if the crossing passes over a rock outcrop, or a rock-based waterway.

Acceptable Outcome: AO5.16

The outermost culvert cells incorporate roughening elements such as baffles on their bankside sidewalls.

(This Outcome only applies to culverts)

Author's Note: 5.16

- This may not be practical on small culverts, especially small pipe culverts.
- On small culverts, such an outcome would likely result in debris blockages within the culvert that will be difficult to remove.
- It is the author's opinion that placing baffles in such small culverts is more likely to create a fish barrier (due to internal debris blockages), than provide favourable fish passage conditions, especially in sand-based and gravel-based waterways.

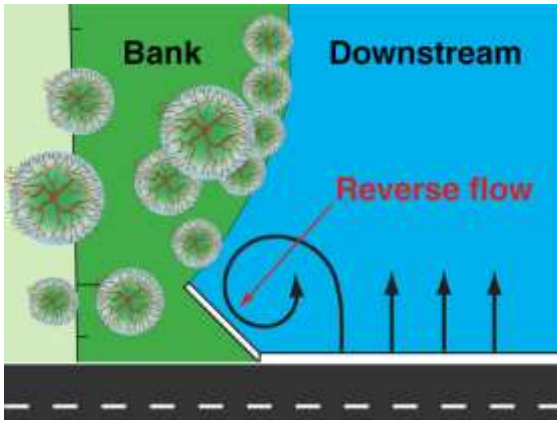
Acceptable Outcome AO5.17 – For culverts only

Wingwall baffles (Qld)

Acceptable Outcome: AO5.17

Roughening elements are installed on the upstream wingwalls on both banks to the height of the upstream obvert or the full height of the wingwall.

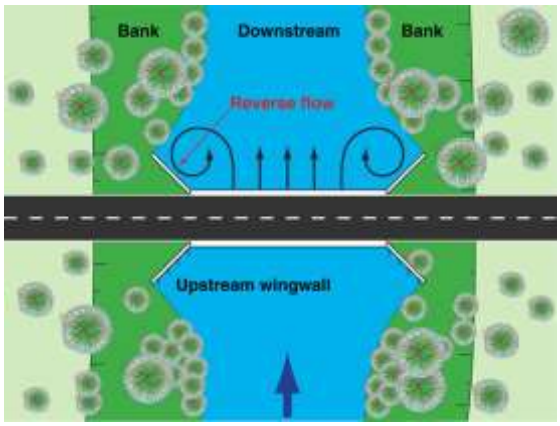
(This Outcome only applies to culverts)



Possible back-flow conditions

Author's Note: 5.17.1

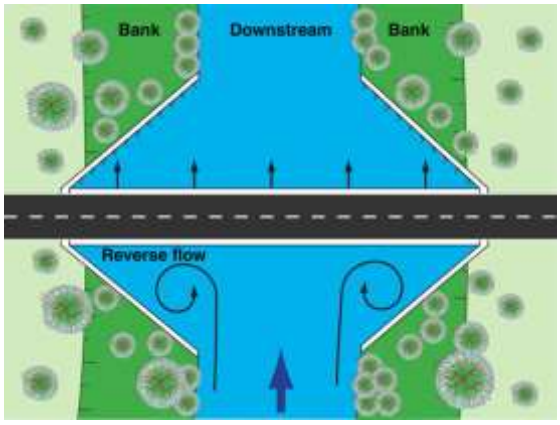
- This Outcome suggests roughening elements are only required on upstream wingwalls.
- This Outcome assumes that adjacent to the downstream wingwalls there will be a reverse-flow current that can help fish enter the culvert.
- These reverse-flow currents are caused by the large-scale eddies that form when the flow expands after exiting the culvert.



Culvert narrower than the channel width

Author's Note: 5.17.2

- The above flow condition will only occur when the culvert's width is narrower than the channel width (which would be in conflict with Acceptable Outcome AO5.14).

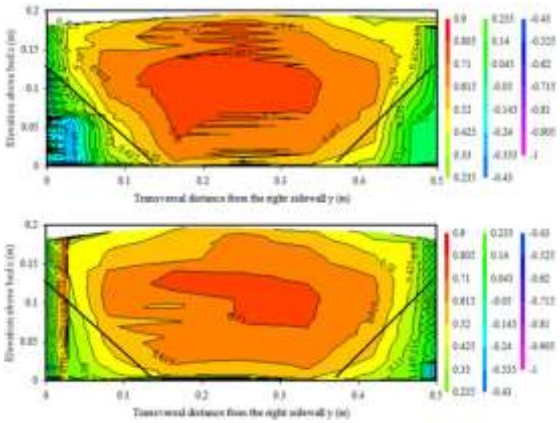


Culvert width close to the channel width

Author's Note: 5.17.3

- However, if the culvert's width is close to, or greater than, the channel width (in agreement with Acceptable Outcome AO5.14), then baffles are more likely to be required on the downstream wingwalls.
- Consequently, the wording of this Outcome should reflect the appropriate flow conditions for a given culvert.

Acceptable Outcome AO5.18 – For culverts only



Comp. Fluid Dynamics (CFD) modelling

Acceptable Outcome: AO5.18

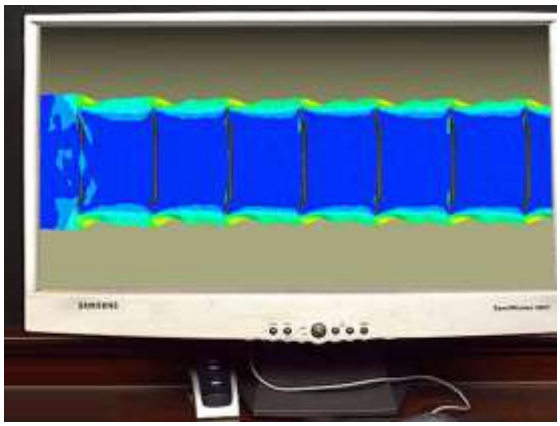
Roughening elements provide a **contiguous** lower velocity zone (no greater than 0.3 metres/second) for at least 100 millimetres width from the wall through the length of the culvert and wingwalls.

(This Outcome only applies to culverts)

Sidewall baffles (NSW)

Author's Note: 5.18.1

- My concerns with this Outcome relate to the following:
  1. The practicality of designers providing evidence of compliance with such an outcome.
  2. The application of the 0.3 m/s value.
  3. The validity of the 0.3 m/s value.
  4. The fairness of this outcome compared to the design of fishways on weirs.
  5. The natural variation in flow conditions that occur with changes in flow velocity.



CFD modelling of flexible baffles

Author's Note: 5.18.2

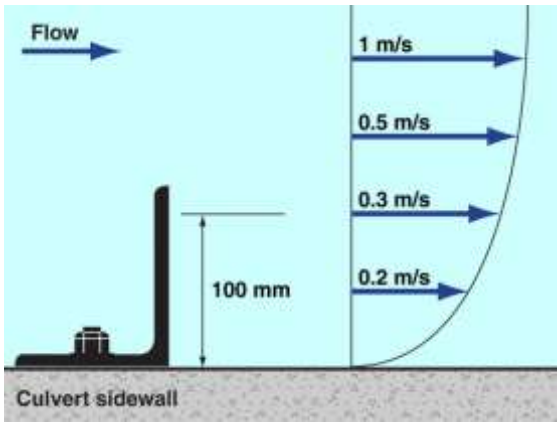
- How are designers expected to demonstrate this Outcome.
- Does 'each' designer need to provide CFD modelling on 'each' roughness system, and peak flow velocity that they would like to use.
- This would appear to me to be an unnecessary waste of public money, not only in model set-up and report writing, but also in the time spent by the department reviewing each design.

Expenditure

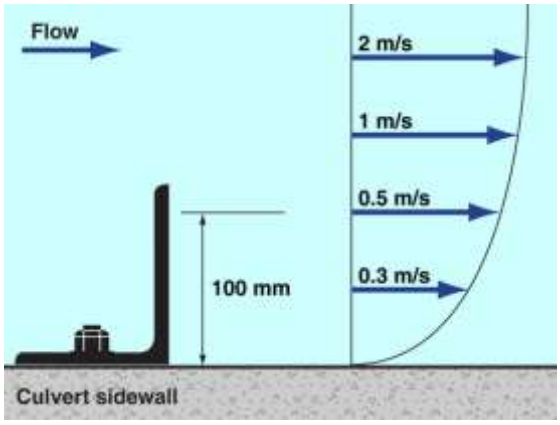
Author's Note: 5.18.3

- The department cannot specify Acceptable Outcomes without appropriate consideration of the possible financial consequences.
- I appreciate that it is the designer's responsibility to:
  - design crossings correctly
  - demonstrate designs are correct.
- However, governments have a responsibility to the community to not waste community resources.

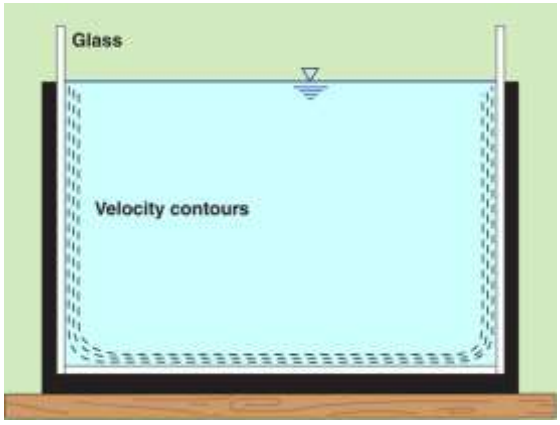
Author's Note: 5.18 (continued)



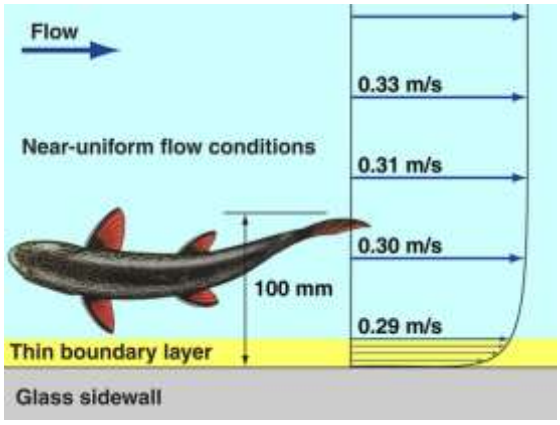
Maximum velocity of 0.3 m/s over 100 mm



Average velocity of 0.3 m/s across 100 mm



Boundary layer in a smooth glass flume



Thin boundary layer in a glass flume

Author's Note: 5.18.4

- Question: Does this 0.3 m/s requirement refer to:
  - the maximum velocity within the specified 100 mm width, or
  - the average flow velocity over this width?
- If this outcome relates to the maximum flow velocity within the specified 100 mm width, then I don't believe the 0.3 m/s requirement is appropriate for this type of flow condition.

Author's Note: 5.18.5

- If this Outcome relates to the average flow velocity within the specified 100 mm width, then I believe such a definition would be more appropriate.
- However, to date I have not seen sufficient CFD modelling results to demonstrate that even an average velocity of 0.3 m/s is appropriate for baffled culverts.

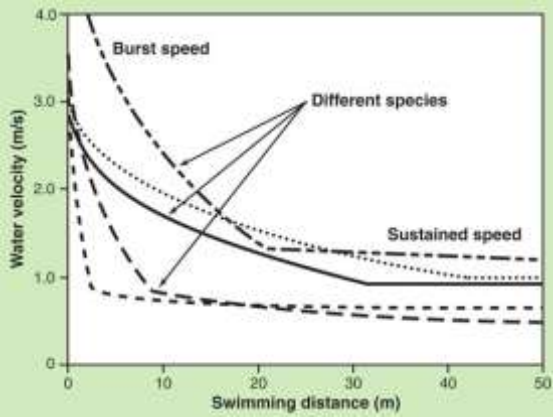
Author's Note: 5.18.6

- Hydraulic testing is often performed in long, glass flumes.
- These flumes are designed to have a very thin boundary layer—too narrow for fish movement.
- If these glass flumes are used for testing the swimming abilities of fish species, then the average velocity in the flume needs to fall below the fish's swim speed.
- This can lead researchers to **incorrectly** conclude that 'average velocity' is important in fish passage.

Boundary layer conditions in a glass flume

- In what is called 'smooth turbulent' flow conditions (often incorrectly termed laminar flow), the average flow velocity across a glass flume needs to be around 0.3 m/s in order for fish to maintain sustained swimming speeds.
- However, in a real waterway, flow velocities vary significantly across the width of the channel, which means fish passage can occur in some rivers even though the flow velocity at the centre of the river exceeds 4 to 5 m/s.

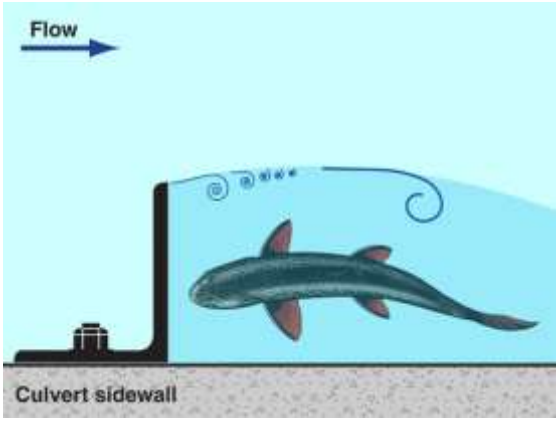
Author's Note: 5.18 (continued)



Typical swimming modes of fish

Author's Note: 5.18.7

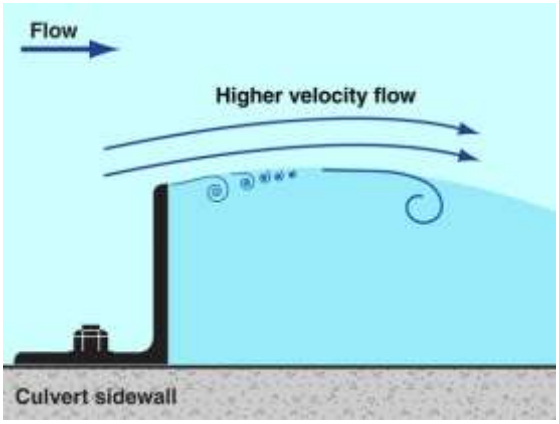
- Acceptable Outcome 5.18 treats waterway crossings differently from the design of fishways on weirs and small dams.
- Fish are assumed to use burst speed and periods of resting when ascending a fishway; however, the specified 0.3 m/s requirement reflects the idea that fish should only need to use sustained speed to pass through a culvert.



