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Enlarged Cotter Dam Fish Management Plan

Version Two

November 2010

Delivered by the Bulk Water Alliance

Abigroup Constructing Australia's Future | ACTEW CORPORATION | GHD | John Holland

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Executive Summary

The Fish Management Plan presents information to assist in the protection of threatened aquatic species potentially impacted by the enlargement of the Cotter Reservoir. The plan is comprised of four versions prepared to coincide with key milestones of the Enlarged Cotter Dam project.

Version 2 of the Plan has been prepared to help minimise potential construction impacts of the Enlarged Cotter Dam on aquatic communities and their habitats in the Cotter Reservoir and Cotter River.

Threatened aquatic species addressed include:

- Macquarie Perch *(Macquaria australasica)*.
- Trout Cod *(Maccullochella macquariensis)*.
- Murray Cod *(Maccullochella peelii).*
- Two-spined Blackfish *(Gadopsis bispinosus)*.
- Murray River Crayfish *(Euastacus armatus)*.

This plan draws on a range of sources including research projects by institutions such as the University of Canberra, the Australian National University and the University of Sydney. Other investigations are also being conducted to inform the Enlarged Cotter Dam project.

The nine projects which are or have been undertaken as part of the Fish Management Plan are:

- Project 1 – Constructed homes for threatened fishes in the Cotter River Catchment. The main aims of this project were to:
  - Determine if adult Macquarie Perch will use constructed habitat for shelter when emergent macrophytes are not available.
  - Develop capacity to facilitate Two-spined Blackfish recolonising the Enlarged Cotter Dam after construction.
  - Provide guidelines for construction of long term shelter habitat to sustain threatened fishes.

  Results have shown that fish have a preference for rock reefs over other constructed habitats. This project is due for completion in December 2010.
- Project 2 – Predicted passage of native and alien freshwater fish based on swimming speed performance. This project assessed the swimming capacity of native fish and applied the results in the design of fish passages (to enable native fish to undertake their spawning migrations). This project was completed in June 2009.
- Project 3 – Crayfish ecology. This project examined the ecology of Murray River Crayfish in the Cotter River system and possible avenues for improving their habitat. This project was completed in July 2010.
- Project 4 – Epizootic Haematopoietic Necrosis (EHN) virus occurrence. This project indicated that the EHN virus was not present in sampled fish. This project was completed in August 2008.
- Project 5 – Research into the establishment of new populations of Macquarie Perch, Trout Cod and Two-spined Blackfish through translocation. This project looks at establishing other populations of Macquarie Perch, Trout Cod and Two spined Blackfish, to supplement populations in the Cotter River. This project is due for completion in August 2011.
- Project 6 – Management program for alien fish species. It is expected that alien fish populations will increase in the enlarged Cotter Reservoir and they may impact on threatened native fish. This project will investigate management options for alien fish and is due for completion by the end of 2011.

- Project 7 – Food sources for Macquarie Perch and drawdown effects. This project is examining the food sources available to Macquarie Perch and the impact of fluctuating reservoir levels on these food levels. This project is due for completion in early to mid 2011.
- Project 8 – Investigation of techniques for mapping instream barriers. This project complements research undertaken as part of Project 2 - Predicted passage of native and alien freshwater fish based on swimming speed performance. This project is due for completion in early 2011.
- Project 9 – Enlarged Cotter Dam fish monitoring. This project will provide monitoring information to answer specific questions on the impacts of the Enlarged Cotter Dam on threatened aquatic species. The monitoring program will extend beyond the completion of the Enlarged Cotter Dam's construction.

The implementation of these projects and the reporting of findings and recommendations relevant to the protection of threatened aquatic species form part of the Australian Capital Territory (ACT) and Commonwealth conditions of the approval for the Enlarged Cotter Dam project. Accordingly, information on each of these projects, as well as discussion of a range of associated projects and supplementary information sources is included in this report (Chapter 4).

Details of all conditions issued by the ACT Planning and Land Authority and the Commonwealth Department of Environment, Water, Heritage and the Arts (now the Department of Sustainability, Environment, Water, Population and Communities) and commitments arising from the Environmental Impact Statement (ACTEW 2009a), the Public Environment Report (ACTEW 2009b) and Version 1 of the Fish Management Plan, and actions to meet them are provided in Chapter 5.

The Community Engagement and Stakeholder Management team within the Bulk Water Alliance has disseminated information about the Fish Management Program through various media releases, internet communication and awareness raising activities at community, school and local stakeholder levels.

The project findings of various university researchers have been presented in a number of technical publications and national conferences.

1 Background

1.1 Enlarged Cotter Dam project description

The Enlarged Cotter Dam is one in a suite of major projects currently being undertaken by ACTEW Corporation (ACTEW) to secure the future water supply for the Australian Capital Territory (ACT) and region. These projects are being delivered through the Bulk Water Alliance (BWA), a partnership between ACTEW and ActewAGL, GHD, Abigroup and John Holland Group.

1.1.1 Location

The Enlarged Cotter Dam is being constructed approximately 125 metres (m) downstream of the existing Cotter Dam on the Cotter River approximately 18 kilometres (km) due west of Canberra (refer to Figure 1.1). The Enlarged Cotter Dam is located upstream of the confluence of the Cotter, Paddy's and Murrumbidgee Rivers and is in the vicinity of a range of recreational areas and water supply infrastructure including Cotter Avenue, Cotter Campground, Casuarina Sands and the Cotter Pumping Station.

1.1.2 Construction method

The main dam will be constructed from roller compacted concrete and two additional earth rock-fill saddle dams will be constructed adjacent to the right abutment of the main dam. The main dam will be approximately 80 m high with the saddle dams approximately 12 and 16 m in height. At the conclusion of construction, the storage capacity of the reservoir will increase from 4 gigalitres (GL) to approximately 78 GL, raising ACT's overall storage capacity by a third.

The existing Cotter Dam and an additional 232 hectares (ha) of land will be inundated as a direct result of the Enlarged Cotter Dam construction and filling of the enlarged reservoir. In addition, a further 38 ha of land will be cleared to facilitate construction and ancillary works. The land surrounding the Cotter Dam has areas classified as having both "high and low environmental value" with some areas still significantly impacted by previous forestry plantation activities and severe bushfires in 2003.

1.1.3 Approval process

Approval for the construction of the Enlarged Cotter Dam was required under both the Territory *Planning and Development Act 2007* and the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999.* Territory matters were assessed by the ACT Planning and Land Authority (ACTPLA) through ACTEW's preparation of an Environmental Impact Statement (EIS) and a Development Application (DA). Commonwealth matters were assessed by the Commonwealth Department of Water Heritage and the Arts (DEWHA) through ACTEW's preparation of a Public Environment Report (PER).

All necessary documentation was prepared and submitted in 2009 with approval of the EIS received in June 2009, the DA in September 2009 and the PER in October 2009. Following the receipt of all major planning approvals, construction of the Enlarged Cotter Dam officially commenced on Monday 23 November 2009.

Approval of the Enlarged Cotter Dam project has been conditioned by both ACTPLA and DEWHA. Conditions of approval relevant to the Fish Management Plan and the management of threatened native aquatic species are presented in Chapter 5.

Figure 1.1 Location of the Enlarged Cotter Dam.

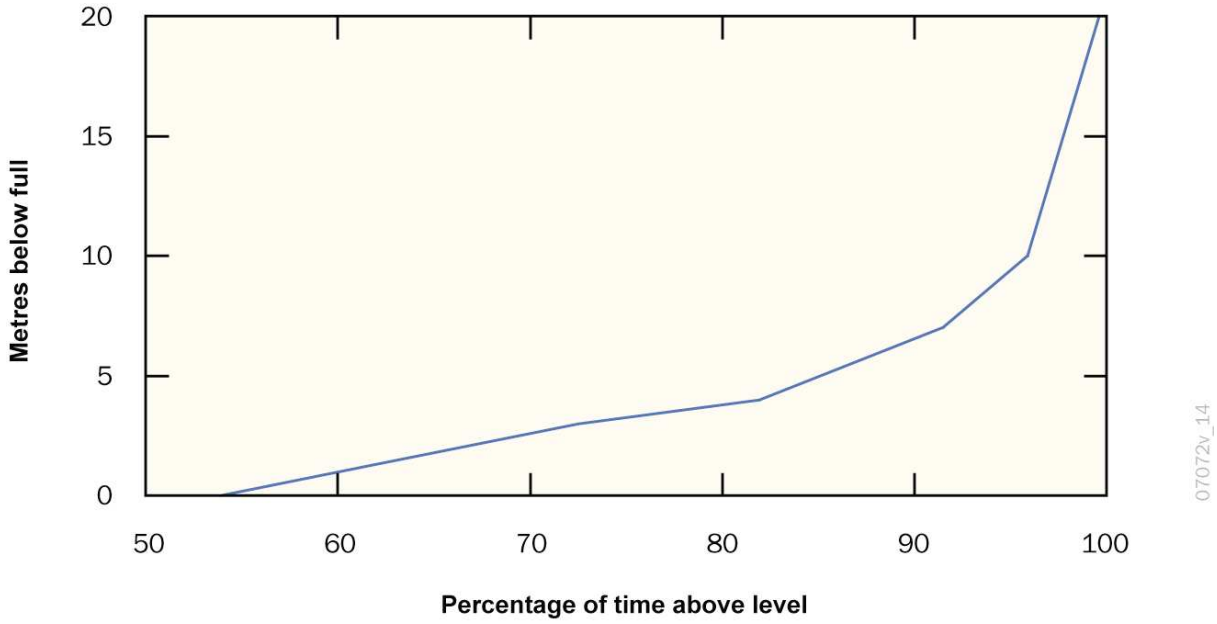
1.1.4 Planned operating regime for the enlarged Cotter Reservoir

ACTEW currently extracts water for potable supply from the Cotter River (Cotter, Bendora and Corin Reservoirs), the Googong Reservoir on the Queanbeyan River and from the Upper Murrumbidgee River by pumping to the Cotter Pump Station. Extraction rules for each of these rivers are regulated by the ACT Government and are based on environmental flows and water quality.

Following completion of the Enlarged Cotter Dam, the enlarged Cotter Reservoir will become an 'active' reservoir characterised by fluctuating water levels, more frequent abstraction of water and a greater capacity to capture additional inflows from the upper Cotter River.

Modelling of the proposed operating regime indicates that the water level in the enlarged Cotter Reservoir will remain within three metres of Full Supply Level (FSL) for approximately 73 per cent of the time, within five metres of FSL for approximately 90 per cent of the time and within 13 metres of FSL for approximately 98 per cent of the time (refer to Figure 1.2).

Figure 1.2 Plot of the modelled results indicating the cumulative percentage of time the water level in the enlarged reservoir will spend above various levels below the full supply (water) line.



1.1.5 Planned operating regime for ACT storages

Following completion of the Enlarged Cotter Dam, ACT storages will be operated in accordance with operating rules developed using a detailed system model to maximise water supply performance and meet environmental objectives, including minimising harm to threatened aquatic species. These rules are yet to be finalised and will require endorsement by ACTEW before they are adopted. It is also likely that the proposed operating rules will be reviewed by ACTEW up to and after the date that the Enlarged Cotter Dam is operational as new information becomes available. This review may highlight necessary changes to the operation of the water supply systems, independent of the impacts of the Enlarged Cotter Dam. The new operating rules will also need to meet the requirements of the ACT Environment Protection Authority (EPA), who issue ACTEW a licence under the ACT Water Resources Act. The predicted changes in the operation of Cotter River storages as a result of the Enlarged Cotter Dam are shown in Figure 1.4. It is not anticipated that the operating regime for Bendora or Corin Reservoirs will change significantly from the current situation.

Water releases from all reservoirs will be sourced from multi-level off-take towers to allow control of temperature (through regular active in situ measurements) to minimise potential impacts of cold water pollution.

Figure 1.3 Operating rules for existing ACT storages.

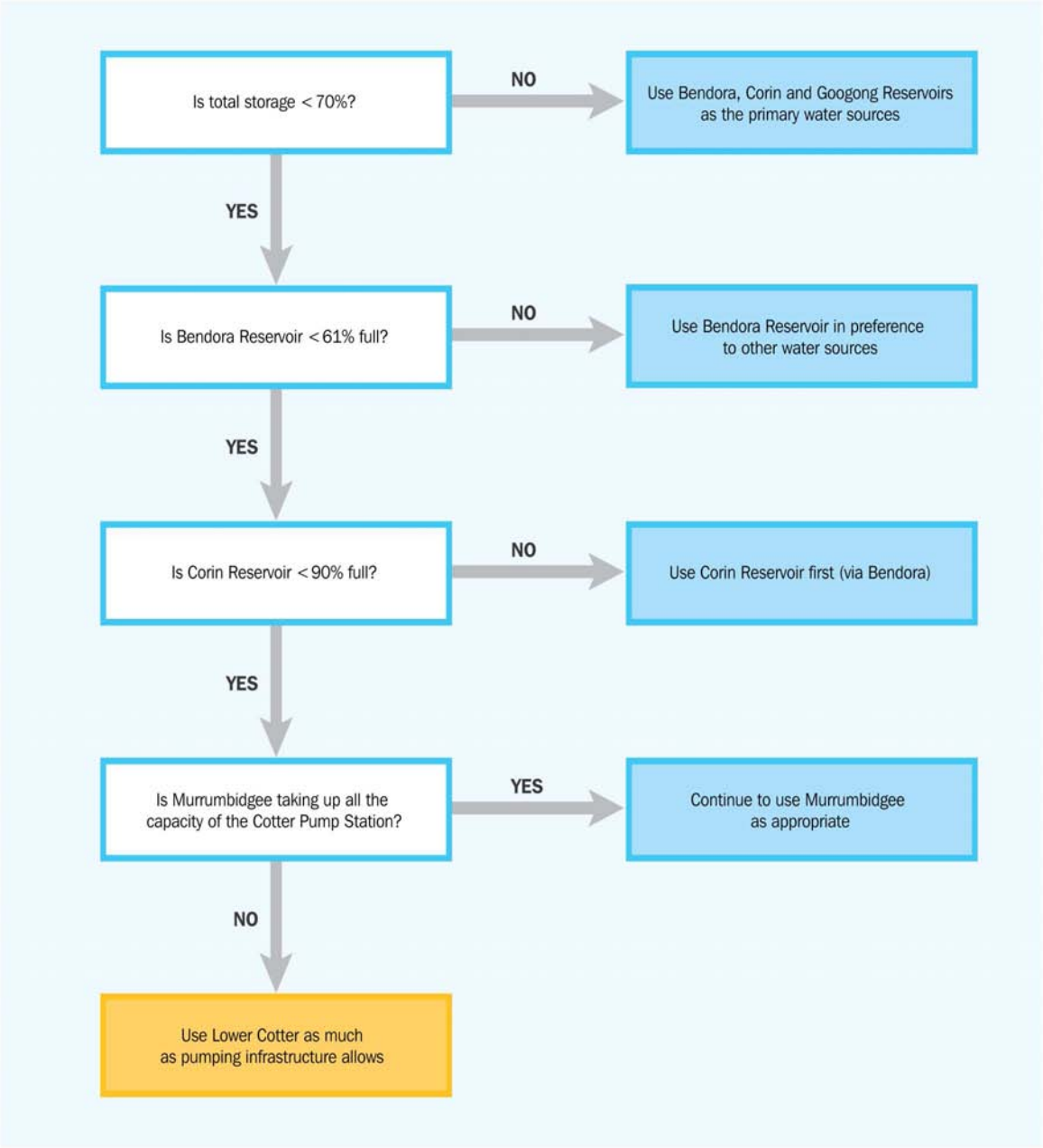
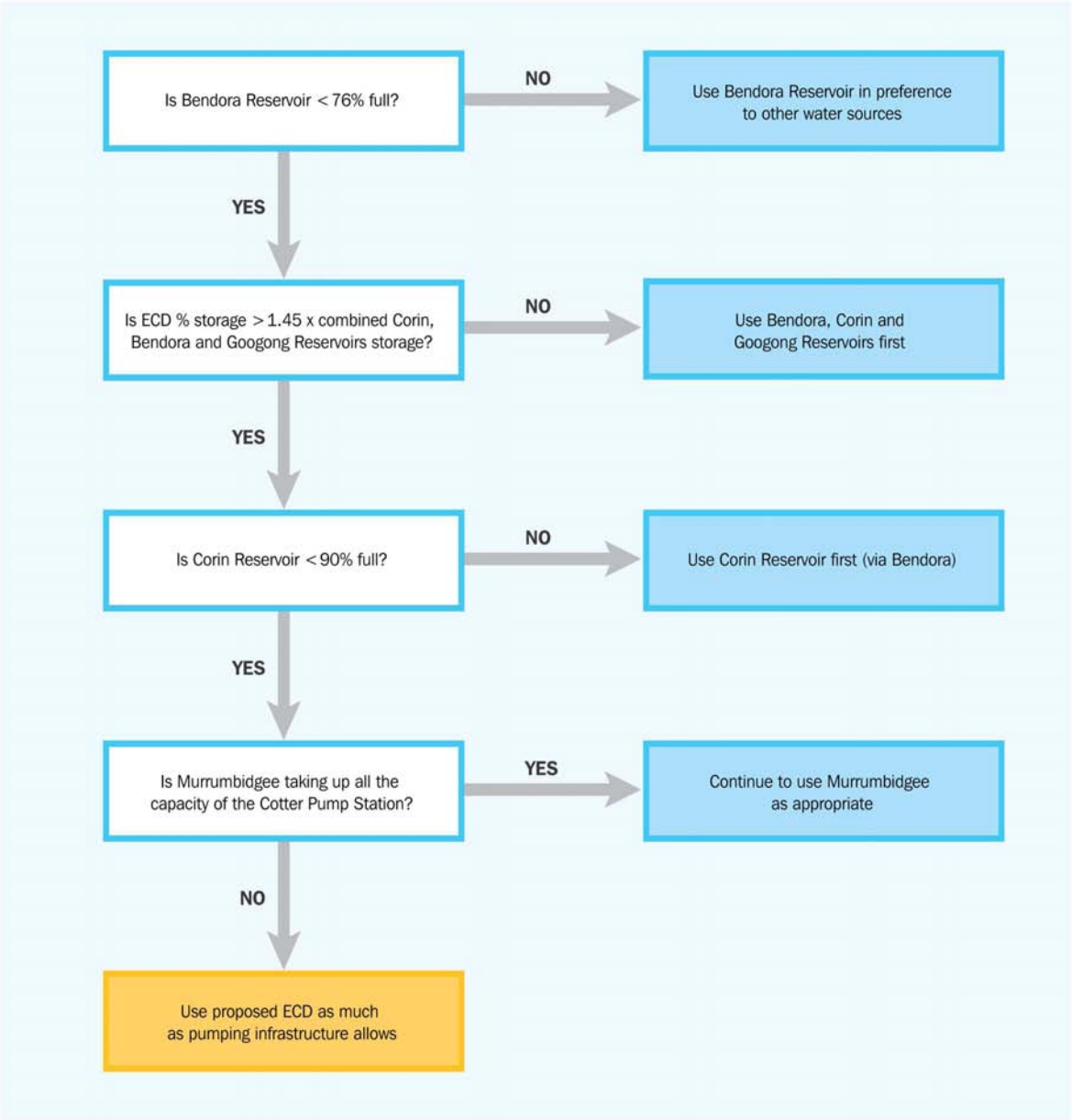


Figure 1.4 Recommended operating rules for ACT storages with the Enlarged Cotter Dam (based on results from modelling).



2 Fish Management Plan

2.1 Introduction

The construction and operation of the Enlarged Cotter Dam raises environmental issues relating to the management of five threatened native aquatic species. These are:

- Macquarie Perch *(Macquaria australasica)*.
- Trout Cod *(Maccullochella macquariensis)*.
- Murray Cod *(Maccullochella peelii).*
- Two-spined Blackfish *(Gadopsis bispinosus)*.
- Murray River Crayfish *(Euastacus armatus)*.

This Fish Management Plan (Version 2) is the second report in a series of four reports designed to provide information to help protect aquatic communities and habitats in the Cotter Reservoir and the Cotter River during the construction and operation of the enlarged Cotter Reservoir. Each of these reports focuses on protection of the species during different key program milestones as detailed in Table 2.1.

Table 2.1 Updating the Fish Management Plan.

Fish Management Plan Version	Key project milestones	Information sources	Fish Management Program milestones	Due Date
1	EIS Submitted.	Current knowledge.	Identify projects to address knowledge gaps.	Feb 2009
2	Construction period.	• Progress reports for Fish Management Program projects. • Reports for Fish Management Program projects were available. • The Aquatic Flora and Fauna Management Plan. • Associated projects by others. • Input from regulators.	• Establish a Fish Management Program Steering Committee. • Implement all projects identified in Fish Management Plan Version 1. • Use information from Project 1 – Constructed homes for threatened fishes to inform design for constructed shelter habitats. • Lodgement of DA for installation of constructed habitats.	May 2010

Fish Management Plan Version	Key project milestones	Information sources	Fish Management Program milestones	Due Date
3	Filling and operational phase.	• Results and recommendations from Fish Management Program projects. • Results from ongoing monitoring. • Input from regulators. • Documented performance against conditions of approval.	To be determined with Fish Management Program Steering Committee.	Early 2012
4	Two years after Enlarged Cotter Dam construction completion. Operational phase.	• Results from ongoing monitoring. • Input from regulators.	To be determined with Fish Management Program Steering Committee.	Early 2014

The reports and their timely delivery form part of both Territory and Commonwealth conditions of approval for the Enlarged Cotter Dam and must be prepared in accordance with legislative requirements. The Fish Management Plan also presents relevant information from a range of other key sources including related studies into aquatic species and their habitats.

