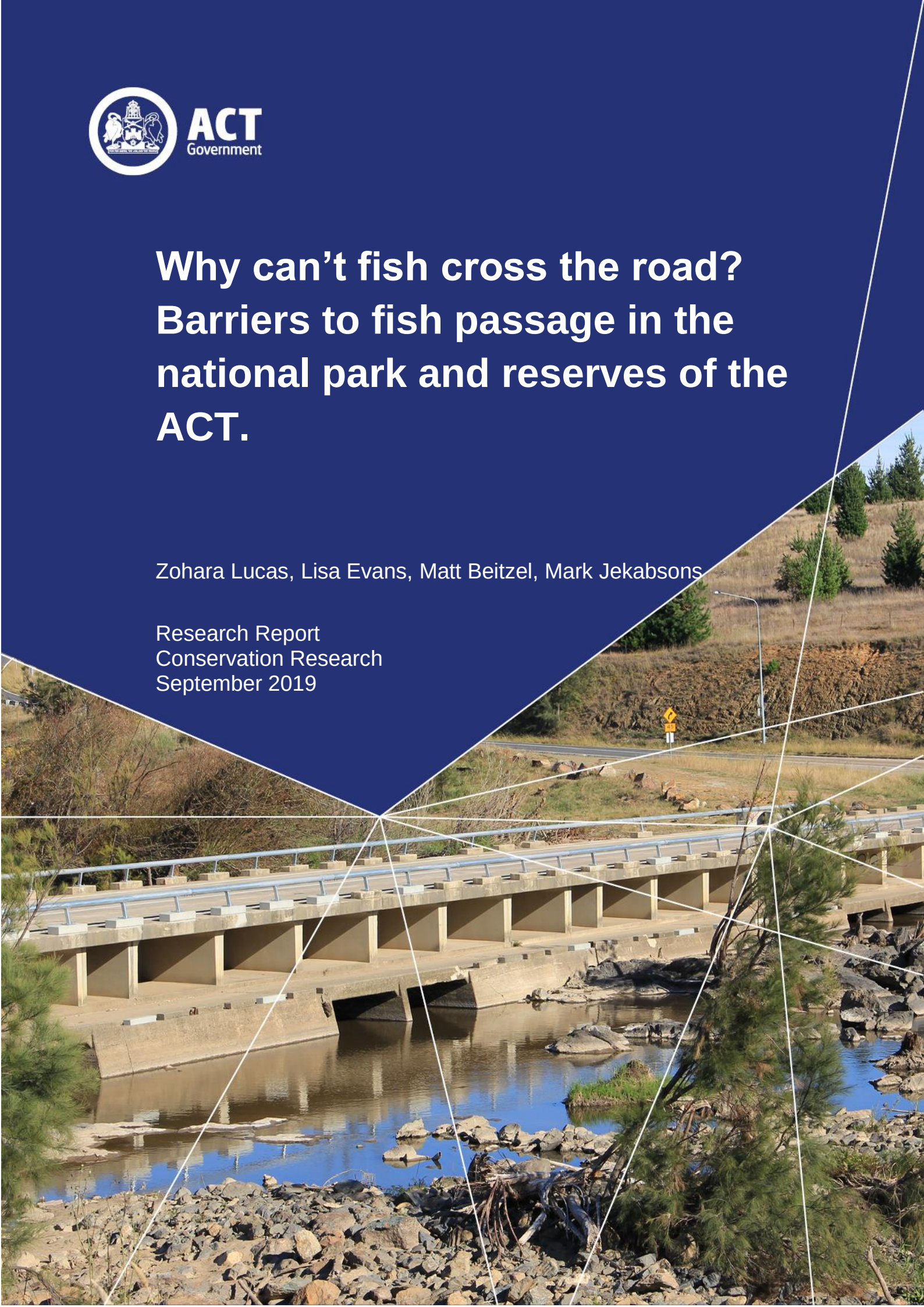
ACT Government

Why can’t fish cross the road? Barriers to fish passage in the national park and reserves of the ACT.

Zohara Lucas, Lisa Evans, Matt Beitzel, Mark Jekabsons

Research Report
Conservation Research
September 2019



Research Report Series

Why can't fish cross the road? Barriers to fish passage in the national park and reserves of the ACT.

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Telephone: Access Canberra 13 22 81

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Executive Summary

Connected waterways are critical for the survival of aquatic organisms, particularly fish. Fish need connected waterways to grow, find food and shelter, breed, find refuge and re-establish populations after disturbance. Barriers that can cause disconnection of waterways such as road crossings, dams, weirs are a significant impact to the conservation of native fish. The aim of this project was to document and assess the human made stream barriers in the ACT conservation estate, assess the degree of blockage they cause and their priority for modification to improve fish passage.

To establish an understanding of the current state of fish passage in the ACT conservation estate this project undertook a field assessment of every identified barrier. The project determined the degree that the barrier prevented or allowed fish movement, mapped the location of constructed barriers and assessed the barriers based on potential ecological impact.

Two hundred and thirty-four potential barriers were identified. However, when these potential barriers were assessed 133 road crossings already allowed fish to pass and do not require modification, 7 barriers had some beneficial role (ie. stop disease of pests from invading upstream areas) and 101 structures were identified as actual barriers potentially impacting fish passage. Of the crossings identified as barriers, 18 were major barriers, 6 medium barriers and 70 structures formed a low level of blockage. Of all the structures identified as barriers, 10 were identified to be environmental priorities.

The issues that caused structures to disrupt passage was from vertical drop, high water velocity and turbulence, shallow water depth, debris and a combinations of these factors. The most common structures to disrupt passage were road culverts placed above the river bed and dry or raised ford crossings. The type of crossing (culvert, bridge, pipe or ford) was not important in the degree of barrier as each type of crossing can, if installed in appropriately, can allow adequate fish passage.

When installing stream crossings to allow fish passage, the construction should:

- consistently match the depth of the upstream and downstream stream channel
- have no vertical drops where the crossing is raised above the natural river bed
- match the velocity of the water in the upstream and downstream channel
- ideally retain the natural stream bed structure (i.e. rocks compared to smooth concrete)
- match the width of the upstream and downstream stream channel

Structures that cannot be installed to allow fish passage can also be made fish passage friendly by installing a fish-way, such as has been done at Vanitys Crossing on the Cotter River and a number of other barriers in the ACT.

Report recommendations:

- keep fish passage as a consideration when building, maintaining and planning vehicle crossings over streams and other water bodies
- design crossings that allow fish to pass
- maintain existing crossings that already allow fish passage
- when maintaining or upgrading roads, modify the crossings that are barriers to allow fish passage
- prioritise improving the crossings identified in this report as environmental priorities.

1 Introduction

Why are connected waterways important?

Freshwater environments are important ecosystems. Entire stretches of waterways are fed by small nutrient rich shallow streams that flow to deeper rivers and pools that eventually flow into the sea. Aquatic organisms such as fish, utilise the different parts of these river systems at different stages through their lifecycle. Fish need these well-connected waterways to maintain healthy and sustainable populations. Unrestricted access to connected stream networks provides the diversity of habitat necessary for fish and other aquatic organisms and is essential to provide resources for large populations (Harig and Fausch 2002).

Connected waterways are critical for the survival of native fish. Fish move within and between waterways to breed and to locate critical resources including food, shelter, nursery sites and spawning grounds. Furthermore, juvenile and adults of the same species have different diet and habitat requirements that are met in different areas of a waterway (Lintermans and Osborne 2002). During disturbance events such as drought, fire or flood, populations of fish that have access to refuge areas through connected streams are more likely to find shelter and survive than those confined to an area with no capacity to move (Magoulick and Kobza 2003).

Barriers lead to fragmented waterways

The fragmentation of waterways has been identified as a major threat to freshwater fish across the world. Barriers that prevent fish passage can cause populations to become isolated; this can lead to inbreeding and genetic bottlenecks (Coleman et al 2018, Pavlova et al 2017).

A barrier to fish passage can be anything that blocks fish moving through a stream, for example dams, weirs and road crossings. There are an estimated 10,000 barriers to fish passage in the Murray Darling Basin alone (Baumgartner et al 2014). These barriers have altered the distribution and contributed to the decline of some fish species. For instance, habitat loss and fragmentation, caused by barriers to movement are believed to be the primary contributors to the decline of populations of Macquarie Perch (*Macquaria australasica*) (Pavlova et al 2017). Macquarie Perch once persisted throughout the Murray-Darling, Hawkesbury-Nepean, Shoalhaven and Georges Basins. This species is now listed as nationally endangered and is restricted to isolated locations across its former range.

Waterways and fish species in the ACT

The rivers that flow through the ACT are significant. The Murrumbidgee River and associated tributaries (including the Molongolo, Gudgenby and Cotter rivers) form part of the headwaters of the Murray Darling River system. Several smaller streams lead into these tributaries (Figure 1). The Cotter River flows for 72 km though Namadgi National Park and has a catchment area of 482 square kilometres. It is the main source of Canberra's drinking water and is habitat to four species of threatened fish and one threatened and two protected crayfish (Table 1).

There is both ecological and social value in maintaining healthy and sustainable populations of fish in the ACT. Fish are an integral part of the aquatic fauna; they fill an important ecological role as both predators and prey. The Murray Cod (*Maccullochella peelii*) is a culturally significant species to local

Traditional Custodians (E. Gilbert Personal communications April 2019). These are also important angling species that persist and breed in ACT waterways.

Species found in the ACT that undertake life cycle migrations include, Murray Cod (*Maccullochella peelii*), Golden Perch (*Macquaria ambigua*) and the now locally extinct Silver Perch (*Bidyanus bidyanus)*. Adult Murray Cod live in deep pools, usually amongst snags, where they feed on small fish and crustaceans (Humpheries 2005). During late winter/early spring when water levels are high, they have been recorded travelling 130 kilometres upstream to spawn in warmer shallower waters. The male stays upstream guarding the eggs for up to one week. After the larvae hatch they remain in faster flowing waters amongst rocks where they feed on small invertebrates and zooplankton. The adults return to the same pre-migration stream (and often the same snag) (Lintermans and Osborne 2002, Koehn et al 2009).

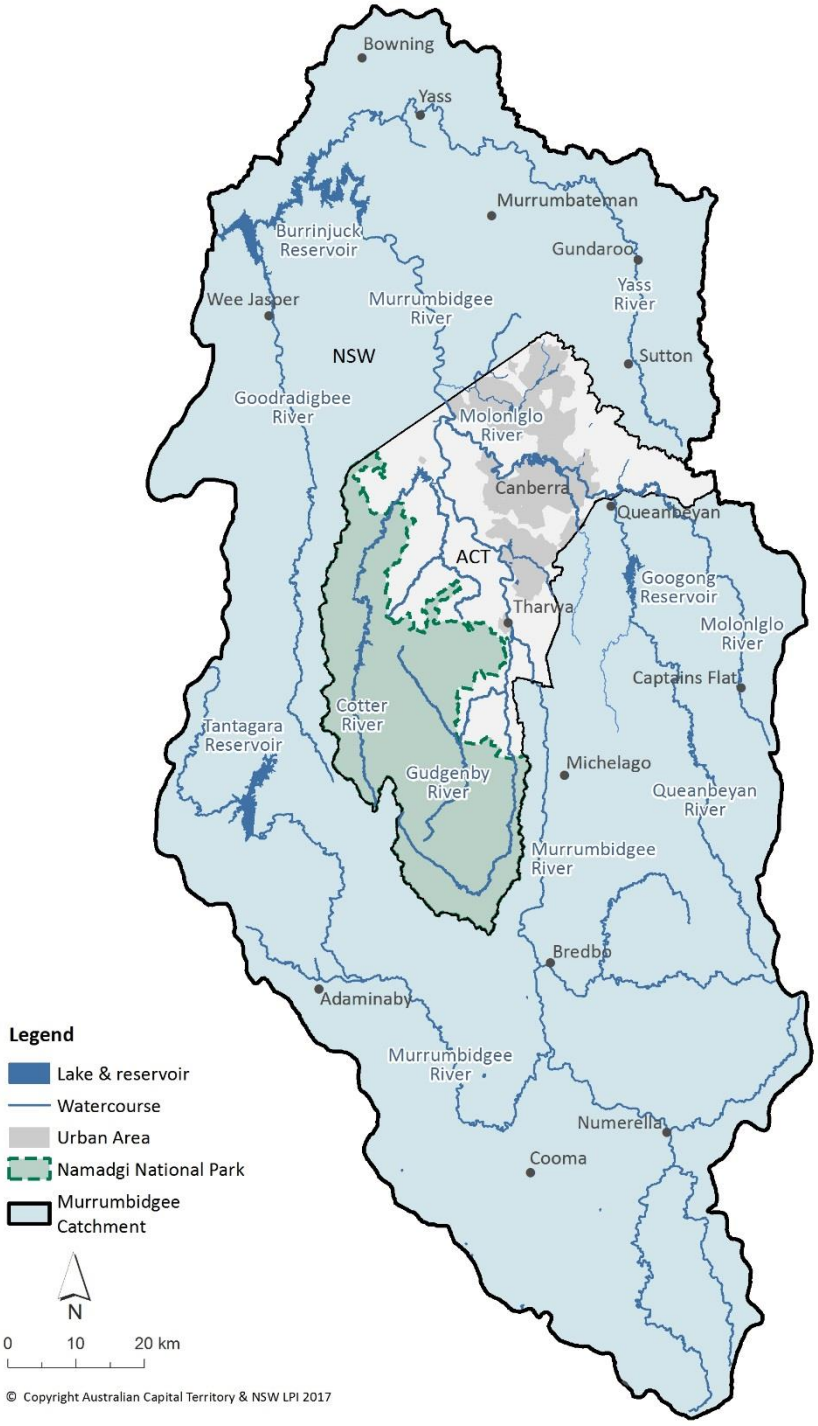
Golden Perch and Silver Perch are migratory species found in the Murray-Darling River system. Golden Perch have been recorded travelling up to 1800 kilometres upstream to spawn (Reynolds 1983, O'Connor et al 2005). In the ACT there is likely to be both resident populations of Golden Perch and those that have migrated here to breed. Silver Perch once undertook spring/summer migrations up the Murrumbidgee River into the ACT. However, they have not been recorded in ACT waterways for over 20 years and barriers to reproductive migratory movements have been listed as a cause of this decline (Lintermans and Osborne 2002). Maintaining good connectivity of waterways is part of maintaining healthy fish populations.