Resting areas

Author's Note: 5.18.8

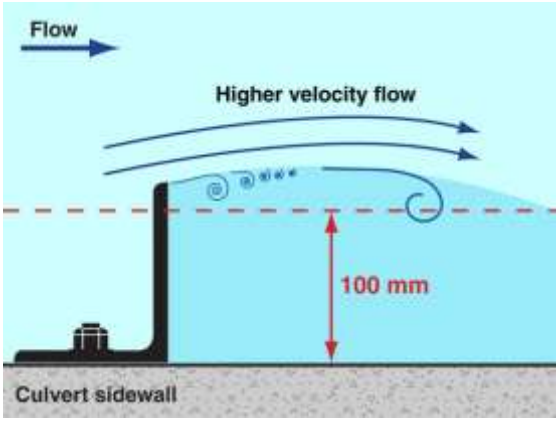
- The adoption of sustained speed may be appropriate when the sidewall roughness is uniform, and provides **no** resting opportunities, such as a textured (roughened) sidewall.
- However, if the sidewall 'roughness' provides resting areas, such as in the use of baffles, then fish can use burst speed, similar to their movement up a fishway, or a natural rock riffle.



Flow around the outer edge of a baffle

Author's Note: 5.18.9

- If baffles are used, then it would be expected that flow velocities greater than 0.3 m/s will exist adjacent to the outer edge of the baffles.

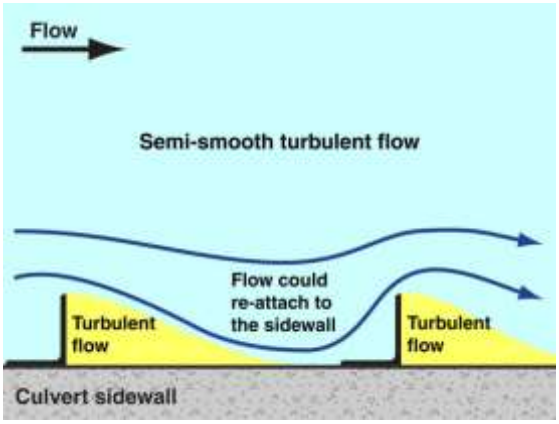


Baffle wider than 100 mm

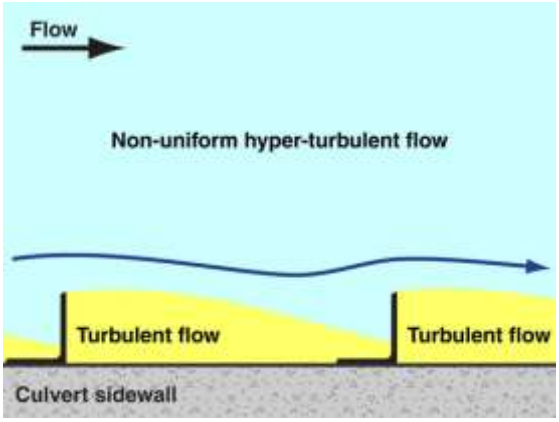
Author's Note: 5.18.10

- If the baffle width exceeds 100 mm, then a literal interpretation of this Outcome would be impossible to achieve.
- As discussed above, it would not be possible to achieve this Outcome around sidewall baffles.
- (Note to reader: 'contiguous' means close to the sidewall)

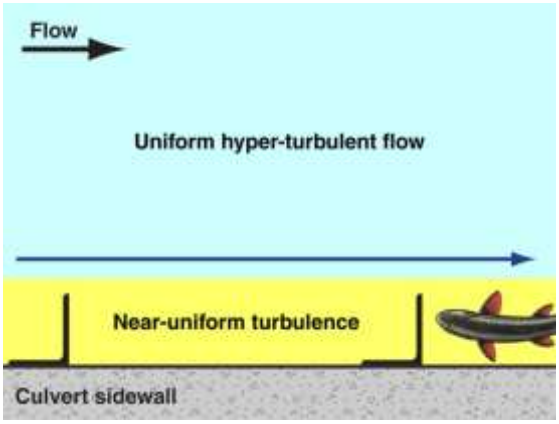
Author's Note: 5.18 (continued)



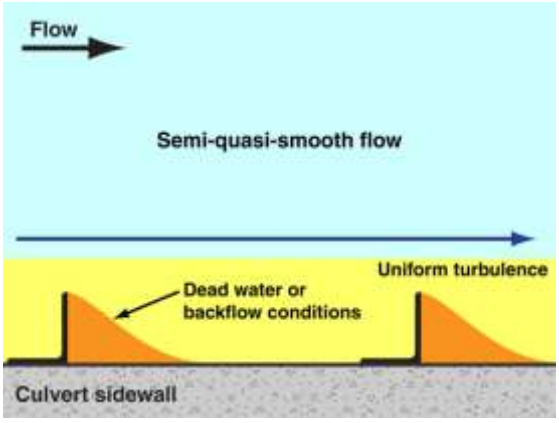
Semi-smooth turbulent flow



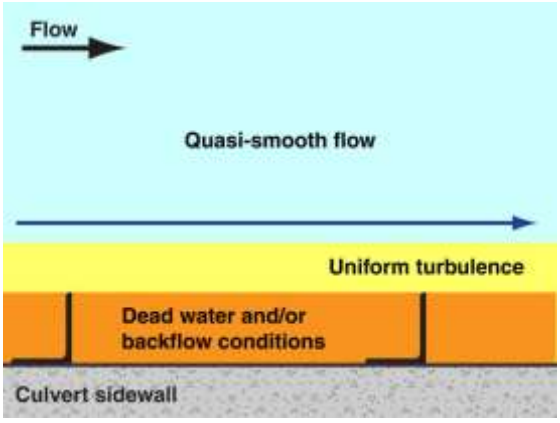
Non-uniform hyper-turbulent flow



Uniform hyper-turbulent flow



Semi-quasi-smooth flow

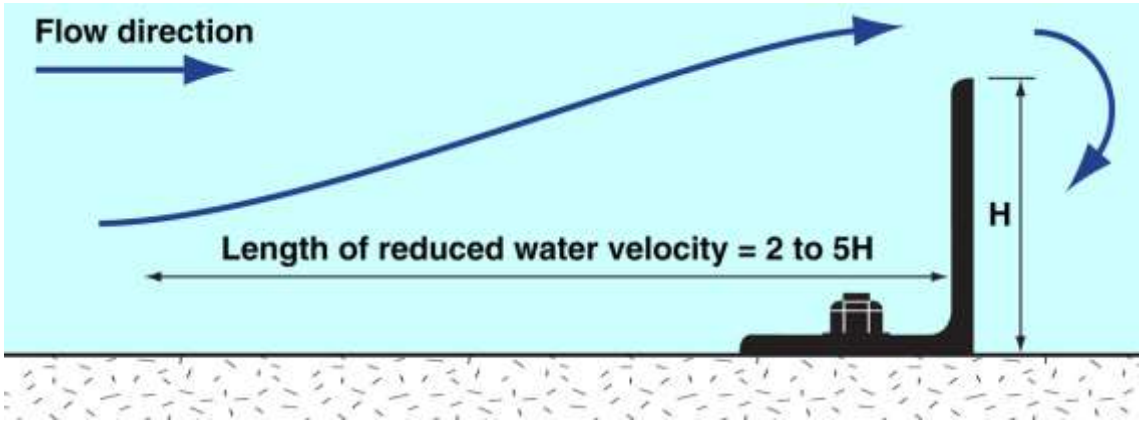


Quasi-smooth flow

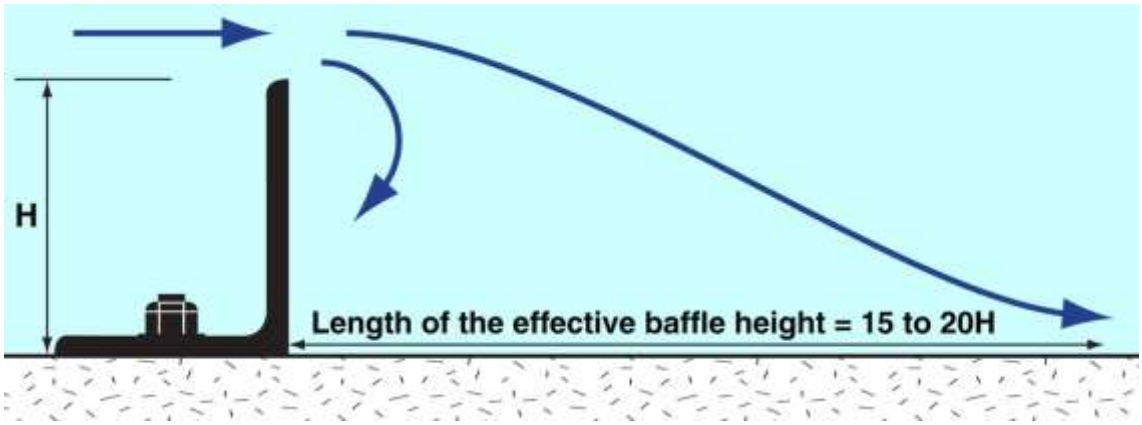
Author's Note: 5.18.11

- In is noted that flow conditions around sidewall baffles, and therefore flow velocities, would vary with the discharge through the culvert, or more correctly, with the Reynolds number of this discharge.
- The Reynolds number being a dimensionless number that relates viscosity forces in a fluid to inertia forces in the same fluid.
- In semi-smooth turbulent flow the wake downstream of the roughness strip (baffle) does not extend to the next baffle, and so the flow can reattach to the sidewall.
- For the non-uniform hyper-turbulent flow the wake just begins to reach the next baffle.
- For the uniform hyper-turbulent flow condition, the individual wakes intermingle resulting in a uniform layer of turbulence covering the baffles.
- In the semi-quasi-smooth flow condition a trapped vortex forms downstream of the baffle, but does not fully fill the space between the baffles.
- For the quasi-smooth flow condition, the water flow effectively skims over the baffles
- What these images show is that as you slow the culvert's average flow velocity, the 'shadow' area downstream of each baffles reduces, and the central flow velocity creeps closer to the culvert sidewall.
- It is noted that in just one flood event, the flow condition inside the culvert can pass through each of the above flow conditions from the beginning of the flood to its peak, then back again to a low-flow condition.

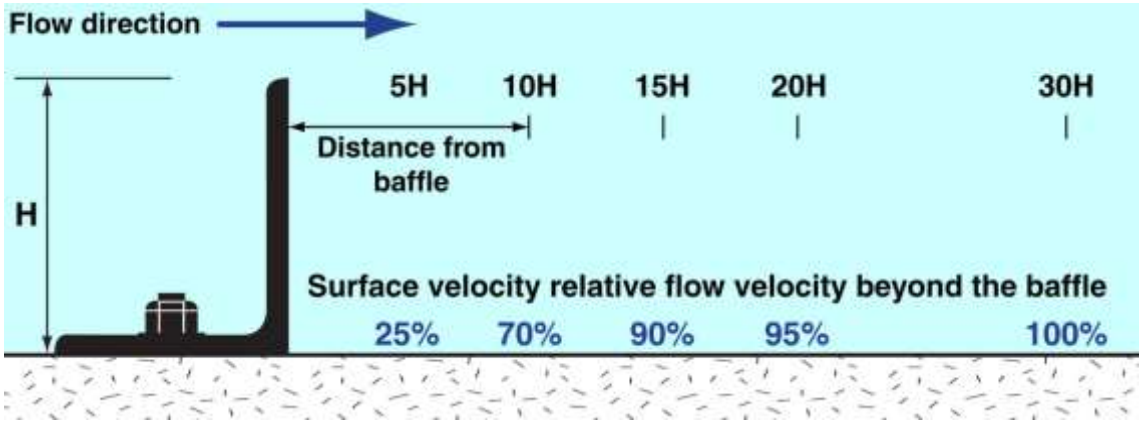
Author's Note: 5.18 (continued) – Data from windbreak analysis



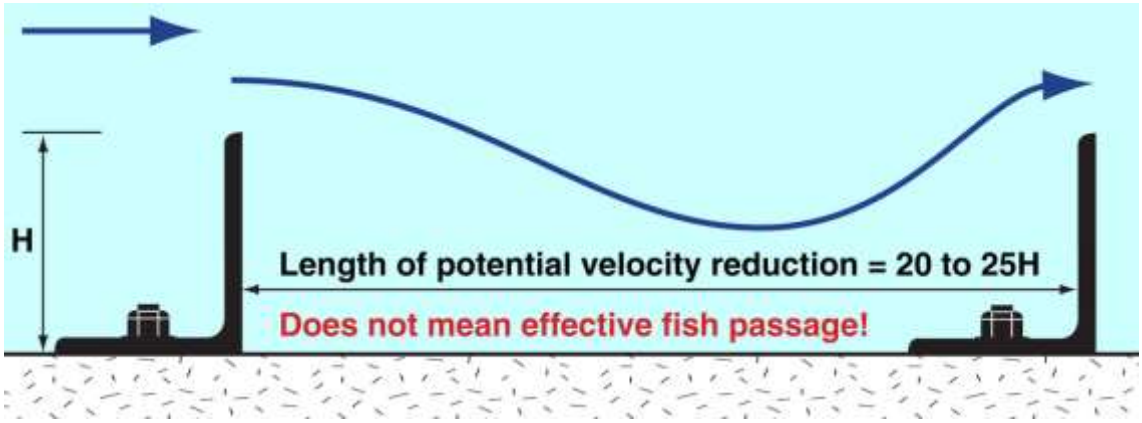
Expected flow conditions upstream of a sidewall baffle



Expected flow conditions downstream of a sidewall baffle

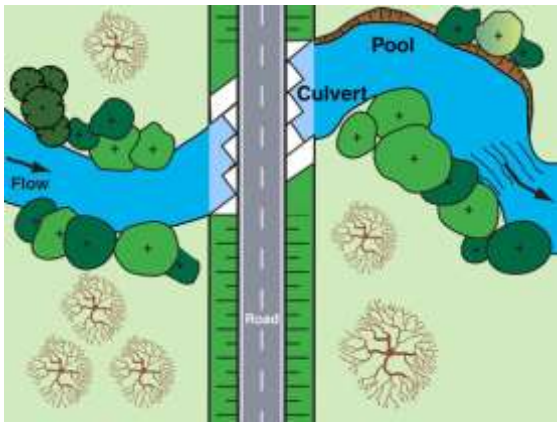


Expected velocity conditions adjacent to the culvert sidewall downstream of a baffle



Expected flow conditions between two closely-spaced sidewall baffles

Acceptable Outcomes AO5.19 & AO5.20 – For culverts only

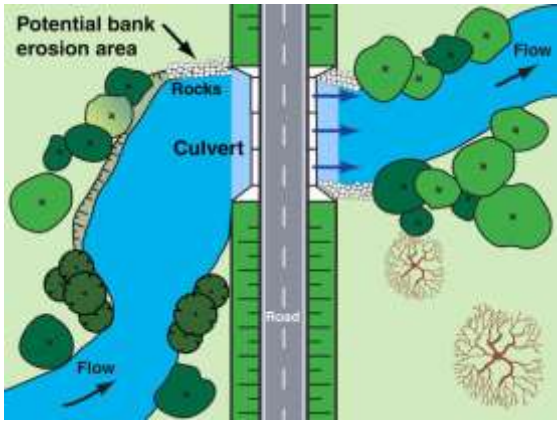


Skewed culvert

Acceptable Outcome: AO5.19

Culvert alignment to the waterway flow minimises water turbulence.