2.2 Objectives

The overarching objective of the Fish Management Plan is to:

- Ensure that the aquatic communities and habitats of the Cotter Reservoir and Cotter River are maintained or rehabilitated to support native fish and crayfish species.

This objective was developed within the context of the *ACT Aquatic Species and Riparian Zone Conservation Strategy* (ACT Government 2007a).

Version 2 of the Fish Management Plan focuses on the protection of threatened aquatic species during the construction phase. The objective for Version 2 of the Fish Management Plan is to:

- Minimise potential construction impacts of the Enlarged Cotter Dam on the aquatic communities and habitats of the Cotter Reservoir and Cotter River.

The Fish Management Plan is:

- Designed to prevent or mitigate risks to threatened aquatic fauna and their habitats.
- Scientifically based, using adaptive management.
- Robust in terms of stakeholder involvement, peer review and public transparency.
- Timely and updated on the basis specified in the approval conditions.
- Developed as part of the overall requirements of the Enlarged Cotter Dam.
- Effective in terms of the use of resources and expertise whilst at the same time ensuring the protection of threatened species.

2.3 Process for update

The Fish Management Plan is designed to be an iterative document which reflects a growing body of knowledge on threatened aquatic species and appropriate measures to minimise the potential impact which the construction and operation of the Enlarged Cotter Dam might have on these species and their habitats.

Version 1 of the Fish Management Plan was prepared by ActewAGL on behalf of ACTEW during the design phase of the Enlarged Cotter Dam. Version 1 established a basis for the nine research projects by identifying key knowledge gaps. Version 1 of the Fish Management Plan was included as an appendix to the ACT EIS and the Commonwealth referral documentation prepared for the Enlarged Cotter Dam project.

Following the formation of the BWA the responsibility for the management of aquatic species, including preparation of Version 2 of the Fish Management Plan, was passed wholly from ActewAGL to the BWA. Version 2 of the Plan is intended to provide an update on each of the nine research projects (refer to Section 4.1), including any findings or recommendations that have been provided since Version 1 was produced in February 2009. Version 2 of the Fish Management Plan was completed in September 2010 (final draft submitted to agencies in May 2010) following an extension of time permitted by ACTPLA to bring the date of submission in line with Commonwealth conditions of approval (refer to Table 5.1 and Table 5.3).

The responsibility for the preparation of subsequent versions of the Fish Management Plan (Versions 3 and 4) will revert to ACTEW at the completion of construction (expected late 2011).

3 Threatened species

3.1 Summary of threatened species

The existing Cotter Reservoir and surrounds provide critical habitat to several species of threatened aquatic fauna including Macquarie Perch, Trout Cod, Murray Cod, Two-spined Blackfish and Murray River Crayfish.

A summary of information on each of these species is provided in the following table.

Table 3.1 Summary of knowledge on threatened aquatic species in, above and below the existing Cotter Reservoir.

Species	Status	Ecology	Distribution in relation to Enlarged Cotter Dam	Known threats
Macquarie Perch	• Listed as endangered under the ACT *Nature Conservation (NC) Act 1980*. • Listed as endangered under the Commonwealth EPBC Act 1999. • Listed as endangered under the New South Wales (NSW) *Fisheries Management Act 1994.* • Listed as threatened under the Victorian *Flora and Fauna Guarantee (FFG) Act 1988.*	• Estimated life span of more than approximately 25 years (Lintermans 2010) • Fish can be reproductively mature at two to three years for males and three to four years for females and continue breeding until at least 10 years old (Koehn & O'Connor 1990; Lintermans 2007). • Preferred habitat is cool, shaded, upland streams with deep rocky pools and substantial cover. • Require flowing water for spawning. • Spawning migration triggered when the water temperature reaches approximately 16.5℃. Once deposited, eggs lodge in rocky or gravel substrate (NSW Department of Primary Industries 2008; Battaglene 1988; Cadwallader & Rogan 1977). • Eggs hatch approximately 10 days after spawning, however they make take up to approximately 18 days in colder waters (Koehn & O'Connor 1990). • Larvae have the capacity to move almost immediately after hatching (Koehn & O'Connor	• The only sustainable population of Macquarie Perch in the ACT is located in the existing Cotter Reservoir and the Cotter River immediately upstream of the existing reservoir (ACT Government 2007a). • Macquarie Perch are known to occur and spawn in the Cotter River at least as far as Pipeline Road Crossing (Ebner & Lintermans 2007) and to spawn above Vanity's Crossing (Broadhurst and Ebner unpublished data). • Small populations of Macquarie Perch (with unknown levels of recruitment) have been previously recorded in (Lintermans 2007): – Murrumbidgee River. – Molonglo River. – Paddy's River. • Translocated population in Bendora Reservoir currently undetectable (Lintermans 2005 &	The *Draft National Recovery Plan for Macquarie Perch* prepared by the NSW Department of Primary Industries (2008) identified a number of threats, which include: • Sedimentation. – Reducing abundance and visibility of prey. – Smothering of spawning habitat and eggs. • Interactions with alien species (Butcher 1967; Lintermans 2006b; Lintermans & Kaminskas in prep): – Competition for food. – Predation. – Carriers of parasites and disease (Lintermans 2005 & 2006b). • Disease. – Macquarie Perch are highly susceptible to the Epizootic Haematopoietic Necrosis (EHN) virus carried by Redfin Perch *(Perca fluviatilis)* (Langdon 1989; Whittington 2008). • Barriers to fish movement limiting access to areas for feeding and spawning. • Altered flow regimes. – High velocities can impact spawning migration. – Low flows can expose barriers to fish movement. • Cold water pollution (Koehn et al. 1995): – Delay or prevention of spawning movements. – Reduced growth rates. • Removal of snags:

Species	Status	Ecology	Distribution in relation to Enlarged Cotter Dam	Known threats
		1990). • Juveniles in the existing Cotter Reservoir have been shown to prefer edge boulder and cobble habitats with interstitial spaces. • Adults in the existing Cotter Reservoir use fringing emergent macrophyte beds as daytime shelter habitat (Ebner & Lintermans 2007; Lintermans et al. 2009a; Lintermans et al. 2009b). • Macquarie Perch also shown to use a range of other shelter habitat types especially structural woody habitat (snags) (Katie Ryan personal communication, October 2009) and constructed rock reefs (Lintermans et al. 2009b).	2006a). • Translocated population in Queanbeyan River upstream of Googong Reservoir currently undetectable (Lintermans unpublished data).	– Loss of shelter habitat. – Limiting the formation of deep pools used by fish. • Illegal fishing, particularly during staging prior to spawning. Other potential threats to Macquarie Perch in the Cotter River Catchment include : • Climate change impacts on rainfall and river flow: – Decreased habitat and increased water temperature. • Impacts of 2003 ACT bushfires, notably increased sedimentation.
Trout Cod	• Listed as endangered under the ACT Nature Conservation Act. • Listed as endangered under the Commonwealth EPBC Act. • Listed as	• Reach sexual maturity at 3–5 years of age when the fish are usually between 0.75–1.5 kg. • Primarily inhabit river systems, preferring areas of flowing water with large woody debris where it can shelter from predators, but also known to survive in impoundments (Trout Cod Recovery Team 2008a). • Adult Trout Cod are often located in deep pools, whilst juveniles	• The only known reproducing population of Trout Cod in the ACT is located in the Bendora Reservoir (Lintermans 2007) as a result of stocking in 1989 and 1990 (Lintermans 1995; ACT Government 2007a). • It is likely that individuals are also present in:	The *National Recovery Plan for Trout Cod* (Trout Cod Recovery Team 2008a & 2008b) identified the following threats: • Removal of large woody debris used as critical habitat (Koehn & Nicol 1998). • River regulation and altered flow regimes may inhibit movement. • Barriers to movements may limit the ability of Trout Cod to recolonise habitat previously within their range. • Loss to irrigation may result in loss of native fish through extraction (Koehn et al. 2004).

Species	Status	Ecology	Distribution in relation to Enlarged Cotter Dam	Known threats
	endangered under the NSW Fisheries Management Act. • Listed as threatened under the Victorian Flora and Fauna Guarantee Act. • Listed as protected under the SA *Fisheries Management Act 2007.*	are generally located in shallow waters. • Appear to have a strong attachment to home sites (Thiem et al. 2008) although they can make extensive exploratory movements of 20–60km (Lintermans 2007). • Spawning occurs in late spring when females produce about 1,000–10,000 adhesive eggs which are deposited on hard surfaces such as logs, rocks and even clay banks, and hatch after 5–10 days (Lintermans 2007; Harris & Rowland 1996). • Do not migrate nor require flows to spawn (Trout Cod Recovery Team 2008a). • Known to hybridise with Murray Cod (Douglas et al. 1995).	– Cotter River upstream of Bendora Reservoir. – Cotter River downstream of Bendora Reservoir. • ACT stocking locations for Trout Cod include (ACT Government 2007a, 2009a): – Murrumbidgee River at Angle Crossing (1996 to 2005). – Murrumbidgee River at Kambah Pool (2009).	• Poor water quality. • Siltation reducing suitability of habitat. • Altered water temperatures: – Reduced water temperatures may impair Trout Cod reproduction as well as stunt the growth of juveniles or favour the growth of competitors (Ryan et al. 2003). • Interaction with alien species: – Competition for food and habitat. – Predation of juvenile Trout Cod. • Recreational fishing as Trout Cod are often misidentified as Murray Cod. • Hybridisation with Murray Cod. Murray Cod must not be stocked into the Cotter River (especially Bendora Reservoir) (ACT Government 2009a). • Diseases including parasitic protozoa and the EHN virus. • Low genetic diversity of hatchery populations may impact long term conservation of species (Bearlin & Tikel 2003). Other potential threats to Trout Cod in the Cotter River Catchment include (ACT Government 2007a): • Climate change impacts on rainfall and river flow: – Decreased habitat and increased water temperature. • Impacts of 2003 ACT bushfires, notably increased sedimentation.

Species	Status	Ecology	Distribution in relation to Enlarged Cotter Dam	Known threats
Murray Cod	• Listed as vulnerable under the Commonwealth EPBC Act. • Listed under the NSW Fisheries Management Act as a member of the listed endangered ecological communities (Lower Murray, Lower Darling, and Lachlan River Catchments). Listed under the Victorian Flora and Fauna Guarantee Act as a threatened ecological community Lowland Riverine Fish Community of the Southern Murray-Darling Basin.	• Fish reach maturity at four to five years and 500 to 600 mm total length (TL) (Kearney & Kildea 2001). • Long-lived species with a lifespan of up to approximately 50 years. • Most widespread and abundant of the four freshwater cod species in Australia (Lintermans et al. 2005; McDowall 1996). • Found across a range of habitats, from turbid slow-flowing rivers to urban lakes to billabongs. • Species generally associated with deep holes in rivers, frequenting main river channels and larger tributaries and anabranches. • Both adult and juvenile Murray Cod prefer habitats with instream cover such as rocks, stumps, fallen trees or undercut banks (National Murray Cod Recovery Team 2008). • The species is sedentary from late summer through to winter (Koehn 1997; Kearney & Kildea 2001). • Spawning migration occurs in spring and early summer when water temperatures range	• Endemic to the Murray-Darling Basin, including streams in the ACT. • The species was formerly widespread in the ACT region and abundant in: – Murrumbidgee River – Molonglo River – Lower Queanbeyan River. • ACT populations are now largely confined to the Murrumbidgee River where they have been recorded as far upstream as Tharwa (Lintermans 2007). • Significant component of recreational freshwater fishing in the ACT with populations located in 'put and take' fisheries in urban lakes including (Lintermans 2000): – Lake Burley Griffin. – Lake Ginninderra. – Lake Tuggeranong. – Gungahlin Pond. – Yerrabi Pond. – Googong Reservoir.	The *Draft National Recovery Plan for Murray Cod* (National Murray Cod Recovery Team 2008) identified a range of threats to the species nationally, which include: • Flow regulation and irrigation: – Impacts on dispersal and recruitment. • Habitat degradation: – Removal of snags and other structural woody habitat. • Lowered water quality as a result of: – Increased turbidity, salinity, low dissolved oxygen and pollution from cold water releases, herbicides and pesticides and wastewater. • Sedimentation: – Filling of undulations and holes used for habitat. – Smothering of spawning sites. – Impacts food sources. • Barriers to movement: – Limiting ability to colonise new areas. – Impeding pre and post spawning movements by adult fish and the dispersal of larvae. • Interaction with alien species, particularly Carp and Redfin Perch: – Competition for habitat and food. – Potential for spread of parasites and disease. • Commercial fishing, although closed down in 2003, may have a lasting impact on the species. • Recreational fishing: – Impacts on prime breeding stocks.

Species	Status	Ecology	Distribution in relation to Enlarged Cotter Dam	Known threats
		between 16–21 ºC, combined with a flood event (Koehn 1997). Fish may travel 40-50 km or more upstream. • Eggs are laid on hard surfaces (rocks, clay) and within large woody debris (Kearny & Kildea 2001). • Following migration, adult fish return downstream to the same territory previously occupied.		• Illegal fishing, with the potential to cause injury and death and loss of populations. • Inappropriate stocking and translocation: – Translocation outside natural range. – Impacts of limited genetic diversity of hatchery fish. • Genetic issues in hatchery bred fish. • Disease including the EHN virus. • Climate change impacts on rainfall and river flow: – Decreased habitat and increased water temperature.

Species	Status	Ecology	Distribution in relation to Enlarged Cotter Dam	Known threats
Two-spined Blackfish	• Listed as vulnerable under the ACT Nature Conservation Act.	• Estimated life span of approximately six to eight years and not more than 10 years. • Grow up to 350 mm TL, however are generally less than 250mm. • Inhabit cool, clear upland or montane streams, generally in forested catchments with limited sediment deposition. • Usually found in medium-sized streams with greater water depth and lower stream velocities. • Require abundant instream cover, usually rocky substrates but also fallen timber and macrophytes (Lintermans 2002; ACT Government 2007a; Lintermans et al. 2009b). • Relatively sedentary with home range of approximately 15 m in streams (Lintermans 1998). In reservoirs they remain predominately stationary within shelter habitat (steep rocky banks) during the day. • Rarely found in areas of bare shore in reservoirs. • In rivers fish spawn in late spring to summer (Sanger 1990; Lintermans 1998) with eggs deposited under logs, boulders and cobble (O'Connor & Zampatti 2006) and protected by	• In the ACT Two-spined Blackfish only occur within the Cotter River Catchment and distribution is limited to (Lintermans 2006c; ACT Government 2007a): – Corin Reservoir and Cotter River upstream of Corin Reservoir. – Bendora Reservoir and Cotter River between Bendora Reservoir and Corin Dam. – Cotter River upstream of Cotter Reservoir. • It is likely that Two-spined Blackfish do not inhabit the existing Cotter Reservoir due to sediment loads and consequent loss of interstitial habitat (Lintermans 2002 & 2006c). • The species no longer occurs in the Cotter River downstream of Cotter Dam as a result of lack of flow and subsequent armouring of the stream bed and consequent loss of interstitial habitat.	The *ACT Aquatic Species and Riparian Zone Conservation Strategy* (ACT Government 2007a) identifies the following threats to Two-spined Blackfish: • Damage to riparian vegetation. • Sedimentation: – Reducing abundance (Doeg & Koehn 1990a &1990b) and visibility of prey. – Smothering of spawning habitat and eggs. • Flow regime alteration. • Reduced water quality. • Thermal pollution – Reduced water temperature reduces growth rates (Hall 2005). – Increased water temperature may have significant adverse impacts (Lintermans 2002; Lintermans & Osborne 2002) • Interaction with alien species: – Competition for food (Lintermans 1998) and spawning sites (ACT Government 1999). – Predation (Koehn & O'Connor 1990). – Potential expansion of Redfin Perch, Carp and Brown Trout populations in the Cotter River. • Impacts of 2003 ACT bushfires, notably increased sedimentation. Another potential impact to Two-spined Blackfish in the Cotter River Catchment may include: • Climate change impacts on rainfall and river flow: – Decreased habitat and increased water temperature.

Species	Status	Ecology	Distribution in relation to Enlarged Cotter Dam	Known threats
		the male (Lintermans 1998). Little is currently known about reproductive behaviours in reservoirs: – Eggs hatch after approximately 15 to 17 days (depending on temperature). – After hatching larvae remain attached to a large yolk sac and require an additional 20 to 26 days to fully develop (Koehn & O'Connor 1990; Lintermans 1998). – Larvae remain at the spawning site under parental care (by the male fish) for approximately 3 weeks after hatching (Lintermans 1998). • In reservoirs, increased movement at night to feed in shallow areas rich in submerged and emergent macrophytes (Lintermans et al. 2009b). • Diet dominated by aquatic insect larvae (mayflies, caddisflies and midges) and occasionally fish and crayfish.		

Species	Status	Ecology	Distribution in relation to Enlarged Cotter Dam	Known threats
Murray River Crayfish	• Listed as vulnerable under the ACT Nature Conservation Act. • Listed as threatened under the Victorian Flora and Fauna Guarantee Act. • Listed as endangered under the SA Fisheries Management Act.	• Large (up to 3 kg) freshwater crustaceans endemic to the Murray-Darling Basin. • Highly susceptible to pollution and poor water quality (notably low levels of dissolved oxygen). • Benthic species which utilise habitat ranging from large woody debris and undercut banks in lowland rivers and cobbles and boulders in upland river systems (Gilligan et al. 2007). Specific habitat preferences of upland Murray River Crayfish include (Fulton et al. 2010): – Deeper river sections such as glide-pools. – Areas of moderate flow velocity (0.1 to 0.4 m s^{-1}). – High percent cover of overhanging riparian vegetation. – Large boulders of diameter 26 to 230 centimetres (cm) (average 48 cm) situated over clean gravel.	• Within the Cotter River Catchment distribution is limited to (Lintermans 2005): – Cotter River downstream of the existing Cotter Dam. – Cotter River immediately upstream of the existing Cotter Reservoir. • Also distributed along the length of the Murrumbidgee River in the ACT as well as parts of the lower Paddy's River (Lintermans & Rutzou 1991; Lintermans 2002).	The *ACT Aquatic Species and Riparian Zone Conservation Strategy* (ACT Government 2007a) identifies the following threats to Murray River Crayfish: • Damage to riparian vegetation. • Sedimentation impacts on habitat and food sources. • Flow regime alteration resulting in: – Loss of connectivity with important river systems. – Changes to instream characteristics. • Illegal harvesting. • Recreational fishing. • Interaction with alien species: – Competition for food (Lintermans 1998) and spawning sites (ACT Government 1999). • Impacts of translocation and stocking of hatchery bred crayfish on wild populations: – Reduction of genetic fitness and hence viability of crayfish populations (Harris 1997; Murray Darling Basin Commission [MDBC] 2004). – Competition for food and habitat (Harris 1997). – Potential to introduce diseases and unwanted species. Other potential impacts to Murray River Crayfish in the Cotter River Catchment include: • Water pollution, particularly hydrocarbons. • Climate change impacts on rainfall and river flow: – Decreased habitat and increased water temperature. • Increased sedimentation due to bushfires.

3.2 Enlarged Cotter Dam risk assessment

Potential risks for threatened native aquatic species were identified through a formal qualitative risk analysis process. The risk assessment process used the same method as in the Enlarged Cotter Dam EIS and PER (Australian Standard AS 4360:2004). This framework is also applied in the BWA Risk Management Plan BWA-PRW-CD-PLN-002-0-00.

The likelihood, consequence and risk rating for each risk were determined using the matrix in Table 3.2 which is informed by information presented in Table 3.3 and Table 3.4.

Risks were identified using the following sources:

- Previous relevant information (ACT Government 2007a; Lintermans 2005; Jones et al. 2007a & 2007b).
- Judgement and expert opinion of the ACTEW Fish Advisor (Mark Lintermans), ACTEW and BWA personnel and agency stakeholders over the period from 2008 to the present.
- There has been additional information collected since the Risk Assessment was compiled for Version 1 of the Fish Management Plan (ActewAGL 2009) and this has been incorporated in the updated Risk Assessment presented below.

Table 3.2 Risk assessment matrix.

		Consequence				
		Minimal 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Likelihood	Remote E	Negligible	Negligible	Low	Low	Medium
	Unlikely D	Negligible	Low	Low	Medium	High
	Possible C	Low	Low	Medium	High	Very high
	Likely B	Low	Medium	High	Very high	Significant
	Almost certain A	Medium	High	Very high	Significant	Significant

Table 3.3 Qualitative measures of likelihood scale.

Level	Categorisation of likelihood	Description
A	Almost certain	Is expected to occur during the project, 90 percent or greater probability.
B	Likely	Will probably occur during the project, approximately 50 percent probability.
C	Possible	Might occur at sometime during the project, approximately 10 percent probability.
D	Unlikely	Could occur at some time during the project, approximately one percent probability.
E	Remote	Only occur in exceptional circumstances, less than one percent probability.

Table 3.4 Qualitative measures of the consequences scale.

Level	Categorisation of consequences	Description
1	Minimal	No detectable impact is noted or expected.
2	Minor	Impact is site limited, minimal and easily controlled.
3	Moderate	Event or practice causes moderate on site impact but is easily controlled, and/or minimal local area impact; and/or will have moderate external effects; and/or is known to have a long term cumulative impact.
4	Major	Event or practice causes high level on site damage which could extend further if not controlled immediately and/or moderate local area impact; and/or will have moderate external effects; and/or is known to have a long term cumulative impact.
5	Catastrophic	Event or practice causes serious or catastrophic on site damage and/or high level local impact; and/or is known to cause significant external effects and/or is known to cause serious long term cumulative effects.