This study recognised that many of the crossings were constructed years ago when environmental protection was a lower priority. In the spirit of continual improvement and applying recent knowledge, the following report provides observations that could assist with future crossings being constructed in a different way, recognising this would need to be matched with sufficient resourcing.

Table 1. Fish commonly found in the ACT region

Species	Scientific name	Status in ACT
Trout Cod	*Maccullochella macquariensis*	Endangered
Macquarie Perch	*Macquaria australasica*	Endangered
Silver Perch	*Bidyanus bidyanus*	Vulnerable
Murray Crayfish	*Euastacus armatus*	Vulnerable
Alpine Spiny Crayfish	*Euastacus crassus*	Protected
Riek's Crayfish	*Euastacus rieki*	Protected
Two-spined Blackfish	*Gadopsis bispinosus*	Vulnerable
Murray Cod	*Maccullochella peelii*	Special Protection Status
Mountain Galaxias	*Galaxias olidus*	Not listed
Australian Smelt	*Retropinna semoni*	Not listed
Western Carp Gudgeon	*Hypseleotris klunzingeri*	Not listed
Golden Perch	*Macquaria ambigua*	Not listed
Carp	*Cyprinus carpio*	Introduced
Rainbow Trout	*Oncorhynchus mykiss*	Introduced
Brown Trout	*Salmo trutta*	Introduced
Redfin	*Perca fluviatilis*	Introduced
Oriental Weather loach	*Misgurnus anguillicaudatus*	Introduced
Gambusia	*Gambusia holbrooki*	Introduced

Figure 1: River systems of the Upper Murrumbidgee Catchment



Study aims

This report describes the outcomes of a study on constructed barriers to fish passage in the ACT conservation estate.

Specific aims of this project are to:

- Establish an understanding of the current state of fish passage in the ACT conservation estate, by:
    - documenting the degree that constructed barriers (dams, weirs, vehicle crossings) prevent or allow fish movement
    - mapping the location of constructed barriers to fish passage within the conservation estate
    - listing the barriers based on potential ecological impact and severity.
- Providing evidence to inform the planning, construction and maintenance of vehicle crossings over waterways, to improve fish passage.

3 Methods

Study sites

All streams within ACT conservation estate were surveyed for barriers to fish passage. Barriers were assessed during winter and spring when water flow is typically at its peak in the ACT. Consequently, if a barrier was identified during the study this status was unlikely to change throughout the year.

Survey Method

Barriers to fish passage were identified using:

1. Spatial mapping in ESRI ArcGIS 10.1 to identify locations where waterways and road crossings intersect (ie. potential barriers to fish passage).
2. The locations identified through spatial mapping were then compared to aerial imagery and topographic maps to identify further possible barrier sites.
3. Rangers and field staff were consulted to determine the presence of additional barriers that had not been identified using desktop spatial analysis.

All intersections between roads and waterways (identified using spatial mapping, step 1 above) were visited and assessed to see if the crossing formed a barrier to fish passage.

Field Method

The on-ground assessment of barriers took place between June to November 2018 (winter and spring). A photo of each site was taken and the GPS location, barrier type and degree of blockage was also recorded (see data sheet, Appendix 1). Datasheets and photos were matched and stored together. All data was entered into Microsoft Office Excel; GPS locations were downloaded onto ESRI ArcGIS 10.1. Data that was not collected in the field was added when in the office (ie. stream order and habitat quality). For this study, assessing habitat quality (as poor or good) was conducted as a desktop exercise using photographs taken at the site. For future studies it is recommended that habitat assessment is conducted in the field.

The data collected in the field included: type of fish barrier, degrees of blockage and reason that fish passage is blocked, these are defined below.

Seven types of fish barrier were identified, these are:
Dam wall: a structure blocking substantial water movement downstream, >2m high and causing water to pool upstream.
Bridge: a structure built over the span of the waterway with a significant gap between the structure and the waterway. Bridges may be single or multi span (have more than one section over the water).
Culvert: a structure in which water passes through pipes or boxes under the road crossing.
Weir: a structure built above the normal water level, creating a backing of water <2m high.
Ford: a structure or splash-through built at the stream bed level, usually allowing the water to pass over the crossing.
Causeway: a structure built above the stream bed level allowing the water to pass under the crossing (usually by means of pipes) in low flow events and over the structure in high flow events.
Floodgate: gate or structure that can be opened or closed to allow or prevent flood waters passing through.

Six degrees of blockage were identified and have been defined as:
Complete barrier: fish are prevented from passing upstream or downstream (unless accidently washed over ie. dam wall)
Major barrier: some fish can pass in certain conditions (ie. high water level and/or low velocity); exposed to risk of predation or injury
Moderate barrier: fish can pass with effort during some flow conditions; exposed to risk of predation or injury
Minor barrier: fish can pass with effort under most flow conditions; exposed to risk of predation or injury
No barrier: fish can pass easily; no additional risk of predation or injury
Beneficial barrier: barrier prevents pest fish from colonising past the barrier.

Eight reasons fish passage is blocked:
Downstream drop: vertical distance > 5cm, between the water in the crossing and the water downstream of the crossing
Upstream jump/drop: vertical distance > 5cm, between the water in the crossing and the water upstream of the crossing
Slope: barrier creates an upward or downward slope of >1:20
High water velocity: water moving at a speed of > 1.5 m/second
Increased turbulence: rough unsteady movement of water
Shallow flow depth: water too shallow for fish to pass, usually created when base of a crossing is raised above the level of the stream bed
Lack of light: inadequate natural light to allow some fish to pass
Debris: wall or bank creates physical obstruction fish cannot pass.

For an illustrated example on how these factors affect fish passage see Appendix 2.

Analysis Method

Several factors were used to determine the degree of blockage for each identified barrier. Beneficial barriers were excluded from the analysis; a barrier was considered beneficial if introduced species were present on one side of the barrier and not on the other.

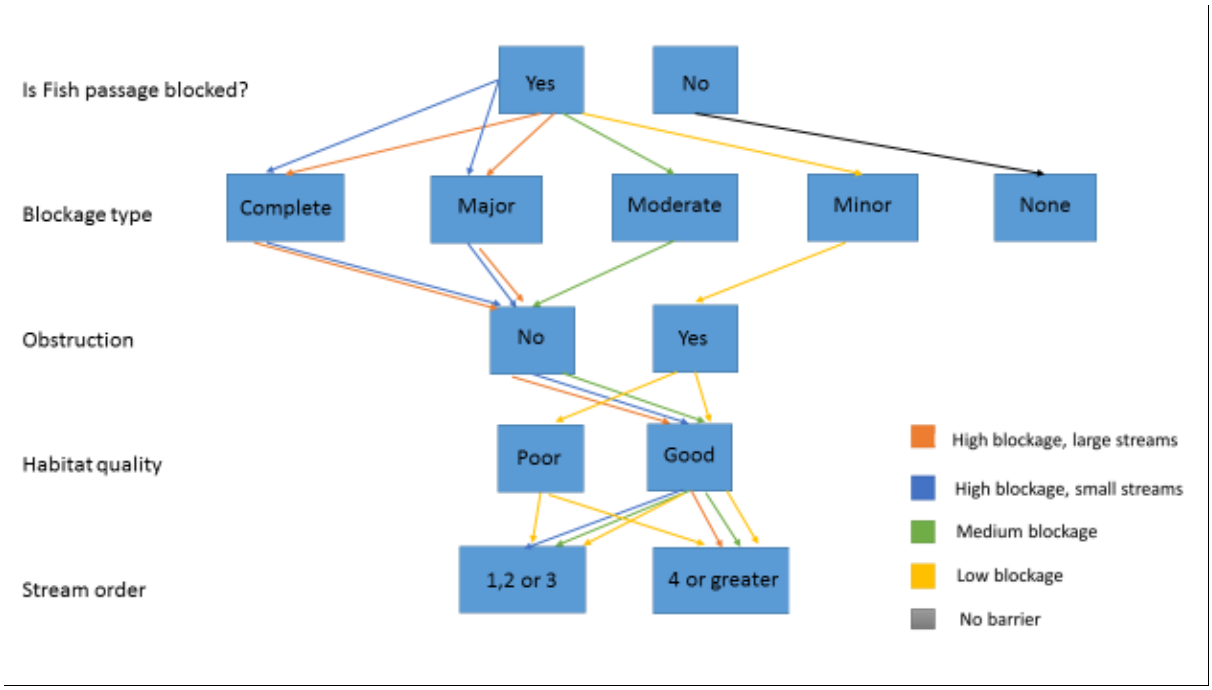
Five factors were considered in combination to determine the degree of blockage:
Fish passage is blocked: fish are stopped from moving past barrier (Yes or No)
Blockage type: degree that passage is obstructed, (Complete, Major, Moderate, Minor or None)
An obstruction within 1 km of the barrier: there is an unpassable barrier (moderate, major or complete) within 1 km of the identified barrier
Habitat quality: habitat is in good or poor condition to support fish
Stream order: measure of stream size, increases as number of streams flowing into waterway increase (ie. a small tributary with no other stream flowing into it is order 1 a large river is 5).

Analysis of these factors are shown in the table and flow chart below (Table 2 and Figure 2).

Table 2: Degree of blockage

Degree of blockage	Fish passage blocked	Blockage type	Obstruction within 1 km	Habitat quality	Stream Order
High blockage (stream order >3)	Yes	Complete or Major	No	Good	4 or greater
High blockage (stream order ≤3)	Yes	Complete or Major	No	Good	1, 2 or 3
Medium blockage	Yes	Moderate	No	Good	all
Low blockage and/or low concern	Yes	Minor		Good/Poor	all
No barrier	No				all

Figure 2. The process to determine degree of blockage for each barrier.



Environmental Prioritisation

Barriers with a high or medium degree of blockage were assessed to determine the likely ecological impact of improving fish passage.

The following factors were considered in prioritising sites based on the likely increase of impact to waterway connectivity:

Fish species: Species found in the stream in question, with importance given to known habitat of threatened species (Blackfish, Trout Cod, Macquarie Perch) or migrating species (Murray Cod, Golden Perch). Presence of these species was determined by comparing records of fish surveys conducted by the ACT government (Lintermans and Rutzou 1990, Howson et al 2018).

Availability of quality habitat: length of aquatic habitat made available if fish passage was restored, which was calculated by measuring distance to next closest unpassable constructed barrier. If a barrier was in a National Park this was given a higher priority than a barrier in a stream surrounded by private properties because the habitat quality and native vegetation was consistently higher in the National Park.

4 Results

Where are barriers to fish movement?

Of the 234 barriers assessed in this project, 101 crossings formed barriers to fish passage (Table 3). These barriers ranged from minor obstacles to complete blockages to fish movement. Importantly 133 water crossings allowed fish passage and seven were identified as beneficial barriers (Figure 5, Table 6). Beneficial barriers restrict the movement of pest fish species into an area with native species. This is particularly important as non-native fish can out compete and predate upon native fish or can carry harmful viruses (e.g. Redfin are the vectors for EHN virus). An example of this is the Cotter Dam, which serves as a barrier to keep the upstream waterways free of Carp and Redfin.

Of the 234 barriers identified, 10 sites were identified as sites of environmental priority (Figure 3, Table 4, for images of each site see Appendix 3). Eighteen presented a high level of blockage to fish passage (Figure 4, Table 5) and 6 sites presented a medium level of blockage (Figure 5, Table 6). The most common type of blockage to fish passage was vehicle crossings over water, especially in smaller streams.

Sites of environmental priority are defined as barriers which are currently blocking fish passage but will have a large positive ecological outcome if they are changed. The degree of ecological impact is determined by the number of threatened or migrating fish in the area or/and amount of river length made accessible if fish passage is allowed through the current barrier.

Table 3. Number of identified barriers and the degree of blockage of each barrier type.

Degree of blockage	Number of sites	Sites of Environmental priority
High level of blockage (stream order ≥ 4)	8	7
High level of blockage (stream order <3)	10	2
Medium level of blockage	6	1
Beneficial barriers	7	
Low level of blockage	70	
No barriers (allow fish passage)	133	

For the maps showing low degree of blockage (Figure 20, Table 10) and no barriers (Figure 21, Table 11) see Appendix 4.

Figure 3: Location of environmental priority sites in the ACT.