(This Outcome only applies to culverts)



Culvert aligned with downstream channel

Author's Note: 5.19

- This Outcome may initially sound like a sensible outcome, but it is important to consider the possible negative consequences of such a proposal.
- A likely outcome of this clause is a skewed culvert, which will be longer than a culvert placed tangential to the crossing.
- Given that the stream flow would be subcritical, the adverse impacts caused by turbulence would be minor, but the adverse impacts caused by culvert length would be significant.

Dark culvert (Qld)

Acceptable Outcome: AO5.20

There is sufficient light at the entrance to and through the culvert so that fish are not discouraged by a sudden darkness.

(This Outcome only applies to culverts)

Skylight in the roof of a box culvert (Qld)

Author's Note: 5.20

- How would it ever be possible for a designer to demonstrate such an outcome?
- This Outcome requires the designer to demonstrate what fish will do!
- We DO NOT want electrical lighting placed in waterway culverts!
- A better Outcome: All reasonable measures are taken to maximise light intrusion into the nominated wet cells.

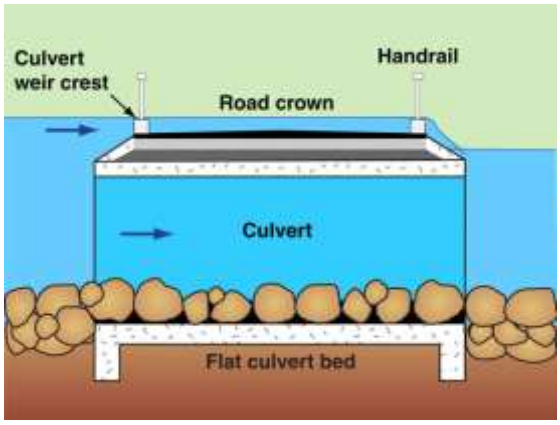
Acceptable Outcomes AO5.21 & AO5.22 – For culverts only

Road base cover over a box culvert (Qld)

Acceptable Outcome: AO5.21

The depth of cover above the culvert is as low as structurally possible, except where culverts have an average recurrence interval (ARI) greater than 50 years.

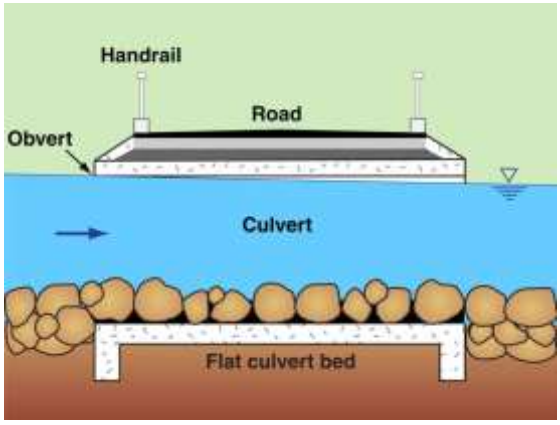
(This Outcome only applies to culverts)



Engineering definition of culvert ARI

Author's Note: 5.21

- What defines the culvert's average recurrence interval?
- Is it:
  - when the culvert starts to flow full
  - when the stream flow is about to bypass the culvert and begin to pass over the approach roads, or
  - when the road crossing is considered unsafe to cross?



Culvert flowing 'full'

Acceptable Outcome: AO5.22

For culvert crossings designed with a flood immunity ARI greater than 50 years, fish passage is provided up to culvert capacity.

(This Outcome only applies to culverts)

Fisheries Act 1994

Author's Note: 5.22

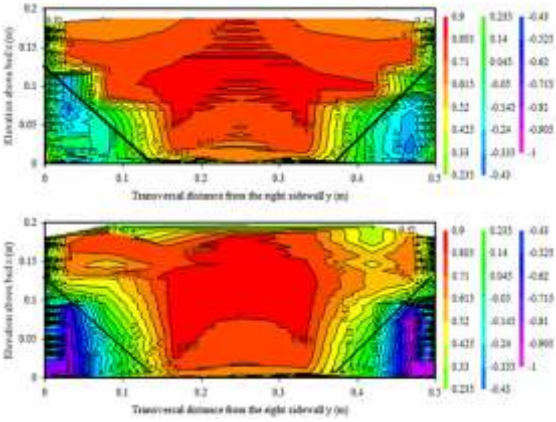
- I assume this outcome overrules Acceptable Outcome AO5.1, which requires fish passage up to 'drownout of the structure'.
- Can the department demonstrate that requiring fish passage at the peak of a 1 in 100 year flood is essential to achieving the aims of the *Fisheries Act 1994*?
- If not, then the Outcome should be considered unlawful.

Information to be submitted with development application (AO5)

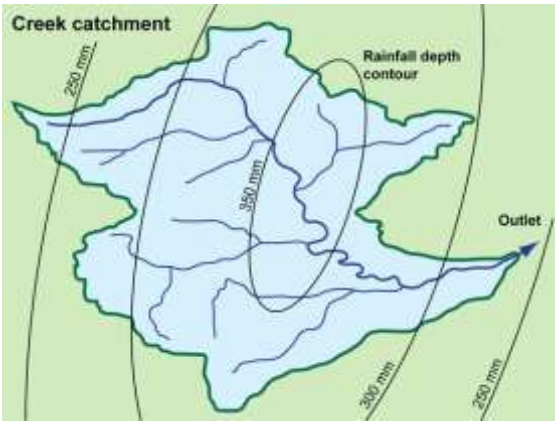
Information to be submitted with development application

- ✓ Submit plans and drawings of the waterway barrier works and any associated structures or works areas. Include detail of all design aspects that will provide fish passage. Refer to section 4 in this guideline for the standard information for all applications. Section 4 provides a comprehensive list of the plans and other information that may be required to enable assessment against this state code.
- ✓ Identify the location of the bed and banks of the waterway and any connected fish habitats such as wetlands within, and adjacent to, the development site. Refer to Appendix 3 for further information on mapping layers that can be used to inform this discussion.
- ✓ Detail aquatic vegetation and riparian areas within the development site on plans.
- ✓ If hydraulic modelling will inform how the waterway barrier provides fish passage (e.g. for culverts that are hydraulically designed, provide information demonstrating how the fish passage provisions of the waterway barrier are adequate for both upstream and downstream passage), provide information based on scientific evidence and hydrological modelling. If hydrological and hydraulic modelling is provided, include the following information to inform the data provided:
  - Inputs, e.g., spatial and temporal scales, source of data
  - outputs, e.g., frequency and duration of flood events in relation to the proposed structure.

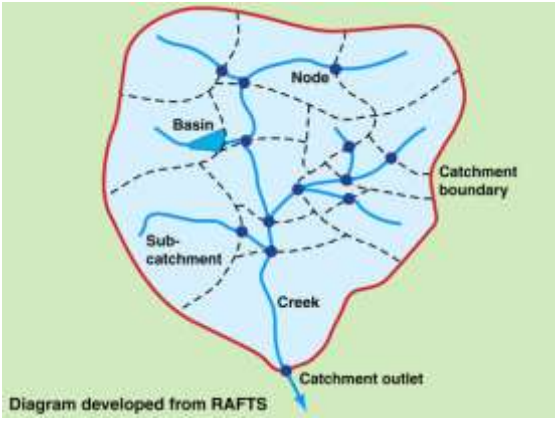
Raising Waterway Barrier Works



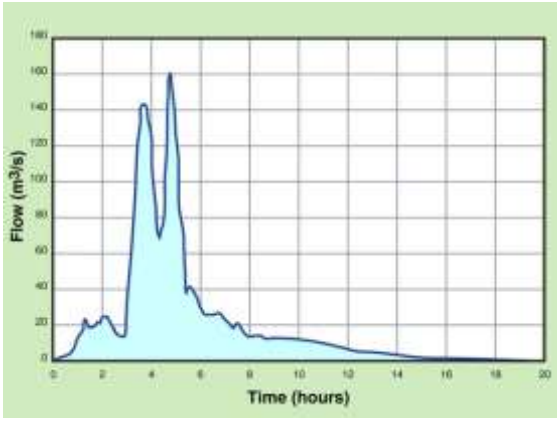
Hydraulic modelling



Rainfall hyetograph



Catchment model (hydrologic model)



Flood hydrograph (runoff graph)

Information to be submitted with development application

- In the Queensland document:

State Development Assessment Provisions (SDAP) guideline – State code 18: Constructing or raising waterway barrier works in fish habitats.

- In Section 5.2.2 Performance outcome 5, discussion is provided on the 'Information to be submitted with development application'.
- The following is the author's comments.

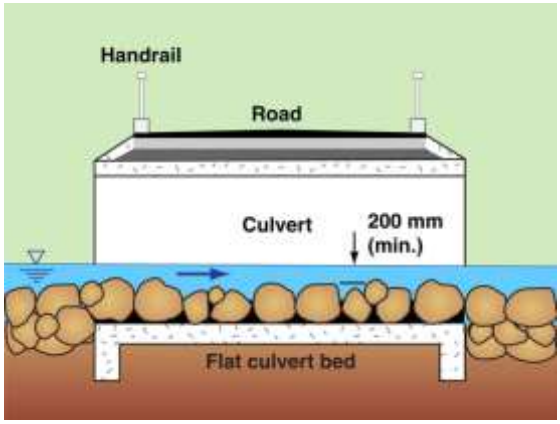
Information to be submitted

- 'If hydraulic modelling will inform how the waterway barrier provides fish passage (e.g. for culverts that are hydraulically designed, provide information demonstrating how the fish passage provisions of the waterway barrier are adequate for both upstream and downstream passage), provide information based on scientific evidence and hydrological modelling.'

Author's Note 5.23

- I am not sure the department can insist on the 'evidence' being 'scientific evidence'.
- Surely any credible 'evidence' would be acceptable.
- The clause starts with reference to hydraulic modelling, then ends by requesting hydrological modelling.
- Hydraulic modelling is the analysis of stream flows and velocities.
- Hydrologic modelling is the analysis of rainfall and runoff rates.

Information to be submitted with development application (AO5)

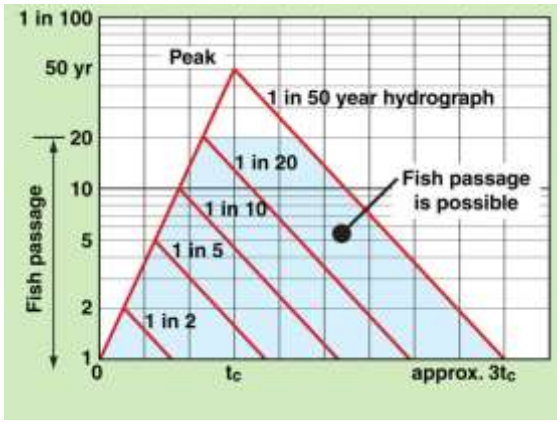


Low-flow event

Information to be submitted

'Fish move frequently within waterways, so if [it] would be useful to include information on:

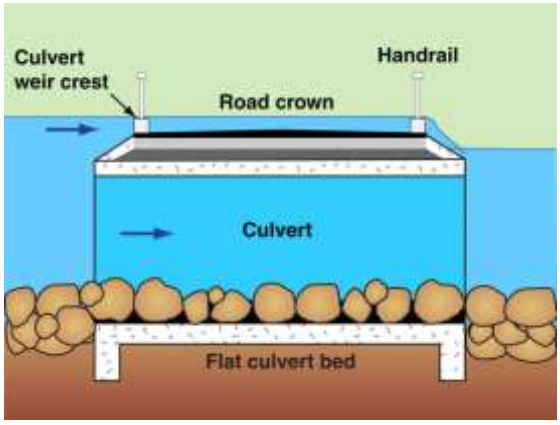
- how the waterway barrier provides fish passage during frequent flow events that occur multiple times per year (e.g. 2 EY, 3 EY)
- how the waterway barrier provides fish passage during flood events that occur up to a 1 in 5 year (20%) event.'



'Simplified' flood hydrographs

Author's Note 5.24

- It is noted that if a culvert provides fish passage during a 1 in 5 year event, then it must also provide fish passage during a 2 EY and a 3 EY event.
- This is because a 1 in 5 year event must pass through the flow conditions of all lower peak events.
- It would appear that the clause is actually referring only to the 'peak' of these flood events; not the full event.



High-flow event

Information to be submitted

'However, this will vary, depending on the development proposed and the nature of the waterways. For example:

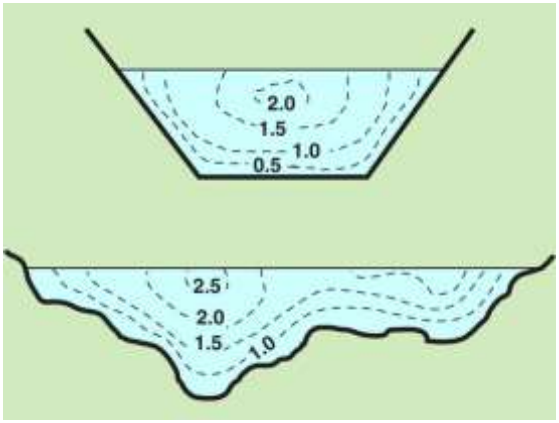
- some waterways are ephemeral and fish passage may only be provided at limited times; however, in larger flood events there may be additional connectivity, for example in braided waterways. – in these types of waterways, information may be requested up to a 10% or 5% annual exceedance probability (1 in 10 year or 1 in 20 year event).'