Table 3.5 presents the unmitigated (current) and residual risks (following mitigation measures to threatened native aquatic species.

Table 3.5 Risks to threatened aquatic species.

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Macquarie Perch							
Long term oxygen depletion due to increased depth of the enlarged reservoir.	A	3	Very high	De-stratification system.	D	3	Low
Long term decline or loss of Macquarie Perch population due to changed fish habitats (loss or reduced survival of macrophyte beds and/or altered condition of edge-boulder environments).	B	4	Very high	Provide constructed habitat, using adaptive management approach, and results of Project 1 - Constructed homes for threatened fishes.	D	4	Medium
Long term increase in cormorant predation on Macquarie Perch through reduced refuge habitat.	C	4	High	Provide constructed refuge habitat, using adaptive management approach, and results of Project 1 - Constructed homes for threatened fishes.	D	4	Medium

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Long term reduced fish passage for Macquarie Perch limiting access to spawning sites in Cotter River.	C	4	High	Water level management during spawning and an adaptive management approach using results of Project 2 - Swimming capacity of Macquarie Perch and Project 8 - Investigation of techniques for mapping instream barriers.	D	4	Medium
Long term altered releases from Bendora Reservoir providing the wrong temperature signal during the spawning season.	B	3	High	Manage temperature of environmental releases from Bendora Reservoir to ensure that the temperature of water released is similar to that in the Cotter River downstream.	D	3	Low
Short term degradation of ecosystem due to major fuel spill, oils and other contaminants entering the aquatic environment during construction.	C	4	High	• Construction Environmental Management Plan (CEMP), training and awareness. • Bunding, spill equipment and implementation of CEMP/management plan.	E	4	Low

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Long term reduction in Macquarie Perch due to aquatic aliens (including Redfin Perch) entering the aquatic environment during construction.	C	4	High	• CEMP, training and awareness. • Procedures to exclude Redfin Perch from the section of the Cotter River between the existing and enlarged Cotter Dams. • Appropriate disinfection procedures for vehicles with the potential to transfer fish spawn into the Cotter Reservoir. • The BWA will advise Parks Conservation and Lands (PCL) of any illegal fishing activities (notably the use of live bait) identified during the course of construction.	E	4	Low
Proposed off-take causing fish mortality or entrainment near off-take structures over the long term.	C	2	Low	Appropriately designed screening around off-take.	E	2	Negligible

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Long term increased mortality of Macquarie Perch by introducing the EHN virus plus Redfin Perch into existing Cotter Reservoir during construction.	C	5	Very high	• CEMP, training and awareness. • Procedures to exclude Redfin Perch from the section of the Cotter River between the existing and enlarged Cotter Dams. • Appropriate disinfection procedures for vehicles with the potential to transfer the EHN virus or fish spawn into the Cotter Reservoir. • Disinfection/sterilisation of the area between the existing and enlarged Cotter Dams. • Water used onsite will only be sourced from the Cotter Reservoir approved ACTEW standpipes. • During construction there will be no connectivity between the Cotter Reservoir and the Cotter River. • The BWA will advise PCL of any illegal fishing activities (notably the use of live bait) identified during the course of construction.	E	5	Medium

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Long term decline in numbers of Macquarie Perch due to loss of potential habitat owing to the inappropriate design of infrastructure	C	3	Medium	Good communication with design team, with particular regard to the design of the final profile of the quarry and saddle dams.	D	3	Low
Short term reduction in fish populations due to increased particulate matter in the aquatic environment upstream and downstream of the Enlarged Cotter Dam due to increased erosion (as a result of the construction activity).	D	2	Negligible	• Design and implementation of an appropriate CEMP combined with related training of personnel. • Installation of related erosion and sediment control measures and sediment basins.	D	2	Negligible
Undetected long term (10-20 years) change in fish assemblage (due to the long term depletion of nutrients and food sources) following the initial surge in productivity after reservoir filling.	C	4	High	ACTEW commitment to ongoing monitoring and adaptive management approach based on results of Project 9 - Enlarged Cotter Dam fish monitoring.	D	4	Medium

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Long term decline or loss of Macquarie Perch population due to impoundment of reservoir waters submerging existing spawning areas in the Cotter River.	B	4	Very high	Provide access to additional spawning habitats e.g. by providing appropriate fish passages in the Cotter River upstream of the Enlarged Cotter Dam.	D	4	Medium
Increased abundance of alien fish in the enlarged Cotter Reservoir causing a decline (both in riverine and reservoir populations) in threatened fish species in the long term.	B	4	Very high	Implementation of the alien fish management strategy from Project 9 - Enlarged Cotter Dam fish monitoring.	D	4	Medium

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Long term decline in Macquarie Perch numbers and/or condition due to reduction in food resources (macroinvertebrates) as a result of loss of macrophytes, possible sedimentation and fluctuating water levels.	C	3	Medium	• Recommendations of Project 7 - Food sources for Macquarie Perch and drawdown effects will be applied to help augment food sources for Macquarie Perch where necessary. • Rehabilitation of the Cotter River Catchment will continue to improve water quality and reduce sedimentation levels.	C	3	Medium
Trout Cod							
Long term decline in Trout Cod population due to change in the operating regime of the Bendora Reservoir.	D	1	Negligible	The operating regime of Bendora will not be significantly altered as a result of the Enlarged Cotter Dam, nor is the Enlarged Cotter Dam expected to have an adverse impact on the Trout Cod in Bendora Reservoir. No specific management or mitigation measures are required.	D	1	Negligible

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Murray Cod							
Operation of the Enlarged Cotter Dam reduces sustainability of downstream habitat for Murray Cod in the long term.	E	2	Negligible	• Environmental flows downstream of Enlarged Cotter Dam are managed as required by the Environmental Flow Guidelines (ACT Government 2006) and the ACTEW's Licence To Take Water. • If any deleterious effects were detected due to unsuitable flows, the licence conditions would be varied to correct the issue. • An average flow of 34 megalitres (ML) d^{-1} will be provided downstream of the Enlarged Cotter Dam project site for the duration of construction period, as required by Commonwealth conditions of approval.	E	2	Negligible
Two-spined Blackfish							
Long term oxygen depletion due to increased depth of the enlarged reservoir.	A	3	Very High	De-stratification system.	D	3	Low

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Long term altered releases from Bendora Reservoir providing the wrong temperature signal during the spawning season.	B	3	High	Manage temperature of environmental releases from Bendora Reservoir	D	3	Low
Short term degradation of ecosystem due to major fuel spill, oils and other contaminants entering the aquatic environment during construction.	C	4	High	• CEMP, training and awareness. • Bunding, spill equipment and implementation of CEMP/management plan.	E	4	Low

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Long term reduction in Two-spined Blackfish due to aquatic aliens (including Redfin Perch) entering the aquatic environment during construction.	C	3	Medium	• CEMP, training and awareness. • Procedures to exclude Redfin Perch from the section of the Cotter River between the existing and enlarged Cotter Dams. • Appropriate disinfection procedures for vehicles with the potential to transfer the fish spawn into the Cotter Reservoir. • The BWA will advise PCL of any illegal fishing activities (notably the use of live bait) identified during the course of construction.	E	4	Low
Proposed off-take causing fish mortality or entrainment near off-take structures over the long term.	D	1	Negligible	Screening around the off-take structure is designed to prohibit Macquarie Perch entrainment and will not prevent Two-spined Blackfish entering the structure. Given the tendency for Two-spined Blackfish to remain close to shore, it is unlikely this species would be in deeper sections of the reservoir in the vicinity of the off-take structure.	D	1	Negligible

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Long term increased mortality of Two-spined Blackfish by introducing the EHN virus plus Redfin Perch into existing Cotter Reservoir during construction.	D	2	Low	• CEMP, training and awareness. • Procedures to exclude Redfin Perch from the section of the Cotter River between the existing and enlarged Cotter Dams. • Appropriate disinfection procedures for vehicles with the potential to transfer the EHN virus or fish spawn into the Cotter Reservoir. • Disinfection/sterilisation of the area between the existing and enlarged Cotter Dams. • Water used onsite will only be sourced from the Cotter Reservoir approved ACTEW standpipes. • During construction there will be no connectivity between the Cotter Reservoir and the Cotter River. • The BWA will advise PCL of any illegal fishing activities (notably the use of live bait) identified during the course of construction.	E	2	Negligible

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Short term reduced fish populations due to increased particulate matter in the aquatic environment upstream of the Enlarged Cotter Dam due to increased erosion (as a result of the construction activity).	D	3	Low	Design and implementation of an appropriate CEMP combined with related training of personnel.	D	2	Negligible
Undetected long term (10-20 years) change in fish assemblage (due to the long term depletion of nutrients and food sources) following the initial surge in productivity after reservoir filling.	D	2	Low	ACTEW commitment to ongoing monitoring, adaptive management approach based on results of Project 9 - Enlarged Cotter Dam fish monitoring.	E	2	Negligible

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Increased abundance of alien fish in the enlarged Cotter Reservoir causing decline (both in riverine and reservoir populations) in threatened fish species in the long term.	B	3	High	Implementation of the strategy from Project 9 - Enlarged Cotter Dam fish monitoring.	D	2	Low
Fluctuating water levels expose deposited Two-spined Blackfish eggs.	C	2	Low	Controls on drawdown during spawning period.	D	1	Negligible
Long term decline in Two-spined Blackfish population due to change in the operating regime of the Bendora Reservoir.	D	1	Negligible	The operating regime of Bendora will not be significantly altered as a result of the Enlarged Cotter Dam, nor is the Enlarged Cotter Dam expected to have an adverse impact on the Two-spined Blackfish in Bendora Reservoir. No specific management or mitigation measures are required.	D	1	Negligible

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Habitat loss due to sedimentation of newly inundated areas.	B	2	Medium	• Catchment management and remediation. • Provide constructed refuge habitat, using adaptive management approach, and results of Project 1 - Constructed homes for threatened fishes.	D	1	Negligible
Murray River Crayfish							
Trout predation on juvenile Murray River Crayfish	C	3	Medium	ACTEW commitment to ongoing monitoring, adaptive management approach based on results of Project 9 - Enlarged Cotter Dam fish monitoring.	E	4	Low
Long term oxygen depletion due to increased depth of the enlarged reservoir.	A	3	Very High	De-stratification system.	D	3	Low

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Operation of the Enlarged Cotter Dam reduces sustainability of downstream habitat for Murray River Crayfish in the long term.	E	2	Negligible	• Environmental flows downstream of Enlarged Cotter Dam are managed as required by the Environmental Flow Guidelines (ACT Government 2006) and ACTEW's Licence To Take Water. • If any deleterious effect was detected due to unsuitable flows the licence conditions would be varied to correct the issue. An average flow of 34 ML d^{-1} will be provided downstream of the Enlarged Cotter Dam project site for the duration of construction period, as required by Commonwealth conditions of approval.	E	2	Negligible
Short term degradation of ecosystem due to major fuel spill, oils and other contaminants entering the aquatic environment during construction.	C	4	High	• CEMP, training and awareness. • Bunding, spill equipment and implementation of CEMP/management plan.	E	4	Low

Potential impacts	Risk assessment						
	Current			Management and mitigation measures	Residual		
	Likelihood	Consequence	Risk rating		Likelihood	Consequence	Risk rating
Short term reduced crayfish populations due to increased particulate matter in the aquatic environment upstream and downstream of the Enlarged Cotter Dam due to increased erosion (as a result of the construction activity).	D	3	Low	Design and implementation of an appropriate CEMP combined with related training of personnel.	D	2	Negligible

3.3 Mitigation and management measures

3.3.1 Documentation of onsite mitigation and management measures

Specific mitigation and management measures have been developed for implementation onsite during the construction period to minimise the risk of harm to threatened native aquatic species. These measures are documented in the Aquatic Flora and Fauna Management Plan and are part of the overall environmental management framework for the Enlarged Cotter Dam project.

The objectives of the Aquatic Flora and Fauna Management Plan (ACTEW 2009c) are to:

- Increase site personnel awareness of threatened native aquatic species within the Cotter Reservoir and associated tributaries and increase their understanding of potential adverse construction impacts on these sensitive communities.
- Outline BWA legal requirements, commitments and obligations to the ongoing management of construction activities in the vicinity of threatened and endangered fauna communities and their habitats.
- Identify potential risks to aquatic flora and fauna species (especially endangered and threatened species) as a result of construction activities.
- Outline effective management and mitigation measures to minimise the identified risks to aquatic flora and fauna species.
- Increase understanding of the risks associated with the EHN virus, particularly in regard to its potential impacts on threatened and endangered aquatic species within the Cotter Reservoir (especially Macquarie Perch).
- Outline construction procedures and methodologies for EHN virus disinfection and fish translocation activities.
- Detail site monitoring and surveillance requirements.
- Communicate the procedures to be followed to prevent the possible entry of the EHN virus into the Cotter Reservoir via Enlarged Cotter Dam construction activities.

In accordance with the objectives of the Aquatic Flora and Fauna Management Plan, a targeted risk assessment was conducted to identify and address construction related risks. Specific mitigation and management measures were then developed to minimise each risk to acceptable levels.

Mitigation and management measures detailed in the Aquatic Flora and Fauna Management Plan include (ACTEW 2009c):

- Measures to manage the risk of the EHN virus entering the Cotter Reservoir, and associated catchments, as a result of BWA activities. This is especially important as the endangered Macquarie Perch within the Cotter Reservoir are known to be highly susceptible to the virus.
- Measures for the rescue translocation of threatened aquatic species within the construction footprint (stilling basin and Cotter River immediately downstream of the existing Cotter Dam) which could otherwise be directly and adversely affected by construction activities.
- Measures to increase awareness of threatened aquatic species which may be at risk from construction activities.

Measures for the management of EHN virus are discussed in further detail in Section 3.3.2.

The Emergency and Incident Response Management Plan (ACTEW 2009d) and the Soil and Water Quality Management Plan (ACTEW 2009e) contain additional measures to minimise water quality impacts in the Cotter Reservoir and Cotter River downstream of the construction site.

3.3.2 Managing the risk of the EHN virus

The EHN virus is unique to Australia and was first identified in Redfin Perch communities in the early 1980s. The EHN virus is associated with sudden high mortality in certain fish populations (especially during spring and summer) due to necrosis of the liver, kidney, spleen and pancreas. Macquarie Perch has been shown to be highly susceptible to the EHN virus (Langdon 1989).

The EHN virus is highly resistant to sunlight, drying and disinfection and as a result can persist for months on infected objects such as fishing gear and potentially construction equipment/plant. Research has indicated that the EHN virus can remain infective for approximately 100 days in water and more than 113 days in dried fish tissues (Centre for Food Security and Public Health [CFSPH] 2007; Langdon 1989).

Once EHNV has entered a water body it is considered impossible to eradicate (Whittington in prep). Given the potentially catastrophic impacts on Macquarie Perch populations should the EHN virus be introduced to the existing or enlarged Cotter Reservoir, specific measures have been designed to minimise the risk of this occurring, these include (ACTEW 2009c):

- No connectivity between the Cotter Reservoir and the Cotter River downstream of the Cotter Dam during construction.
- Appropriate disinfection procedures for all vehicles and plant operating in zones which have the potential to contain the EHN virus or fish spawn, prior to use in other areas of the Cotter River Catchment.
- Onsite disinfection wash bay for vehicles and plant.
- Regular documented audits to be undertaken by environment personnel onsite to ensure disinfection procedures are being implemented effectively.
- Appropriate signage onsite to delineate disinfection zones where there is considered to be a high risk that the EHN virus is present.
- Water used onsite will only be sourced from the Cotter Reservoir via installed standpipes or approved ACTEW standpipes. No water will be extracted and used from the Cotter River downstream of the existing Cotter Dam, given that Redfin Perch, a primary indicator of the presence of the EHN virus, have been commonly found in the Cotter River downstream of the existing Cotter Dam.
- Appropriate training and awareness of site personnel regarding the potential transfer of the EHN virus through onsite activities (including illegal fishing) and potential impact on sensitive fish species.
- Removal of aquatic fauna from the stilling basin and Cotter River between the existing Cotter Dam and the downstream coffer dam prior to work in the Cotter River commencing.
- Removal of all water between the existing Cotter Dam and downstream coffer dam.
- Sterilisation of the area between the existing and enlarged Cotter Dams.

Additional measures documented in the EHN Virus Response Plan (ACTEW 2010a) include:

- Monitoring for the presence of Redfin Perch (as vector for the EHN virus).
- Notifying the appropriate authorities if the presence of the EHN virus in the Cotter Reservoir is confirmed.

EHN virus experts

Experts from the Faculty of Veterinary Science, University of Sydney, have provided training and advice to Enlarged Cotter Dam project personnel regarding the dangers posed by the EHN virus. Recommendations from the University of Sydney regarding the management of the EHN virus are summarised in Sections 4.1.4 and 4.2.2.

Further relevant advice from these EHN virus experts will be obtained as necessary during the construction of the Enlarged Cotter Dam.

Communicating the risk of the EHN virus

Communication and understanding of the risks associated with the introduction of EHN Virus into the Cotter Reservoir is vital for management on site. As a result, the BWA has implemented an EHNV awareness program to increase the understanding of construction personnel and sub-contractors.

The awareness program covers the following topics:

- What is the EHN virus?
- What are the risks associated with EHN virus?
- What are the project implications if the EHN virus is introduced into the Cotter Reservoir?
- Where the EHN virus is currently found and how is it spread?
- What are the possible risks related to EHN virus during construction of the Enlarged Cotter Dam?
- What steps are BWA taking to minimise these risks during the construction of the Enlarged Cotter Dam?

This awareness program was developed by the Fish Program Management team, in consultation with the BWA Environment Team based on information provided by EHNV experts and incorporated into induction and information sessions. This training aims to provide useful and practical information on the ENH virus and related management strategies to minimise the risk of its entry into the Enlarged Cotter Dam construction site and Cotter River Catchment.

Treatment of the area between the existing and enlarged Cotter Dams

The method for the sterilisation, or treatment of the area between the two dam walls, covering a distance of approximately 145 m, is being developed. Experts from the University of Canberra and University of Sydney will be consulted during development of the method. The method will be presented to the Fish Management Plan Steering Committee prior to implementation.

Works that support the removal of the EHN Virus from the area between the two dam walls during construction are:

- The removal of all fish from the Cotter River between the existing Cotter Dam and downstream coffer dam (including Redfin Perch, the primary carrier of the EHN Virus);
- Substantial physical modification of the area between the two Dam walls by dewatering and by excavation (down to 2 to 4 metres) and removal of significant quantities of rock, silt and sediment materials that might potentially be infected by pathogens;
- Exposure of the site between the existing dam and Enlarged Cotter Dam to the effects of sun and air, which enhanced the natural breakdown of pathogens;
- Importation of clean materials to provide a clean working platform, separating plant and machinery working in the area between the existing and enlarged Cotter Dams from sediment potentially infected with the EHN Virus. In the event that flood waters exceed the capacity of diversion works and water/sediment potentially carrying the EHN virus is brought to the surface of the work platform, further clean material will be brought in and all plant and machinery will be re-disinfected;
- Adoption of zoning and disinfection measures to contain the spread of any pathogens (via vehicles, equipment or personnel), particularly EHN Virus, from the area below the Cotter Dam wall to the Enlarged Cotter Dam reservoir or catchment.

Monitoring for the EHN virus

The presence of the EHN Virus will be monitored using the presence (or absence) of Redfin Perch, as this species is the primary vector in the spread of the disease and has a high mortality rate.

The Enlarged Cotter Dam Monitoring Program (Project 9) includes sampling for a range of alien and native fish species within and upstream of the Cotter Reservoir. During the course of this monitoring any Redfin

Perch that are collected will be inspected for signs of infection. If symptoms of the virus are present the fish will be tested to determine if they are infected with the EHN virus.

If the EHN virus is present in the Cotter Reservoir (identified by the presence of diseased Redfin Perch) it will be impossible to eradicate (Whittington, in prep). Accordingly, the focus of the Aquatic Flora and Fauna Management Plan and the EHN Virus Response Plan is therefore to prevent the EHN Virus from entering the Cotter River Catchment and the Enlarged Cotter Dam construction site.