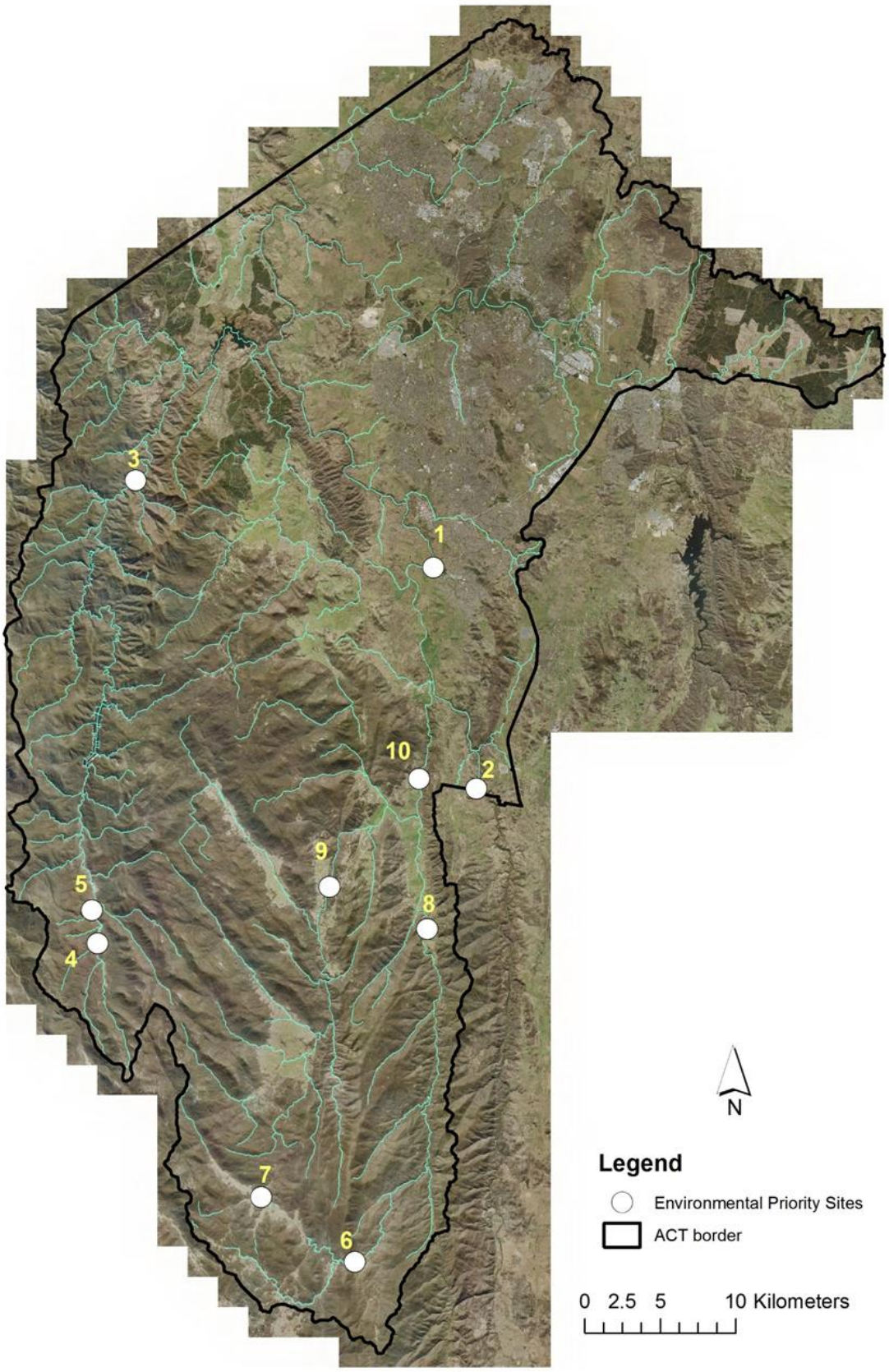


Table 4: Sites of environmental priority for addressing in-stream barriers in the ACT.

Map No.	River / Stream name	Location UTM Eastings and Northings	Native fish species present	Surrounding land	Available habitat distance to next barrier	Comments and reasons for listing
1	Murrumbidgee River	Point Hut Crossing 688238 6074815	Galaxias Murray Cod Golden Perch (Possibly Tout Cod Macquarie Perch) Many introduced species	Murrumbidgee River Corridor	18 km upstream to Angle crossing 25 km downstream to the confluence with Cotter River	Migratory species Golden Perch and Murray Cod in area Opens 43 km in Murrumbidgee River
2	Murrumbidgee River	Angle Crossing 691093 6060210	Galaxias Murray Cod Tout Cod Macquarie Perch Many introduced species	Murrumbidgee River Corridor	Clear upstream into NSW 20 km downstream to Point Hut Crossing	Migratory species in area Opens 20k m in Murrumbidgee River
3	Cotter River	Burkes Creek Road crossing Cotter River, Namadgi NP 668558 6080585	Galaxias Macquarie Perch Two-spined Blackfish Trout Cod (trout)	National Park	7 km upstream to Bendora Dam 13 km downstream into Cotter Reservoir	Endangered Macquarie Perch. While crossing is listed as a medium blockage it can be improved to allow fish passage Opens up 20 km in Cotter River
4	Jacks Creek	Yaouk Fire Trail crossing Jacks Creek, Namadgi NP 666046 6049989	Galaxias Two-spined Blackfish (trout)	National Park	3 km upstream 16 km downstream to Corin Reservoir	Vulnerable Two-spined Blackfish in area. Opens 19 km of river. Part of wilderness area, care must be taken to ensure minimal disturbance upstream and downstream
5	Bimberi Creek	Yaouk Fir Trail crossing Bimberi Creek, Namadgi NP 665665 6052203	Galaxias (trout)	National Park	3 km upstream 14 km downstream to Corin Reservoir	Opens 17 km of river. Part of wilderness area, care must be taken to ensure minimal disturbance upstream and downstream

Map No.	River / Stream name	Location UTM Eastings and Northings	Native fish species present	Surrounding land	Available habitat distance to next barrier	Comments and reasons for listing
6	Naas Creek	Naas Creek Fire Trail crossing Naas Creek (2nd ford crossing, 3rd river crossing, when driving North along Naas Valley Fire Trail) 683052 6028958	Galaxias	National Park	8 km upstream to ford barrier on Naas Creek and Old Boboyan Road 26 km downstream to causeway at Caloola Farm	Opens up 34 km of Naas Creek
7	Naas Creek	Old Boboyan Road crossing Naas Creek 676845 6033219	Galaxias	National Park	9 km upstream 8 km downstream (to ford on Naas creek and Naas Valley Fire trail)	Opens up 17 km of Naas Creek
8	Naas Creek	Causeway at Caloola Farm crossing over Naas Creek 687833 6050942	Galaxias	Private properties	26 km upstream to ford barrier on Naas creek crossing Old Boboyan Road 10 km downstream to Sunshine Road crossing	Opens up 36 km of Naas Creek
9	Rocky Crossing	Orroral Road crossing Gudgenby River 681378 6053741	Galaxias (trout)	Private properties	20 km upstream 9 km downstream to confluence with Naas Creek	Opens 29 km of Orroral River
10	Naas Creek	Sunshine Road crossing Naas Creek 687290 6060872	Galaxias	Private properties	10 km upstream to causeway at Caloola Farm 17 km downstream to Point Hut	Opens up 27 km of Naas Creek

Figure 4: Location of sites for major barriers on large and small streams in the ACT.

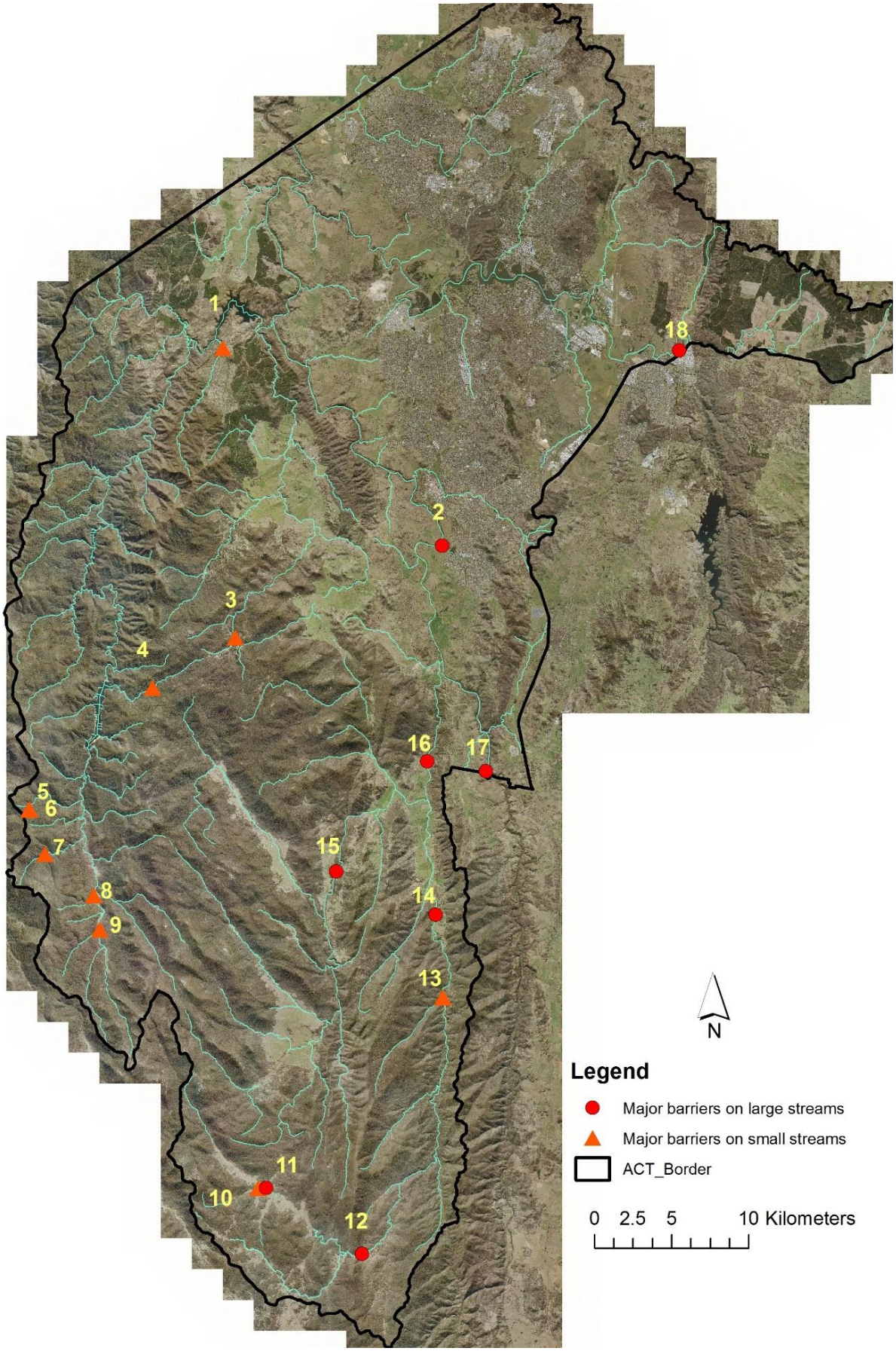


Table 5: Major barriers on large and small streams in the ACT.

Map No.	River / Stream name	Location UTM Eastings and Northings	Small or large stream	Type of crossing	Obstacle category	Cause of blockage
1	Pierces Creek	Concrete Crossing 674033 6087672	Small	Ford	Complete barrier	Downstream drop
2	Murrumbidgee River	Point Hut Crossing 688238 6074815	Large	Bridge with culverts	Complete barrier	Minimal flow depth Downstream drop
3	Gibraltar Creek	Corin Road 674837 6068893	Small	Bridge	Major obstacle	Downstream drop
4	Kangaroo Creek	Corin Road Crossing 669466 6065650	Small	Bridge	Major obstacle	Downstream drop
5	Cribbs Creek	Mt Franklin Road (3rd crossing driving uphill from Cotter Hut Road) 661496 6057738	Small	Culvert	Major obstacle	Downstream drop
6	Cribbs Creek	Mt Franklin Road (4th crossing driving uphill from Cotter Hut Road) 661511 6057734	Small	Culvert	Complete barrier	Downstream drop
7	McKeanhies Creek	Mt Franklin Road (2nd crossing driving uphill from Cotter Hut Road) 662498 6054873	Small	Culvert	Complete barrier	Downstream drop
8	Bimberi Creek	Bimberi culvert 665665 6052203	Small	Culvert	Complete barrier	Downstream drop

Map No.	River / Stream name	Location UTM Eastings and Northings	Small or large stream	Type of crossing	Obstacle category	Cause of blockage
9	Jacks Creek	Jack's Creek 666046 6049989	Small	Ford	Major obstacle	Downstream drop
10	Sams Creek	Sam's River Trail 676328 6033233	Small	Causeway	Complete barrier	Minimal flow depth
11	Naas Creek	Old Boboyan Road 676845 6033219	Large	Ford	Complete barrier	Downstream drop
12	Tributary to Naas Creek	Naas Valley Fire Trail 688285	Small	Ford	Major obstacle	Upstream jump and downstream drop
13	Naas Creek	Naas Valley Fire Trail crossing 688285 6045589	Large	Ford	Major obstacle	Downstream drop
14	Naas Creek	Causeway at Caloola Farm 687833 6050942	Large	Causeway	Major obstacle	Minimal flow depth
15	Orroral River	Rocky Crossing 681378 6053741	Large	Causeway	Major obstacle	Downstream drop
16	Naas Creek	Sunshine Road Crossing 687290 6060872	Large	Causeway	Major obstacle	Downstream drop
17	Murrumbidgee River	Angle Crossing 691093 6060210	Large	Ford	Major Obstacle	Minimal flow depth
18	Molonglo River	Weir beside Pialligo Road bridge (near ACT/NSW border) 691283 6064329	Large	Old Causeway/ weir	Major obstacle	Downstream drop High velocity

Figure 5: Location of beneficial barriers and barriers with a medium degree of blockage in the ACT