Inner-harbour fish school (NSW)

Author's Note 5.25

- Can the department demonstrate that requiring fish passage at the peak of a 1 in 20 year flood is essential to achieving the aims of the *Fisheries Act 1994*?
- What flood event is considered essential for achieving the primary purpose of the *Fisheries Act 1994,* that being to provide for the use, conservation and enhancement of the community's fisheries resources and fish habitats.
- The department needs to demonstrate that their requests are fair and reasonable.

Information to be submitted with development application (AO5)



Variable flow velocities

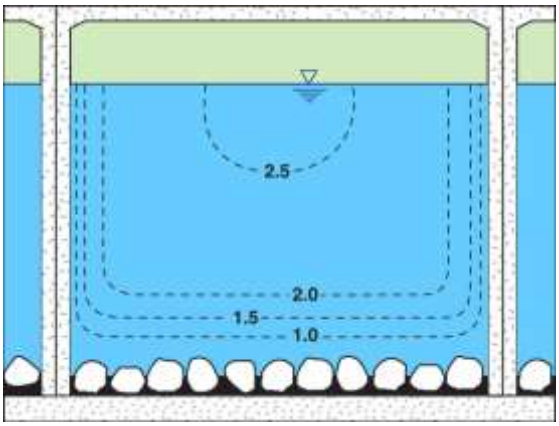
Information to be submitted

'Provide the expected duration of flows, water depth and water velocities for the above events through the structure in comparison to those within the natural waterway.'

Questionable relevance

Author's Note 5.26

- In the author's opinion, this is a pointless request.
- Flow durations will not change between that of the culvert and natural waterway.
- Flow depths in the natural waterway will likely be highly variable, and if fish passage has been shown to be viable, then flow depth is irrelevant.
- Average flow velocities in a culvert and in a waterway are irrelevant to fish passage.



Information to be submitted

'Provide context on the information provided, for example whether they are peak velocities of short duration, or whether velocities are the average peak velocities through the structure.'

Clear explanation

Author's Note 5.27

- I agree that all flow velocities discussed in a report must be clearly defined within the report.

Information to be submitted with development application (AO5)

Government low-flow monitoring (Qld)

Information to be submitted

'Provide context on the hydrological characteristics of the waterway. For example, some waterways may have ephemeral flows, only flowing for 40% of the year, whilst others may contain water year-round.'

Looking for historical waterway data

Author's Note 5.28

- Such information may not be available to the culvert designer.

Fish passage (Qld)

Information to be submitted

'Detail the operational range of the fish passage provisions in terms of the fish movement and fish behavioural requirements (based on fish assemblage, biomass and seasonality) and the natural flow regime of the waterway.'

Unsure

Author's Note 5.29

- Unsure why the department believes designers would have 'reasonable' access to such data when the department does not have 'reasonable' access to such data.
- For a small, local government culvert, the collection of a *'detail the operational range of the fish passage provisions'* would cost more than the culvert.
- For a culvert on a private rural property such data collection would be considered an unreasonable request.

Performance Outcomes
PO6 to PO22 (All Crossings)

Performance Outcome PO6 – All crossings

Full debris blockage of a culvert (Qld)

Near-full sediment blockage of a culvert

Monitoring flow turbulence

Unsure

Performance Outcome PO6

Waterway barrier works are designed, constructed, operated and maintained to provide lateral and longitudinal fish passage for all members of the fish community.

No acceptable outcome is prescribed.

Author's Note: 6.1

- I am unsure if the department has the authority to require fish passage for non-native (introduced) fish species, which are a part of 'the fish community'.
- The authority proposing a waterway crossing (i.e. the developer) is unlikely to have any control over the 'operation' and 'maintenance' of the crossing, which is likely to be managed by a third party.
- This may be considered an unreasonable, and therefore unlawful, request.

Information to be submitted

'To demonstrate compliance with this performance outcome, the seasonal and flow-related biomass of the fish community at the location of the proposed waterway barrier works is to be surveyed and addressed in the design of the fish way by a person suitably qualified and experienced in fish passage biology.'

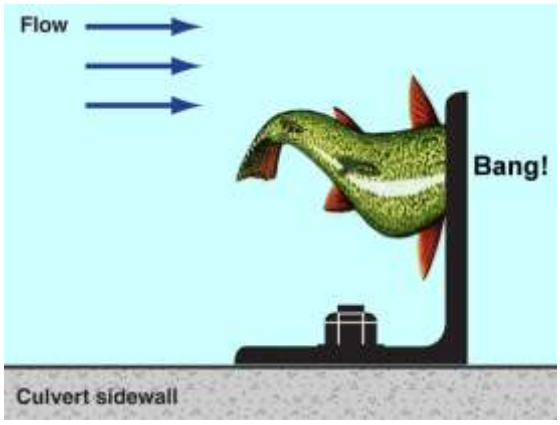
'In addition, any future increases in fish biomass should be quantified and catered for.'

Author's Note: 6.2

- This clause suggests that every waterway crossing, independent of its size and budget, is required to complete the same degree of investigation, numerical modelling, and reporting.
- Obviously, fisheries officers would show appropriate discretion in the amount of information that would be required for each structure, but such 'discretion' by the officer results in uncertainty for engineers that are required to present to their client a fixed fee for completing a culvert design.

Performance Outcome PO7 – All crossings

Stepped spillway



Point of impact!

Torrens River fishway (SA)

Plastic baffles (USA)

Performance Outcome PO7

Development is designed and operated so that all components of waterway barrier works and pathways of potential fish movement provide for safe fish passage.

Stepped spillways are not acceptable.

No acceptable outcome is prescribed.

Author's Note: 7.1

- It is noted that sidewall baffles, and most floor baffle systems, are unsafe for fish passing downstream through a culvert during a high-flow event.

Information to be submitted

With reference to waterway barrier work plans and designs, identify all potential pathways for fish movement.

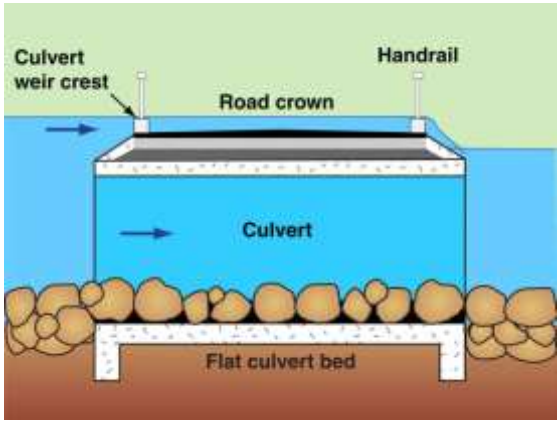
Consideration should be given to all flow conditions.

Discuss risks to safe fish passage and how these risks will be alleviated.

Author's Note: 7.2

- It will be difficult to alleviate the safety risks to fish being swept downstream through a culvert without compromising the passage of fish swimming upstream through the culvert.

Performance Outcome PO8 – All crossings



Overtopping flow condition

Performance Outcome PO8

The drownout characteristics of the waterway barrier works are designed and constructed to not result in adverse impacts to fish passage.

No acceptable outcome is prescribed.

Not the best example of the problem!

Author's Note: 8.1

- This condition is likely to conflict with the AustRoads standards for the safety of pedestrians and motor vehicles on road crossings.
- Pedestrian safety fencing will almost certainly 'result in adverse impacts to fish passage.'

Floodwater overtopping a culvert (Qld)

Information to be submitted

Detail and discuss the frequency, duration and timing of drownout of the waterway barrier . .

Detail drownout flow conditions that will provide fish passage (velocities, turbulence, water depth).

Detail any delays caused by the barrier in reaching drownout conditions, for example:

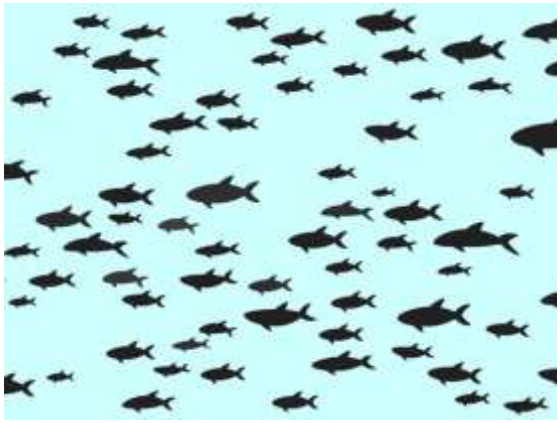
- for culverts and weirs, the delay between the time it takes from when culverts are at capacity (flowing full) until drownout is achieved

Unsure

Author's Note: 8.2

- There is an infinite number of 'durations' and 'timings' of potential overtopping events for most waterway crossings!
- How does the department expect designers to model the turbulence of water passing over a culvert?
- Flood events come in all 'sizes'. There is no set 'delay' between a culvert flowing full and a culvert overtopping.

Performance Outcome PO9 – All crossings



Fish resources

Performance Outcome PO9

Development does not result in adverse impacts to fisheries resources.

No acceptable outcome is prescribed.

Fishers

Author's Note: 9.1

- A worthy 'aim', but not a practical 'Acceptable Outcome'.
- Acceptable Outcomes must be achievable.
- It is not possible for development to occur without causing some level of adverse impacts to fisheries resources; therefore, this Outcome must be considered unlawful.

Pest species (Goldfish)

Information to be submitted

Discuss any potential impacts, including:

- biotic and abiotic conditions, such as water and sediment quality
- design of structures
- impacts on reproductive success
- effect on fish energy reserves
- whether fish may be physically damaged, injured, killed, trapped or stranded
- fish passage and access to habitat generally
- impacts of pest fish and other relevant pest species.

Pipe culvert on a rural property driveway

Author's Note: 9.2

- This essentially requires a biologist to review each and every waterway crossing that crosses an identified fish habitat.
- This is a worthy objective; however, all development conditions must satisfy the fair and reasonable test.
- Governments must consider the financial burden that this Outcome places on the community.
- What is required here are some examples of Acceptable Outcomes.

Performance Outcome PO10 – All crossings

Excessive 'hardening' of the waterway

Performance Outcome PO10

The design, construction and maintenance of the development does not result in non-essential hardening or unnatural modification of the main channel of the waterway.

No acceptable outcome is prescribed.

Fisheries Act 1994

Author's Note: 10.1

- State Code 18 is a development code.
- Such a code refers only to the 'development' phase; not to the operational phase.
- It is not lawful to specify 'maintenance' requirements in a development code.
- However, a code can request a Maintenance Plan.
- The regulation of maintenance must exist within Acts, not codes.

Minimising impacts on the waterway

Information to be submitted

Demonstrate that impacts to fish habitats and fish passage have been avoided and natural fish habitats and waterway features have been retained.

If any hardening of the waterway is proposed, demonstrate why it is essential for the development, taking into consideration designs that would not require hardening or modifying fish habitats.

For example, culverts should be sized appropriately to minimise any scour protection within the waterway.

Expenditure

Author's Note: 10.2

- In general, works are not conducted unless they are essential.
- Few councils and land developers enjoy wasting time and money.
- Again, I believe it would be an unlawful Outcome to require developers to 'demonstrate that impacts to fish habitats and fish passage have been avoided.'

Performance Outcome PO11 – All crossings

Retention of pond upstream of culvert

Performance Outcome PO11

The development retains natural fish habitat and features such as shade, pools, riffles, rock outcrops and boulders, wherever possible.

No acceptable outcome is prescribed.

Whitewater rafting bypass channel

Author's Note: 11.1

- It is important for designers to avoid the 'Field of Dreams' concept.
- The 'Field of Dreams' concept takes its name from the Kevin Costner movie of the same name, where a baseball field was constructed in a cornfield in order to attract past baseball players.
- Introducing waterway habitats that are not normally associated with a given waterway may attract non-native wildlife.

Creek rehabilitation master plan

Information to be submitted

Submit supporting material, including plans and discussion, to demonstrate how the development retains natural fish habitats and habitat complexity.

Sediment basins linked to new road works

Author's Note: 11.2

- It is noted that many road crossings are constructed with the aid of temporary sediment basins, which are often converted into stormwater treatment ponds after completion of the construction works.
- These stormwater treatment ponds ideally should attract aquatic life to help control mosquito breading.

Performance Outcome PO12 – All crossings

Meandering waterway (Qld)

Performance Outcome PO12

The design, construction and maintenance of the development does not result in straightening of meandering waterways.

No acceptable outcome is prescribed.

Creek straightened between road & ovals

Author's Note: 12.1

- Some realignment of the channel may be required in order to reduce the length of the culvert, and as a result, reduce the overall impact on fish passage.

Straightened waterway

Information to be submitted

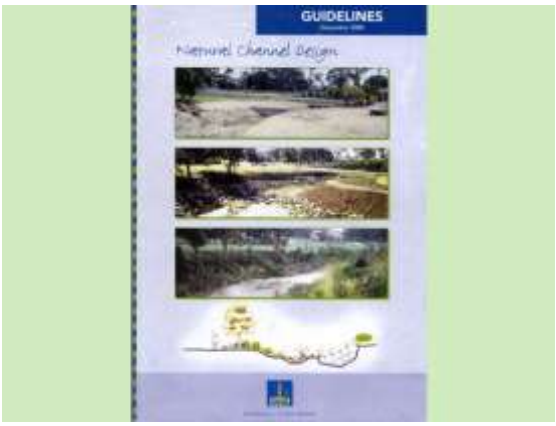
Demonstrate that the design, construction and maintenance of the development avoids straightening natural meanders of the waterway.

Temporary machinery access to site

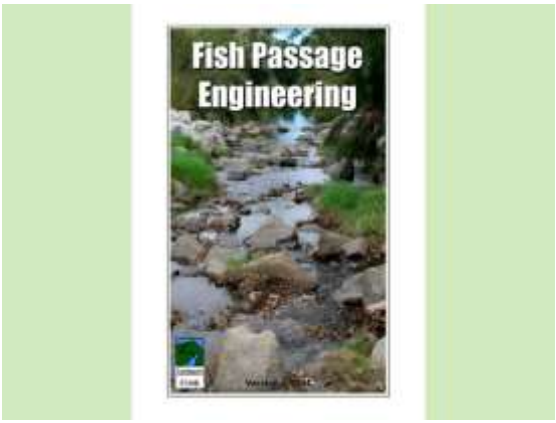
Author's Note: 12.2

- In order to provide access for equipment while constructing the waterway crossing, it may be necessary to modify aspects of the waterway banks.
- In some cases it can be judged more important to disturb (straighten) one side of the waterway in order to minimise disturbance to high-valued riparian vegetation on the opposite bank.
- Construction access can be difficult when there is healthy riparian vegetation.