Reporting and notification

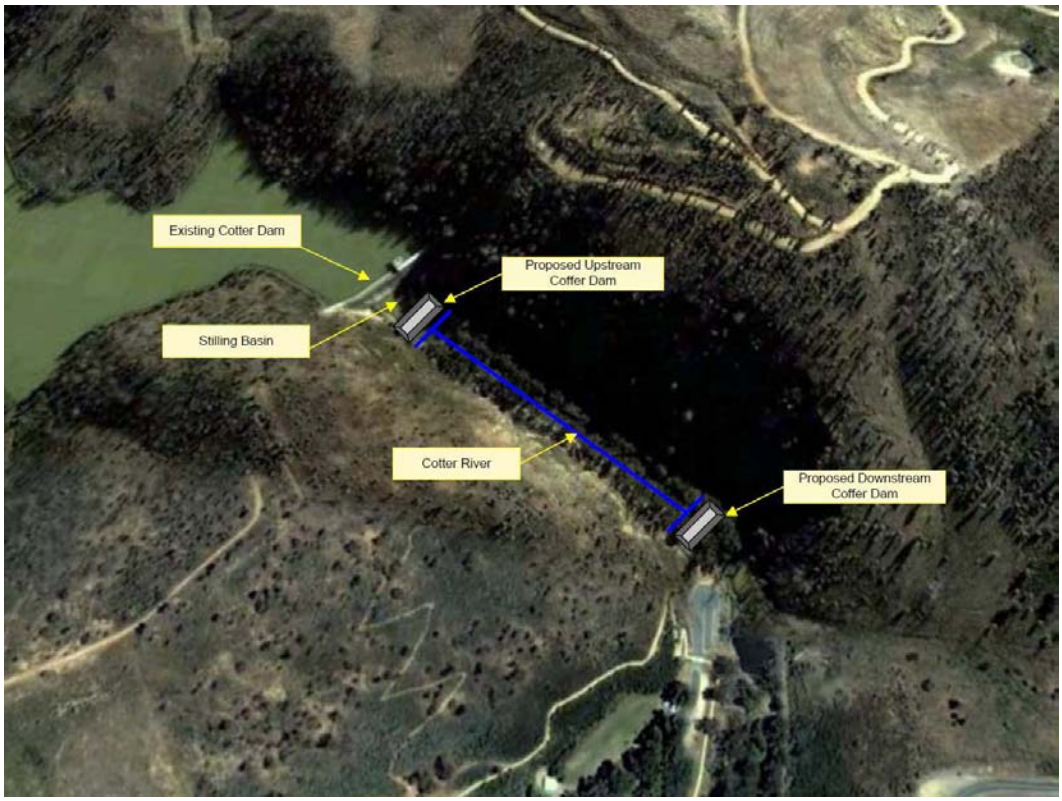
All environmental incidents will be managed in accordance with the Enlarged Cotter Dam Emergency and Incident Response Management Plan (ACTEW 2009d). This plan details all reporting and notification requirements required by the BWA in accordance with relevant licences and approvals. Incidents which have a potential to impact aquatic flora and fauna communities will be reported to the Fish Management Program team via the BWA Environmental Manager.

If the EHN virus is confirmed to be present in the Cotter Reservoir, the relevant agencies at State, Territory, National and International levels will need to be notified.

3.3.3 Fish and crayfish rescue translocation

In order to minimise the impact of construction on threatened native aquatic species and remove potential vectors for the EHN virus, it was necessary to remove fish and crayfish in the section of the Cotter River between the existing Cotter Dam and the downstream coffer dam, a distance of approximately 275 m. This included fish and crayfish in the stilling basin of the existing Cotter Dam.

Figure 3.1 Location of impacted areas downstream of the existing Cotter Dam.



Method for capture

Aquatic species were captured by the Research and Planning Section of PCL and Biosis Research Pty Ltd (Biosis) between 3 January and 8 January 2010 in accordance with the method described in Lintermans (2009). This involved lowering the water level in the stilling basin to allow the capture of fish and crayfish

using first fyke nets set overnight. Once the catch rate from fyke nets dropped below three fish per night, the water level was lowered further to allow the use of a combination of active capture techniques including backpack and boat electro-fishing and dip-netting.

This method was replicated for the section of river between the stilling basin and the downstream coffer dam.

Results of fish and crayfish capture

A total of 150 fish where captured during the operation including the following threatened native aquatic species (Matt Beitzel personal communications, January 2010):

- 32 Macquarie Perch.
- 3 Murray Cod.
- 10 Murray River Crayfish.

A large number of alien fish were also captured including:

- 40 Redfin Perch (known carriers of the EHN virus).
- 1 Eastern Gambusia *(Gambusia holbrookii)* (inferred susceptibility to the EHN virus based on susceptibility of Western Gambusia *(Gambusia affinis)*).
- 1 Rainbow Trout *(Oncorhynchus mykiss)* (known carriers of the EHN virus).

Fate of captured fish and crayfish

Aquatic fauna downstream of the existing Cotter Dam are suspected to be carriers or have come in contact with the EHN virus and so could not be placed in the existing Cotter Reservoir, due to the risk they pose to healthy fish populations. Captured fauna were handled in accordance with the methodologies described in Lintermans (2009):

- 17 of the captured Macquarie Perch were relocated to the Paddy's River at Murrays Corner. The remaining 15 Macquarie Perch were relocated to the confluence of the Cotter and Paddy's River.
- The 10 Murray River Crayfish were relocated to the Murrumbidgee River between the confluence with the Cotter River and Casuarina Sands.
- Other native fauna including Murray Cod, Mountain Galaxias *(Galaxias olidus)*, Western Carp Gudgeon *(Hypseleotris klunzingeri)* and a number of Eastern Longneck Turtles *(Chelodina longicollis)* were also relocated to the Murrumbidgee River between the confluence with the Cotter River and Casuarina Sands.
- All alien fish were euthanased.

3.3.4 Provision of environmental flows

The provision of environmental flows is important to maintain the health of the Cotter River upstream and downstream of the Enlarged Cotter Dam construction site. In accordance with conditions of approval and ACTEW's Licence To Take Water, ACTEW is required to provide environmental flows for the duration of the construction period and beyond. Flows are released in accordance with the ACT Water Resources Act and are stipulated in ACTEW's Licence To Take Water. Additional flow requirements are also stated in Commonwealth approval conditions. The requirements of ACTEW's licence are complex and pertain to the provision of environmental flows from all reservoirs on the Cotter and Queanbeyan Rivers, as well requirements for the protection of environmental flows in the Murrumbidgee River. The Commonwealth condition relates specifically to environmental flow requirements in the Cotter River below the Cotter Dam. The DEWHA requirement is to provide an environmental flow of 34 ML d^{-1} (averaged over 12 months) downstream of the Enlarged Cotter Dam project site for the duration of the construction period.

The environmental flows downstream of Cotter Dam are made of both Cotter Reservoir water and water recirculated from the Murrumbidgee River. Neither of these sources of environmental flow causes any losses to the Murrumbidgee River, with the exception of an insignificant seepage through the Cotter River system from below Cotter Dam to the Murrumbidgee confluence (a distance of approximately 3km). To avoid the

potential introduction of the EHN virus, the infrastructure which releases recirculated water has been specifically designed to ensure that water from the Murrumbidgee River cannot enter the Cotter Reservoir.

The ACTEW licence and the DEWHA conditions include a condition to report on compliance with environmental flow requirements and ecological monitoring undertaken. Monthly compliance reports prepared in accordance with DEWHA conditions are posted on the ACTEW website (www.actew.com.au); monthly licence compliance reports are provided to the ACT EPA.

The daily average flow for the period from January 2010 to September 2010 was 172 ML d^{-1} (ACTEW 2010b).

The Environmental Flow Guidelines are regularly reviewed to ensure water resources continue to be appropriately managed. The next review is expected from mid 2010 to mid 2011. The updated Guidelines may be used by the ACT EPA to make amendments to ACTEW's Licence To Take Water.

3.3.5 Cooperation and coordination with government agencies

To ensure ongoing cooperation and coordination with government agencies ACTEW and the BWA have established a Fish Management Program Steering Committee, comprised of representatives from the ACT EPA, the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (SEWPaC, formerly DEWHA), the ACT Government, the University of Canberra, ACTEW and the BWA.

The Steering Committee will:

- Oversee the activities being undertaken to meet DEWHA and ACTPLA approval conditions and commitments made in the PER and EIS.
- Work with ACTEW and BWA to ensure approval conditions and commitments are met.
- Provide strategic direction and inform the implementation of the broader project.
- Represent the interests and needs of the organisations represented by the Steering Committee and the broader stakeholder group.
- Provide advice and assist in the communication of Fish Management Plan outcomes.

The Steering Committee has met regularly since the commencement of construction.

3.3.6 Review by an independent auditor

In accordance with ACTPLA approval conditions, an independent auditor has been appointed to audit the Enlarged Cotter Dam project and ensure compliance with ACTPLA and/or DEWHA conditions of approval. The key responsibilities of the external auditor include:

- Review and develop a good working knowledge of the Conditions of Approval (DA and PER), EIS commitments as well as the CEMP's and associated sub-plans and ancillary Construction Method Statements.
- Participate in regular site inspections in the company of the BWA Environment Manager, Enlarged Cotter Dam Site environmental representatives and relevant Construction Managers to monitor construction environmental activities and evaluate compliance against the Conditions of Approval and the CEMP's.
- Develop and use a suitable site visit report / compliance checklist for recording of field based observations in consultation with the relevant members of the construction team. This report would list the various construction activities and have a column to mark the exact location of any compliance or issue of concern. Non compliance with any Condition of Approval or project commitments would be noted in another column, with additional space for comments on environmental risk ranking.
- A communication protocol will be established to ensure that site environmental controls and Conditions of Approvals are effectively managed. This protocol will include:
  - Verbal (face to face) discussion with construction personnel on site.

– A written site communication Record.

– A Recommendation for a Non-Conformance Record.

- Provide a written progress report to the BWA on matters of on-going compliance/non-compliance with the conditions of approval (DA and PER), EIS commitments and CEMP and relevant sub-plans observed or identified. The auditor would prepare a monthly report related to the monitoring of construction activities and assessment of compliance. This report would document the site visit findings and recommendations for improvement or suggested rectification. This report would be presented to the BWA Environment Manager.
- The auditor would be available to the BWA at a mutually agreeable time to discuss any of the items covered by the auditor's reports, the applicable regulatory context, the performance of the works, or any other issue pertinent to the completion of the works commensurate with the budget allocated for this role.
- The auditor would attend site on a monthly basis during construction of the Enlarged Cotter Dam project.
- Monitor the BWA's compliance tracking system and periodically produce a snap-shot report of the state of compliance against Conditions of Approval (DA and PER), EIS commitments, as well as CEMP's and associated sub-plans and ancillary Construction Method Statements for the project.

In addition to ACTPLA Notice of Decision commitments, the independent auditor also monitors onsite compliance with environmental approvals and permits (i.e. Environmental Authorisation) and provides compliance reports to the BWA Environmental Manager. The BWA Environmental Manager then submits these reports to the ACT EPA.

Independent audits have been conducted on a monthly basis since December 2009 and will continue for the duration of construction (Hobbs 2009, 2010a, 2010b & 2010c).

3.3.7 Provision of shelter habitat

In accordance with conditions of approval and commitments made in the EIS and PER, ACTEW will provide shelter habitat in the enlarged Cotter Reservoir to compensate for the almost certain loss of macrophytes currently used by adult Macquarie Perch as daytime refuge. ACTEW is aiming to provide the same proportion of rock reef habitat along the shoreline of the enlarged Cotter Reservoir as is currently provided by macrophytes on the shoreline of the existing Cotter Reservoir. Proposed locations for rock reefs, based on ACTPLA's approval of the DA (in June 2010), are shown in Figure 3.2.

Macquarie Perch shelter habitat requirements will be met through the installation of constructed rock reefs. Rock reefs have been designed using the findings of Project 1 – Constructed homes for threatened fishes in the Cotter River Catchment, investigations by the BWA Fish Management Team and ongoing discussions between ACTEW, the BWA and the University of Canberra. Reef design criteria include:

- Located within 5 to 28 metres below the FSL of the enlarged reservoir to provide shelter habitat for Macquarie Perch for 98 per cent of the time (refer to Section 1.1.4).
- Positioned close to the shoreline, running along and across various contours to provide shelter across a range of reservoir depths.
- Constructed from good quality, large, rounded rocks, ideally 1 metre in diameter to provide sufficient interstitial spaces and to resist fracture during transport, stockpiling and placement.
- Rock material to contain no or minimal fines and small rocks as these waste materials may fill the interstitial spaces, reducing the usefulness of the reef as shelter habitat for fish.
- Reefs to provide interstitial spaces (void size) between approximately 0.15 to 0.25 metres wide to allow access to adult Macquarie Perch.
- Erosion and sediment control measures and landscape rehabilitation will be undertaken to minimise sediment accumulation in interstitial spaces and transfer of sediment to watercourses.

Rock material for rock reefs will be produced in the onsite quarry and transported to rock reef sites using existing roads and access tracks, minimising wherever possible the impacts on local road users. Rock reefs will be constructed to the above specifications in accordance with construction methodologies developed through consultation with the BWA construction and environmental management teams.

Following lodgement in May 2010, the DA for the proposed rock reefs has been approved by ACTPLA, with construction of rock reefs is likely to commence by the end of 2010, based on availability of appropriate rock material.

It should be noted that some shelter habitat can also be provided by natural in situ structures such as rocky outcrops and vegetation as described in Section 4.2.1.

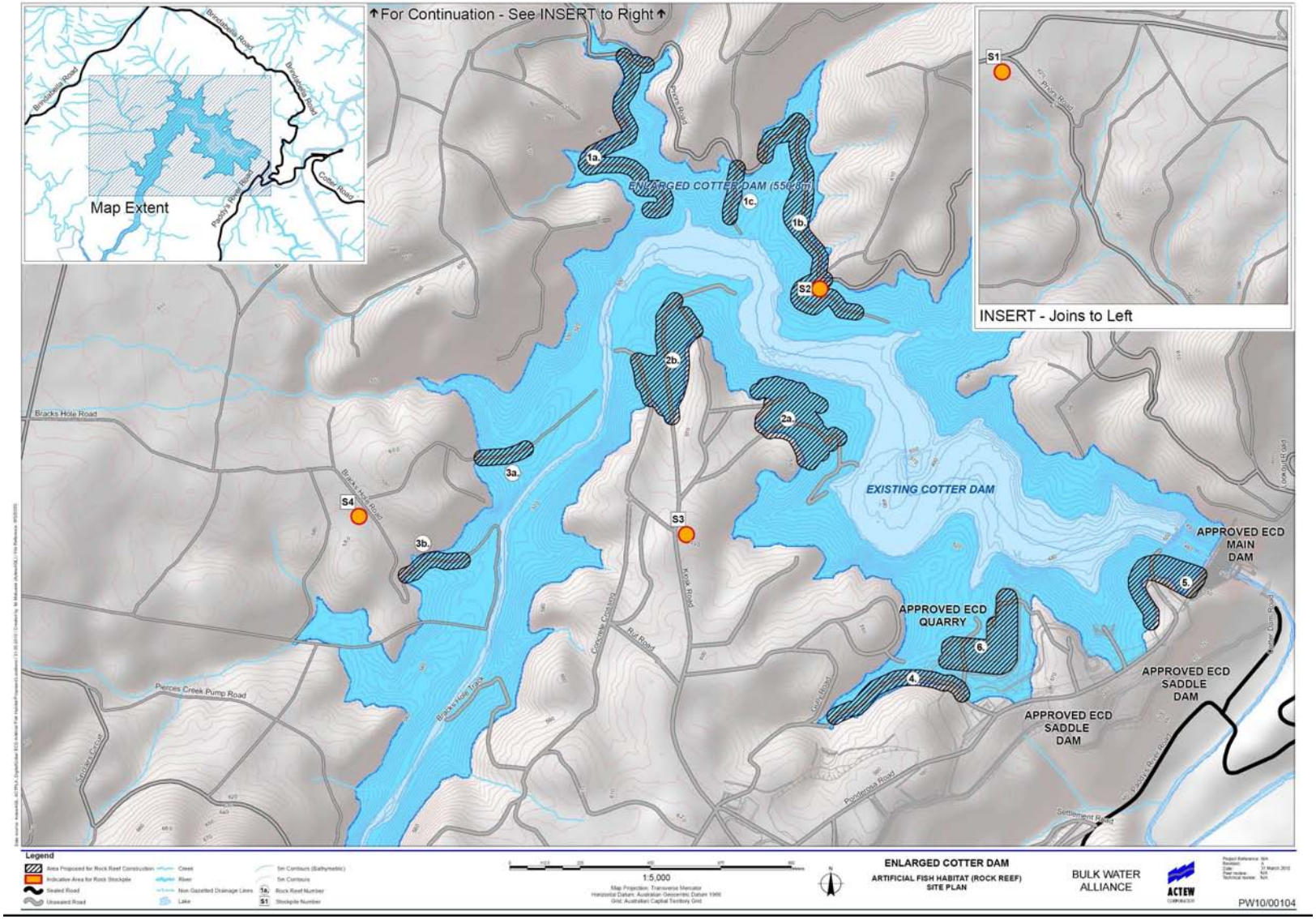
3.3.8 Remediation of instream barriers to fish passage

Studies undertaken as part of Project 2 – Predicted passage of native and alien freshwater fish based on swimming speed performance, have indicated that Pipeline Road Crossing and potentially Bourke's Creek Crossing pose barriers to the upstream migration of adult Macquarie Perch. Both these crossings currently consist of pipe-culverts which generate flow velocities above the swimming capacity of all but the largest Macquarie Perch for the majority of river discharges. The remediation of these barriers was identified as a commitment in both the EIS and the PER and is a Territory and Commonwealth condition of approval.

The suggested remediation strategy is to replace existing pipe culverts with rock-ramp fishways similar to that installed at Vanity's Crossing. Investigations are currently underway to develop an appropriate design and construction method. Detailed design is due by early 2011.

Following installation, the fishways will be monitored to ensure each is providing adequate fish passage.

Figure 3.2 Proposed rock reef locations.



4 Projects and information update

The projects identified in the Fish Management Plan Version 1 are currently being undertaken, or have been completed, to inform future mitigation and management measures for the protection of threatened native aquatic species. The projects cover a wide range of topics including key knowledge gaps identified and refined in the initial stages of the Enlarged Cotter Dam project (refer to Section 4.1) and knowledge gaps which been identified during the course of the Enlarged Cotter Dam project (associated projects) (refer to Section 4.2). Information has also been derived from a range of supplementary sources independent of the Enlarged Cotter Dam project (refer to Section 4.2).

4.1 Fish Management Program projects

In the initial stages of the Enlarged Cotter Dam project, ACTEW identified nine research and monitoring projects relevant to the conservation of threatened native aquatic species in the ACT. This research, undertaken as part of the Fish Management Program, was initiated to provide a better understanding of the threatened aquatic species in the Cotter River system and to inform management and mitigation measures for the Enlarged Cotter Dam project.

The nine projects have involved scientists and researchers from the University of Canberra, the Australian National University, University of Sydney and Griffith University. The following sections describe the projects, their findings to date and recommendations (where available) for the protection of threatened native aquatic species.

The updates provided in the following section are largely derived from progress reports prepared by the University of Canberra and the Australian National University, with the University of Sydney providing information on Project 4. The progress reports and the information presented from them are not final and therefore should be treated as preliminary information only and should not be cited. Final conclusions of the various projects may vary from the preliminary conclusions presented in these progress reports.

4.1.1 Project 1 - Constructed homes for threatened fishes in the Cotter River Catchment

The enlargement of the Cotter Reservoir will alter habitat availability for threatened aquatic species in the existing reservoir and the Cotter River upstream of the Cotter Reservoir. This project, being undertaken by the University of Canberra, has been designed to fully assess feasible habitat alternatives.

The main aims of Project 1 are to:

- Determine if adult Macquarie Perch will use constructed habitat for shelter when emergent macrophytes are not available.
- Test which constructed habitat is preferred for diurnal refuge by adult Macquarie Perch.
- Develop capacity to facilitate Two-spined Blackfish recolonising the enlarged Cotter Reservoir after construction of the Enlarged Cotter Dam.
- Provide guidelines for construction of long term habitat to sustain threatened fishes.
- Showcase the achievement of ecological sustainability in the construction and management of reservoirs nationally and internationally.

This project is being delivered in two phases.

Phase One (now complete) involved the establishment of the project including literature review, development of study method and the installation of trial constructed fish habitats and associated monitoring equipment. Phase One has been peer reviewed, with the experimental approach found to be sound, reliable and capable of generating the necessary data to assess the use of constructed habitats by adult Macquarie Perch. The potential for providing constructed spawning habitats for Trout Cod and Two-spined Blackfish was also explored (Lintermans et al. 2009a).

Following the first phase of Project 1, it was decided that the impact of the Enlarged Cotter Dam and any associated minor proposed changes in the operation of Bendora Reservoir would not be expected to have significant impacts on Trout Cod in Bendora Reservoir (refer to Table 3.5) and therefore further investigation of the provision of constructed habitat for this species in Bendora Reservoir was not pursued.

Phase Two is currently underway.

The information presented in this section was summarised from Lintermans et al. (2009b) and Lintermans et al. (2010).