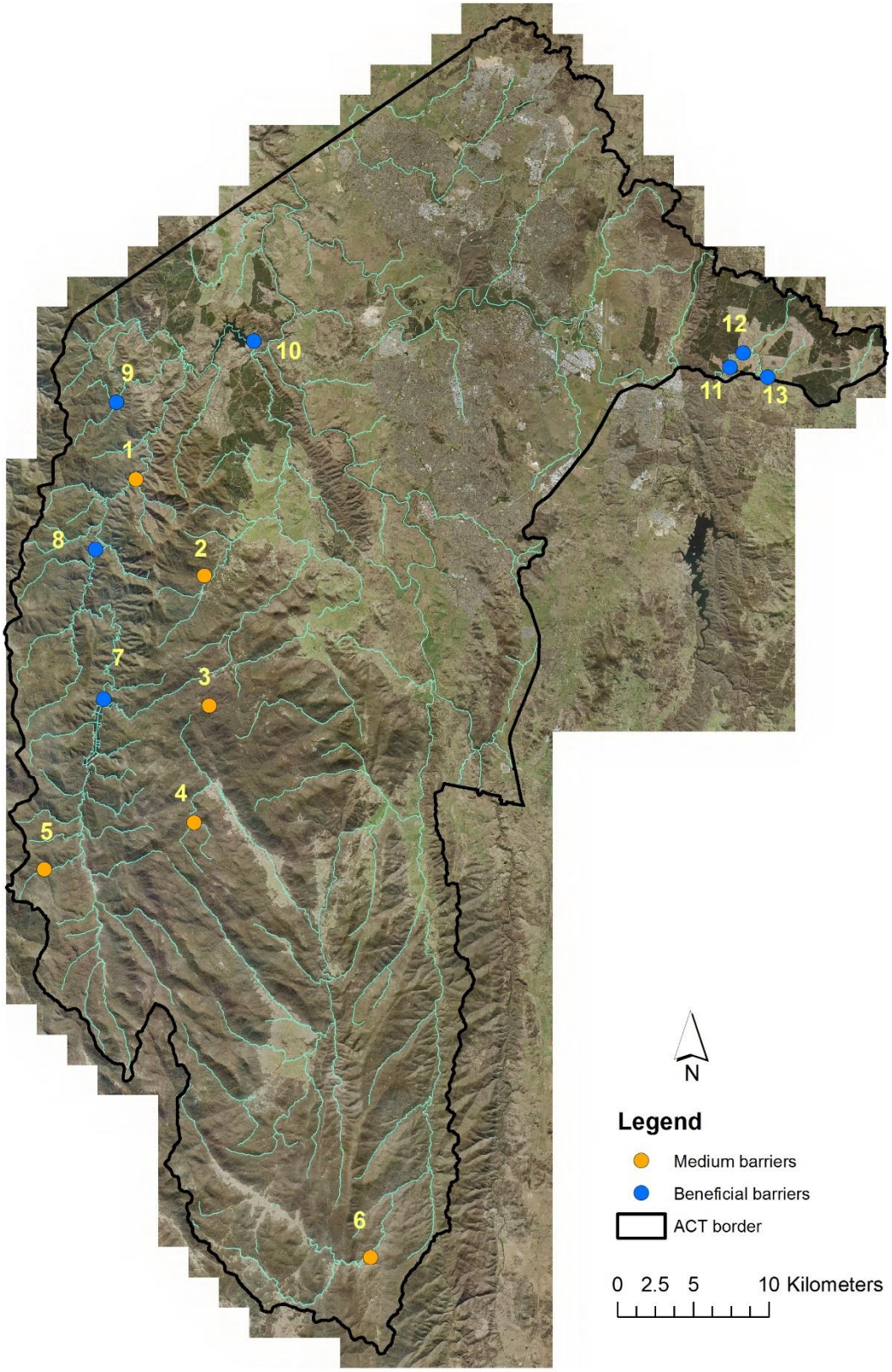


Table 6: Sites with beneficial barriers or barriers with a medium degree of blockage in the ACT.

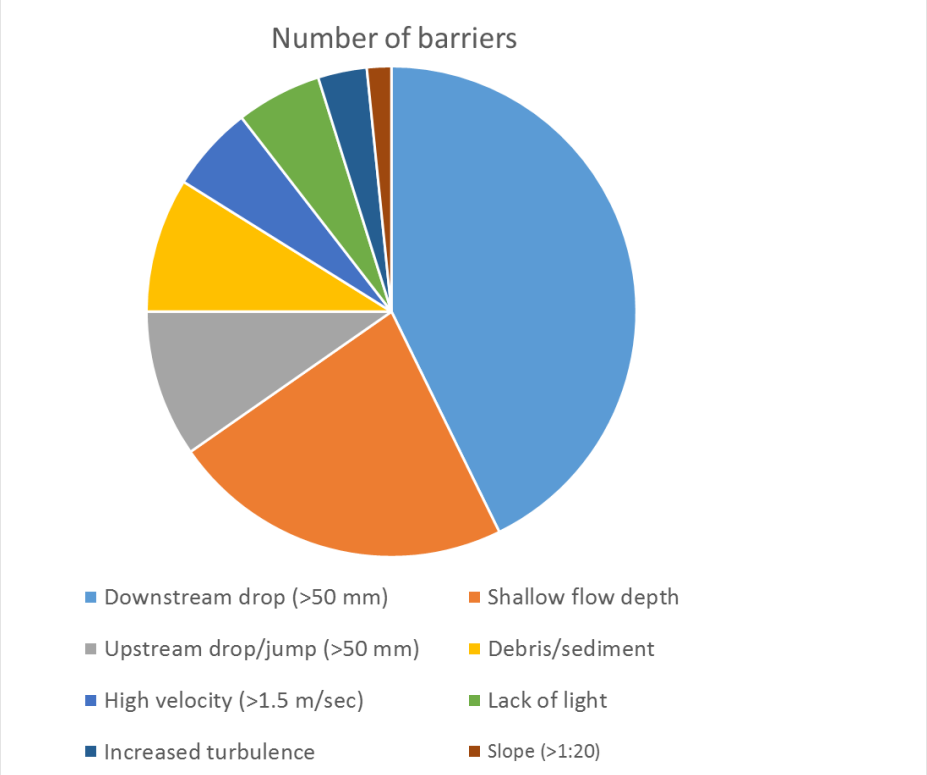
Map No.	River / Stream name	Location UTM Eastings and Northings	Type of crossing	Obstacle category	Cause of blockage	Comments
1	Cotter River	Burkes Creek Road crossing Cotter River, Namadgi National Park (between Bendora and Corin Dams) 668558 6080585	Causeway	Moderate obstacle	High velocity (>1.5 m/sec)	
2	Mountain Creek	Tidbinbilla Ring Road crossing Mountain Creek 673083 6074225	Causeway	Moderate obstacle	Downstream drop	Pipes are sitting above stream level
3	Booroomba Creek	Smokers Fire Trail crossing tributary of Booroomba Creek 673404 6065643	Culvert	Moderate obstacle	Downstream drop	37 cm drop Pool below
4	Sawpit Creek	Cotter Hut Road crossing Sawpit Creek 672402 6057934	Culvert	Moderate obstacle	Downstream drop	17 cm downstream drop and high water velocity
5	McKeahnie Creek	Mt Franklin Road crossing tributary to McKeahnie Creek 662526 6054845	Culvert	Moderate obstacle	Downstream drop	
6	Naas Creek	Naas Fire Trail crossing tributary to Naas Creek (4th crossing over Naas Creek stream when driving North from Mt Clear camp ground) 684020 6029269	Ford	Moderate obstacle	Minimal flow depth	Ford has been built up with rocks, this blocks the flow of water and passage of fish.

Map No.	River / Stream name	Location UTM Eastings and Northings	Type of crossing	Obstacle category	Cause of blockage	Comments
7	Cotter River	Corin Dam 666439 6066073	Dam	Beneficial barrier	Downstream drop High velocity	Beneficial excludes Brown trout
8	Cotter River	Bendora Dam 665910 6075964	Dam	Beneficial barrier	Downstream drop High velocity	Beneficial excludes Brown trout
9	Lees Creek	Lees Creek Weir 665910 6075964	Weir	Beneficial barrier	Downstream drop High velocity	Beneficial excludes Rainbow trout
10	Cotter River	Cotter Dam 667284 6085673	Dam	Beneficial barrier	Downstream drop High velocity	Beneficial excludes Carp and Redfin
11	Molonglo River	Ford crossing in Kowan Forest 707730 6087957	Ford	Beneficial obstacle	Upstream jump	Beneficial excludes Redfin
12	Molonglo River	Ford crossing in Kowan forest 707602 6088923	Ford	Beneficial barrier	Downstream drop	Beneficial excludes Redfin
13	Molonglo River	Weir close to NSW border and Kings Highway 710200 6087351	Weir	Beneficial barrier	High velocity	Beneficial excludes Redfin

What causes aquatic barriers in the ACT?

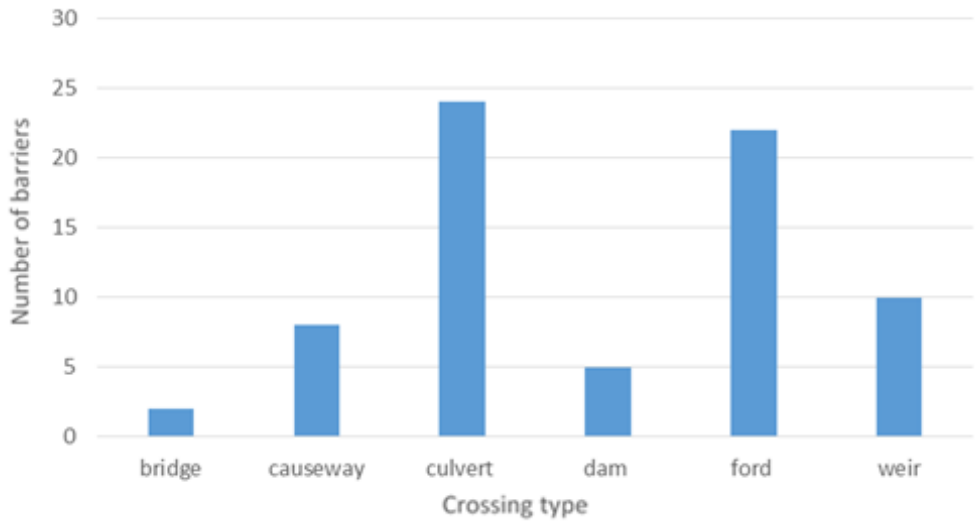
This study found the two most common reasons road crossings that create barriers to fish passage are vertical downstream drops and shallow water depth. In this study vertical downstream drops account for 42% of barriers and shallow flow depth causes 23% of barriers. Other reasons for barriers to fish passage include high water velocity and debris/sediment build up (Figure 6).

Figure 6. Reasons fish passage is blocked in the ACT.



From all the structures that allow vehicles to cross streams, culverts and fords made the most barriers to fish passage (Figure 7).

Figure 7. Complete and major barriers to fish passage in the ACT.



What causes vertical drops?

Vertical drops are most commonly associated with culverts (Figure 8 and Figure 9). When culverts are placed above the water level a lip is created; while water can flow through, fish cannot pass. All culverts that were recorded as a barrier to fish movement were placed too high above the river bed for fish to swim through.

Figure 8. Association of vertical drops (>50 mm) with crossing type.

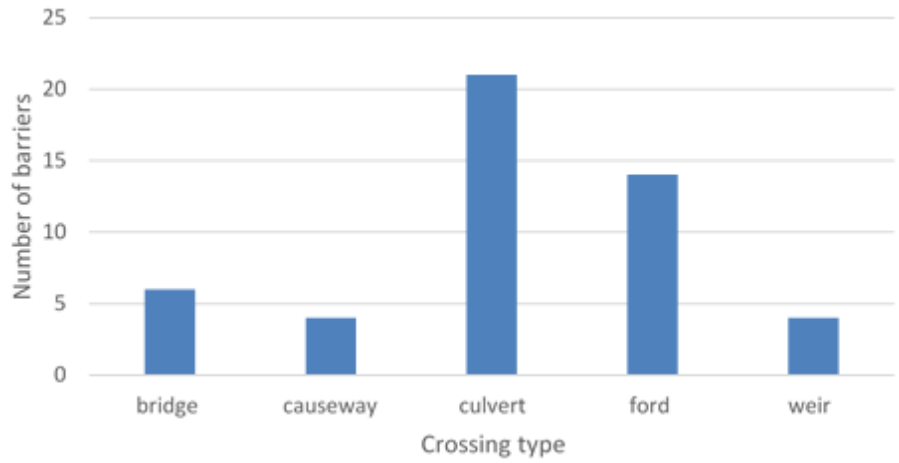


Figure 9. A vertical drop from a pipe culvert on Smokers trail crossing Sawpit Creek, Namadgi National Park.

What causes shallow flow depth?

Shallow flow depth (water too shallow for fish to pass) are most commonly associated with ford crossings (Figure 10 and Figure 11). Raised ford crossings, which are made by piling rocks or gravel to create a dry vehicle crossing, block fish passage by creating a shallow water depth. In some instances, the flow of water is blocked entirely.

Figure 10. Association of shallow flow depth with crossing type

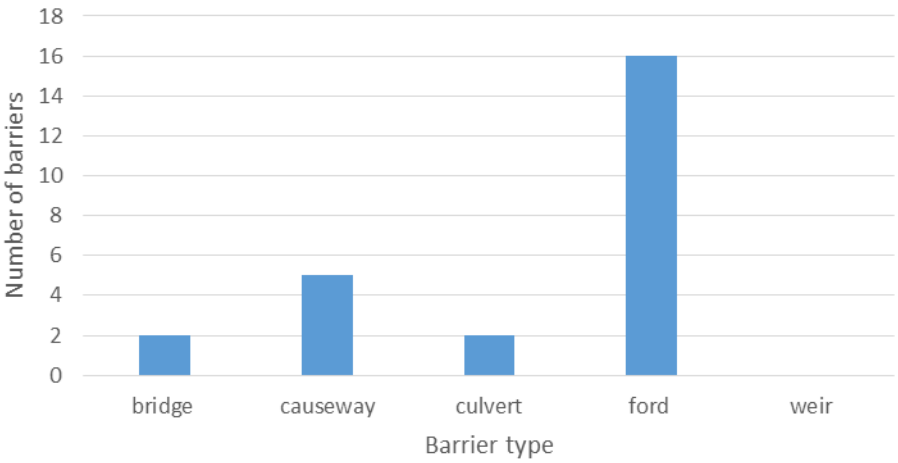


Figure 11. Shallow flow depth caused by a ford over a tributary to Naas Creek crossing on Naas Fire Trail.

What crossings allow fish to pass?

Of all crossings surveyed, open span bridges are least likely to block fish passage. They account for 52% of all crossings that allow fish passage in the ACT. Twenty five percent of crossings that allow fish passage are deep fords and 21% are low set culverts (Figure 12). While fords and culverts can create fish barriers, when they are designed and constructed to specific criteria they can allow fish passage. Thus, it is important to note that the design of the crossing (rather than the type) is essential to maintain effective fish passage. For example, when bridges span over a stream bed water flow is not significantly changed and the natural stream bed is kept intact. Similarly, when fords and culverts are placed within a stream water can flow over and/or through the crossing (Table 7). Examples of crossings that allow fish passage are illustrated in Figure 13.