Performance Outcome PO13 – All crossings

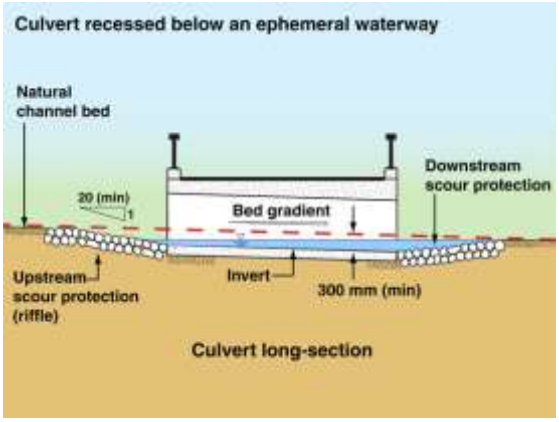


Natural Channel Design (2000)



Fish Passage Engineering (due late 2024)

Constructed rock riffle (Qld)



Recessed culvert

Performance Outcome PO13

Where channels are to be significantly modified, the design and construction of the development replicates natural waterways and habitat features.

No acceptable outcome is prescribed.

Author's Note: 13.1

- The reader may find useful information in the Catchments and Creeks' field guide:
  - *Fish Passage Engineering* (expected release in late 2024, early 2025)
- Also refer to the Brisbane City Council publication:
  - *Natural Channel Design* (2000)

Information to be submitted

If it has been demonstrated that significant modification to the waterway cannot be avoided and there is a functional requirement for the development to be located within the waterway, discuss the natural habitat features that are incorporated into the development.

This could include pools, riffles, shaded and open sections, deep and shallow sections, and different types of substrata.

Provide a revegetation plan if relevant.

Author's Note: 13.2

- Designers should generally avoid introducing 'natural habitat features' that are not normally found at the location of the waterway crossing.
- however, in some cases, new features are justifiable in order to compensate for the loss of natural features that cannot be easily reproduced (refer to expert advice).
- Pools and riffles may be required in a waterway in order to control flow depths through a culvert.

Performance Outcome PO14 – All crossings

Exposure of sewer by lowering water levels

Performance Outcome PO14

Where waterway barrier works will modify water levels or flow characteristics of the waterway, existing up and downstream structures are upgraded to provide adequate fish passage in accordance with the new levels or flow characteristics.

No acceptable outcome is prescribed.

Property boundaries

Author's Note: 14.1

- A worthy outcome that should be supported.
- However, this Outcome requires the 'developer' of the waterway crossings to have some level of authority over the existing upstream and downstream structures.

Site map

Information to be submitted

Identify and discuss the extent of the changes to flow regimes and water levels of the waterway.

Identify all structures within the waterway or catchment that will be affected by the proposed waterway barrier works and the impact the works will have on their ability to provide fish passage.

Clearly outline any activities or measures that will be undertaken to mitigate impacts to fish passage,

Barrier formed by lowering of tailwater

Author's Note: 14.2

- A worthy outcome that should be supported.

Performance Outcome PO15 – All crossings

Dedicated low-flow fishway in a culvert

Performance Outcome PO15

The development is designed, constructed and maintained to provide water exchange sufficient to maintain or improve water quality and flow conditions on which fisheries resources depend.

No acceptable outcome is prescribed.

Controlling the passage of low flows

Author's Note: 15.1

- Not likely to be relevant to the design of a waterway crossing.
- It is not lawful to specify 'maintenance' requirements in a development code; however, a code can request a Maintenance Plan.
- The regulation of maintenance must exist within Acts and Regulations, not codes.

Tidal culvert (NSW)

Information to be submitted

Identify if the extent and duration of existing tidal or freshwater inundation and drainage patterns will be restricted or impacted either temporarily or permanently by the proposed work . . .

Confirm if the duration of tidal inundation or hydrological regime will change as a result of the works and any new infrastructure, and detail and quantify the impacts to fisheries resources.

Retention of a local fishing hole (NSW)

Author's Note: 15.2

- Upgrading an existing culvert (i.e. increasing its flow capacity) could:
  - reduce temporary water detention upstream of the culvert during flood events, which could . . .
  - increase peak flows during some flood events.

Performance Outcome PO16 – All crossings

Acid sulfate affected waterway

Performance Outcome PO16

Development likely to cause drainage or disturbance to acid sulfate soils prevents the release of contaminants and impacts on fisheries resources and fish habitats.

No acceptable outcome is prescribed.

Queensland ASS Manual (2002)

Author's Note: 16.1

Queensland Acid Sulfate Soil Technical Manual (2002)

Dear SE, Moore NG, Dobos SK, Watling KM and Ahern CR (2002). Soil Management Guidelines. In Queensland Acid

Sulfate Soil Technical Manual. Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia.

Runoff from an exposed acid sulfate soil

Information to be submitted

Identify if the proposal will expose, disturb or drain acid sulfate soils.

Provide an overview of potential acid sulfate soil management and measures to minimise impacts of acid sulfate soils on fisheries resources and fish habitats.

Demonstrate that the proposed management is consistent with the current version of the *Queensland acid sulfate soil technical manual*.

Damage to culvert by acidic waters

Author's Note: 16.2

- If acidic water can 'eat' concrete, imagine the potential impacts on aquatic life.

Performance Outcome PO17 – All crossings

Placement of scour protection (Qld)

Performance Outcome PO17

The development is designed, constructed and maintained to not result in adverse impacts to beds, banks and vegetation adjacent to the permanent development footprint.

No acceptable outcome is prescribed.

Temporary bypass road (Bruce Hwy)

Author's Note: 17.1

- It would be very difficult, if not impossible, to construct a waterway crossing without causing adverse impacts to beds, banks and vegetation adjacent to the permanent development footprint.
- Typical disturbances 'adjacent to the permanent development footprint' include:
  - site access
  - equipment access into the channel
  - temporary public/road bypass
  - removal of flood debris.

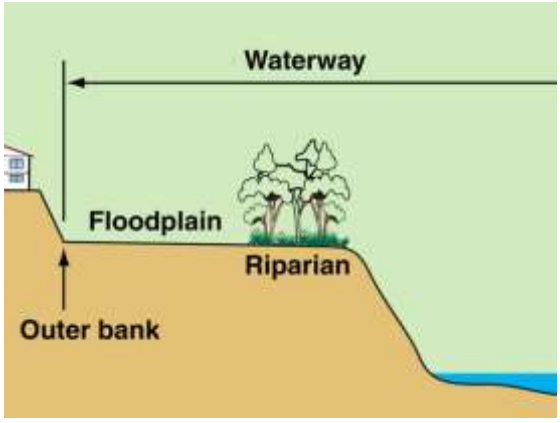
Wording!

Information to be submitted

Demonstrate how the design of the development prevents adverse impacts to the bed, banks and adjacent vegetation of the waterway.

Demonstrate that any temporarily disturbed areas adjacent to the permanent footprint are kept to a minimum.

Demonstrate that the use of any machinery required is outside of the waterway and the size of machinery and extent of impacts to adjacent areas are minimised.



Outer bank

Author's Note: 17.2

- There appears to be a contradiction in this wording:
  - firstly it must be demonstrated that impacts are 'prevented', but then
  - temporary disturbances are to be 'kept to a minimum'.
- Conditions will always exist where machinery must enter the waterway.
- Also note that this Code defines a waterway as extending to the limits of flooding (i.e. the full floodplain).

Performance Outcome PO18 – All crossings

Bank disturbance upstream of bridge

Discontinuity in bank profile post works

Site revegetation (Qld)

Post-revegetation site inspection (Qld)

Performance Outcome PO18

After completion of works, disturbed areas of the bed and banks of the waterway outside the permanent development footprint are returned to their original profile and stabilised to promote regeneration of natural fish habitats.

No acceptable outcome is prescribed.

Author's Note: 18.1

- It would appear that this Outcome overlaps with the *Water Act 2000*, and the Waterway Permit system operated by Natural Resources.
- It is not likely to be appropriate to return the banks 'to their original profile' if:
  - the existing bank profile is unstable
  - stabilising the existing bank profile requires unnecessary hard engineering
  - the bank profile needs to blend smoothly with the new works.

Information to be submitted

Detail any reprofiling, revegetation or other methods proposed within disturbed areas of the bed, banks and immediately adjacent to the waterway.

Detail any proposed monitoring to ensure the successful establishment of fish habitat regeneration within, and adjacent to, the work site.

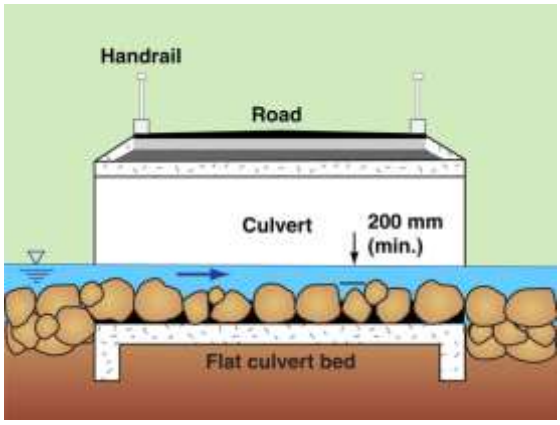
Outline the timeline and quantitative benchmarks that will be used to measure the success of the regeneration.

Author's Note: 18.2

- 'As-constructed' plans should be submitted showing the actual extent of site disturbance and revegetation.

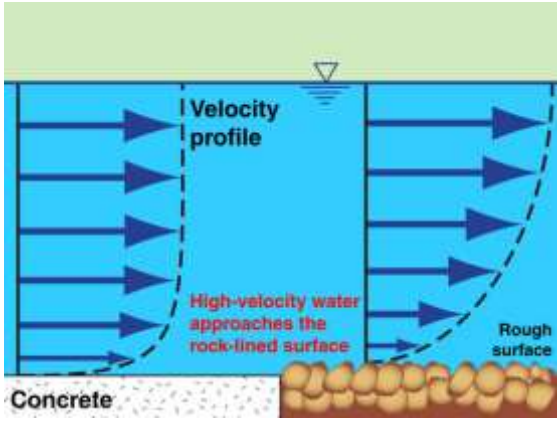
Performance Outcome PO19 – All crossings

Loose bed rock (NSW)



Rocks grouted to the culvert floor

Natural sedimentation (NSW)



Developing a favourable boundary layer

Performance Outcome PO19

The development is designed and constructed to maintain or restore the natural substrate of the waterway bed.

No acceptable outcome is prescribed.

Author's Note: 19.1

- This outcome may not be the best possible outcome for fish passage.
- In clay-based waterways, the natural substrate is most unlikely to be suitable within a culvert for the following reasons:
  - the bed material is usually stabilised with aquatic plants, which will not establish inside a culvert cell
  - rock often needs to be grouted to the culvert bed in order to achieve the natural bed roughness (i.e. without plants).

Information to be submitted

Demonstrate that the design of the waterway barrier works allows for deposition and retention of natural sediments.

Demonstrate that any permanent structures proposed are designed to allow replication of the natural substrate in terms of size and consistency.

For example, demonstrate that any scour protection is buried 300 mm below bed level and backfilled with natural bed material.

Author's Note: 19.2

- With regards to burying scour protection 300 mm below the final bed level, such an outcome may not be desirable for the following reasons:
  - the surface roughness of an outlet rock scour pad helps to develop a favourable boundary layer condition in the flow, which helps to reduce bed scour downstream of the culvert
  - the deeper the scour protection is buried, the greater the overall disturbance to the waterway.

Performance Outcome PO20 – All crossings

Recreational fishing

Performance Outcome PO20

Development does not adversely impact on community access to tidal land and waterways.

No acceptable outcome is prescribed.

Open public access

Author's Note: 20.1

- Unsure if this Outcome can lawfully be regulated by Fisheries?
- Community access for what purpose?
- Does this outcome refer to:
  - existing community access
  - access through private property
  - access for swimming?
- What if there are safety issues:
  - allowing public access to waterways adjacent to dams and weirs?

Safety fencing (Qld)

Information to be submitted

Demonstrate that the community use of, and access to, tidal land and waterways will not be adversely impacted.

If any temporary impacts to community access are required, detail the extent of the impacts and management of this issue.

Warning sign (NT)

Author's Note: 20.2

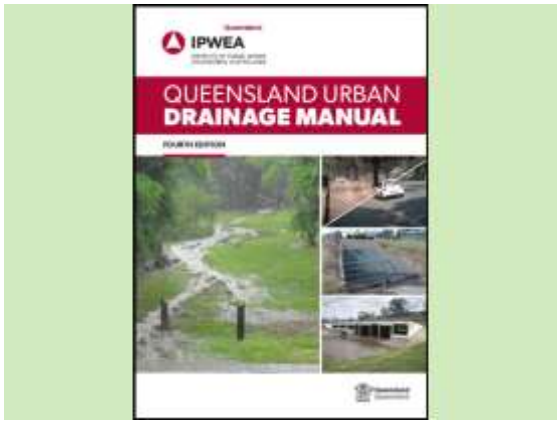
- The management of safety risks must take priority over free public access.

Performance Outcome PO21 – All crossings

Recreational fishing (SA)

Recreational fishing (Qld)

Community consultation (Qld)



Queensland Urban Drainage Manual

Performance Outcome PO21

Development does not adversely impact on community access to fisheries resources and fish habitats including recreational and Indigenous fishing access.

No acceptable outcome is prescribed.

Author's Note: 21.1

- This Outcome appears to be more appropriate than PO20, so why have PO20?

Information to be submitted

Discuss existing community access arrangements to fisheries resources.

Discuss all aspects of the proposed development that have been incorporated to maintain community access arrangements to fisheries resources and fish habitats.

Detail any industry consultation undertaken, including any agreed outcomes.

Detail any fisheries adjustment initiatives that have been, or will be, undertaken to compensate for any adverse impacts.

Author's Note: 21.2

- Readers should note the recommendations in the *Queensland Urban Drainage Manual* (QUDM) with regards to Safety Aspects.

Performance Outcome PO22 – All crossings

Commercial fishing (NSW)

Performance Outcome PO22

Development does not adversely impact on commercial fishing access and linkages between a commercial fishery and infrastructure, services and facilities.

No acceptable outcome is prescribed.

Commercial fishing (NSW)

Author's Note: 22.1

- Unlikely to be an issue for waterway crossings.