Macquarie Perch use of constructed habitats in the Cotter Reservoir

Monitoring of constructed habitat use

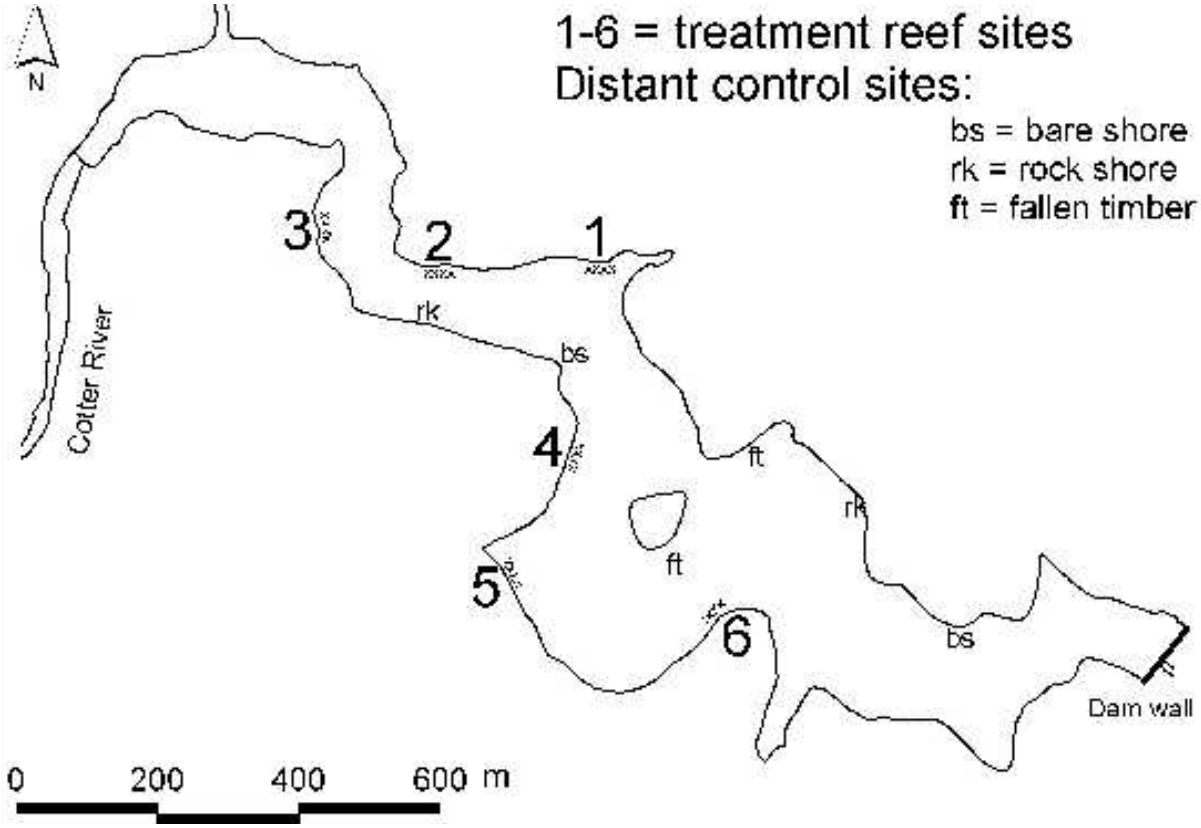
As part of the first phase of Project 1, trial constructed habitats including rock reefs, pipes and pipes with grills, were installed in the Cotter Reservoir. The use of these constructed habitats by adult Macquarie Perch and other biota was then monitored using two different monitoring techniques, remote radio telemetry (supplemented with manual radio telemetry) and underwater video assessment.

Remote telemetry was used to:

- Determine whether adult Macquarie Perch will use constructed habitats for daytime shelter habitat in an enlarged Cotter Reservoir.
- Test which constructed habitat is preferred for daytime shelter by adult Macquarie Perch.

The constructed habitats tested in this project included rock reefs, pipes and pipes with grills. The study also monitored three types of natural habitat as a reference (control) including fallen timber, rocky shore and bare shore. The location of constructed and natural habitat sites is shown in Figure 4.1.

Figure 4.1 Location of constructed reef and control sites.



Manual radio telemetry was used to:

- Determine diel (24 hour) movement metrics of Macquarie Perch across seasons for comparison with a previous radio tracking study in the Cotter Reservoir by Ebner & Lintermans (2007).
- Assist with the identification of those tags which are no longer active, for example due to tag failure or fish mortality.

Underwater video was used to:

- Monitor the use of constructed reefs by Macquarie Perch (since this may be important when considering which reef type is most suitable as constructed shelter habitat).
- Complement radio telemetry by monitoring fish of any age-class, not just the adult radio-tagged sample.
- Record other biota at the reef sites, their interactions with the reefs and their interactions with Macquarie Perch.

Following recording, footage from each of the cameras was reviewed and analysed in the laboratory.

Investigation of Macquarie Perch spawning movements

Macquarie Perch migrate upstream from reservoirs into flowing waters to spawn (Harris & Rowland 1996; Douglas 2002; Lintermans 2007). In the existing Cotter Reservoir, prior to and during their spawning migration Macquarie Perch are believed to be particularly susceptible to predation by avian predators, notably cormorants (Mark Lintermans personal communication, 2009; Ebner & Lintermans 2007). The aim of this component of the study was to gain a better understanding of spawning movements, which may then be used to inform the management of the enlarged Cotter Reservoir to ensure fish have sufficient cover prior to and during their migration.

The investigation also tested the effectiveness of selected Passive Integrated Transponder (PIT) equipment and antenna design in the monitoring of spawning migrations.

Macquarie Perch for the study were collected from the Cotter Reservoir between March 2008 and July 2009. A total of 196 Macquarie Perch were implanted with PIT tags, each with a unique frequency to allow differentiation between individual fishes.

Investigation of upstream movements of individuals at a finer temporal scale are continuing to provide more detailed information on timing and duration of upstream movements and allow continued exploration into differences in movement patterns between individuals.

Two-spined Blackfish recolonisation of enlarged Cotter Reservoir

Two-spined Blackfish currently inhabit the entire length of the Cotter River and the lower reaches of major tributaries upstream of Cotter Reservoir and also Corin and Bendora Reservoirs (Lintermans et al. 2005; Ebner & Lintermans 2007; Ebner et al. 2008). This species is notably absent from the existing Cotter Reservoir, most probably due to the sedimentation of areas of previously suitable shelter and spawning habitat (Lintermans 2005). It is unknown whether the species breeds in reservoir habitats, or whether breeding occurs in upstream rivers with subsequent dispersal downstream into reservoirs. To investigate whether the species will breed and colonise the enlarged Cotter Reservoir. The following has been assessed:

- The movements of Two-spined Blackfish in Bendora Reservoir.
- Whether Two-spined Blackfish recruitment is occurring in Bendora Reservoir.
- Whether it is possible to enhance recruitment with constructed spawning habitat (if recruitment is occurring).

Movements of Two-spined Blackfish in Bendora Reservoir

The study of fish movement used a combination of manual radio tracking and remote telemetry. The study commenced in February 2009 with the capture and radio-tagging of 31 Two-spined Blackfish from the shores of the Bendora Reservoir.

To assess the spatio-temporal behaviour of Two-spined Blackfish different movement metrics including home range, diel range, diel mobility and diel activity were defined and measured (refer to Table 4.1). Depth and surrounding habitat features were also recorded for each location.

Table 4.1 Movement metrics measured for Two-spined Blackfish based on manual radio tracking.

Metric	Definition
Home range (daily only)	The total length of shoreline used by an individual based on daily tracks only.
Home range (total)	The total length of shoreline used by an individual for all tracks.
Diel range	Length of shoreline used by an individual in a complete diel period.
Diel mobility	Sum of all movements of an individual in a complete diel period.
Diel activity	Mean percentage of distance covered by an individual for each interval between tracks for each diel period.

Two-spined Blackfish recruitment in Bendora Reservoir and investigations of constructed spawning habitat

This component of the study used a combination of constructed spawning tubes and direct visual survey to determine both if recruitment is occurring in the Bendora Reservoir and if Two-spined Blackfish will utilise constructed spawning habitat. The study was conducted to coincide with estimated spawning times in Bendora Reservoir.

Spawning tubes were placed in shallow sections of the reservoir (depths ranged between 0.6 to 1.2 m) at three bankside sites. Each site exhibited a range of different habitat types including bare shore, rocky shore, fallen timber and submerged macrophytes (predominately *Cyperus eragrostis*).

Once deployed, spawning tubes were monitored weekly for evidence of Two-spined Blackfish presence or spawning. The trial was adversely impacted by fluctuations in water levels in Bendora Reservoir (Two-spined Blackfish spawning coincided with a period of drawdown to meet municipal water supply demands) and was subsequently terminated as tubes were left out of the water for a significant period of time.

A direct visual survey via snorkel was conducted at the northern end of Bendora Reservoir on 10 December 2009 to detect the presence of any young-of-year Two-spined Blackfish. Due to the failure of the spawning tube trial, this survey was important to determine if recruitment was occurring in Bendora Reservoir.

Preliminary Findings

The following are preliminary findings from Phase Two of Project 1. Work on Macquarie Perch and Two-spined Blackfish is continuing, with the final Project 1 report due in late 2010.

Macquarie Perch habitat use

Preliminary findings of remote radio telemetry show that (Lintermans et al. 2009b):

- Macquarie Perch were detected on all three constructed habitat types (rock reefs, pipes and pipes with grills) following installation.
- During the day, Macquarie Perch were shown to occupy deeper water depths in summer than spring, autumn and winter.

Preliminary findings of manual radio tracking show that (Lintermans et al. 2009b):

- Macquarie Perch movements were generally greatest during crepuscular (evening) or nocturnal (night) periods in all seasons.
- Diel mobility and diel range were comparable across spring, summer and autumn however were greatest during winter.
- Macquarie Perch were able to move throughout the extent of the existing reservoir during all seasons.

The preliminary results of the video processing show that (Lintermans et al. 2009b):

- Rock reef is the preferred constructed habitat type for Macquarie Perch.
- Three types of piscivorous birds, namely Great Cormorants, Little Pied Cormorants and Darter were hunting in the vicinity of the habitats.
- Macquarie Perch shelter in the interstitial spaces between rocks to avoid bird predation.

Investigation of Macquarie Perch spawning movements

Preliminary findings of PIT telemetry show that (Lintermans et al. 2010):

- There was a substantial increase in movement past antennas during the first major rise in river water temperature (in early to mid October).
- Fish moving past the antennas were significantly larger than the average of the entire PIT tagged population.
- Within the group of fish that were detected by the PIT array, larger fish appeared to start and finish movements past antennas earlier than smaller fish.

Movements of Two-spined Blackfish in Bendora Reservoir

Preliminary analysis of manual tracking data showed that:

- Two-spined Blackfish exhibit a preference for two broad habitat types, namely steep rocky banks (with or without woody structure) for daytime shelter and shallow banks with a high density of macrophytes for foraging during the night.
- Two-spined Blackfish in the reservoir travelled much greater distances than have been recorded in previous riverine studies (Lintermans 1998; Broadhurst et al. unpublished data), however these movements were almost exclusively undertaken at night.
- Based on survey results Two-spined Blackfish are believed to make return diel migrations, leaving the cover of steep rocky shorelines to migrate up to shallower areas which were rich in submerged and emergent macrophytes, presumably to feed.
- Two-spined Blackfish swim significantly greater distances at night, travelling between day-time shelter and night-time foraging areas.

The scale of movement observed in this study suggests that Two-spined Blackfish are capable of moving on larger spatial scales but these movements are almost exclusively undertaken at night. If these movement patterns are transferable between impoundments on the Cotter River, the correct spacing of habitats is likely to enable the recolonisation of Two-spined Blackfish in the enlarged Cotter Reservoir. It is anticipated that the habitats provided for Macquarie Perch will also be suitable Two-spined Blackfish.

Two-spined Blackfish recruitment in Bendora Reservoir and investigations of constructed spawning habitat

The trial of spawning tubes was largely unsuccessful due to two factors; dramatic changes in water level in early November (resulting in the tubes being out of the water for substantial periods) and high levels of sediment in tubes in downstream and middle reaches of the Bendora Reservoir. No Two-spined Blackfish or evidence of their spawning were detected in the spawning tubes during the study.

Small Two-spined Blackfish were observed near the Bendora Dam during the direct visual survey, indicating that recruitment occurred in the Bendora Reservoir in 2009, despite fluctuations in water levels of up to 5

metres. The presence of young-of-year suggests that at least some of the Two-spined Blackfish population spawned at depths greater than 5 metres (below FSL). It remains possible however, that spawning was attempted at shallower depths and eggs or larvae may have perished following reservoir drawdown, showing the potential impact that fluctuating water levels during the spawning period may have on the recruitment of Two-spined Blackfish in the Bendora Reservoir.

Recommendations

To be provided following project completion, expected late 2010.

4.1.2 Project 2 - Predicted passage of native and alien freshwater fish based on swimming speed performance

The upstream migration of Macquarie Perch is contingent on the species being able to overcome ambient flows and instream barriers in the Cotter River. To facilitate the identification and remediation of potential barriers to Macquarie Perch movement and provide an overview of fish passage in the Cotter River, an understanding of the swimming capacity of Macquarie Perch and other alien fish species is required.

The objectives of Project 2 were to:

- Assess the swimming speed performance of various size classes of Macquarie Perch across a range of environmental temperatures.
- Identify potential man-made barriers to Macquarie Perch in the Cotter River under various river discharge and temperature regimes by comparing swimming speed performance against measured flow velocities.
- Assess the swimming speed performance of established and potential invading alien fish species in relation to Macquarie Perch to help determine whether range expansions by alien species may occur through the remediation of barriers to Macquarie Perch migration within the Cotter River.

The information presented in this section was summarised from Starrs et al. (2009).

Swimming trials

Fish for the study were collected in the Cotter River and other nearby river catchments between August 2008 and January 2009. This included 32 Macquarie Perch collected from the Cotter River, Eastern Gambusia and Goldfish *(Carassius auratus auratus)* from the Cotter River at Brack's Hole, Goldfish and Oriental Weatherloach *(Misgurnus anguillicaudatus)* from the Cotter Reservoir and Redfin Perch from the Molonglo River.

Following capture, the fish were transported to the ANU Aquarium Facility. Both prolonged and sprint swimming performance of Macquarie Perch were assessed at 10 ℃, 16 ℃ and 22 ℃ to determine the effect temperatures within the Cotter River system may have on swimming performance. Swimming trials for alien fish were conducted at a single temperature of 16 ℃.

Prolonged and sprint performance trials were attempted for all fish however Oriental Weatherloach refused to undertake sprint swimming and immediately sought shelter rather than the normal swimming response. The methodologies described above were replicated for all species, with the exception of Gambusia which were swum in a smaller tank at lower velocities due to their significantly smaller size.

Flow profiling

Flow profiling was conducted at Vanity's Crossing and Pipeline Road Crossing, two potential barriers to fish passage upstream in the Cotter River.

Profiling at Vanity's Crossing was undertaken between 24 October 2008 to 23 February 2009 to encompass four different river discharge levels (2.7 ML d^{-1}, 15 ML d^{-1}, 30 ML d^{-1} and 160 ML d^{-1}). Profiling was conducted in the rock-ramp fishway and in natural structures in the vicinity of the fishway.

Flow velocities were recorded with a portable flow probe and river discharge data was collected by nearby remote data loggers operated by Ecowise Environmental.

Flow profiling was also conducted at Pipeline Road Crossing between 24 October 2008 to 23 February 2009, at four river discharges (2.7 ML d^{-1}, 10 ML d^{-1}, 30 ML d^{-1} and 166 ML d^{-1}). Pipeline Road Crossing is a 3.7

metre wide concrete roadway, approximately 9 metres long and 2 metres high with seven straight 0.85 metre diameter concrete pipes with smooth internal surfaces to allow water to flow underneath the crossing. It was noted that during low flows (<10 ML d^{-1}) only two of the pipes carry any water however flows through other pipes increase with rising discharges. Three randomly selected 4 metre sections of riffles immediately upstream and downstream riffles of the crossing were also sampled, with five main-stream and refuge velocities recorded in each four metre section.

Modelling fish passage

Macquarie Perch sprint performance data at 10 ºC and 16 ºC was compared with the recorded flow velocities to determine if the fish could theoretically pass the barriers assessed. Passage was considered likely if Macquarie Perch sprint speed was greater than flow velocity to the extent that an individual had enough positive groundspeed (calculated as sprint swimming speed minus flow velocity) to actually pass over these short barriers (less than one metre in length).

To assess whether Macquarie Perch could successfully pass riffles, fishway and pipes, a combined groundspeed and time analysis was used. Passage was considered successful if:

- A fish could generate positive groundspeed.
- Passage time did not exceed five minutes at this groundspeed (the time each fish could maintain their measured sprint speed).

Flow sensitivity of Macquarie Perch was also explored with both first quartile and mean flow velocities within each section of Vanity's Crossing fishway and the natural riffles utilised. The study assumed that fish were flow sensitive and would select a route through lower flow velocities.

Findings

Based on direct measurements of swimming speed performance of the five freshwater fish species (Macquarie Perch, Gambusia, Goldfish, Oriental Weatherloach and Redfin Perch) and flow measurements at potential barriers in the Cotter River upstream of the Cotter Reservoir, it was found that:

- Body size had a significant effect on swimming speed performance in Macquarie Perch, with a general trend of increasing speed with increasing body size.
- Temperature also exerted an influence on swimming speed performance. While prolonged performance was significantly higher at 22 ºC than at 16 ºC, increases above 16 ºC had an insignificant effect on sprint speed performance in Macquarie Perch. Both prolonged and sprint speed performance was significantly reduced at 10 ºC, with this 'coldwater' effect greater in juvenile Macquarie Perch (<10 cm TL) compared to adult fish.
- Flow velocities through two man-made obstacles on the Cotter River between Bendora Dam and Cotter Dam were measured across a wide range of environmental flows. Vanity's Crossing fishway exhibited flow velocities that were similar to nearby natural riffle habitats across all measured river discharges. Conversely, Pipeline Road Crossing contained exceptionally high flow velocities through the culvert pipes under most discharge conditions.
- The combination of Macquarie Perch swimming performance and flow velocities revealed that river discharge, temperature and Macquarie Perch size were significant factors in determining likely upstream passage through in-stream obstacles.
  - Adult Macquarie Perch passage through Vanities Crossing fishway is likely under discharges between 15 Ml d^{-1} and 160 ML d^{-1} (river discharges of 2.7 ML d^{-1} produced sections of very shallow water likely to physically block fish passage).
  - Conversely, Pipeline Road Crossing may be a major barrier to Macquarie Perch with passage unlikely over most discharges and perched outlets at low discharges (2.7 ML d^{-1}) requiring fish to leap into the pipe outlets (not a natural tendency of the species). The study predicted that only very large individuals could negotiate this pipe culvert during flows of approximately 150 ML d^{-1}.

- The natural riffles adjacent to both Pipeline Road Crossing and Vanity's Crossing appear to be passable at all flows, with the potential exception of 160 ML d^{-1} (sampling was not completed under this flow velocity due to concerns for researcher safety).
- Preliminary work on the prolonged and sprint speed performance of introduced Eastern Gambusia, Redfin Perch, Goldfish and Oriental Weatherloach indicate that Macquarie Perch swimming performance is intermediate to alien fish species in the ACT. Strong overlap is apparent in the swimming performance of Redfin Perch, Goldfish and Macquarie Perch, suggesting that any efforts to facilitate Macquarie Perch passage through remediation of in-stream barriers may also increase the probability of upstream migration by these alien species. However, slower alien species like Eastern Gambusia could be excluded by having flows set sufficiently high for their exclusion, while allowing access for the faster Macquarie Perch.

Recommendations

Based on the findings of this study, the following recommendations to maintain and enhance Macquarie Perch access to spawning and recruitment grounds in the Cotter River have been made:

- Minimise releases of cold-stratified water from Bendora Reservoir. This study found Macquarie Perch swimming performance was significantly reduced in cold water, particularly in regard to juveniles.
- Maintain sustained flows in excess of 10 ML d^{-1} and less than 150 ML d^{-1} in the Cotter River between Bendora and Cotter Reservoirs during possible spawning migration events (September to December). This study found Macquarie Perch are unlikely to pass through both Vanity's Crossing fishway and Pipeline Road Crossing at a discharge of 2.7 ML d^{-1} (insufficient water depth). While flows in excess of 100 ML d^{-1} are unlikely to have negative effects on adults, the possible displacement of larvae at high flows needs investigation.
- Install a suitable fish passage structure at Pipeline Road Crossing to attain suitably low flow velocities (less than 60 cm s^{-1}) to enhance Macquarie Perch upstream migration past this crossing. Similar works may also be needed at Burkes Creek Crossing (which has a similar under-road pipe culvert).
- Enact a regular maintenance program for the Vanity's Crossing fishway. Major leaks in this structure require immediate attention, due to the negative impacts this can have on fish guidance into and through the fishway for successful upstream passage.
- Examine the possibility of natural barriers to Macquarie Perch passage in the Cotter River between Bendora and Cotter Reservoirs. Barriers in this reach are likely to have major impacts on successful spawning by Macquarie Perch.
- Consideration of the removal of barriers to Macquarie Perch passage should include a parallel analysis of whether range expansions by alien species are possible, due to similarities in swimming performance.

4.1.3 Project 3 - Crayfish ecology

Project 3 was designed to address key knowledge gaps for Murray River Crayfish by meeting the following objectives:

- Assess the current distribution and abundance of Murray River Crayfish in upland river systems, with particular attention to the Murrumbidgee and Cotter Rivers in the ACT.
- Evaluate the habitat and water quality preferences of Murray River Crayfish in upland river systems and assess whether suitable habitats are present in the Cotter River.

The project, completed in mid 2010, was divided into three key components to assess the distribution and abundance of Murray River Crayfish, compare survey techniques and evaluate Murray River Crayfish habitat requirements. This project used the Goobarragandra River, an unregulated river near Tumut in NSW with high abundances of Murray River Crayfish, to gauge the effectiveness of survey methods and as a basis for comparison of habitat characteristics.

The information presented in this section was summarised from Fulton et al. (2010).

Murray River Crayfish distribution and abundance

The study of Murray River Crayfish distribution and abundance was undertaken during July to November 2008 within the Cotter and Murrumbidgee rivers. The sites selected for the survey were based on earlier work by Lintermans and Rutzou (1991).

The survey used baited hoop nets placed along the banks or in the mid-channel of larger pools. All captured individuals were marked for identification purposes in accordance with the marking system of Ryan et al. (2008), which involves removing a small portion of the tail fin.

Comparison of survey techniques

As survey technique is a critical factor in detecting adult crayfish (Rabeni et al. 1997), an integral component of this project was the examination of the effectiveness of three different techniques for identifying Murray River Crayfish in the Murrumbidgee, Paddy's, Cotter and Goobarragandra Rivers. Techniques included:

- Direct visual survey.
- Baited remote underwater video (BRUV).
- Baited hoop nets.