Figure 12: Number of barriers associated with each crossing type that allow fish passage in ACT National Parks and Reserves.

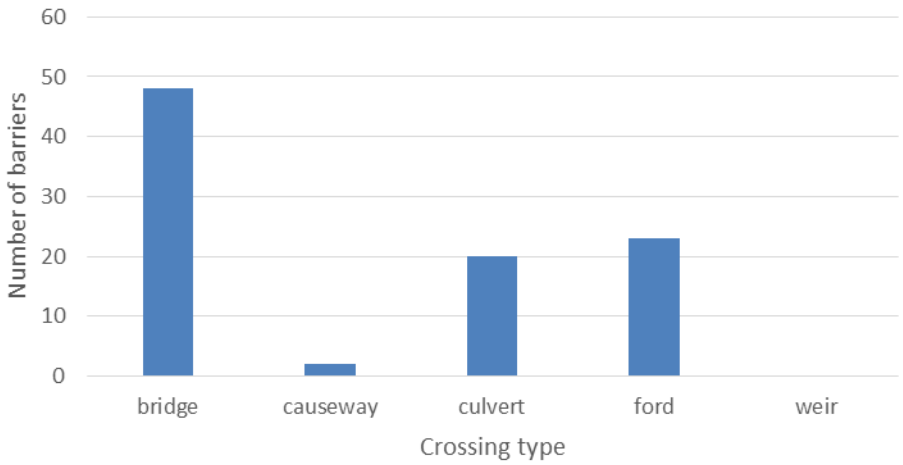


Table 7: Common features for crossings that allow fish passage. Refer to Figure 13 for photos of different types of crossing.

Type of crossing	Attributes that allow fish passage
Bridges (Figure 13 A)	**Open span**: width matches width of stream channel **Uninterrupted water flow and natural base**: water velocity matches the velocity in the stream channel
Culverts (Figure 13 B)	**Wide culverts**: width matches width of stream channel **Deep culverts**: depth matches depth of stream channel
Fords (Figure 13 C)	**Deep ford**: depth matches depth of stream channel
Causeways	**Wide pipes**: width matches width of stream channel and water velocity matches that of stream channel **Deep pipes**: depth matches depth of stream channel

Figure 13. Examples of crossings that allow fish passage

A. Bridge on Mountain creek Road crossing Swamp Creek.

B. Low culvert on Bogong Flat fire trail crossing Bogong Creek.

C. Deep ford on Lickhole track crossing Gingera Creek.

5 How to design fish friendly crossings

Effective fish passage can be assured through the construction of well-designed crossings that avoid downstream drops and shallow flow depths. The road crossing over a stream should not create a greater obstacle than the stream channel it is crossing. There are a number of crossings in the ACT that allow fish passage, the common features of these crossings are:

1. A depth that matches the depth of the natural upstream and downstream water channel, stream bed is not raised
2. The velocity of the upstream and downstream water channel is maintained, natural substrate is maintained throughout crossing
3. A span that matches the width of the upstream and downstream water channel

Details of several examples of crossings with effective fish passage are illustrated in Figures 14, 15 and 16.

Figure 14. Culvert construction of crossing along Tidbinbilla Ring Road that allows fish passage. Note the wide pipe placed in the stream bed with natural substrate.

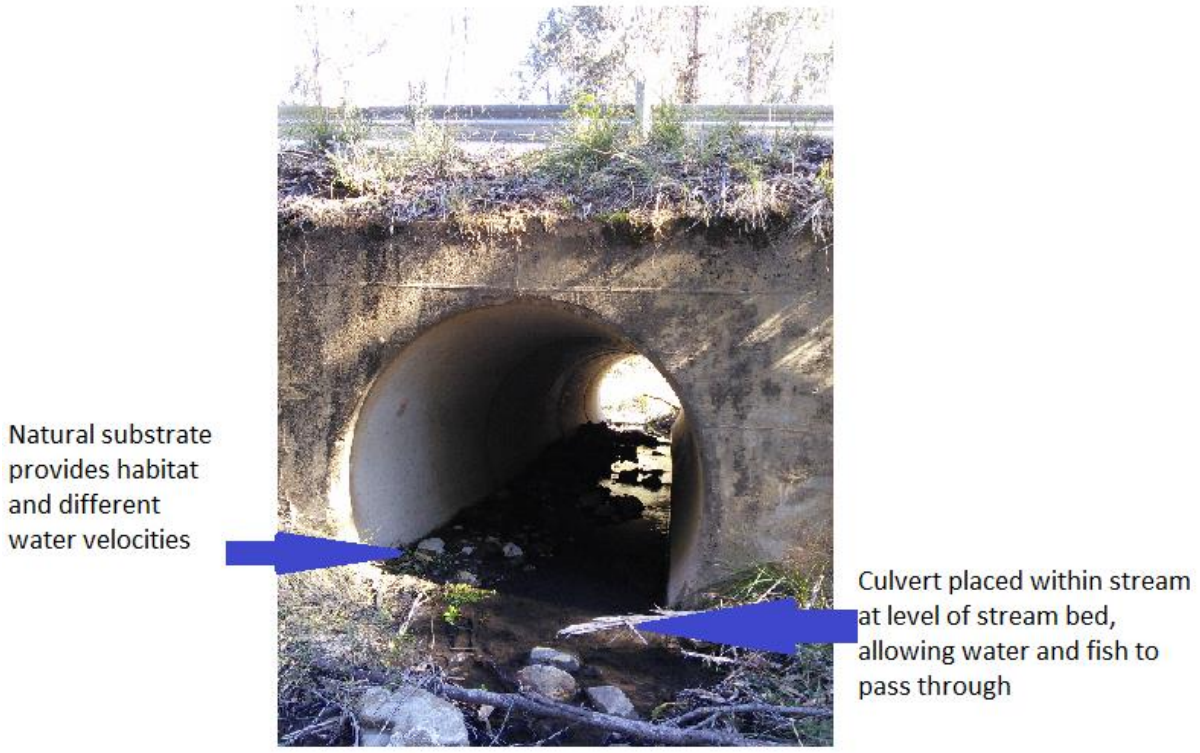
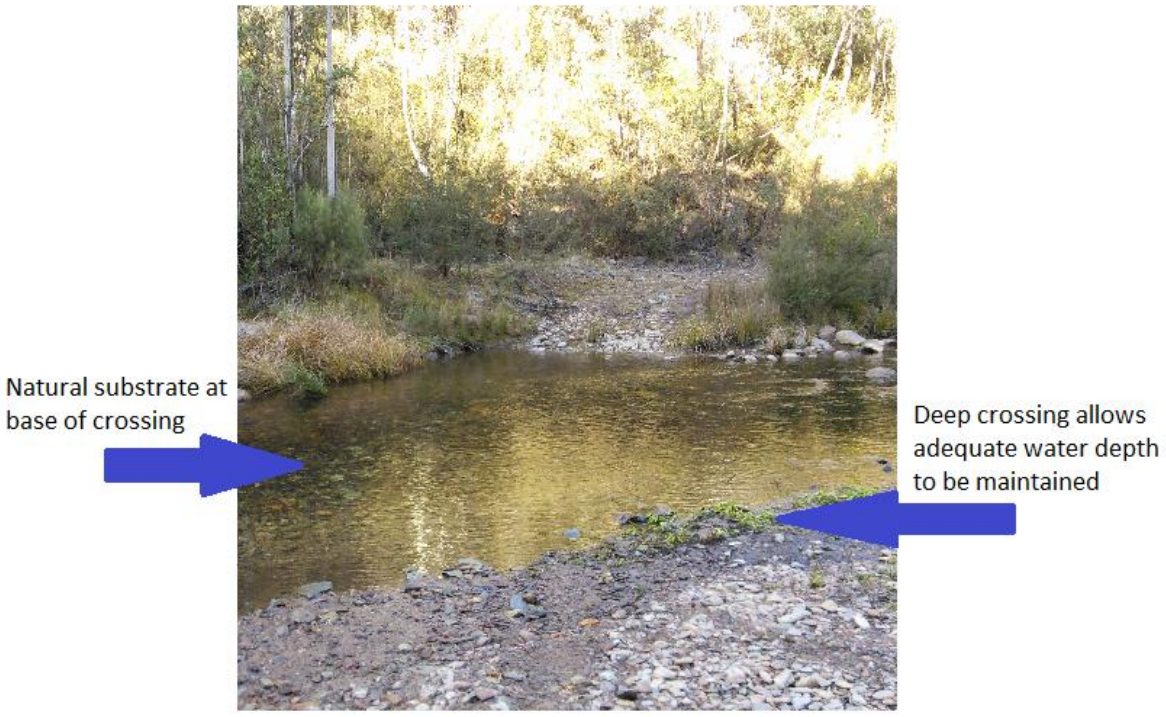


Figure 15. Cotter Road bridge that allows fish passage in the Cotter River, note the wide span and natural stream base that allows adequate water depth and velocity to be maintained.

Figure 16. Ford crossing over Cotter River, note that the ford maintains natural river depth and base to allow uninterrupted water flow.



While vehicle crossings over streams must meet the needs of vehicles fish passage (and the needs of other aquatic organisms) must be an integral part of the design, construction and maintenance (Fairfull and Witheridge 2003, Franklin et al. 2018, USDA 2008). Best practice design will maintain the integrity of stream bed and banks as much as possible.

Current international guidelines on the design and construction of water crossings is called 'stream simulation'. Stream simulation is a concept adapted from guidelines developed in the United States, where the road crossing is formed over the existing stream, disturbing as little as possible of the stream bed, water velocity and water depth (USDA 2008). Where this is not possible then effort is made to construct a crossing that simulates the stream width, water velocity and depth. Stream simulation can be directly adapted to the the water crossings through the ACT and is especially important in areas of ecological significance. Essentially, stream simulation aims to ensure a crossing that creates the least obstacle to fish passage as possible. Many of the principles of stream simulation can be incorporated into maintenance activities to maintain or improve fish passage of existing crossings.

This report presents a number of options to create a crossing with minimal change to the stream structure. This project demonstrates that the design of crossings is adaptable for many types of crossing structures. Guidelines to create crossings that ensure fish passage (identified as part of this project) provide general guidance that can be applied to each stream, local environment and budget.

6 Conclusions and crossing guidelines

The primary objective of this work was to establish an understanding of the current state of fish passage in the ACT, provide data on each of the crossings and provide information on the current best-practice approaches to inform the planning, construction and maintenance of fish passage in the ACT. This is particularly relevant in the conservation areas where high populations of native fish species reside.

The desired long-term outcome is to improve fish passage and avoid the creation of new barriers, specifically road crossings (which were found to be a major form of barrier to fish passage). Adequate consideration of fish passage requirements and the consideration of stream simulation principles is needed at all phases of road works. This includes the design, construction and maintenance stages.

This project demonstrates that the two most common non-natural barriers to fish passage in the ACT are vertical drops and shallow water depth. Poorly designed crossings most frequently culverts and raised fords, account for the greatest number of barriers investigated as part of this study. However, well designed and constructed crossings allow fish passage. Thus the design of the crossing, rather than type, is essential for creating effective fish passage (Table 8).

Table 8: Features of crossings that allow effective fish passage.

Features	**Construct crossings that:**
Depth	• consistently match the depth of the upstream and downstream water channel • no vertical drops • no raised crossings
Velocity	• match the velocity of the water in the upstream and downstream water channel • retain natural stream bed
Span	• match the width of the upstream and downstream water channel ie. no narrow channels

Future design, construction and maintenance of track crossings over water could consider these crossing guidelines. Where possible, fish passage would become part of the planning process for road construction, design and maintenance that include road crossings and water ways.

The information could be developed to direct the integration of fish passage into road crossings and other barrier designs and construction within the ACT and maintenance and replacement programs include measures to maintain or improve fish passage of the barriers identified in this report. This has resource implications which would need assessment and prioritisation.

Sites identified in this report as environmental priorities required assessment and prioritisation to allow adequate fish passage. When designing crossings over water ways, fish passage could be included as a consideration in the design and construction phase. There is now information to inform

future road works (including maintenance) to follow the crossing design guidelines and allow for fish passage (Table 9).

Table 9: Actions to address barriers identified in this report.

Degree of blockage	Priority	Actions required
Environmental priority sites	High	Modify or replace crossing to allow for fish passage using crossing guidelines and stream simulation principles.
High degree of blockage	Medium -High	Alter crossing to allow for fish passage when maintenance or upgrade is required, taking care not to alter the surrounding stream habitat (e.g. maintain fens as fens and streams as streams). If upgrade is required allow fish passage using stream simulation principles.
Medium degree of blockage	Medium	When maintenance on road is required, improve crossing to allow for fish passage, taking care not to alter the surrounding stream habitat (e.g. maintain fens as fens and streams as streams). If upgrade is required allow fish passage using stream simulation principles.
Low degree of blockage	Low	When maintenance is required for roads, improve crossing to allow for fish passage. If road upgrade is required maintain fish passage using stream simulation principles.
No barrier and beneficial barriers	No action required	When maintenance is required for roads, do not change crossing type or layout.

7 References

Baumgartner, L.., Zampatti, B., Jones, M., Stuart, I., Mallen-Cooper, M. (2014). Fish passage in the Murray-Darling Basin, Australia: Not just an upstream battle*. Ecological Management and Restoration* 15, 28-39.