Port services

Information to be submitted

Identify existing commercial fishing activities.

Discuss all aspects of the proposed development that have been incorporated to maintain commercial fishing access.

Detail any industry consultation undertaken, including any agreed outcomes.

Detail any fisheries adjustment initiatives that have been, or will be, undertaken to compensate for any adverse impacts to commercial fishing access arrangements.

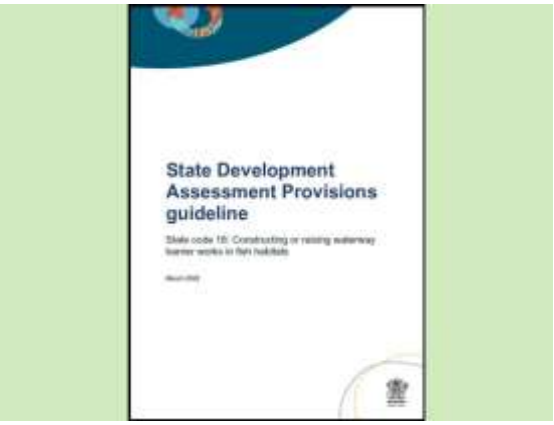
Commercial fishing (Qld)

Author's Note: 22.2

- Unlikely to be an issue for waterway crossings.

Performance Outcomes for Fishways, PO23 to PO31

Introduction



Raising Waterway Barrier Works, 2022

State Code 18

State Development Assessment Provisions (SDAP) guideline – State code 18: Constructing or raising waterway barrier works in fish habitats.

The Department of Agriculture and Fisheries.

State of Queensland, 2022.

Fisheries Act 1994

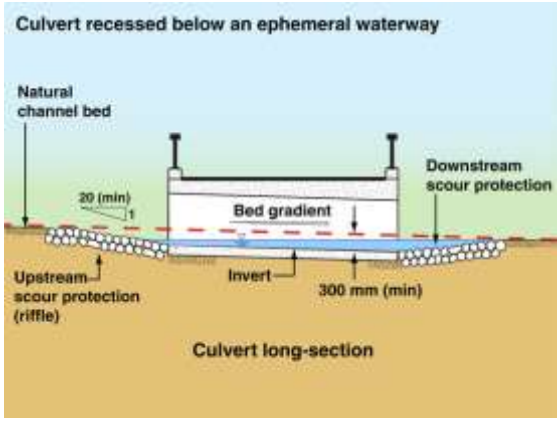
Defining a fishway

- For a definition of a fishway, the Code refers to the *Fisheries Act 1994.*
- A fishway means 'a fish ladder, or another structure, or device, by which fish can pass through, by or over waterway barrier works'.
- A non-mechanical fishway, such as **rock ramp**, cone, or vertical slot.

Rock ramp upstream of a culvert (NSW)

Rock ramps

- Rock ramps are also known as:
  - rock chutes
  - grade control structure
  - drop structure
  - rock riffle.
- The term 'ramp' is normally used when referring to fish passing up a ramp.
- The term 'chute' is normally used when referring to stream flows passing down a chute.



Recessed culvert

Use of rock ramps at waterway crossings

- Rock ramps can be used to:
  - raise low-flow tailwater levels to provide better fish passage through a culvert
  - stabilise the inlet and outlet channels of a recessed culvert (i.e. a culvert designed to exist as part of a 'pool')
  - raise upstream water levels to return flow conditions to a previous state, or to maintain ideal low-flow conditions at an upstream structure (as per PO14).

Performance Outcome PO23

Design phase

Performance Outcome PO23

Having regard to the hydrology of the site and fish movement characteristics, the fish way is capable of operating, and will operate:

1. for as long as the waterway barrier work is in position; and
2. whenever there are inflows into the impoundment or waterway, release out of the impoundment and during overtopping events; and
3. when the impoundment is above dead storage level.

Damaged rock chute

Author's Note: 23.1

- State Code 18 is a development code.
- Such a code should refer only to the development phase, not to the operational phase.
- However, a code can request an *Operation and Maintenance Plan*.
- The regulation of ongoing maintenance must exist within Acts, not codes.

Construction supervision

Information to be submitted

Provide evidence that the fish way has been designed by a person that is suitably qualified and experienced in fish passage biology.

Demonstrate that the fish way construction will be overseen by a person that is suitably qualified and experienced in fish passage biology.

Detail the hydrology of the site.

Detail the fish community at the site.

Detail when the fish way will operate in relation to the proposed works.

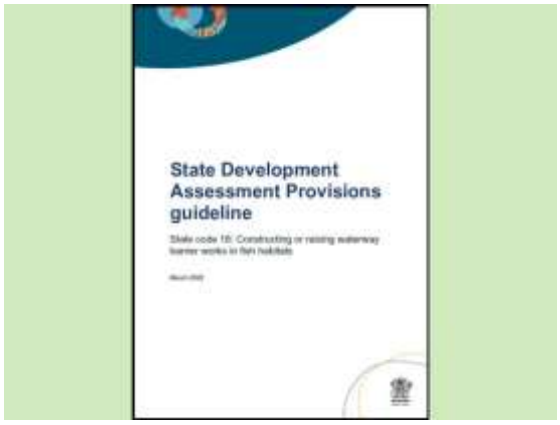
Professional Engineering Act 2002

Author's Note: 23.2

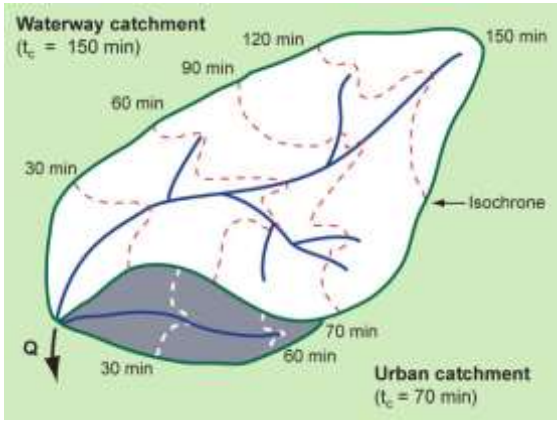
- Are all constructed rock riffles now to be designed by biologists?
- I believe this is in contradiction to the *Professional Engineering Act 2002*.
- Is the construction of all rock riffles now to be observed/supervised by a biologist?
- If a demonstrated design procedure is followed, then there should be no need for this added expense.
- Inspections are one thing, but overseeing the construction is a much bigger issue.

Performance Outcome PO24

Waterway catchment plan



Raising Waterway Barrier Works, 2022



Catchment modelling

Ephemeral waterway (Qld)

Performance Outcome PO24

The development is designed, constructed and maintained to ensure the hydrology allows for fish movement for the life of the waterway barrier works.

No acceptable outcome is prescribed.

Author's Note: 24.1

- I do not believe that it is lawful to specify operational issues within a development code.

Information to be submitted

Demonstrate that the expected hydraulic characteristics of the waterway barrier works will allow the fish way and any associated fish passage mechanisms to operate to provide adequate fish passage.

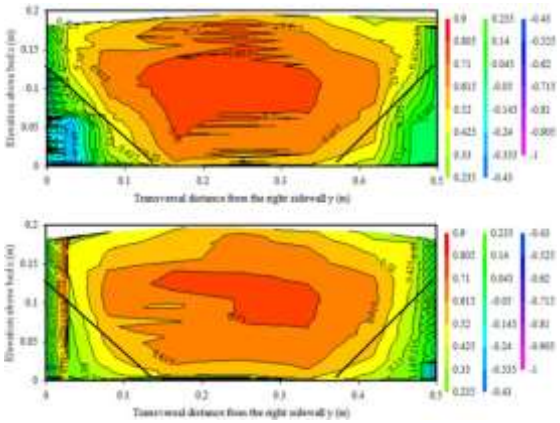
Detail the natural hydrology within the catchment.

This includes whether waterways typically have a standing level of water or contain flows that are ephemeral.

Author's Note: 24.2

- This information would have already been prepared in response to Performance Outcomes PO01 to PO22.

Performance Outcome PO24 (additional information to be submitted)



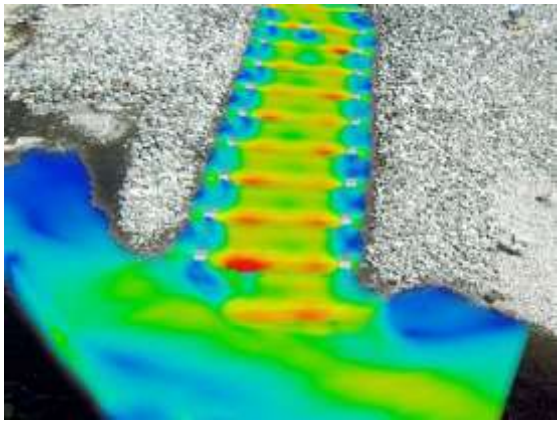
CFD modelling

Information to be submitted

Demonstrate how the fish way is designed, constructed and maintained to maximise the natural hydrology of the system and provide for fish movement.

This may include, for example, computational fluid dynamics and other modelling for mechanical fish ways.

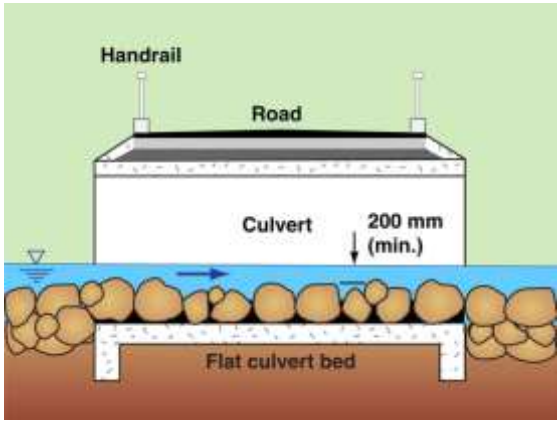
Demonstrate that the allocation of water resources required for fish passage is adequate and will be made available for the effective operation of the fish way.



CFD modelling of a fish ladder

Author's Note: 24.3

- Computational Fluid Dynamics (CFD) modelling of constructed rock riffles would be a pointless exercise which would provide no useful information.
- Flow conditions down a rock riffle (rock ramp) are so variable, that the flow conditions at any instant in time are irrelevant.
- Also, you will not know the actual profile of the riffle's surface at the time of modelling, and this surface will change over time.



Previously-recommended flow condition

Information to be submitted

Detail the operational range of the fish way.

If possible, the lower operational range of the fish way should be at least 0.5 metres below the minimum headwater drawdown level* and 0.5 metres below the minimum tailwater level at the site.

If this is not achievable, adequate justification must be provided demonstrating why it is not achievable.

Recessed culvert (NSW)

Author's Note: 24.4

- A minimum flow depth of 500 mm is unrealistic for constructed rock riffles.
- It is not realistic to require the minimum operational water level of a constructed rock riffle/chute to be 500 mm below the minimum tailwater level at the site.

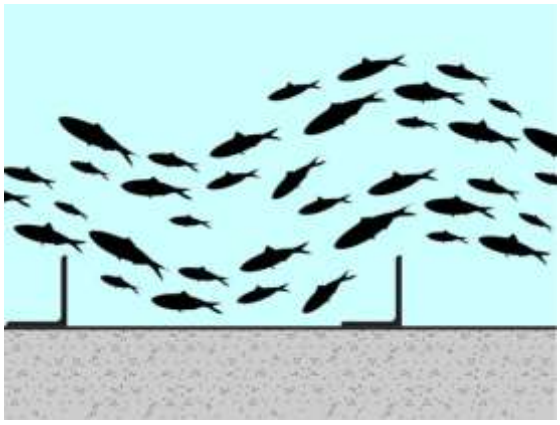
Performance Outcome PO24 (additional information to be submitted)

Fish migration

Information to be submitted

Discuss the expected timing of fish migrations and how the design and construction of the fish way ensures suitable hydrological conditions that will avoid any delays in fish movement during times of spawning migrations.

Demonstrate how delays in fish movement will be minimised immediately following times of flow.



Fish migration

Author's Note: 24.5

- Unlikely to be relevant to a culvert fishway or the construction of a supporting rock ramp.

Low flows directed into central cell

Information to be submitted

Demonstrate that fish are able to exit upstream and downstream fish ways at water level over the full range of headwater and tailwater conditions.

Demonstrate that exits are located to avoid fish being washed back over the spillway during overtopping.

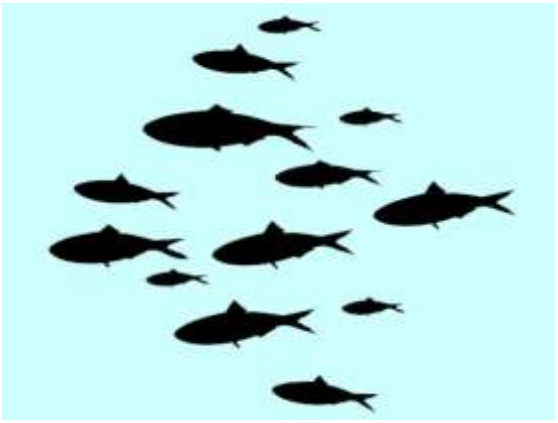
Demonstrate that there are continuous attraction flows at the fish way entrance under all flow conditions within the fish way's operating range.

Poor location of a fishway outlet

Author's Note: 24.6

- Not appropriate for constructed rock riffles.
- It is important to ensure the outlet of any fishway that passes through a culvert, discharges at or near the location where fish will be expected to collect.
- Problems can occur if the entry point of the fishway (i.e. its flow outlet) is downstream of the actual fish barrier where fish are likely to collect.

Performance Outcome PO24 (additional information to be submitted)



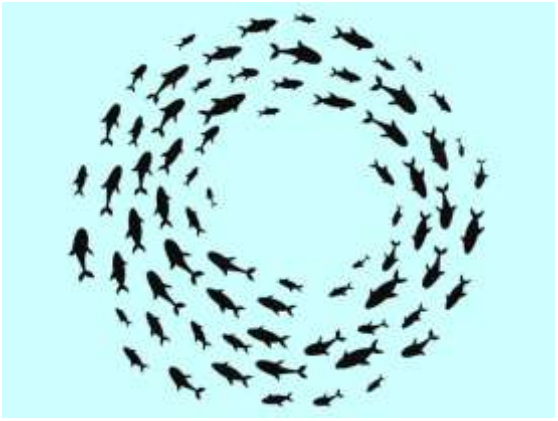
Fish migration

Information to be submitted

Demonstrate that, if required, additional means of fish attraction are included in the fish way design.