Each of these survey techniques were trialled in the Goobarragandra River as part of a pilot study to evaluate their use and relative effectiveness for detecting Murray River Crayfish. These techniques were then replicated (where appropriate) in the Murrumbidgee, Paddy's and Cotter rivers in accordance with the methodologies established during the pilot study.

Direct visual survey

Direct visual surveys were conducted in the Goobarragandra River during February 2009 by two observers on snorkel, swimming in a zig zag pattern across the entire pool site (following Fulton et al. 2001). Murray River Crayfish observed during the survey were captured using dip nets and their occipital carapace length (OCL), width and mass recorded.

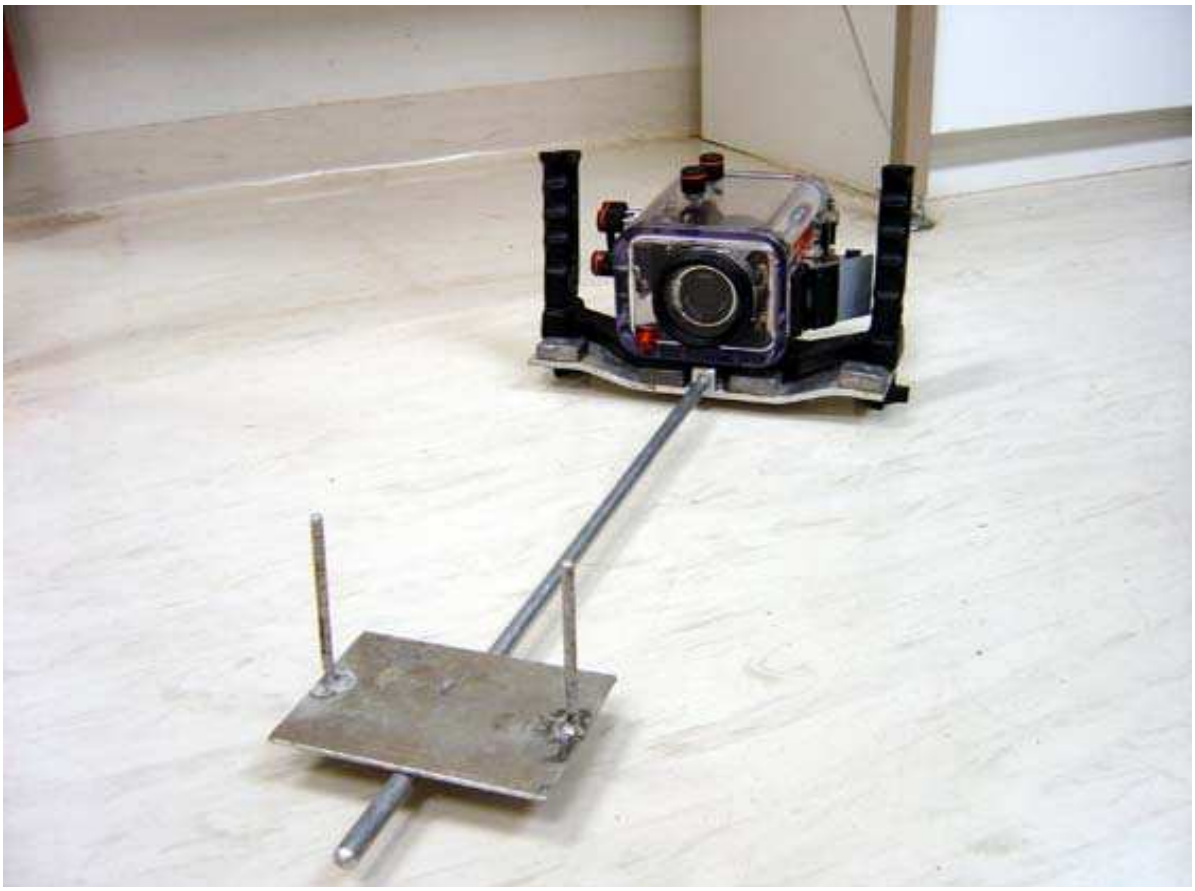
This method was found to be unsuitable for the Murrumbidgee River due to high sediment loads and associated low visibility. However as direct visual survey was successfully trialled in the Goobarragandra River, it could be used in other rivers with reasonable water clarity, for example the Cotter River.

Baited remote underwater video

BRUV uses a digital camcorder mounted inside an acrylic underwater camera housing directed at a plate to which the bait is secured. The housing and bait plate are mounted on an adjustable frame, allowing filming in a variety of water clarity conditions (by bringing the bait plate closer to the camera) and providing a consistent scale factor to enable the estimation of Murray River Crayfish size (refer to Figure 4.2).

The use of BRUV was trialled in the Goobarragandra River during March 2009 and later replicated in the Murrumbidgee, Paddy's and Cotter rivers during August to November 2009. Each site was monitored using three BRUVs set approximately 2 m from the bank and at least 10 m apart and positioned to view across the stream, either facing towards the bank or away from it depending on lighting conditions.

Figure 4.2 BRUV used for sampling Murray River Crayfish (Fulton et al., 2010).



Following each deployment, video files were reviewed with records made of the time each Murray River Crayfish entered and exited the frame of view, their behaviour towards the bait and any other species present in the frame of view, including carp, Redfin Perch and yabbies. Estimates of OCL and/or propodus size were made for any individuals in close proximity to the bait plate, based on its known dimensions.

Baited hoop nets

Baited hoop nets were used in the Goobarragandra and Cotter Rivers in accordance with the methodologies established during the 2008 survey and by Lintermans and Rutzou (1991). Nets were deployed in the same glide pools as the BRUV survey, with the exception of Casuarina Sands on the Murrumbidgee River and the footbridge on the Paddy's River. Hoop nets were not deployed in riffle run habitats due to the high currents in these areas unsettling the nets.

At the completion of the survey, capture rates were calculated for all three methods by dividing the total number of Murray River Crayfish caught by the sampling effort (hours of searching/soaking) to provide a standardised number of individuals per hour. Standardised results were then used to evaluate the relative effectiveness of each sampling method (refer to Table 4.2).

Habitat and flow preferences of Murray River Crayfish

The aims of this component of the project were to:

- Examine the habitat usage by Murray River Crayfish in an unregulated river system (the Goobarragandra River) both across and within river sections (glide pool and riffle run).

- Assess whether the habitat and flow characteristics within the Cotter River appear suitable for Murray River Crayfish based on their usage in the Goobarragandra River.

The study examined the characteristics of both microhabitat (a small specific habitat type where an organism resides, contained within a 1 to 10 m scale) and mesohabitat (overall habitat on a 10 to 100 m scale).

The study was conducted in both the Goobarragandra and Cotter Rivers with examination of the substrate composition, water depth and flow velocity in both areas where Murray River Crayfish had been sighted (identified by direct observation) and randomly selected areas. The relative proportions of fines, gravel, pebble, cobble, boulder and bedrock, percentage cover of organic material (leaf litter, tree roots, aquatic vegetation and woody debris), total water depth and flow velocity for each random quadrat were recorded. The percentage of overhanging vegetation was recorded for each section.

Due to the scarcity of Murray River Crayfish in the Cotter River (zero individuals sighted during habitat censuses), the assessment of habitat characteristics, based on sightings of Murray River Crayfish, could not be replicated. The survey could not be conducted in the Murrumbidgee River as excessively high turbidity precluded the visual survey methods necessary to assess habitat characteristics.

Following the surveys, the availability of Murray River Crayfish preferred habitat was compared between the Goobarragandra and Cotter Rivers to determine if this had an impact on Murray River Crayfish abundance.

Preliminary findings

Murray River Crayfish distribution and abundance

Surveys found that (Fulton et al. 2010):

- 86 per cent of Murray River Crayfish reside in glide pools (with glide pools representing only 61 per cent of all mesohabitats surveyed).
- Murray River Crayfish have a preference for deeper sections of glide pools and riffle run habitats within flow velocities equivalent to average flows (6.4 – 15.6 cm s^{-1}).
- Murray River Crayfish have a preference for bedrock and boulders and avoid pebbles, fines and leaf litter/vegetation/woody debris in glide pools.
- Catch rates for the Murrumbidgee and Cotter Rivers were generally low, with most catches in areas without easy public access. The majority of Murray River Crayfish captured had an OCL less than 80 mm (female Murray River Crayfish generally reach sexual maturity at greater than 80 mm OCL (O'Connor unpublished data).

Comparison of survey methods

To assist in future surveys of Murray River Crayfish populations and to provide revised estimates of population numbers, estimates of catch per unit effort (CPUE) (in this study CPUE is defined as the number of crayfish caught per sampling hour) were calculated for the Murrumbidgee, Cotter and Goobarragandra rivers for each of the survey methods. As shown in Table 4.2, the CPUE for the Goobarragandra River are considerably higher than the Cotter River for all survey methods. Where water clarity is suitable, direct visual survey is the most effective method of survey followed by BRUV. As visual survey and BRUV are more effective at detecting Murray River Crayfish, the study recommends that an efficiency adjustment is applied to the results of hoop netting (which may be the only suitable survey method if visibility is poor) to give a to give a better estimate of Murray River Crayfish abundance.

Table 4.2 Estimated CPUE for hoop nets, BRUV and direct visual survey methods (Fulton et al. 2010).

Survey method	Cotter	Murrumbidgee	Goobarragandra
Hoop net	0.00	0.08	0.13
BRUV	0.17	0.40*	0.63
Direct visual	0.79*	1.88*	2.94

**Figures are estimates calculated from the conversion of BRUV to direct visual survey (multiplication factor of 4.7), hoop net to BRUV (multiplication factor of 5) and hoop net to direct visual survey (multiplication factor of 23.5) in the Goobarragandra River.*

Overall CPUEs were comparable with those recorded in previous surveys by Lintermans and Rutzou (1991), however many sites in the Cotter River, where Murray River Crayfish have been previously recorded, provided zero observations.

Comparison of habitat features and availability

The composition and availability of microhabitats and mesohabitats in the Goobarragandra and Cotter Rivers were compared. It was found that:

- There is little difference in microhabitat composition and boulder sizes between the two rivers.
- There are major differences in mesohabitat features. Most significant to the Murray River Crayfish is an absence of overhanging vegetation, and much shallower glide pools in the Cotter River.
- Under the discharges during the survey, the differences in flow velocity were marginal (Goobarragandra River natural average discharge of 49.8 ML d^{-1} (NSW Government 2009) and Cotter River regulated discharge of 20 ML d^{-1} (Jonathon Thirkell personal communication, 2009)).

Recommendations

Based on the findings of this study, the following recommendations to increase Murray River Crayfish numbers in the Cotter and Murrumbidgee Rivers have been made (Fulton et al. 2010):

- Prepare a management plan that collectively includes Murray River Crayfish populations across the lower Cotter, Paddys and Murrumbidgee Rivers via targeted remediation and protection strategies (following the ACT Aquatic Species and Riparian Zone Conservation Strategy, ACT Government 2007a) that encompass all three rivers.
- Preserve or remediate habitats critical to the survival of Murray River Crayfish via critical habitat designations under the ACT Aquatic Species and Riparian Zone Conservation Strategy (ACT Government 2007a). Critical habitats include deeper river sections such as glide-pools where Murray River Crayfish utilise clean boulders, bedrock and gravel substrates to build their burrow shelters.
- Future reviews of the Environmental Flow Guidelines (ACT Government 2006) should consider Murray River Crayfish flow preferences. Namely, that Murray River Crayfish tend to prefer moderate levels of flow velocity (0.1 to 0.4 m s^{-1}). Short-term deviations towards high velocities (over 1 m s^{-1}) are unlikely to be detrimental to Murray River Crayfish and would help minimise build-up of fines that occlude Murray River Crayfish preferred microhabitats. Investigations into what volume of environmental flow releases are likely to produce such flow velocities in the lower Cotter and Murrumbidgee Rivers are needed.
- Natural microhabitats preferred by Murray River Crayfish (boulders, bedrock and gravel) are currently available throughout most of the lower Cotter River, suggesting that the addition of constructed habitats (e.g. concrete pipes, bricks, boulder piles) is unlikely to result in significant Murray River Crayfish population increases in this system.
- Remediate glide-pool habitats that are heavily impacted by sediment deposition in the lower Paddy's River to improve chances of Murray River Crayfish colonisation.

- Amend the ACT Aquatic Species and Riparian Zone Conservation Strategy (ACT Government 2007a) to include the need for maintenance and/or enhancement of riparian vegetation along ACT rivers such that overhanging vegetation shades at least 30 per cent (ideally 50 per cent or more) of the wetted river area, especially in critical Murray River Crayfish areas.
- Increased public education of the biology and ecology of Murray River Crayfish to highlight their vulnerability to overfishing (slow-growing, long-lived, late-maturing) using appropriately placed signage and pamphlets. Potential audio-visual educational resources could be developed using our high-definition digital underwater footage of Murray River Crayfish.
- Rigorous enforcement of fishing closures for Murray River Crayfish, as even low levels of illegal or accidental fishing captures can drive this species to local extinction in a very short time (1 to 2 years). Glide-pool habitats should be areas of high priority for enforcement patrols/surveillance.
- Regular monitoring should employ the most efficient census technique for recording Murray River Crayfish abundance under each type of in-water conditions: direct snorkel censuses or BRUVs in clear-water conditions, hoop-netting in turbid conditions (the latter being catch-adjusted to account for lower efficiency).
- Future research should examine whether the abundance of potential competitors (e.g. Yabbies) and predators (for example Carp, Redfin Perch) in habitats preferred by Murray River Crayfish is linked to presence/absence of Murray River Crayfish via behavioural interaction and predation studies.
- Investigate the reasons behind a correlation between percent cover of overhanging riparian vegetation and Murray River Crayfish abundance.
- Explore methods for detecting and monitoring early life history stages of Murray River Crayfish so that reliable sampling of larval and juvenile crayfish can allow for measurement of their habitat preferences and interaction with adult Murray River Crayfish.

4.1.4 Project 4 - EHN virus occurrence

The objective of Project 4 was to determine if the EHN virus is present in samples of the fish populations in and adjacent to the existing Cotter Reservoir.

The information in this section was summarised from Whittington (2008).

EHN virus sampling

Sampling was undertaken in 2008 by researchers from the University of Sydney Faculty of Veterinary Science. Fish samples were collected upstream and within the Cotter Reservoir (with some opportunistic sampling downstream of the Cotter Dam) by aquatic biologists from the University of Canberra.

The species sampled were selected based on documented susceptibility to the EHN virus, catchability and ease of procurement. Species sampled for the project included (Whittington 2008):

- Eastern Gambrusia; Inferred susceptibility to the EHN virus based on susceptibility (death) of related species Western Gambusia (Langdon 1989).
- Mountain Galaxias; Known susceptibility (death) to EHN virus (Langdon 1989).
- Rainbow Trout; Known natural hosts of EHN virus (Langdon 1989), however this species has shown relative resistance during previous outbreaks of the virus (Whittington et al. 1994; Whittington et al. 1999)
- Redfin Perch (collected downstream of the Cotter Dam): Known natural hosts of EHN virus (Langdon 1989).

It is impossible to prove that the entire fish population is free from the EHN virus unless every individual of every susceptible species in the water body is tested (Whittington 2008), however it is generally accepted that testing to detect a specific prevalence (the percentage of the sampled fish that would be infected if the EHN virus was present in the population) with a given confidence limit of 95 per cent (certainty that the survey will identify infected fish) is adequate. Actual numbers of populations sampled, sample sites and results of sampling are shown in Table 4.3 (based on Whittington 2008).

Table 4.3 EHN virus sampling results (Whittington 2008).

Species	Sample site	Number of individual fish	Number of positive test results	Estimated population size
Eastern Gambrusia	Above Cotter Dam	200	0	10,000
	Below Cotter Dam	200	0	10,000
Mountain Galaxias	Above Cotter Dam	59	0	1,000
Rainbow Trout	Above Cotter Dam	114	0	5,000
Redfin Perch	Below Cotter Dam	19	0	5,000

Findings
No sampled fish tested positive for the EHN virus.

Recommendations
Given the significant risk the EHN virus poses to Macquarie Perch and other threatened native species, it is recommended that the virus and its known carrier Redfin Perch continue to be excluded from the Cotter Reservoir.

In accordance with this recommendation, ACTEW and the BWA have developed mitigation and management measures to reduce the risk of introducing the EHN virus to the existing or enlarged Cotter Reservoirs as described in Section 3.3.2.

4.1.5 Project 5 - Research into the establishment of new populations of Macquarie Perch, Trout Cod and Two-spined Blackfish through translocation

To minimise the impact of the Enlarged Cotter Dam on threatened fish populations, the translocation of Macquarie Perch, Trout Cod and Two-spined Blackfish is being investigated.

The aims of Project 5 are to:

- Identify potential additional translocation sites for Macquarie Perch.
- Investigate the existing fish fauna at potential translocation sites.
- Continue the translocation program for Macquarie Perch to existing translocation sites.
- Monitor the success of translocation efforts for Macquarie Perch.
- Construct a preliminary population model for Macquarie Perch to guide translocation efforts.
- Construct a preliminary population model for Two-spined Blackfish to assess risk to the Cotter River population.
- Review the translocation requirements for Two-spined Blackfish and Trout Cod.
- Provide guidelines for future translocation and monitoring programs for threatened fish species in the Cotter River Catchment.

The information in this section is summarised from Lintermans (2010).

Identification and selection of potential long-term translocation sites
Macquarie Perch are currently translocated to three sites, one on the Cotter River, one on the Molonglo River and one on the Paddy's River. These sites were selected due to the following advantages:

- Located within the ACT and are therefore not subject to cross-border management or legislation.
- Two are relatively secure with little or no access to recreational fishing.

- Devoid of Redfin Perch.
- In unregulated or largely unregulated sections of river so there are no potential impacts from thermal pollution or alteration of natural flow patterns.

The Molonglo and Paddy's river sites also have the advantage of being outside the Cotter River Catchment, potentially minimising the risk of localised impacts on the Macquarie Perch population in the Cotter River.

To supplement these existing sites, potential additional long-term translocation sites have been identified, including:

- Paddy's River.
- Bendora Reservoir.
- Queanbeyan River.

Following further investigation, sites will be scored and selected based on habitat quality, recreational fishing access, potential upstream impacts, composition of existing fish fauna and the presence or abundance of alien species.

Investigation of the fish fauna and habitat conditions at potential translocation sites

To ensure there are no adverse impacts on remnant populations of Macquarie Perch, or a risk of exposing translocated Macquarie Perch to Redfin Perch (and potentially the EHN virus), further investigation of the existing fauna and habitat conditions at potential translocation sites on the Paddy's and Queanbeyan River is required.

Translocation of Macquarie Perch from Cotter Reservoir

As the only viable population in the ACT, Macquarie Perch for the translocation program are being sourced from the Cotter Reservoir. To minimise potential harm to the donor population, the program is targeting young-of-year (75 to 100 mm TL) and juvenile fish (101 to 150 mm TL) as an alternative to removing potentially reproducing adults. Due to predation and other environmental pressures large numbers of Macquarie Perch do not survive their first one to two years of life and therefore removing a proportion of young-of-year and juvenile fish is not expected to impact significantly on overall Cotter Reservoir population numbers.

During 2009 a total of 386 Macquarie Perch were captured, of which 152 were selected for translocation (based on size) and translocated to the three existing release sites.

Monitoring of translocations

A translocation program cannot be considered successful until the translocated individuals reproduce and the resultant offspring successfully recruit to the adult population and breed. Monitoring will be conducted to detect the survival (or otherwise) of translocated individuals at release sites, the successful breeding from the translocated individuals and whether regular recruitment is occurring in translocated populations. Accordingly, the monitoring program will need to be suitably long-term and may be required for at least 10 to 20 years following translocation. Monitoring on the Cotter River translocation site in 2009 and 2010 captured small numbers of Macquarie Perch, indicating that fish had survived the translocation process. Monitoring at the remaining two sites will occur in 2011.

Population modelling for Macquarie Perch and Two-spined Blackfish

The translocation program aims to maximise the chance of re-establishing a self sustaining population. This requires appropriate decisions to be made regarding the number of fish to translocate, the timeframe over which stocking should occur and the age of the individuals which should be translocated. The decision making process can be assisted by the development and application of a population model to provide information on species demographics and other relevant ecological information to provide results relevant to the conservation of the species, including the risk of extinction, the likelihood of population persistence, expected persistence time and projected range of population abundances.

Preliminary models are being prepared for both Macquarie Perch and Two-spined Blackfish. Ongoing investigations have provided an early indication that there is no need for translocation of Trout Cod and Two-spined Blackfish.

This project is continuing with additional translocations proposed in 2010 and 2011.

4.1.6 Project 6 - Management program for alien fish species

It is anticipated that the abundance of alien salmonid species will increase in the enlarged Cotter Reservoir as a result of increased food resources (due to newly flooded habitat), an increased thermal refuge (due to deeper water) and improved water quality (due to destratification of the water column). Consequently, increases in trout abundance may require active management to prevent adverse impacts on threatened native fish.

Project 6 will investigate options for the design and siting of alien fish trap on the Cotter River upstream of the existing Cotter Reservoir to allow monitoring of alien fish as they make their upstream spawning migration. The fish trap will be installed prior to the completion of construction, with the project expected to be completed by the end of 2011.

The monitoring component of this project has been incorporated into Project 9 - Enlarged Cotter Dam fish monitoring (refer to Section 4.1.9).

4.1.7 Project 7 - Food sources for Macquarie Perch and drawdown effects

The enlargement of the Cotter Reservoir and its subsequent operation will lead to a variety of changes to the ecosystems that currently provide food for the resident fish populations.