Coleman, RA., Gauffre, B., Pavlova, A., Beheregaray, L.B., Kearns, J., Lyon, J., Sasaki, M., Leblois, R., Sgro, C., Sunnucks, P. (2018). Artificial barriers prevent genetic recovery of small isolated populations of a low-mobility freshwater fish. *Heredity* 120, 515-532

Fairfull, S., Witheridge, G. (2003). *Why do fish need to cross the Road? Fish passage requirements for waterway crossings.* NSW Fisheries, Cronulla, NSW

Franklin, P., Gee, E., Baker, C. F., Bowie, S. (2018). *New Zealand Fish Passage Guidelines: For structures up to 4 meters.* Hamilton: NIWA Publication

Harig, A. L., Fausch K. D. (2002). Minimum habitat requirements for establishing translocated cutthroat trout populations*. Ecological Applications* 12, 535-551

Howson, T., Evans, L., Beitzel, M. and Jekabsons, M. (2018). *Small streams Project: Fish survey report 2014-2015*, Conservation Research, ACT Government, Unpublished Report

Humphries, P. (2005). Spawning time and early life history of Murray Cod, *Maccullochella peelii* (Mitchell) in an Australian river. *Environmental Biology of Fishes* 72, 393-407

Koehn, J.D., McKenzie, J.A., O'Mahoney. D.J., Nicol, S.J., O'Connor, J.P., O'Connor W.G. (2009). Movements of Murray Cod (*Maccullochella peelii peelii*) in a large Australian Lowland river. *Ecology of Freshwater Fish* 18, 594-602

Lintermans, M., Osborne W. (2002). *Wet and Wild: A field guide to the freshwater animals of the Southern tablelands and high country of the ACT and NSW*. Canberra: Environment ACT

Lintermans, M., Rutzou, T. (1990). *The fish and fauna of the Upper Cotter River catchment* (Research Report 4) Canberra: ACT Government

Magoulick, D.D., Kobza, R.M., (2003). The role of refugia for fishes during drought: a review and synthesis. *Freshwater Biology* 48, 1186-1198

O'Connor, J.P. O'Mahony D.J., O'Mahoney, J.M. (2005). Movements of *Macquaria ambigua* in the Murray River, south-eastern Australia. *Journal of Fish Biology* 66, 392-403

Pavlova, A., Beheregaray, L.B., Coleman, R., Gilligan, D., Harrisson, K.A., Ingram, B.A., Kearns, J., Lamb, A.M., Lintermans, M., Lyons, J., Nguyen, T.T.T., Sasaki, M., Tonkin, Z., Sunnucks, P. (2017). Severe consequences of habitat fragmentation on genetic diversity of an endangered Australian freshwater fish: A call for assisted gene flow. *Evolutionary Applications* 10 (6): 531-550

Reynolds L. F., (1983). Migration Patterns of five fish species in the Murray-Darling River System. *Australian Journal of Marine and Freshwater Research* 34, 857 -871

US Department of Agriculture, Forestry Service (2008). *Stream Simulation: An ecological approach to providing passage for aquatic organisms at Road-stream crossings*. Washington, USDA Publication

Webb, P.W. (1975). Hydrodynamics and energetics of fish propulsion. *Bulletin of the Fisheries Research Board of Canada*, 190

Appendix 1

Field data sheet

Staff	initials of staff member
Date	DD/MM/YY of site visit
GPS Easting:	MGA easting
Northing	MGA Northing
Waterway	River or creek name if known
Catchment	major catchment
Bank height at crossing	estimate height (0.0m) from normal water level to top of bank
Channel width at crossing	estimate or laser ranger finder width (0.0m) from normal water level of pre crossing channel width
Flow Level at time of visit	**High, Medium, Low, Dry**
Min Thalweg depth through crossing (m)	estimate or measure minimum Thalweg depth (0.00m) within/beneath the crossing (not fish way if present)
Depth Upstream of barrier	estimate or measure minimum Thalweg depth (0.00m) directly upstream of the barrier
Downstream of barrier	estimate or measure minimum Thalweg depth (0.00m) directly downstream of the barrier
Fish barrier type	**Dam wall**: structure (earth rock or concrete) backing water higher than 2m (note undershot or overshot)
	Bridge: structure built over waterway with significant gap beneath may be single or multi span.
	Culvert: structure in which the water predominantly passes through pipes or boxes under the crossing
	Weir: structure above the normal water level backing water < 2m high including notched weirs (note undershot or overshot)
	Causeway: structure built above the bed level water level in which the water passes over the crossing

Staff	initials of staff member
	Ford: structure or splash through at the bed level in which the water passes over the crossing
	Floodgate: gate or structure which can be opened to allow or prevent flood waters through
	Other
Culvert Type	shape of the structure- usually a box, pipe, arch, channel or open span
Number of cells	Number of cells or bridge bays
Cell width/diameter (m)	The cross sectional width of the cells. If more than one size is present then list all widths from natural left bank to right bank.
Cell height	The height of the cells (if different from the width. If more than one size is present then list all from natural left bank to right bank.
Barrier width (m)	barrier width
Barrier height (m)	barrier height
Barrier breadth (m)	barrier breadth
If fish passage is blocked why?	**Downstream Drop (>5cm) Downstream drop**: vertical distance > 5cm, between the water in the crossing and the water downstream of the crossing
	Upstream drop or jump (>5cm) vertical distance > 5cm, between the water in the crossing and the water upstream of the crossing
	Slope (>1:20): barrier creates an upward or downward slope of >1:20
	High Velocity >1.5m/s: water moving at a speed of > 1.5 m/second
	Increased turbulence: rough unsteady movement of water
	Shallow flow depth: water too shallow for fish to pass, usually created when base of a crossing is raised above the level of the stream bed
	Debris (large woody/sediment) : wall or bank creates physical obstruction fish cannot pass
	Lack of light: inadequate natural light to allow some fish to pass
Construction material	**Timber, Concrete etc.**

Staff	initials of staff member
Road	Sealed or unsealed approaches to the crossing
Is there a fish way?	**Yes/No**
Fish way Type	rock pool and ridge, rock ramp, vertical slot, full or partial width, single or multi pitch
Is the fish passage effective?	**Yes/No**
Degree of blockage	**Complete**: no fish can pass
	Major: some fish are able to pass in certain conditions (i.e. high water level, low velocity)
	Moderate: fish can pass with effort
	Minor: fish can pass, but may be challenged or in a position of increased predation
	No barrier: fish can pass easily, with no additional risk of predation or injury
	Beneficial: fish species are significantly different each side of the crossing (ie. carp not found upstream of the crossing)
Flow over/through site?	**Yes/No**
Water flow	**Gentle incline**: gradual slope of water slope < 1:20
	Steep cascade: vertical fall of water
	Moderate cascade: fall of water less than 90 degrees
	High velocity: >1.5 m/sec
	Moderate velocity: 1.5-0.5m/sec
	Low Flow: slight movement of water <0.5 m/sec
	No Flow: stagnant water
Obstacle upstream or downstream of the structure?	Record location and type of obstacle

Appendix 2

What creates barriers to fish movement?

Common barriers to fish movement found during the project are vertical drops (created by the crossing sitting well above water level), shallow water though crossings, high velocity and debris and sediment build up.

Vertical drops (downstream drops and upstream jumps)

This distance between the natural channel base water and the structure creates a vertical obstacle to fish and usually a higher velocity at the outlet. A vertical drop can be present at the upstream and /or downstream end of the structure. The vertical distance between the water and structure may be created by a culvert placed above water level, or over time through erosion of the stream bed (Figure 17).

Figure 17. Pipe culvert in Bimberi Creek along Yaouk Fire Trail, and pipe culvert in Sawpit Creek fire trail, Namadgi National Park, both showing a significant lip between the culvert and stream.

Shallow Flow Depth

When the base of a crossing is raised above the level of the stream bed the shallow water prevents the movement of fish that need a minimum depth of water to move thorough. In shallow water fish are prevented from swimming, gills are not saturated (resulting in lack of oxygen) and with body designs requiring emersion in water, movement is impaired (Webb 1975). In addition the crossing can dry out completely in times of low stream flow, creating a complete barrier for all fish (Figure 18).

Figure 18. Gibraltar Creek and Corin Road crossing, demonstrating barrier to fish with shallow flow depth in the crossing, this crossing also has a downstream drop.

High Velocity and Increased Turbulence

The pressure of water flowing through pipes creates high velocity that acts as a physical barrier which fish are unable to swim through. In sites where water turbulence exceeds the swimming capability of the fish in the area these sites of high velocity are barriers to fish passage (Webb 1975). In the ACT only trout are able to swim through such strong flows (Figure 19).

Figure 19. Crossing of the Cotter River below Bendora Dam showing high velocity of water from pipes and downstream drop.

Debris and Sediment

Debris and sediment block fish passage by creating a wall or bank that fish cannot pass. Narrow culverts for example more easily clog up with debris than wider culverts, where the water flow pushes the debris through (Figure 20).

Figure 20. Debris caught at the outlet of a culvert, blocking upstream fish movement, on Warks Road crossing Lees Creek.

Appendix 3

Images of identified environmental priority sites

Environmental priority site 1 Point Hut Crossing

Environmental priority site 2 Angle Crossing

Environmental priority site 3 Burkes Creek Road crossing

Environmental priority site 4 Jacks Creek

Environmetal priority site 5 Bimberi Creek

Environmental priority site 6 Naas Creek firetrail

Environmental priority site 7 Old Boboyan Road crossings Naas Creek

Environmental priority site 8 causeway over Naas Creek, near Caloola Farm

Environmental priority site 9 Rocky Crossing, Orroral Road crossing Gudgenby Creek

Environmental priority site 10 Sunshine Road crossing Naas Creek

Appendix 4

Maps of sites

Figure 21. Map showing sites of barrier with a low degree of blockage and/or of low concern in the ACT.

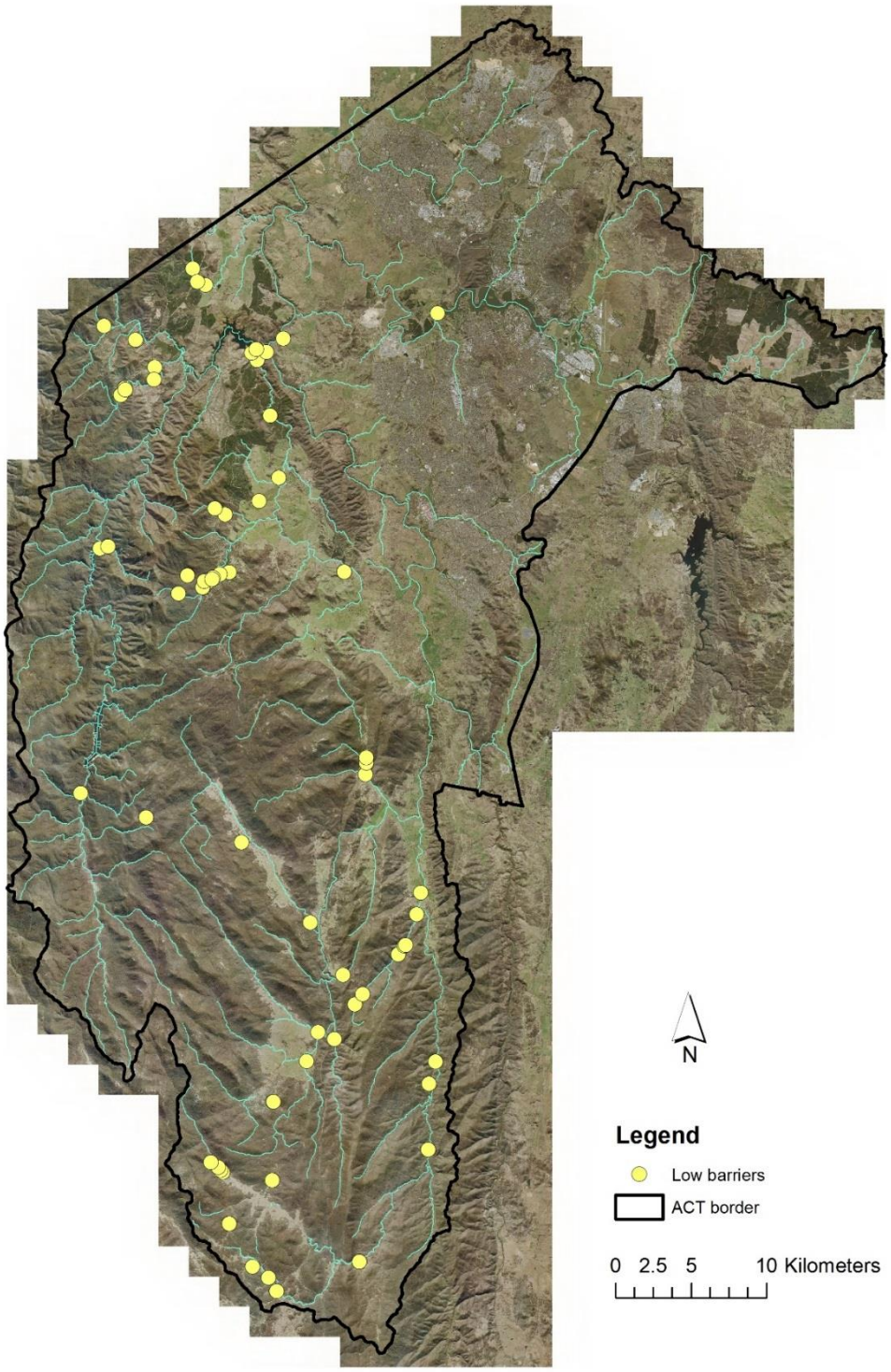


Table 10 List of crossings that have a low degree of blockage and/or of low concern to fish passage in the ACT.