Demonstrate that attraction flow velocities are suitable and variable to attract the whole fish community and expected variations in seasonal biomass.

Demonstrate that fish attracted to the spillway or outlet flows are able to access the fish way without having to swim back downstream.



Fish migrating through a large eddy

Author's Note: 24.7

- With respect to culvert fishways and constructed rock riffles, this clause is the same as the previous clause.

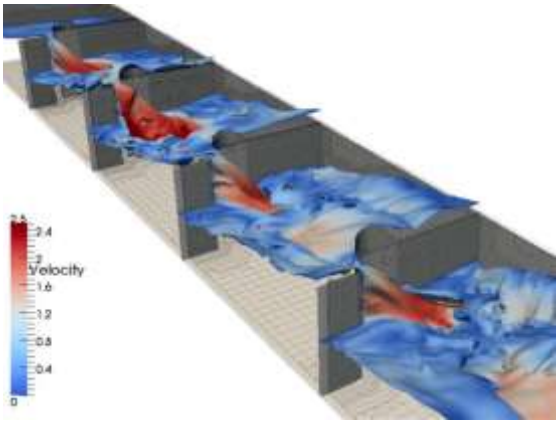
Monitoring flow velocity and turbulence

Information to be submitted

Demonstrate that adequate hydraulic conditions and minimum water depth for fish passage is maintained throughout the fish way.

Demonstrate that turbulence throughout the fish way is suitable for the whole fish community within the operating range of the fish way.

Demonstrate that the exit conditions are adequate for downstream fish passage.



Modelling flow velocity and turbulence

Author's Note: 24.8

- I am unsure if there is sufficient knowledge available to:
  - 'demonstrate that turbulence throughout the fish way is suitable for the whole fish community within the operating range of the fish way'.
- It seems to be a significant waste of community resources to request the same modelling and reporting each time the same waterway crossings are designed.

Performance Outcome PO24 (additional information to be submitted)

Constructed rock ramp/riffle/chute (Qld)

Information to be submitted

For non-mechanical style fish ways, such as rock ramp, bypass, trapezoidal and cone fish ways, demonstrate that appropriate resting areas are available for fish moving through the fish way.

If possible, these should be vegetated and/or include suitable refuge comparable to natural waterway conditions.

Natural rock riffle (Qld)

Author's Note: 24.9

- How do you provide resting areas for fish moving up a rock ramp?
- How do you demonstrate that your design provides appropriate resting areas for fish moving up a rock ramp?

Mechanical fishway in a culvert (Qld)

Information to be submitted

For mechanical style fish ways, such as lock and lift fish ways, demonstrate that the holding chamber is adequate for the expected fish biomass, taking into consideration migration periods and any potential future increases in biomass.

Provide a maintenance plan, including contingency measures.

Refer to the beginning of section 5.3 for the details to be included.

Mechanical fishway outside a culvert

Author's Note: 24.10

- The provision of a Maintenance Plan is a reasonable request.
- This Maintenance Plan can be passed onto the future owner/operator of the waterway crossing.

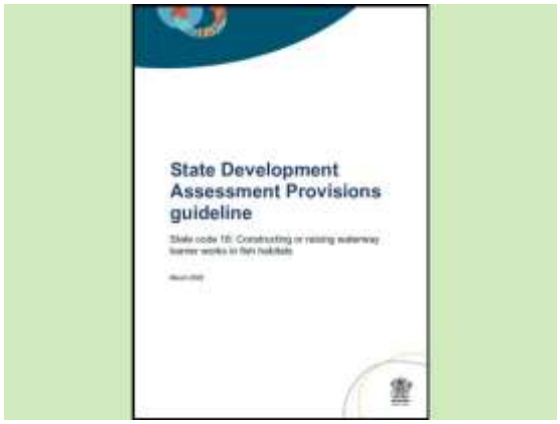
Performance Outcome PO25

Fish passage (SA)

Performance Outcome PO25

Fish ways are designed, constructed and maintained to not adversely impact on fish and fish movement.

No acceptable outcome is prescribed.



Raising Waterway Barrier Works, 2022

Author's Note: 25.1

- It is not lawful to specify 'maintenance' requirements in a development code.
- This information would have already been prepared in response to Performance Outcomes PO01 to PO22.
- Again, this Outcome refers to an absolute outcome of no impact.

Skylight placed in a box culvert (Qld)

Information to be submitted

Provide evidence that appropriate light levels are maintained at entrances, exits and throughout the fish way to ensure successful use by fish.

Demonstrate that the fish way is designed and maintained so that rubbish and debris do not impede fish passage or cause blockages or damage the fish way.

Provide a maintenance plan that includes contingency measures to ensure the continued and effective operation of the fish way.

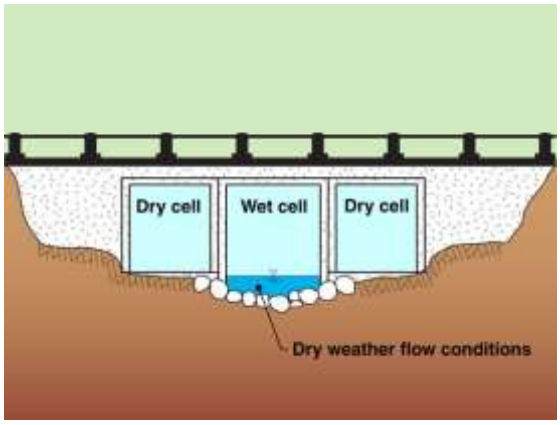
Full debris blockage of culvert entrance

Author's Note: 25.2

- To the best of my understanding, nobody has been able to document what are appropriate light levels within a culvert.
- It would be impossible to design or maintain a culvert in a manner that prevents debris blockage from time to time.
- The designer/developer are unlikely to be responsible for, or have any control over, ongoing culvert maintenance.

Performance Outcome PO26

Baffles used to direct flows in the fishway



Low flow passing through central cell

Low flows directed into central cell

Low-flow channel under an arch (NSW)

Performance Outcome PO26

Fish ways are designed, constructed and operated to direct release water through the fish way as a priority over the outlet works.

No acceptable outcome is prescribed.

Author's Note: 26.1

- A design problem can exist where the waterway's low-flow channel first directs water into one of the central cells of the culvert, while most of the fish passage features are located in the cells adjacent to the banks, as per:
  - Acceptable Outcome: AO5.16, 'The outermost culvert cells incorporate roughening elements such as baffles on their bank-side sidewalls.'

Information to be submitted

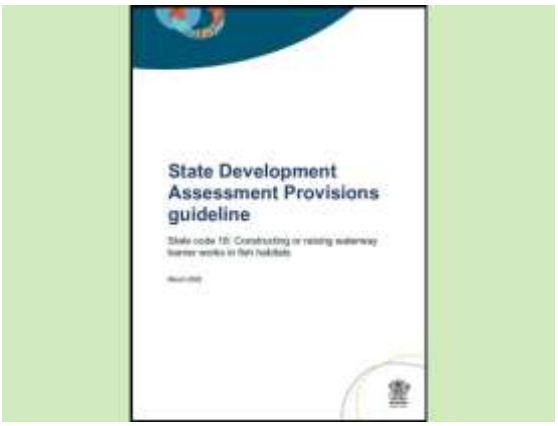
Demonstrate that the design of the fish way allows water to be released through the fish way as a priority over the outlet works.

Demonstrate that sufficient water releases, including environmental flows, are directed through the fish way as a priority over any outlet works to ensure the effective operation of the fish way.

Author's Note: 26.2

- Unlikely to be relevant to culvert fishways and constructed rock riffles.

Performance Outcome PO27

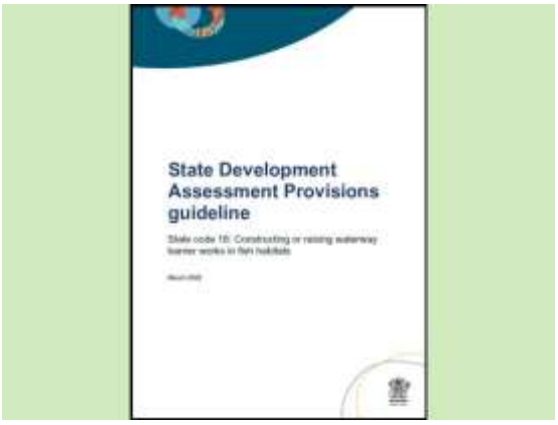


Raising Waterway Barrier Works, 2022

Performance Outcome PO27

Fish ways are designed, constructed and operated to ensure flows and releases of water do not result in adverse impacts to fish or fish passage.

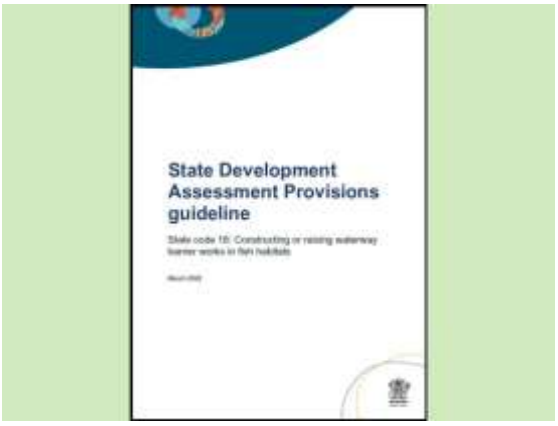
No acceptable outcome is prescribed.



Raising Waterway Barrier Works, 2022

Author's Note: 27.1

- Unlikely to be relevant to culvert fishways and constructed rock riffles.



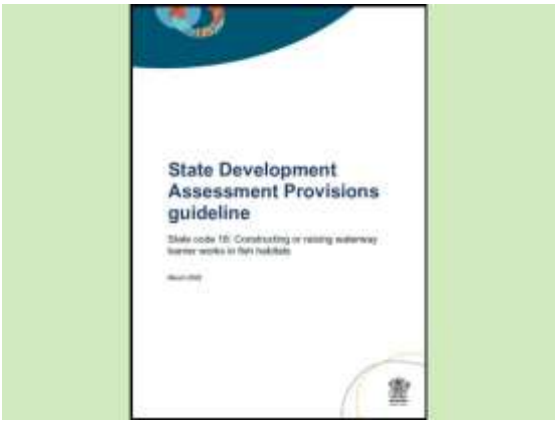
Raising Waterway Barrier Works, 2022

Information to be submitted

Demonstrate that flows will be provided for the fish way as a priority over all other components of the waterway barrier works to minimise delays in fish passage.

Provide evidence that all flows and releases initiate and terminate adjacent to the fish way or are directed parallel to the fish way entrance.

Demonstrate that all flows are transferred to the fish way as soon as possible during a flow recession.



Raising Waterway Barrier Works, 2022

Author's Note: 27.2

- With respect to culvert fishways and constructed rock riffles, this outcome appears to be the same as PO26.

Performance Outcome PO28

Recently-installed galvanised steel baffles

Rusted steel baffles 13 years later

Plastic baffles (USA)

Culvert de-silting

Performance Outcome PO28

The development is designed, constructed and operated to ensure fish way operational issues are promptly rectified for the life of the fish way including:

1. all components are designed to be durable, reliable and adequately protected from damage during high flow events
2. all components can be replaced
3. a contingency plan ensures provision of alternate adequate fish passage during the fish way re-instatement process.

Author's Note: 28.1

- Loose rock roughness placed on a culvert floor will likely be subject to displacement during high flows.
- However, because loose rocks (i.e. rocks not grouted to the floor) should only be used in gravel-based waterways, the intent is for any rocks displaced by flood events to be replaced by natural migration of the bed substrate.
- Steel baffles will rust over time.

Information to be submitted

Detail the structural integrity and durability of fish way components and demonstrate that they are unlikely to fail or become damaged during high flow events or other environmental conditions such as high winds.

Provide a maintenance plan including contingency measures that detail how fish passage is provided in the event that the fish way becomes non-operational, the timeframe associated with implementation and the expected timeframe to rectify any issues.

Author's Note: 28.2

- The provision of a Maintenance Plan is a reasonable request.
- This Maintenance Plan can be passed onto the future owner/operator of the waterway crossing.

Performance Outcome PO29

Monitoring station (Qld)

Site access for monitoring (Qld)

Water quality monitoring

Water quality monitoring station

Performance Outcome PO29

The development is designed to allow for installation of monitoring equipment and to allow access for monitoring and maintenance.

No acceptable outcome is prescribed.

Author's Note: 29.1

- Such a request would only be reasonable at locations focused on the protection of threatened species.

Information to be submitted

Demonstrate that the design of the development allows for the installation of monitoring equipment.

Demonstrate that the development allows access for personnel, cars and boats for monitoring, maintenance and operational purposes at the fish way entry and exit.

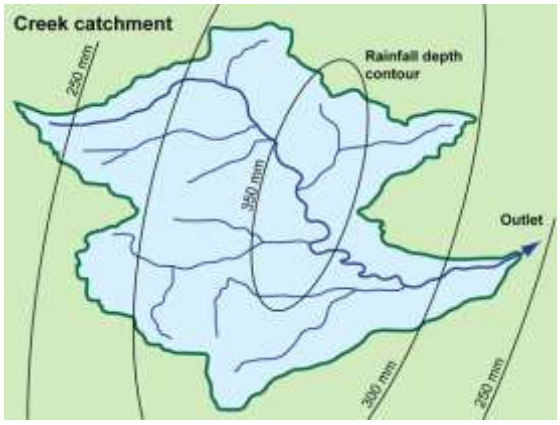
Ensure that relevant health and safety procedures are in place to allow effective monitoring over the range of headwater and tailwater conditions.

Author's Note: 29.2

- Such a request would only be reasonable at locations focused on the protection of threatened species.

Performance Outcome PO30

Waterway catchment plan



Catchment hydrology

pH testing

Water quality samples

Performance Outcome PO30

Fish ways are designed, constructed and operated to source water supply from surface water or equivalent water quality.

No acceptable outcome is prescribed.

Author's Note: 30.1

- Always the case for waterway crossings.

Information to be submitted

Detail the location for all sources of water used in fish way operation, including for any supplementary attraction flows if required.