The objectives of Project 7 are to assess:

- The main food of Macquarie Perch and the other resident fish species in the existing Cotter Reservoir.
- The habitat features that support macroinvertebrate production as food items.
- The availability of food items and the effects of drawdown based on comparisons with other reservoirs with drawdown characteristics (Corin, Googong and Cataract Reservoirs).
- Whether sufficient food will be available in the long term to support the fish population and consider if competition for food within the reservoir is likely to limit the Macquarie Perch population.
- Whether habitats may be provided, or enhanced, to promote the production of fish food.

The information in this section was summarised from Bourke & Norris (2009).

Food sources of Macquarie Perch

Assessment of the main food sources of two self sustaining populations of Macquarie Perch was conducted in Cotter (two sites) and Cataract reservoirs (one site). Cataract Reservoir was used as a reference site to compare food sources in a reservoir characterised by frequent drawdown. Adult and sub-adult Macquarie Perch were collected with assessment of diet completed non-destructively using a catheter to flush stomach contents through the mouth of the fish.

Stomach contents were identified under a stereo dissecting microscope. The number of items and a visual assessment of the percentage volume of each dietary category were recorded for each stomach sampled (Mark Lintermans personal communication, 2010).

A range of methods of dietary analysis (percent occurrence, volumetric abundance, numerical abundance, Index of Relative Importance) were used to achieve a more complete understanding of dietary composition (Hyslop 1980; Wootton 1990).

In addition to providing a holistic view of importance of different dietary items, using a range of methods helps to overcome the limitations of particular methods if used in isolation.

A total of 22 Macquarie Perch were collected from the Cotter Reservoir and 44 Macquarie Perch were collected from the Cataract Reservoir. It is planned to collect an additional 20 fish from the Cotter Reservoir during autumn 2010.

Habitat features of macroinvertebrates and the effects of drawdown on food availability

Habitat structure plays a significant role in influencing distribution and assemblage of macroinvertebrates (the main food source of Macquarie Perch), with increased taxa richness and density typically found with increasing habitat complexity (Strayer et al. 2003; Taniguchi & Tokeshi 2004; Freitas et al. 2005; Dallas & Day 2007). To determine the habitat features necessary to support macroinvertebrates samples of macroinvertebrates were collected from the Cotter, Cataract, Corin and Googong Reservoirs.

Surveys were conducted at available habitat types, including:

- Emergent and submergent macrophytes, fallen timber, rocky and bare shores in the Cotter Reservoir.
- Rocky and bare shores in the Cataract, Corin and Googong reservoirs.

Following collection, each sample was analysed, then preserved and identified (to taxonomic order) in the laboratory.

This method was repeated in the Cotter Reservoir seven days after original sampling to assess the effect of an intentional two metre drawdown on macroinvertebrate abundance and biomass. All habitat types described above were re-sampled after the drawdown, with the exception of emergent macrophytes which were no longer within the extent of the reservoir (due to lower water level).

To allow comparison of habitat types, the means for macroinvertebrate abundance and biomass were calculated based on the results from both Cotter and Cataract Reservoirs and all replicate sites for each habitat type.

Measurements of water quality (temperature, turbidity, dissolved oxygen, conductivity and pH) were also taken and satellite imagery was used to estimate the percentage of each of the available habitat types relative to total shoreline length of the Cotter Reservoir.

Preliminary findings

The following is a summary of the preliminary findings documented in Bourke & Norris (2009).

Composition of the diet of Macquarie Perch

Analysis of Macquarie Perch sampled from the Cotter Reservoir found that the majority of their diet was comprised of Cladocera (small crustaceans commonly referred to as water fleas found in areas of open water), followed by Decapoda (crustaceans including freshwater shrimp *Paratya australiensis* and freshwater prawns *Macrobrachium australiense*). The dominance of Cladocera from the Cotter Reservoir fish was an unexpected result, given that adult Macquarie Perch have a tendency to prey on larger food items (Chao & Musick 1977; Hunter 1981; Sanchez-Velasco 1998).

Major dietary items of Macquarie Perch in the Cataract Reservoir were Diptera (insects of which the primary dietary item was Chironomidae (midges)), followed by Ephemeroptera (mayflies) and Trichoptera (caddisflies). Miscellaneous items for Cataract Reservoir contained Coleoptera (beetles) and unidentifiable insects.

Availability of macroinvertebrates

Cotter Reservoir had the highest total mean abundance and biomass for all storages, primarily as a result of the dominance of Decapoda which were significantly greater in abundance than any other macroinvertebrate. Decapoda also had a significantly greater biomass than any other macroinvertebrate. In the Cotter Reservoir, the abundance and biomass of macroinvertebrates was greatest in rocky and bare shore habitats.

Decapoda also represented the macroinvertebrate that were most abundant and had the highest biomass in Googong Reservoir. Coleoptera had the highest abundance and biomass at Cataract Reservoir, while

Hemiptera (true bugs) had the highest abundance and Odonata (dragonflies) had the highest biomass at Corin Dam. This was consistent across both rocky shore and bare shore habitats.

Food is less abundant in the Cataract Reservoir, which is believed to be the cause of stunted growth in adult Macquarie Perch in this reservoir.

Habitat of macroinvertebrates

Water quality for all dams recorded similar results with the only notable differences being high turbidity levels at Cotter Dam, and higher conductivity levels at Googong and Cataract Dams compared to the other dams sampled.

Satellite imagery revealed a total loss of emergent macrophyte habitat area as a result of the 2 m drawdown with a corresponding increase in percentage of bare shore habitat available.

The greatest Decapoda abundance was recorded in the submerged macrophyte habitat in the Cotter Reservoir. No Decapoda were found in Cataract or Corin Reservoirs despite the presence of suitable habitat characteristics. Hemiptera abundance was greatest on rocky shores.

The abundance of the remaining macroinvertebrate orders was significantly greater in the emergent macrophyte habitat.

The habitat that supported the greatest biomass of Decapoda was the submerged macrophytes in the Cotter Reservoir. Across all sites (Cotter and Cataract Reservoirs combined) woody debris had least macroinvertebrate biomass.

Effects of drawdown

While there were noticeable differences in the distribution of macroinvertebrates across the five habitat types, the study indicated that following drawdown there remains suitable alternate foraging habitat and macroinvertebrate availability in the Cotter Reservoir. It is possible however that this result may be due to the short duration between sampling dates, as an accumulation of displaced macroinvertebrates in remaining habitat may have potentially skewed the results. Decapoda in particular are highly mobile (Gooderham & Tsyrlin 2005) and may have moved with the receding water from the drying emergent macrophyte habitat into the remaining alternative habitats. This would have the impact of, at least in the shorter term, increasing local invertebrate density in such alternative habitats (Dewson et al. 2007). It may take up to several months for changes to biomass and community composition following a drawdown to become evident (Humphries 1996).

Recommendations

Recommendations to be provided on project completion, expected early to mid 2011.

4.1.8 Project 8 – Investigation of techniques for mapping instream barriers

The Macquarie Perch completes an annual migration in order to find suitable riverine spawning habitat and is therefore susceptible to hindrance by instream barriers.

Project 8 is intended to complement research undertaken as part of Project 2 - Predicted passage of native and alien freshwater fish based on swimming speed performance. Project 8 will:

- Test whether digital models and geographic information systems (GIS) can be used to identify natural physical barriers to fish movement.
- Determine the best resolution of the digital models to identify the natural and anthropogenic barriers to fish dispersal.

Digital modelling of barriers

To predict possible barriers to fish movement, a digital model of the Cotter River Catchment was created using existing data for the terrain variables of slope, profile curvature, plan curvature, tangential curvature, catchment area, relative steepness, geology, lithological boundaries and faulting.

The resultant model was then analysed using different statistical methodologies to determine the probability that the model could successfully predict the occurrence of barriers and reveal any relationship between the occurrence of barriers and the surrounding site characteristics.

The effect of different spatial resolutions (one metre, five metre, 10 metre and 20 metre) on the efficacy of the model was also examined,

Field survey of barrier and non-barrier sites

To create a reference for the accuracy and performance of the digital model in identifying instream barriers, a field survey of barrier and non-barrier sites was conducted. The sites examined were located in the Cotter River and minor tributaries, including Condor Creek, Lee's Creek and Pierce's Creek, between Bendora Dam and the upstream extent of the existing Cotter Reservoir.

The sites studied were chosen to sample a range of different geological types and slope classes, the two major factors which influence the location of instream barriers. At each site measurements of channel geomorphology and flow were taken to gain an understanding of the relationship between the occurrence of barriers and local and catchment scale landscape characteristics.

Geomorphologic measurements included assessment of valley form, channel form, bedform and any barriers present at the survey site.

Flow measurements were taken using a flow meter at two main field sites under a range of flow regimes including baseflow, flow after a large rain event, flow following environmental releases from Bendora Reservoir.

Preliminary findings

Results of this project are expected to be published in early 2011, however preliminary findings are provided below (S. Hugh, personal communications, July 2010).

- A one metre resolution produced the most efficient model.
- Modelling was able to indentify 88 per cent of the barriers identified in the field.
- Relative steepness was found to be a key factor in the identification of barriers.
- The predictions from the model provide a means for prioritising areas containing possible physical barriers in the Cotter River. These predictions are intended to complement traditional field based methods of barrier identification.

Recommendations

Recommendations to be provided on project completion, early 2011.

4.1.9 Project 9 - Enlarged Cotter Dam fish monitoring

The Enlarged Cotter Dam fish monitoring program has been developed to meet the following aims:

- Develop and implement a comprehensive field sampling program to assess the potential impacts of the Enlarged Cotter Dam on aquatic vertebrates (primarily fish, but also including piscivorous birds) in the Cotter River Catchment (the existing and enlarged Cotter Reservoirs and the Cotter River below Bendora Dam) answering the following specific questions:
  - Will there be significant changes in the abundance of Macquarie Perch in the Enlarged Cotter Dam (Young-of-Year, juveniles and adults)?
  - Will there be a significant change in annual recruitment in the Macquarie Perch population in the Enlarged Cotter Dam relative to a reference site (Kissop's Flat)?
  - Will there be significant changes in the abundance, distribution and size composition of adult trout in the Enlarged Cotter Dam?
  - What are the levels of predation on Macquarie Perch larvae and juveniles by trout in the Enlarged Cotter Dam and river upstream?

  - Will there be significant changes in the abundance, distribution and species composition of piscivorous birds in the Enlarged Cotter Dam?
  - Will there be significant changes in the abundance and size composition of trout in the Cotter River upstream of the Enlarged Cotter Dam?
  - Will there be a significant increase in the levels of predation on Two-spined Blackfish by trout in the Cotter River upstream of the Enlarged Cotter Dam?
  - Will there be significant changes in the abundance and distribution of the Macquarie Perch population in the Cotter River above and below Vanity's Crossing?
  - Will macrophyte beds re-establish in the Enlarged Cotter Dam?
  - Will translocated Macquarie Perch populations survive the initial translocation procedure and reproduce?
  - Will Two-spined Blackfish establish a reproducing population in the Enlarged Cotter Dam and will they persist in the newly inundated section of the river?
  - Will there be significant changes in the abundance and distribution of Goldfish and Oriental Weatherloach in the Enlarged Cotter Dam?
- Implement monitoring of the proposed alien fish trapping facility on the Cotter River upstream of the Enlarged Cotter Dam (once the trap is constructed).
- Develop specific thresholds for management intervention relevant to the specific questions listed above.
- Collect data to satisfy the reporting requirements under DEWHA conditions of approval for the Enlarged Cotter Dam (refer to Section 5.25.2).

Monitoring will be conducted within the Cotter River Catchment (refer to Figure 4.4) and at a number of reference sites in other river systems (refer to Figure 4.3). Monitoring will encompass baseline, filling and operational phases for the Enlarged Cotter Dam.

Annual reviews of data collected will form an essential component of the monitoring program, with more formal reviews of the program conducted every 3-5 years (or at agreed logical break points). Such reviews should be conducted by external peers to ensure robust interpretation of results.

The information in this section was summarised from Lintermans & Broadhurst (2010).

Figure 4.3 Monitoring sites outside the Cotter River Catchment (Lintermans & Broadhurst 2010).

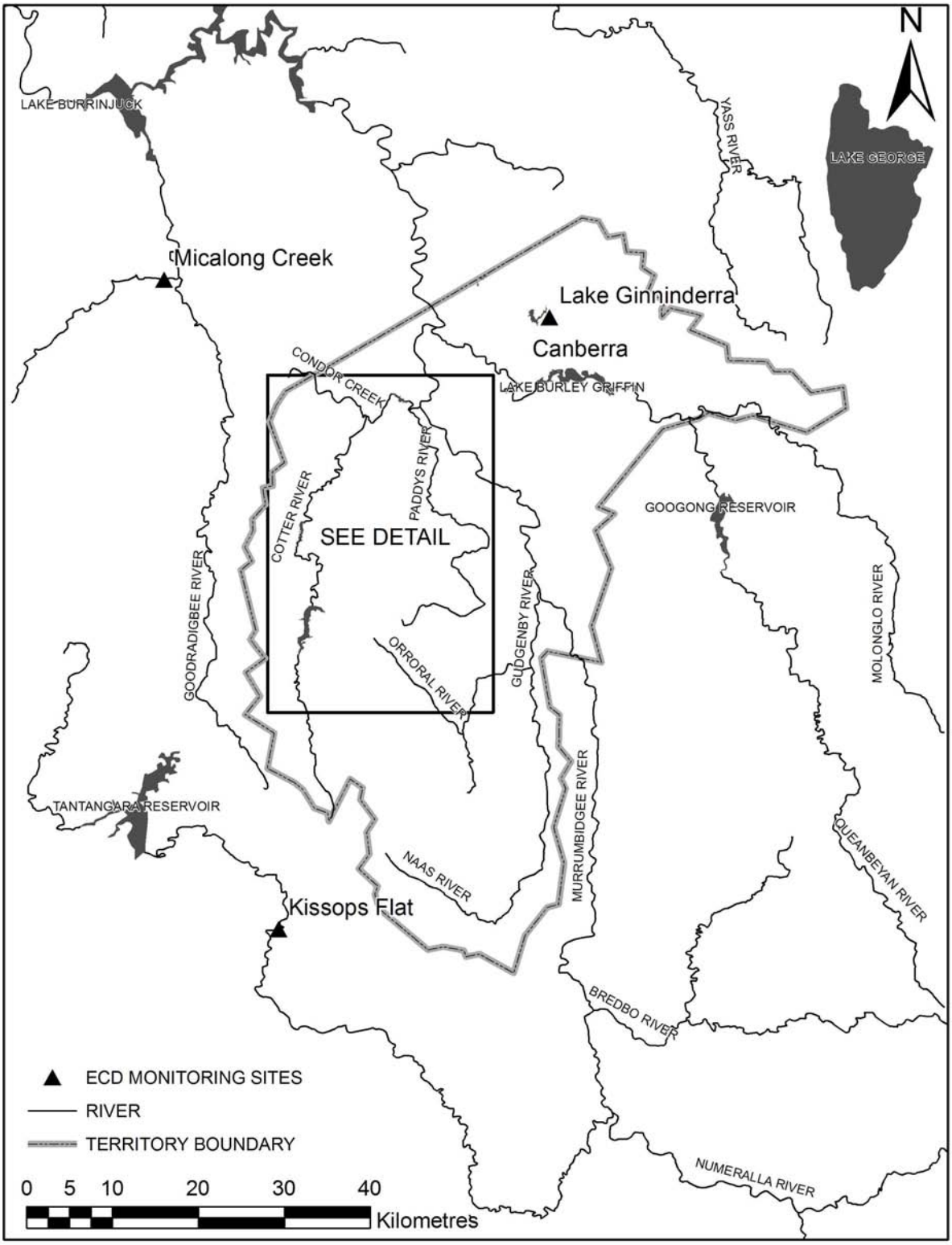
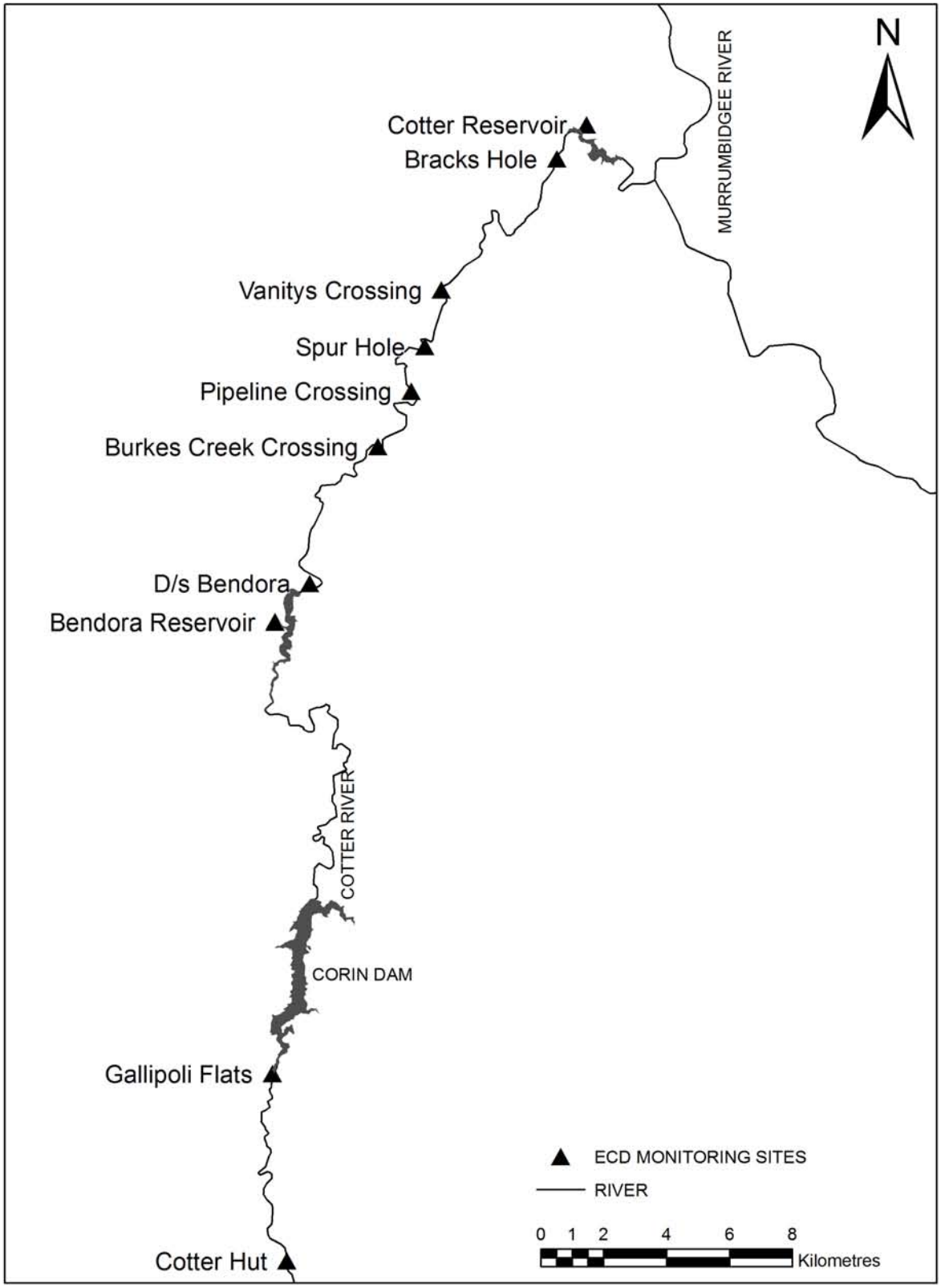


Figure 4.4 Location of monitoring sites in the Cotter River Catchment (Lintermans & Broadhurst 2010).



Monitoring has been designed so that sampling methodologies will answer multiple questions, minimising both sampling effort and the impacts on threatened native species.

It is expected that the monitoring program will run for 10-20 years (depending on results) and will encompass three distinct phases:

- Phase One: Establishing a baseline (~3 years plus existing baseline data where available).
- Phase Two: Filling of the Enlarged Cotter Dam (2-6 years) (essentially a watching brief to detect any potential impacts at the earliest possible time).
- Phase Three: Ongoing operational monitoring following filling of the enlarged Cotter Reservoir.

Monitoring of proposed alien fish trap

In addition to the 12 monitoring questions detailed above, numbers of alien fish (notably adult trout) will also be monitored at a purpose built trout trap to be constructed on the Cotter River between the upstream limit of the enlarged Cotter Reservoir and Vanity's Crossing (location to be determined following further geotechnical investigations to identify a suitable area of rock to anchor the trap). The trap will be in operation only during the trout spawning season (May to August) to avoid the Macquarie Perch spawning season (October to December).

The trap is likely to be comprised of removable grills and funnels which can be set to allow fish passage outside of the trout spawning migration. Final design is still being investigated.

Techniques for monitoring and fish clearing will be based on methodologies established for a fish trap installed on the Murrumbidgee River at Casuarina Sands which was operational between 1990 and 2000. Monitoring of the fish trap will target adult trout approximately 250 to 600 mm TL. During operation, fish will regularly (once or twice weekly) be cleared from the trap to release any native species. Treatment of trout following capture will be determined by ACT Government through their strategy for the future management of the Cotter River between the Enlarged Cotter Dam and Bendora Dam. If the area is to be retained as a trout fishery area, any trout captured in the fish trap may be monitored (without removal) or conversely trout may be harvested from the trap (with varying levels of intensity) should the intention be to restore this section of river for native fish and create an exclusion zone prohibiting recreational fishing.