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
1	Cotter	Condor Creek	Brindabella Road, uphill from Thompsons Corner	668575	6089876
2	Cotter	Cotter	Below Bendora	666151	6076106
3	Cotter	Cotter	Brindabella Road second crossing (uphill) from Thompsons Corner	668509	6089889
4	Cotter	Cotter	Weir below Cotter Dam (approximately 500 m upstream of 'The Bend ' Picnic Area)	676191	6089014
5	Cotter	Cotter	Weir Between Cotter Dam and Cotter Road	676499	6089278
6	Cotter	Cow Creek	Cow Creek Ford	666685	6076229
7	Cotter	Gingera Creek	Gingera Creek crossing Lick Hole Track	664884	6059902
8	Cotter	James Creek	James Creek Ccrossing Cotter Hut Road	675518	6056655
9	Cotter	Musk Creek	Musk Creek crossing Parral Road	666428	6090608
10	Cotter	Paddys River	Paddys River crossing near Caves, Road leads to fire trail up to Bullen Range	676540	6088547
11	Cotter	Tributary To Cotter	Cotter Hut Road Culvert	669202	6058331
12	Cotter	Lees Creek	Lees Creek	667794	6086711
13	Cotter	Lees Creek	Warks Road crossing Lees Creek	667532	6086250
14	Cotter	Lees Creek	Warks Road	667845	6086595
15	Cotter	Tributary of Lees Creek	Warks Road	669773	6088065

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
16	Cotter	Tributary of Lees Creek	Warks Road crossing tributary of Lees Creek	669722	6087268
17	Gudgenby	Booroomba Creek	Large culvert crossing on Mt Tennant Fire Trail Namadgi NP climbing up Mt Tennant (before turn off to hut)	683757	6061905
18	Gudgenby	Gudgenby Creek	Gudgenby Creek Fire Trail ford when driving North from Brandy Flat Hut	685871	6049242
19	Gudgenby	Honeysuckle Creek	Ford crossing on Mt Tennant Fire Trail in Ballaneen Property, Namadgi NP	683724	6061153
20	Gudgenby	Reedy Creek	Brandy Flats Fire Trail crossing Reedy Creek	682229	6047910
21	Gudgenby	Tributary to Gudgenby Creek	Gudgenby Creek Fire Trail first ford when driving from locked gate at border of Namadgi NP, closest to Caloola Farm	686368	6049876
22	Gudgenby	Tributary to Gudgenby Creek	Gudgenby Creek Fire Trail 2nd culvert when driving to Caloola Farm from Brandy Flat Hut (along Gudgenby Fire Trail)	683019	6045951
23	Gudgenby	Tributary to Gudgenby Creek	Gudgenby Creek Fire Trail 3rd Culvert when driving North from Brandy Flat Hut	683520	6046623
24	Gudgenby	Tributary to Gudgenby Creek	Gudgenby Creek Fire Trail second ford when driving North from Brandy Flat Hut	686275	6049831
25	Gudgenby	Tributary to Booroomba Creek	Small culvert crossing on Mt Tennant Fire Trail Namadgi NP, climbing up Mt Tennant (less than 1 km before turn off to Hut)	683763	6062269
26	Molongolo	Molongolo	Scrivener Dam	688487	6091660
27	Murrumbidgee	Ashbrook Creek	Ashbrook Fire Trail crossing Ashbrook Creek	671342	6073123

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
28	Murrumbidgee	Hurdle Creek	Heritage swimming pool outside Nil Desperadum	674441	6078345
29	Murrumbidgee	Hurdle Creek	Hurdle Creek crossing under Gilmore Road	673759	6078754
30	Murrumbidgee	Mountain Creek	Ashbrook Fire Trail	671956	6074298
31	Murrumbidgee	Murrumbidgee	Casuarina Sands Weir	678271	6089962
32	Murrumbidgee	Cotter	Weir at Cotter Campground	677158	6089088
33	Murrumbidgee	Tidbinbilla River	Dam and footbridge at wetlands. Damming lower end of wetland pond	673139	6073969
34	Murrumbidgee	Tidbinbilla River	Footbridge 8 m downstream of weir	672958	6073512
35	Murrumbidgee	Tidbinbilla River	Gauge station beneath Rockwallaby Enclosure	673560	6074067
36	Murrumbidgee	Tidbinbilla River	Inside Wetlands Enclosure	673066	6073927
37	Murrumbidgee	Tidbinbilla River	Major weir at top of Tidbinbilla Wetlands	672973	6073498
38	Murrumbidgee	Tributary of Tidbinbilla River	Tidbinbilla wetlands channel running under fence	673182	6073797
39	Murrumbidgee	Tributary of Tidbinbilla River	Intersection of Tidbinbilla Road North Tidbinbilla Ring Road	674703	6074526
40	Murrumbidgee	Tributary of Tidbinbilla River	Ring Road past Flints Picnic Grounds	674090	6074393
41	Murrumbidgee	Tidbinbilla River	Tidbinbilla foot track (ford) inside Black Flats Enclosure	673613	6074171
42	Murrumbidgee	Tributary of Uriarra Creek	Along Sherwood Road, South of Sherwood Homestead heritage site	672304	6094612

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
43	Murrumbidgee	Tributary of Uriarra Creek	Along Sherwood Road	672607	6093735
44	Murrumbidgee	Uriarra Creek	Uriarra Creek behind Uriarra Station	673143	6093507
45	Naas	Dry Creek	Dry Creek crossing Brandy Flat Fire Trail	681659	6043641
46	Naas	Tributary of Grassy Creek	Fen crossing along Waterhole Creek Fire Trail Namadgi Westermans Hut	677847	6026985
47	Naas	Naas Creek	Naas Creek Fire Trail	683302	6028943
48	Naas	Tributary of Naas Creek	Naas Creek Fire Trail	687847	6036356
49	Naas	Tributary of Naas Creek	Naas Creek Fire Trail	687927	6040693
50	Naas	Tributary of Naas Creek	Naas Creek Fire Trail	688332	6042156
51	Naas	Rendezvous Creek	Boboyan Road crossing Rendezvous Creek	680584	6044124
52	Naas	Tributary Of Naas Creek	Old Boboyan Road crossing over tributary to Naas Creek, North of Naas Creek Crossing	677544	6034312
53	Naas	Bogong Creek	Southern Namadgi Intersection of Bogong Creek Fire Trail and Old Boboyan Road	677618	6039504
54	Naas	Bogong Creek	Southern Namadgi on Old Boboyan Road, close to intersection with Bogong Creek Fire Trail	677618	6039504
55	Naas	Tributary To Grassy creek	Fen crossing along Waterhole Creek Fire Trail, Namadgi NP	677306	6027873
56	Naas	Tributary to Grassy creek	Fen crossing along Waterhole Creek Fire trail Namadgi	676241	6028612
57	Naas	Tributary to Sams Creek	Sams Creek along Sams River Fire Trail	674273	6034846

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
58	Naas	Tributary to Sams Creek	Sams Creek along Sams River Fire Trail	674130	6034990
59	Naas	Tributary to Sams Creek	Sams Creek along Sams River Fire Trail	673974	6035193
60	Naas	Tributary to Sams Creek	Sams Creek along Sams River Fire Trail	673477	6035522
61	Naas	Tributary to Sheep Station Creek	Tributary to Sheep Station Creek along Grassy Creek Fire Trail	674698	6031445
62	Naas	Tributary of Middle Creek	Old Boboyan Road ford crossing near Gudgenby Homestead	679810	6042200
63	Naas	Naas	Causeway 1 km NW of Caloola Farm	687108	6051911
64	Naas	Breakfast Creek	Old Boboyan Road crossing over Breakfast Creek	677212	6036176
65	Naas	Naas Tributary	Crossing of Naas Road over tributary to Naas Creek 2 km NW from Caloola Farm	687376	6053331
66	Orroral	Orroral River	Orroral River, downstream of Orroral gauge	680062	6051372
67	Paddys	Tributary of Paddys River	Geals Creek tributary to Paddys River	682304	6074560
68	Paddys	Tributary of Paddys River	Congwarra Farm, Paddys River Road	676684	6079234
69	Paddys	Paddys River	Murrays Corner	677426	6084878
70	Paddys	Tanners Flat Creek	Small Dam in stream in Tanners Creek, upstream of bridge	677967	6080761

Figure 22 Map showing sites of crossings that allow fish passage in the ACT.

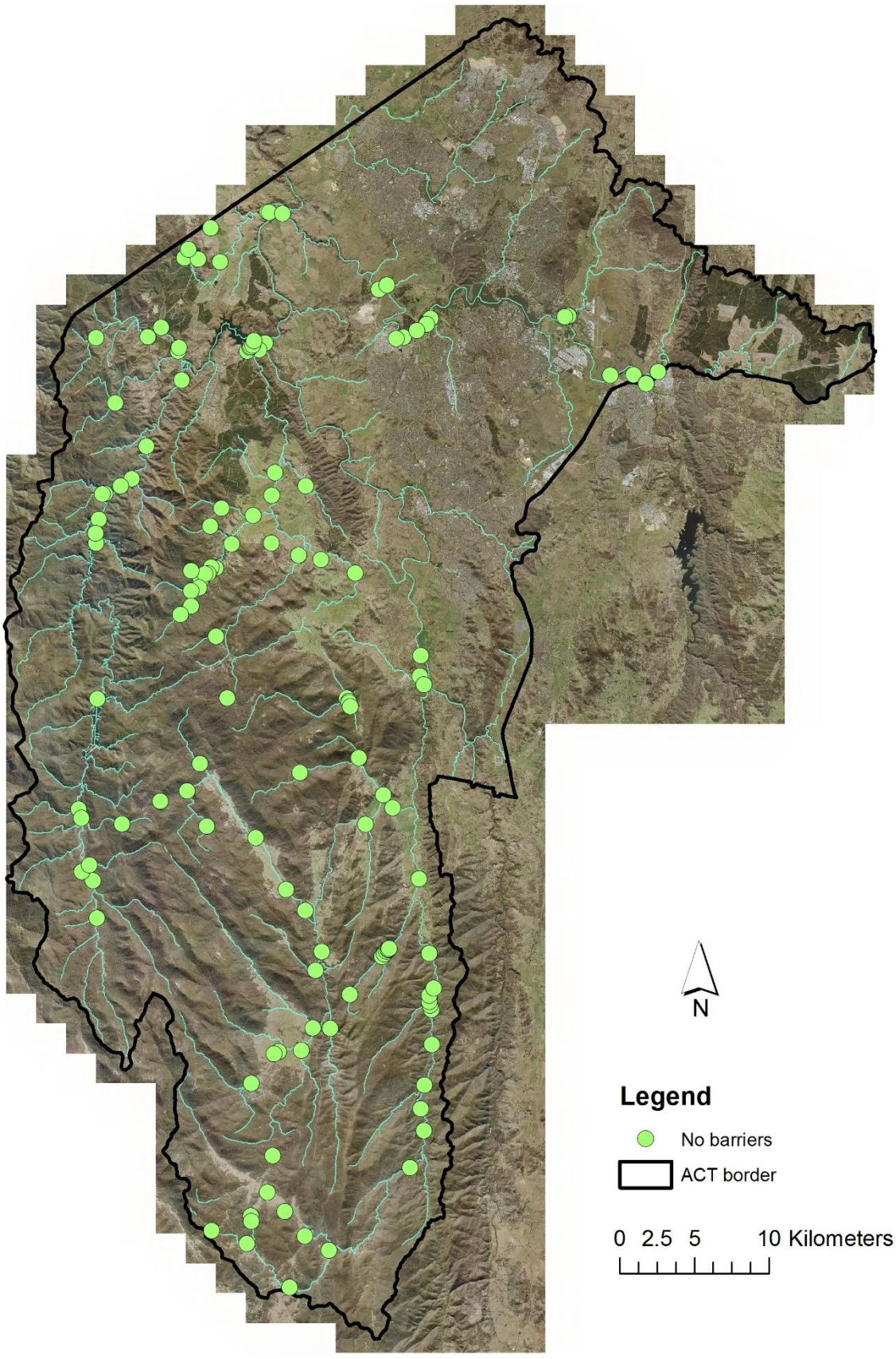


Table 11 Crossings that allow fish passage

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
1	Cotter	Cotter River	Ford on Burkes Creek Track	668398	6080357
2	Cotter	Cotter River	Burkes Road Crossing, Cotter River	667652	6079879
3	Cotter	Collins Creek	Bendora Road Crossing, Collins Creek	666191	6077621
4	Cotter	Cotter River	Directly below Bendora Dam	666032	6076046
5	Cotter	Cotter River	Cow Flat Crossing, approximately 1 km below Bendora Dam	666001	6076707
6	Cotter	Cotter River	Vanitys crossing	671730	6086942
7	Cotter	Lees Creek	Lees Creek Cliff Road and Bullock Paddock Road intersection	671506	6088857
8	Cotter	Condor Creek	Padovans Crossing	671558	6089110
9	Cotter	Condor Creek	Thompsons Corner	669472	6089821
10	Cotter	Condor Creek	Blundells Flat, off Currys Road	666022	6089767
11	Cotter	Cotter River	Ford crossing where Bushrangers Creek enters Cotter River	666604	6079347
12	Cotter	Bushrangers	Bridge over Bushrangers Creek along Bendora Road	666440	6079326
13	Cotter	Little Bimberi Creek	Little Bimberi crossing Yaouk Fire Trail	666089	6051016
14	Cotter	Cotter River	Where Cotter River crosses Cotter Hut Fire Trail (1 km) down from Cotter Hut	665809	6053522
15	Cotter	Tributary to Cotter River	Mt Franklin Road crossing tributary to Cotter (Near Y intersection of Mt Franklin,	665054	6054116

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
			Cotter Hut Road and Yaouk Fire Trail)		
16	Cotter	Cotter River	Bridge over Cotter Hut Road (Near Y Intersection with Yaouk Fire Trail and Mt Franklin Road)	665561	6054549
17	Cotter	Cribbs Creek	Cribbs Creek crossing over Lick Hole Track	664846	6058287
18	Cotter	Tributary to Saw Pit Creek	Sawpit Creek crossing Cotter Hut Road, near locked gate	670304	6058806
19	Cotter	Cotter River	Pipeline Crossing	669377	6082520
20	Cotter	Cotter River	Footbridge at 'The Bend' Picnic Area upstream of where Paddys River flows into Cotter River	676124	6088879
21	Cotter	Cotter River	Footbridge below Cotter Bridge (At Thompsons Corner) site of old burnt down Pub	676306	9089115
22	Cotter	Cotter River	Cotter Road vehicle bridge over Cotter River 1 km downstream of Cotter Dam	676377	6089185
23	Cotter	Cotter River	Footbridge at Cotter Avenue Picnic Area'	676488	6089263
24	Cotter	Cotter River	Footbridge 200 m below Cotter Dam	676572	6089569
25	Cotter	Licking Hole Creek	Lick Hole Track Crossing, Cotter River (First creek crossing North off Cotter Hut Road and Lick Hole Creek Track intersection)	665026	6057678
26	Cotter	Tributary to Cotter River	Cotter Hut Road culvert	667742	6057283