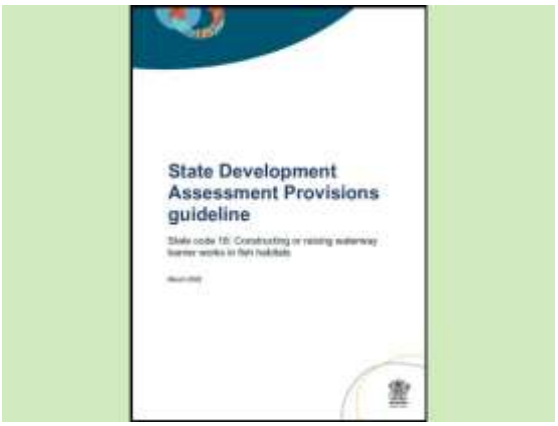
Demonstrate that the characteristics and quality of the surface water being released is similar to that of the receiving environment (e.g. similar pH and chemical composition).

Demonstrate that the quality of water used and released is appropriate to maintain aquatic ecosystem values . . .

Author's Note: 30.2

- At a waterway crossing, the source of water is the upstream drainage catchment.
- The operators of the waterway crossings cannot be held responsible for the quality of water approaching the crossings.

Performance Outcome PO31

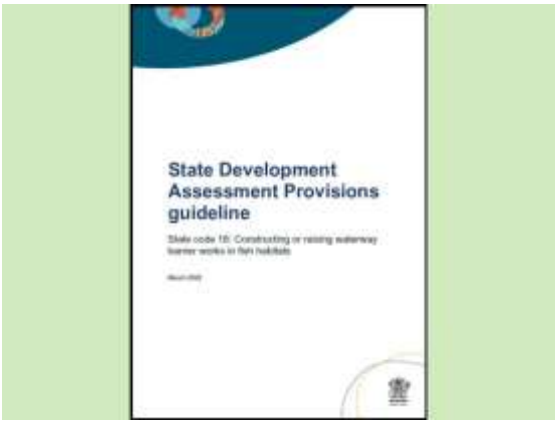


Raising Waterway Barrier Works, 2022

Performance Outcome PO31

Tailwater control structures are designed, constructed and maintained to allow for fish passage.

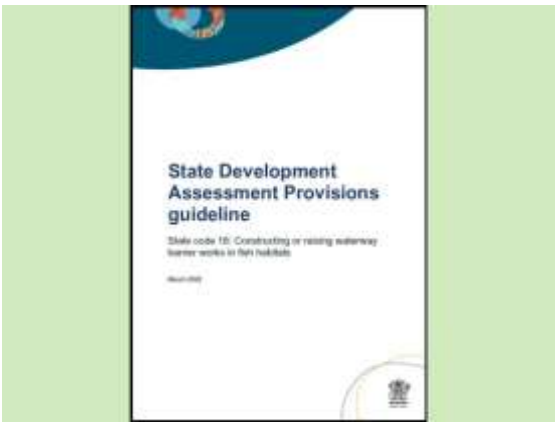
No acceptable outcome is prescribed.



Raising Waterway Barrier Works, 2022

Author's Note: 31.1

- Unlikely to be relevant to culvert fishways and constructed rock riffles.

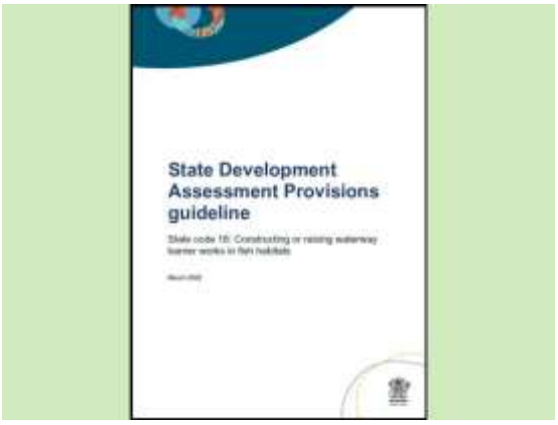


Raising Waterway Barrier Works, 2022

Information to be submitted

Detail any structures downstream of the fish way that act as a tailwater control structure.

Demonstrate that the tailwater control structures are designed to provide for adequate fish passage and will not compromise the ability for fish to access upstream fish habitats, including a fish way where relevant.



Raising Waterway Barrier Works, 2022

Author's Note: 31.2

- Unlikely to be relevant to culvert fishways and constructed rock riffles.

Glossary (State Code 18)

Meaning of ‘fish’ (State Code 18)

Australian Smelt (Queensland Museum)

Fish

- Fish means an animal (whether living or dead) of a species that throughout its life cycle usually lives:
  - in water (whether freshwater or saltwater)
  - in or on foreshores
  - in or on land under water.

Crayfish

Included in the definition of ‘fish’

- Fish includes:
  - prawns, crayfish, rock lobsters, crabs and other crustaceans
  - scallops, oysters, pearl oysters and other molluscs
  - sponges, annelid worms, bêche-de-mer and other holothurians
  - trochus and green snails.

Crocodile

What is <u>not</u> included in the term ‘fish’

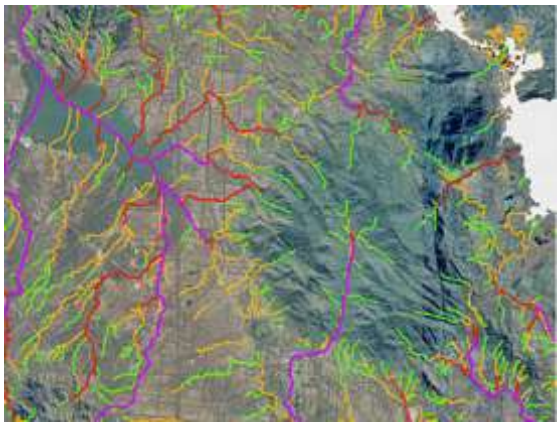
- However, fish does not include:
  - crocodiles
  - protected animals under the *Nature Conservation Act 1992* for which a wildlife authority or a protected area authority under that Act is required to take, keep, use, move or deal with the animal
  - pests under the *Medicines and Poisons Act 2019*
  - animals prescribed by regulation not to be fish.

Fish eggs

Also included in the definition of ‘fish’

- Fish also includes:
  - the spat, spawn and eggs of fish
  - any part of fish or spat, spawn or eggs of fish
  - treated fish, including treated spat, spawn and eggs of fish
  - coral, coral limestone, shell grit or star sand
  - freshwater or saltwater products declared under a regulation to be fish.

Fish habitat, fish way, fisheries resources, and marine plant



Example of colour-coded waterways

Fish habitat

- Refer to the *Fisheries Act 1994.*
- Note: Fish habitat includes land, waters and plants associated with the life cycle of fish, and includes land and waters not presently occupied by fisheries resources.

Retro-fitted fishway (Walaman)

Fish way (or fishway)

- Refer to the *Fisheries Act 1994.*
- Note: Fish way means a fish ladder or another structure or device by which fish can pass through, by or over waterway barrier works.

Marine plants (seagrass)

Fisheries resources

- Refer to the *Fisheries Act 1994.*
- Note: Fisheries resources includes fish and marine plants.

Mangroves

Marine plant

- Refer to Section 8, the *Fisheries Act 1994.*
- Marine plant includes the following:
  - a plant (a tidal plant) that usually grows on, or adjacent to, tidal land, whether it is living, dead, standing or fallen
  - material of a tidal plant, or other plant material on tidal land
  - a plant, or material of a plant, prescribed by regulation to be a marine plant.

Waterway, waterway barrier works, and wetland

Waterway (watercourse/creek/stream)

Waterway

- Refer to the *Fisheries Act 1994.*
- Note: Waterway includes a river, creek, stream, watercourse, drainage feature or inlet of the sea.
- For further guidance see fact sheet Maintaining Fish Passage in Queensland: What is a waterway?, Department of Agriculture, Fisheries and Forestry, 2014.

Causeway

Waterway barrier works

- Note: Waterway barrier works means a dam, weir or other barrier across a waterway if the barrier limits fish stock access and movement along a waterway.
- For further guidance see the fact sheets:
  - *Maintaining Fish Passage in Queensland: What is a waterway barrier work?*
  - *Maintaining Fish Passage in Queensland: What is not a waterway barrier work?,* 2014, Department of Agriculture, Fisheries and Forestry.

Freshwater wetland

Saline (tidal) wetland

Wetland

- Note: Wetlands are areas of permanent or periodic/intermittent inundation, with water that is static or flowing fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres.
- To be a wetland the area must have one or more of the following attributes:
  - at least periodically the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle
  - the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers
  - the substratum is not soil and is saturated with water, or covered by water at some time.
- The wetland definition used on WetlandInfo is based on the Ramsar Convention (1971).

Identification of Channel Width and the Low-flow Channel

(Developed from Appendix 3 of WWBW01, April 2013)

Defining the main channel and low-flow channel

Purple: Leichardt River (Coolullah Station)

Purple zone: Bottle Creek (Rosedale)

Purple zone: Elizabeth Creek (Burketown)

Purple zone: Gilliat River (Julia Creek)

Main channel

- The main channel of a given waterway is the active component of the flow channel.
- The extent of the main channel is also referred to as bankful level.
- The majority of creeks and rivers display geomorphologic features indicative of the main (active) channel.
- The channel may contain more than one active channel, especially in low gradient waterways with sand and gravel sediments.

Defining the main channel

- The furthest extent of the main channel can be characterised by a distinct change in the appearance of the bank at a certain level, including:
  - undercutting
  - changes in vegetation density
  - sudden changes in bank slope
  - boundary levels for water marks
  - mosses or lichens
  - changes in sediment particle size
  - the height of a point bar on the inside of a meander bend.

Main channel width

- The determination of the main channel should be made in an area of the waterway that is relatively stable and not severely altered by localised scouring and erosion.
- Where the main channel width is variable at a given site, an average width for the site may be used for determining dimensions of the waterway.
- Overseas studies have found that the bankful discharge occurs at an average recurrence interval between 1 and 2 yrs.

Example photos

- These photos are examples of waterways throughout Queensland and show the main and low flow channels.
- In some waterways the low flow and main channels may be difficult to differentiate such as the waterhole sections of wallum and low slope western waterways.

Defining the main channel and low-flow channel

Purple zone: Splitters Creek (Bundaberg)

Purple zone: Thomson River (Stonehenge)

Red zone: Un-named tributary (Rosedale)

Red zone: Splitters Creek (Bundaberg)

Amber: Un-named tributary (Baffle Ck)

Amber; Un-named tributary (Condamine)

Green: Butha Creek (Great Sandy Straits)

Green zone: Deepwater National Park

Author's Glossary of Terms

Acid Sulfate Soils (ASS)	Acid sulfate soils are soils that contain iron sulfides. When exposed to air these sulfides oxidise to produce sulfuric acid, which has negative consequences for animals, plants and humans. Acid sulfate soils are mainly found on coastal lowland areas below five metres Australian Height Datum (AHD).
AEP	Annual exceedance probability. This describes the likelihood of a flood of any given size or larger. AEP is expressed as a percentage for a given flood discharge, e.g. an AEP of 5% means a 1 in 20 chance of that discharge occurring in any one year.
Aperture	The internal (open) width of the culvert cell(s)
Array	Collective term for culvert cells, where more than one culvert is used in a crossing to span the waterway.
Bank-side	The side of a culvert cell adjacent to the waterway bank.
Barrier	For the purposes of this code a waterway barrier is a crossing that incorporates a culvert and is located on a marked waterway. A waterway barrier limits fish access and movement along a waterway. Culvert crossings can act as barriers through increased water velocity and turbulence, shallow water depth, lack of resting and hiding areas, steps and drops in elevation across the gradient, constriction of channel, low lighting and debris blockage etc.
Bed level	Bed level is considered to be the lowest point of the natural stream bed (pre-construction), within the footprint of the proposed crossing.
Causeway	A raised carriageway constructed across a watercourse or tidal waterway.
Culvert cell	Culvert cell is a support structure for a crossing over a waterway. Common culvert cell types include bottomless, box and pipe.
Culvert crossing	A crossing over a waterway that incorporates culvert cells.
Deck height	The height of the road/pavement surface above the stream bed at the point where a measurement is taken.
Depth of cover	The height of fill from the obvert of the culvert cell to the surface of the road/pavement.
Emergency maintenance works	The necessary works undertaken on a culvert crossing to re-open a road that is no longer safely functional due to the sudden unforeseen failure or destruction of the crossing as a direct result of flooding, fire, earthquake, or accidental vehicle impact. The definition of emergency maintenance works does not include: failure due to wear and tear; increased traffic; obsolescence; inadequate design or materials; or construction practices.
Elevated flows	Flows other than no flow, base flow or low flow conditions.
Footprint of works	The works footprint includes the base of the culvert crossing structure, apron works, scour protection works, headwall and wingwalls and abutments. It does not include approach roads and access tracks.
Ford	A carriageway formed directly on the channel bed in a shallow section of a watercourse.
Freshwater	Waters that are upstream of tidal influence.
Invert	The bottom floor of the culvert cell
Leading edge	The edge of the roughening element that is perpendicular to the flow.

Leg (culvert)	The vertical members (sidewalls) of a box culvert cell.
Low flow	For perennial waterways, low flows are taken as the base flow volumes or levels. For ephemeral waterways, low flows are taken from the moment flows commence, up to the level or volume of a one in one year flow event. Each region and state could have a different definition.
Main channel	The active component of the flow channel characterised by a distinct change in appearance or structure at the upper limit of the channel such as undercutting, changes in vegetation density, sudden changes in bank slope, boundary levels for water marks, mosses or lichens, changes in sediment particle size. Approximate Q values of Q1 – Q2 or AEP equivalent. Where the main channel width is variable, use an average width for the site.
Marine plants	As defined under the Fisheries Act 1994, section 8. Includes but is not limited to mangroves, seagrass, saltcouch, algae and samphire (succulent) vegetation and adjacent plants such as Melaleuca and Casuarina.
Obvert	The interior top of the culvert cell.
Permanent waterway barrier works	For the purposes of this code, permanent waterway barrier works are waterway barrier works that are (or will be) in place for a period longer than twelve months.
Rock chute	A rock chute is a section of stream bed or channel that has been armoured with rock, generally for erosion protection. In this context the rock chute is constructed within a waterway, adjacent to a bank, culvert or low flow section of a crossing in order to provide a level of fish passage at the crossing prior to drown-out.
Scour protection	Stream bed structures upstream and downstream of culvert crossings installed to prevent or repair destabilisation and/or removal of substrate by the action of water flows on the waterway bed, adjacent to the hard structures of the works.
Tidal	Tidal waters are waters that are tidal or subjected to tidal influence.
Waterway bed gradient	The waterway bed gradient is the slope, rise or fall of the waterway. This is usually dependent on the location along the waterway.