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
27	Cotter	Condor Creek	Warks Road near Brindabella Road	670376	6090444
28	Cotter	Lees Creek	Warks Road, Blundell's Creek intersection	667293	6085411
29	Gudgenby	Booroomba Creek	Apollo Road near Willowvale Farm	685207	6059235
30	Gudgenby	Tributary to Honeysuckle Creek	Apollo Road near Honeysuckle Campground	679643	6060739
31	Gudgenby	Gudgenby River	Naas Road Bridge near Caloola Farm turn off near sign.	685850	6058363
32	Gudgenby	Half Moon Creek	Naas Road at base of Fitz's Hill	684038	6057274
33	Gudgenby	Tributary to Gudgenby Creek	Gudgenby Creek Fire Trail first culvert when driving to Caloola Farm from Brandy Flat Hut	682994	6045901
34	Gudgenby	Tributary To Gudgenby Creek	First ford crossing when driving North from Brandy Flat Hut to Caloola Farm along Gudgenby Creek Fire Trail	685135	6048440
35	Gudgenby	Gudgenby Creek	Gudgenby Creek Fire Trail 2nd ford when driving from Brandy Flat Hut to Caloola Farm	685269	6048686
36	Gudgenby	Gudgenby Creek	Gudgenby Creek Fire Trail 3rd Ford when driving from Brandy Flat Hut to Caloola Farm	685433	6048801
37	Gudgenby	Gudgenby Creek	Gudgenby Creek Fire Trail 4thford when driving from Brandy Flat Hut to Caloola Farm	685539	6048883

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
38	Gudgenby	Small Tributary to Gudgenby Creek	Gudgenby Creek Fire Trail ford when driving North from Brandy Flat Hut	685557	6048915
39	Gudgenby	Gudgenby Creek	Gudgenby Creek Fire Trail ford crossing over Gudgenby River (3rd ford when driving from Brandy Flat Hut to Caloola Farm)	685597	6048968
40	Gudgenby	Bogong Creek	First bridge crossing Bogong Creek on walking trail to Yankee Hat Art Site (when walking from car park) Namadgi NP	678219	6042091
41	Gudgenby	Tributary to Bogong Creek	Raised walking platform crossing tributary to Bogong Creek on walking trail to Yankee Hat Art Site Namadgi NP	677926	6041950
42	Gudgenby	Blue Gum Creek	Ford crossing Bluegum Creek Fire Trail over Bluegum Creek 1st crossing	682774	6065715
43	Gudgenby	Georges Creek	Ford crossing Bluegum Creek Fire Trail over Georges Creek 2nd crossing	682935	6065504
44	Gudgenby	Georges Creek	Ford crossing Bluegum Creek Fire Trail over Georges Creek 3rd crossing	682931	6065417
45	Gudgenby	Georges Creek	Ford crossing Bluegum Creek Fire Trail over Georges Creek 4th crossing	683024	6065417
46	Gudgenby	Booroomba Creek	Culvert crossing on Mt Tennant Fire Trail, Namadgi NP, after passing through gate (uphill) marking boundary between	683593	6061697

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
			Namadgi NP and Balneen Property		
47	Molonglo	Molonglo River	Bridge near ACT/NSW border on Pialligo Road	703560	6087519
48	Molonglo	Molonglo River	Bridge to Oakes Estate, Oakes Estate Road Crossing, Molonglo River	701964	6087301
49	Molonglo	Queanbeyan River	Weir under railway bridge crossing Queanbeyan River (500 m from Queanbeyan Railway Station)	702789	6086714
50	Molonglo	Queanbeyan River	Railway bridge near Oakes Estate (500 m from Queanbeyan Railway Station)	702797	6086696
51	Molonglo	Molonglo River	Abandoned bridge	700409	6087275
52	Molonglo	Molonglo River	Sylvia Curley bridge, Monaro Highway over Molonglo River, single lane bridge	697670	6091200
53	Molonglo	Molonglo River	Monaro Highway crossing Molonglo River (4 lanes, dual carriageway)	697590	6091233
54	Molonglo	Molonglo River	Morshead Drive Bridge crossing over Molonglo River	697356	6091161
55	Molonglo	Molonglo River	Footbridge behind RSPCA crossing the Molonglo River	686583	6089783
56	Molonglo	Molonglo River	Butters Bridge, crossing Molonglo River 1 km downstream from Coppins Crossing	684918	6092982
57	Molonglo	Molonglo River	Coppins Crossing	685460	6093295

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
58	Molonglo	Woden Creek	Cycle path over Woden Creek flowing into Molonglo River, downstream of Scrivener Dam	688382	6091047
59	Molonglo	Molonglo River	Pedestrian crossing Between Scrivener Dam and Tuggeranong Parkway	688103	6090661
60	Molonglo	Molonglo River	Behind Denman Prospect development	686097	6089700
61	Molonglo	Molonglo River	Tuggeranong Parkway Bridge	687477	6090247
62	Molonglo	Molonglo River	Footbridge over Molonglo River between Uriarra Picnic Grounds and sewage treatment plant.	678470	6098052
63	Murrumbidgee	Tributary of Tidbinbilla River	Tidbinbilla Picnic Grounds	675086	6075998
64	Murrumbidgee	Tributary of Tidbinbilla River	Ring Road past Tidbinbilla Picnic Grounds	674018	6074370
65	Murrumbidgee	Tributary of Tidbinbilla River	Tidbinbilla Ring Road crossing Tidbinbilla River, at Rock Wallaby enclosure.	673623	6074180
66	Murrumbidgee	Tidbinbilla River	Ford behind Tidbinbilla depot	673719	6074446
67	Murrumbidgee	Tidbinbilla River	Foot Bridge 50 m downstream from weir	673012	6073601
68	Murrumbidgee	Tidbinbilla River	Foot Bridge in wetland enclosure below wetlands	673292	6073988
69	Murrumbidgee	Tidbinbilla River	River Flowing into Tidbinbilla Wetlands	672913	6073084
70	Murrumbidgee	Mountain Creek	Behind Koala enclosure	672360	6074201

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
71	Murrumbidgee	Ashbrook Creek	Vehicle bridge near Hanging Rock, Tidbinbilla	672381	6072853
72	Murrumbidgee	Tidbinbilla River	Bridge near Fishing Gap Carpark	672355	6071844
73	Murrumbidgee	Tidbinbilla River	Fishing Gap Road crossing Tidbinbilla River	671653	6071272
74	Murrumbidgee	Swamp Creek	Bridge over Swamp Creek, near Uriarra Crossing	677462	6098173
75	Murrumbidgee	Uriarra Creek	Bridge along Mountain Creek Road closest to Uriarra Road.	674306	6094851
76	Murrumbidgee	Swamp Creek	Bridge along Mountain Creek Road, second bridge from Uriarra Road.	673684	6097112
77	Murrumbidgee	Uriarra Creek	Sherwood Fire Trail crossing Uriarra Creek	671910	6095102
78	Murrumbidgee	Tributary to Uriarra Creek	Along Sherwood Road	672836	6095010
79	Murrumbidgee	Tributary to Uriarra Creek	Along Sherwood Road	672204	6095686
80	Murrumbidgee	Tributary to Tidbinbilla River	Tributary to Tidbinbilla River along Gilmores Fire Trail	673643	6077172
81	Murrumbidgee	Hurdle Creek	Footpath to Camilia Garden outside Nil Desperadum	674400	6078370
82	Murrumbidgee	Tributary to Booroomba Creek	First stream crossing on Smokers Fire Trail entering from Corin Dam Road	674773	6065704
83	Murrumbidgee	Booroomba Creek	Smokers Fire Trail entering from Corin Dam Road	672967	6061311
84	Murrumbidgee	Murrumbidgee	Cotter Road traffic light bridge (next to Old	677320	6089410

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
			Pumping Station on Cotter Road)		
85	Murrumbidgee	Murrumbidgee	Footbridge at Cotter Campground	676892	6088975
86	Murrumbidgee	Murrumbidgee	Uriarra Crossing	677572	6098150
87	Murrumbidgee	Spring Station Creek	Spring Station Creek on Naas Road between Outward Bound School and Namadgi Visitors Centre	687664	6067165
88	Murrumbidgee	Murrumbidgee	Smith's Road	687927	6066614
89	Murrumbidgee	Murrumbidgee	Tharwa Bridge	687789	6068576
90	Naas	Gudgenby	Glendale Crossing	681114	6048773
91	Naas	Nursery Creek	Boboyan Road crossing Nursery Creek	680677	6047507
92	Naas	Gudgenby	Boboyan Road crossing Gudgenby River, near Gudgenby homestead	680521	6043660
93	Naas	Naas Creek	Boboyan Road crossing Naas Creek	681674	6043640
94	Naas	Grassy Creek	Naas Valley Fire Trail crossing Grassy Creek	681593	6028826
95	Naas	Tributary to Middle Creek	Old Boboyan Road ford crossing near Gudgenby Homestead Hut	679749	6042170
96	Naas	Naas Creek	Old Boboyan Road ford crossing over tributary to Naas Creek	677834	6035148
97	Naas	Tributary to Naas Creek	Old Boboyan Road crossing over tributary to Naas Creek, before locked gate to Old Boboyan Road	679987	6029773

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
98	Naas	Tributary to Naas Creek	Old Boboyan Road crossing over tributary to Naas Creek, near ruins	678619	6031417
99	Naas	Tributary to Naas Creek	Old Boboyan Road crossing over tributary to Naas Creek, South of Nass Creek and Old Boboyan Road Crossing	677457	6032690
100	Naas	Naas Creek	Naas Creek Fire Trail 1st crossing	687009	6034338
101	Naas	Tributary to Naas Creek	Naas Creek Fire Trail 2nd crossing	687921	6036807
102	Naas	Tributary to Naas Creek	Naas Creek Fire Trail 3rd crossing	687733	6038273
103	Naas	Reedy Creek	Naas Creek Fire Trail 4th crossing	687972	6039862
104	Naas	Tributary to Naas Creek	Naas Creek Fire Trail 5th crossing	688466	6042577
105	Naas	Tributary to Naas Creek	Naas Creek Fire Trail 6th crossing	688453	6044882
106	Naas	Tributary to Naas Creek	Naas Creek Fire Trail 7th crossing	688340	6045192
107	Naas	Tributary to Naas Creek	Naas Creek Fire Trail 8th crossing	688290	6045431
108	Naas	Tributary to Naas Creek	Naas Creek Fire Trail 9th crossing	688308	6045852
109	Naas	Tributary to Naas Creek	Naas Creek Fire Trail 10th crossing	688585	6046320
110	Naas	Tributary to Naas Creek	Naas Creek Fire Trail 11th crossing ng	688283	6048633
111	Naas	Tributary to Naas Creek	Naas Creek Fire Trail 12th crossing	687599	6053641

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
112	Naas	Grassy Creek	Southern Namadgi Along Boboyan Road Almost at NSW border	678954	6026332
113	Naas	Grassy Creek	Southern Namadgi along Grassy Creek Fire Trail	673745	6030139
114	Naas	Bogong Creek	Southern Namadgi along Bogong Creek Fire Trail	676381	6039956
115	Naas	Bulls Flat Creek	Fen crossing 50 m from intersection of Bulls Flat Fire Trail and Waterhole Creek Fire Trail Namadgi NP	676364	6031113
116	Naas	Bulls Flat Creek	Fen crossing 1 km from intersection of Bulls Flat Fire Trail and Waterhole Creek Fire Trail Namadgi NP	676401	6030748
117	Naas	Grassy Creek	Fen crossing along Waterhole Creek Fire Trail Namadgi NP, close to old cattleyards	676100	6029268
118	Orroral	Orroral	Footbridge over Orroral River	678732	6052905
119	Orroral	Orroral	Link Fire Trail over Orroral River	676693	6056363
120	Orroral	Orroral	Cotter Hut Road crossing Orroral River	673411	6057139
121	Orroral	Tributary to Saw Pit Creek	Cotter Hut Road	672113	6059512
122	Orroral	Orroral River	Causeway at Orroral Campground	680001	6051506
123	Paddys	Paddys River	Tidbinbilla Road crossing Paddys River	683343	6074058

Site	Catchment	River Name	Location	UTM Easting	UTM Northing
124	Paddys	Gibraltar Creek	Gibraltar Creek crossing under Tidbinbilla Road	679560	6075246
125	Paddys	Billy Billy Creek	Corin Road crossing Billy Billy Creek	674047	6069825
126	Paddys	Tributary to Kangaroo Creek	Tributary of Kangaroo Creek Crossing with Corin Road	666439	6066069
127	Paddys	Tributary to Paddys	Crossing under Paddys River Road between Gibraltar Creek and Paddys River	681034	6074957
128	Paddys	Tidbibnilla Creek	Crossing under Paddy River Road	676523	6077890
129	Paddys	Tanners Flat Creek	Tanners Creek	677967	6080761
130	Paddys	Paddys River	Discovery Drive river crossing closest to Paddys River Road	677758	6079247
131	Paddys	Larrys Creek	Tidbinbilla Tracking Station, close to satellite disks	680043	6079882
132	Paddys	Tidbinbilla Creek	A muddy creek crossing under Paddy River Road	676523	6077890
133	Paddys	Tributary to Paddys River	Bridge outside Birrigai	677740	6076039

Additional resources for understanding and designing fish passage.

Fairfull, S., Witheridge, G. (2003). *Why do fish need to cross the Road? Fish passage requirements for waterway crossings*. NSW Fisheries, Cronulla, NSW.

US Department of Agriculture, Forestry Service (2008). *Stream Simulation: An ecological approach to providing passage for aquatic organisms at Road-stream crossings*. Washington, USDA Publication

Franklin, P., Gee, E., Baker, C. F., Bowie, S. (2018). *New Zealand Fish Passage Guidelines: For structures up to 4 meters.* Hamilton: NIWA Publication

O'Connor, J., Stuart, I., Campbell-Beschorner, R. (2017). *Guidelines for fish passage at small structures.* Arthur Rylah Institute Environmental Research. Technical Report Series No. 276. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.