Thresholds for management intervention

In accordance with conditions of approval for the Enlarged Cotter Dam, implementation of the monitoring program will include the development of formal thresholds to allow remedial action should monitoring demonstrate that populations of threatened native species are declining. It is anticipated that initial thresholds will be established in the first year of baseline monitoring, with ongoing refinement expected with the growing body of knowledge on threatened native aquatic species and threats to their survival in the Cotter River Catchment.

The defining of such indicator values will allow non-compliance to be readily evaluated.

These thresholds will initially be based on existing information and the longstanding experience of ACTEW's Technical Advisor on fish management (Mark Lintermans), with further refinement based on review of data collected. As fish abundance and recruitment varies between years, the thresholds are likely to encompass both spatial and temporal factors, including defined fish abundance as well as the number of years that abundance must be recorded to trigger remedial action.

4.1.10 Monitoring for the Enlarged Cotter Dam

This table summarises the monitoring locations for each of the Fish Management Program projects.

Table 4.4 Monitoring locations for Fish Management Program projects

Survey Sites	Project 1 : Constructed Homes	Project 2: Swimming capacity of native fish	Project 3: Murray River Crayfish ecology	Project 4: EHN Virus	Project 5: Translocation	Project 6: Alien fish management	Project 7 : Food sources	Project 9 : Enlarged Cotter Dam Monitoring
Cotter Reservoir	X			X	X	X	X	X
Below Cotter Reservior				X				
Brack's Hole						X		X
Vanity's Crossing		X (flows)				X		X
Spur Hole						X		X
Pipeline Rd Crossing		X (flows)				X		X
Burkes Creek Crossing						X		X
D/S Bendora						X		X
Bendora Reservoir	X					X		X
Corin Reservoir						X	X	X
Gallipoli Flats					X	X		X
Cotter Flats						X		X
Cotter Campground			X					
Casuarina Sands			X					

Survey Sites	Project 1 : Constructed Homes	Project 2: Swimming capacity of native fish	Project 3: Murray River Crayfish ecology	Project 4: EHN Virus	Project 5: Translocation	Project 6: Alien fish management	Project 7 : Food sources	Project 9 : Enlarged Cotter Dam Monitoring
Jews Corner			X					
Kambah Pool			X					
Allens Ck			X					
Pine Island			X					
Point Hut Xing			X					
Kissops Flat						X		X
Micalong Creek (Goodradigbee R)								X
Lake Ginninderra						X		X
Trout trap (2012 only)						X		X
Cataract Dam							X	
Googong Dam							X	
Blue Tiles (Molonglo R)					X			
Murrays Corner (Paddys R)					X			
Uriarra Sandwash			X					
Uriarra Crossing			X					

4.2 Associated projects and supplementary information sources

There are a range of associated projects and supplementary information sources which complement the works being undertaken as part of the Fish Management Program research projects (refer to Section 4.1).

4.2.1 Natural supplementary habitat investigations

In order to provide a holistic overview of shelter habitat opportunities for threatened fish species, the BWA Fish Management Team has been working with the University of Canberra to identify the type of natural habitat that might be used by fish as supplementary shelter habitat, with rock reefs forming the main habitat type.

Natural in situ habitat investigations

Investigation of natural in situ habitat involved identifying rocky outcrops and vegetation which could provide suitable fish habitat without modification.

Rocky outcrops

During spring of 2009 the ACTEW and the BWA Fish Management Team surveyed the Enlarged Cotter Dam site for all available rocky outcrops within the inundation zone of the Enlarged Cotter Dam. Photographs were taken of each site and the location was recorded on a digital map showing FSL using Global Positioning System (GPS) technology. An approximate FSL was overlaid on all photographs to show each location relative to FSL and allow for calculation of the approximate extent of each outcrop. Overlaid photographs were then presented at a workshop held in October 2009 between ACTEW, the University of Canberra and the BWA.

Researchers from the University of Canberra identified those outcrops which they thought would provide suitable shelter habitat for Macquarie Perch. The most important considerations for suitable habitat included size of rocks, complexity and the extent and depth of interstitial spaces between rocks. A significant area of good shelter habitat was located at the confluence of Pierces Creek and some limited sections of the Cotter River (upstream of the existing Cotter Reservoir), however other areas of rocky outcrops provided only poor to fair shelter habitat.

Vegetation

Following the 2003 bushfires, a large amount of timber and woody debris collected around the shore of the existing Cotter Reservoir. This timber has been shown to be an important source of shelter habitat for adult Macquarie Perch (Katie Ryan unpublished data 2009). In the enlarged Cotter Reservoir it is highly likely that structural woody habitat will continue to be used by Macquarie Perch and may be particularly important during the filling phase when other forms of habitat are unavailable. This particularly includes the constructed rock reefs which will be located in the top 5 to 28 metres of FSL.

To determine the extent of supplementary shelter habitat that could be provided by existing native vegetation, a desktop review of information and mapping of vegetation has been undertaken by Biosis. Biosis utilised information prepared for the Enlarged Cotter Dam EIS (ACTEW 2009a) along with other sources including (Smith &Troy 2010):

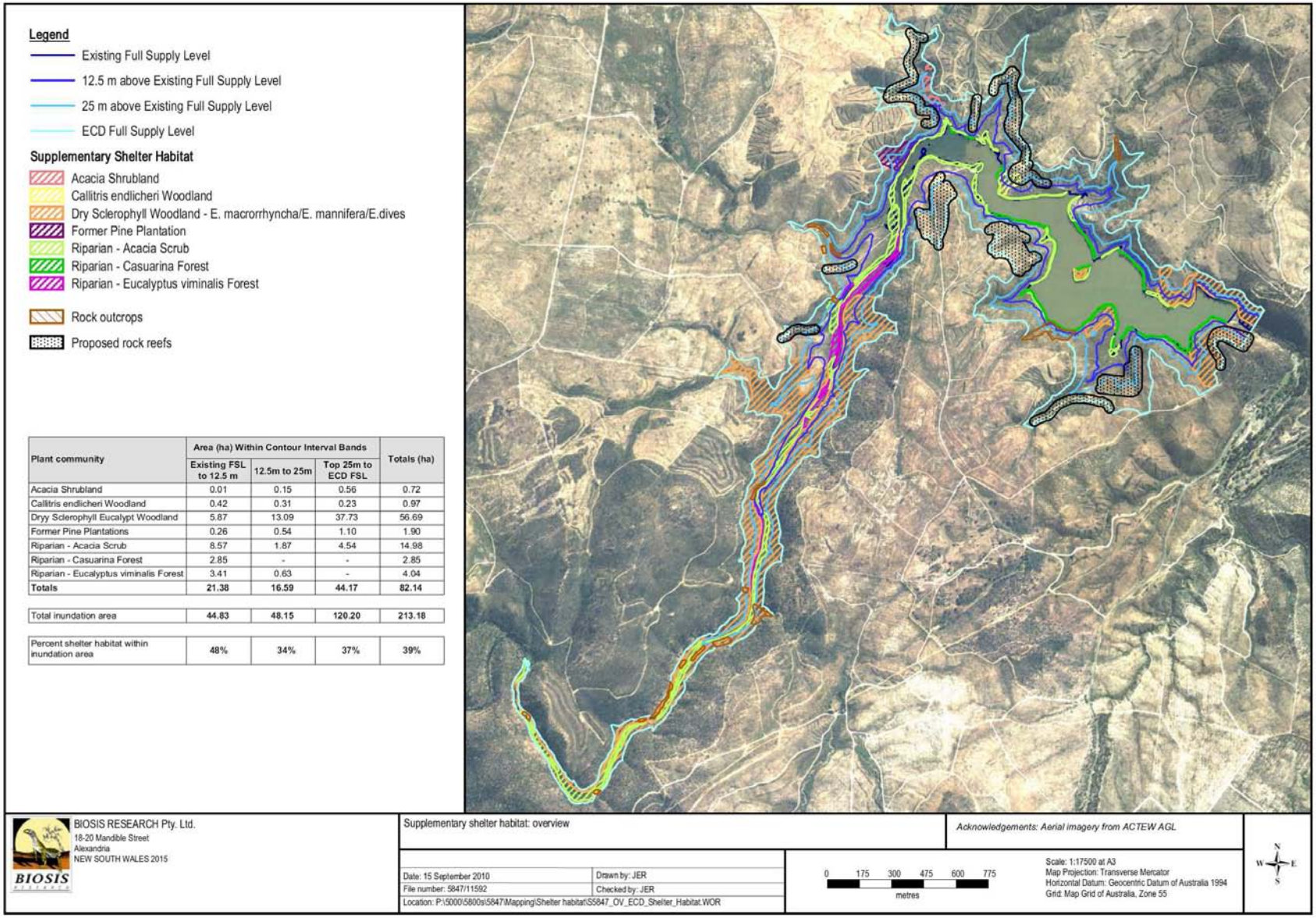
- Vegetation mapping based on field survey and aerial photo interpretation (Biosis 2009).
- Vegetation descriptions including vegetation types and species composition (derived from field data sheets completed during surveys) (Biosis 2009).
- Visual estimates of canopy cover and tree heights within the different vegetation types (derived from field data sheets completed during field surveys) (Biosis 2009).
- Mapping of standing and fallen timber (Ecowise Environmental 2009).
- Extensive photographic records of the inundation zone gathered during the surveys by both Biosis and the BWA Fish Management Team.

Existing vegetation mapping of the study area and contour data was used to calculate the area of potential supplementary habitat provided by different vegetation types within specific contour bands within the inundation zone, notably:

- Existing FSL to 12 m contour
- 12 m contour to 25 m contour
- Top 25 m to Enlarged Cotter Dam FSL.

The results of this vegetation mapping are provided in Figure 4.5.

Figure 4.5 Overview of supplementary shelter habitat.



Plant community	Area (ha) Within Contour Interval Bands			Totals (ha)
	Existing FSL to 12.5 m	12.5m to 25m	Top 25m to ECD FSL	
Acacia Shrubland	0.01	0.15	0.56	0.72
Callitris endlicheri Woodland	0.42	0.31	0.23	0.97
Dryy Sclerophyll Eucalypt Woodland	5.87	13.09	37.73	56.69
Former Pine Plantations	0.26	0.54	1.10	1.90
Riparian - Acacia Scrub	8.57	1.87	4.54	14.98
Riparian - Casuarina Forest	2.85	-	-	2.85
Riparian - Eucalyptus viminalis Forest	3.41	0.63	-	4.04
Totals	**21.38**	**16.59**	**44.17**	**82.14**
Total inundation area	**44.83**	**48.15**	**120.20**	**213.18**
Percent shelter habitat within inundation area	**48%**	**34%**	**37%**	**39%**

4.2.2 Cotter River Catchment monitoring

Monitoring of a broad range of environmental characteristics is currently being undertaken in the Cotter River Catchment on an ongoing basis. This ongoing monitoring has provided a basis for the establishment of baselines from which change can be measured and continues to provide information which complements and informs works being undertaken as part of the Fish Management Program. The environmental characteristics monitored include:

- Rainfall and river flow.
- Water quality monitoring.
- Fish population surveys and monitoring.
- River health (macroinvertebrate/periphyton).
- Climate change observations and projections.

Rainfall and river flow

Rainfall and river flow monitoring in the Cotter River Catchment is undertaken for ACTEW by Ecowise and ActewAGL at a number of sites, including:

- Upstream of Corin Reservoir (to provide information on flows into Corin Reservoir). This stretch of the Cotter River is unregulated.
- Between Corin and Bendora Reservoirs (to provide information on flows into Bendora Reservoir). This stretch of the Cotter River receives natural runoff, as well as releases from Corin Reservoir.
- Between Bendora and Cotter Reservoirs (to provide information on flows into Cotter Reservoir). This stretch of the Cotter River receives natural runoff, as well as releases from Bendora Reservoir.

Additional monitoring is conducted within Corin, Bendora and Cotter reservoirs to measure water levels. Results are used to calculate storage volumes and to calibrate rainfall and runoff models.

It is expected that rainfall and river flow monitoring will continue in the future.

Water quality monitoring

Water quality monitoring in the Cotter River Catchment is undertaken for ACTEW by Ecowise at sites within each of the storage reservoirs (Corin, Bendora and Cotter) and the Cotter River (and its tributaries).

Sites within the reservoirs are sampled at three metre depth intervals either once every two weeks (if the reservoir is being used for water supply), or once every four weeks.

Water quality characteristics include:

- Physical and chemical parameters such as temperature, turbidity, dissolved oxygen and pH.
- Metals (particularly iron and manganese).
- Nutrients such as nitrogen and phosphorus.
- Algae.
- Bacteria.
- Pesticides.

Water quality information has been collected on the Cotter River Catchment for over 50 years and it is expected that water quality monitoring will continue in the future.

Additional water quality monitoring is undertaken by Territory and Municipal Services (TAMS) for a range of sites in the ACT. These include nutrients, suspended solids, turbidity, faecal coliforms, conductivity, pH, dissolved oxygen, chlorophyll-a, algae and macroinvertebrates (ACT Government 2007b & 2008). It is expected that the TAMS water quality monitoring will also continue in the future.

Fish population monitoring

Bi-annual monitoring of threatened fish in the Cotter River Catchment is conducted by the Research and Planning unit of TAMS, on behalf of ACTEW. The monitoring assists in meeting the requirements of ACTEW's Licence To Take Water (ACT Government 2008) and has been undertaken since 2001. The aim of monitoring is to monitor the abundance and breeding of Macquarie Perch and other threatened species in the Cotter Reservoir and Cotter River (ACT Government 2009b) in order to inform environmental flow decisions and assist in ongoing management of these species.

Monitoring uses a number of different sampling techniques to target a variety of age and size classes, including electrofishing, fyke nets, gill nets and more recently snorkelling.

Monitoring is conducted in the upper Cotter River, above Bendora Dam and the lower Cotter River between Bendora and Cotter Dams, including Cotter and Bendora Reservoirs, and targets Macquarie Perch, Trout Cod, Two-spined Blackfish (ACT Government 2009b). Additional sites used as reference sites are located in the Queanbeyan River, Upper Murrumbidgee River above Burrinjuck Dam and other rivers and creeks of the region.

Fish population monitoring is expected to continue in the future and will be complemented by the works undertaken as part of Project 9 – Enlarged Cotter Dam fish monitoring (refer to Section 4.1.9).

River Health

Monitoring of river health is undertaken by the University of Canberra for ACTEW. The monitoring uses the macroinvertebrate data to determine an AUSRIVAS river health assessment index. Periphyton and sediment data is also collected. The data is compared to other sites in the ACT, with autumn and spring reports delivered annually (ACT Government 2007b & 2008). This is a requirement under ACTEW's Licence To Take Water and is expected to continue in the future.

Climate change observation and projections

Climate monitoring in the Cotter River Catchment (and surrounding area) is undertaken by the Bureau of Meteorology. There are a number of rainfall monitoring sites in the catchment (which are also used by ACTEW and ActewAGL to estimate runoff and to calibrate runoff models).

It is expected that this climate monitoring will continue in the future.

5 Commitments and conditions

5.1 ACTPLA/EIS conditions/commitments

The following tables summarise the conditions stipulated by ACTPLA in their approval of the Enlarged Cotter Dam project and the commitments made the *Enlargement of the Cotter Reservoir and associated works: Environmental Impact Statement* (ACTEW 2009a).

The actions to be undertaken to meet each condition or commitment are also documented.

Table 5.1 ACTPLA conditions.

ACTPLA Approval Conditions	Approval Condition	ACTEW action to meet condition	Delivery
Map of areas of Environomental Significance **Condition B15**	A map that identifies areas of environmental significance, including areas identified for rehabilitation, offsets and for special consideration such as artificial fish habitat and research areas and endorsed by PCL, TAMS shall be submitted to and approved by ACTPLA prior to the commencement of works.	A map endorsed by PCL, TAMS showing constructed shelter habitat and research areas was submitted to ACTPLA in line with conditions of approval.	August 2010.
Fish Management Plan, Aquatic Studies and results **Condition C2**	A Fish Management Plan and other aquatic ecology studies and their results and recommendations as required shall be submitted to and endorsed by PCL, TAMS and DEWHA prior to the commencement of the dam.	Version 2 of the Fish Management Plan has been submitted to relevant stakeholders in line with conditions approval. Consultation with PCL, TAMS and SEWPaC (formerly DEWHA) will be primarily through the Fish Management Program Steering Committee.	Version Two of the Fish Management Plan was submitted to and endorsed by relevant stakeholders in May 2010. Consultation with the Fish Management Program Steering Committee will be ongoing
Fish Management Plan, Aquatic Studies and results **Condition C3**	That the results of condition C2. Fish Management Plan, Aquatic studies and results are implemented as required to the satisfaction of PCL, TAMS and DEWHA.	This condition will be met through the Fish Management Program Steering Committee.	Consultation with the Fish Management Program Steering Committee will be ongoing

ACTPLA Approval Conditions	Approval Condition	ACTEW action to meet condition	Delivery
Fish Management	The construction of the Enlarged Cotter Dam poses a significant risk to a number of Macquarie Perch in the existing stilling pond below the current dam wall. These fish have come through from the reservoir and need to be translocated before construction works begin. Due to the risk of EHN virus in fish from below Cotter dam wall, these fish will not be relocated back into the reservoir but will most likely be released into the Murrumbidgee River. It is required that any mitigation measures and / or recommendations identified in the Fish Management Plan and associated aquatic ecology studies and their results are implemented as required after endorsement by PCL, TAMS.	The translocation of Macquarie Perch from the stilling basin has been undertaken (refer to Section 3.3.3). Agency endorsement of mitigation and management measures and recommendations will be through the Fish Management Program Steering Committee.	Translocation was conducted in January 2010. Consultation with the Fish Management Program Steering Committee will be ongoing
Mitigation and Management Plans	Areas of Environmental Significance including areas identified for rehabilitation, offsets and for special consideration such as artificial fish habitat and research areas are required to be mapped and the result produced be submitted to and endorsed by PCL, TAMS.	A map showing constructed shelter habitat and research areas was submitted to and endorsed by PCL, TAMS in line with conditions of approval.	The map was submitted in June 2010.

Table 5.2 EIS commitments.

Impact	Commitment	ACTEW action to meet commitment	Delivery
Prevent upstream migration of introduced fish species	Fish passage is intentionally not provided in the Enlarged Cotter Dam to prevent the upstream migration of introduced fish species.	No further action required. This commitment was met through design and details included in the DA for Enlarged Cotter Dam.	No further action.
Develop Fish Management Plans that will minimise the impact on threatened species	Current investigations will provide the information required to design and implement suitable mitigation measures that will minimise the impacts of the Enlarged Cotter Dam on threatened fish species (Fish Management Plan) including Macquarie Perch and Two-spined Blackfish.	Version Two of the Fish Management Plan was submitted in line with conditions of approval.	Version Two of the Fish Management Plan was submitted to and endorsed by relevant stakeholders in May 2010.
	Prepare Versions Two, Three and Four of the Fish Management Plan by 2009 (prior to construction), 2011 (at completion of construction) and 2013 (two years after completion of construction).	Version Two of the Fish Management Plan was submitted in line with conditions of approval. Subsequent versions (three and four) of the Fish Management Plan will be prepared in accordance with conditions of approval.	Version Two of the Fish Management Plan was submitted to and endorsed by relevant stakeholders in May 2010. Versions three and four will be submitted in early 2012 and early 2014 respectively.
	ACTEW will adopt the recommendations that stem from the nine projects identified in the Fish Management Plan.	Recommendations relating to ACTEW's activities will be adopted.	Adoption of recommendations will be undertaken in ongoing consultation with the Fish Management Program Steering Committee.
	A series of monitoring projects will be conducted as part of the Fish Management Plan.	Project 9 – Enlarged Cotter Dam fish monitoring, will be conducted as part of the Fish Management Program.	Monitoring will be ongoing.

Impact	Commitment	ACTEW action to meet commitment	Delivery
Protect and enhance Macquarie Perch spawning habitat	Projects 2, 8 and 9 of the Fish Management Plan will be implemented to identify and address issues surrounding the Macquarie Perch spawning habitat.	Project 2 - Predicted passage of native and alien freshwater fish based on swimming speed performance has been completed. (refer to Section 4.1.2) Project 8 – Investigation of techniques for mapping of instream barriers has been implemented (refer to Section 4.1.8**.** The scope for Project 9 – Enlarged Cotter Dam fish monitoring is being finalised (refer to Section 4.1.9).	Project 2 was completed in July 2009. Project 8 will be completed in early 2011. The monitoring conducted as part of Project 9 will be ongoing.
	ACTEW will adopt the recommendations of projects 2, 8 and 9 of the Fish Management Plan.	ACTEW will adopt recommendations of projects where they are relevant to ACTEW activities. Currently, recommendations are only available for Project 2 - Predicted passage of native and alien freshwater fish based on swimming speed performance (refer to Section 4.1.2)	Adoption of recommendations will be undertaken in ongoing consultation with the Fish Management Program Steering Committee.
Manage threat of alien fish populations	A coordinated management program to investigate, monitor and mitigate the negative impacts of alien fish populations is included in the Fish Management Plan.	Investigations to monitor and mitigate the negative impacts of alien fish populations form part of the scope of works for Project 9 – Enlarged Cotter Dam fish monitoring. The design and siting of the alien fish management structure (fish trap) will be finalised as part of Project 6 - Management program for alien fish species.	The monitoring conducted as part of Project 9 will be ongoing. The fish trap will be installed prior to the end of the construction period, with the project expected to be completed by the end of 2011.
	Project 6 of the Fish Management Plan will be implemented to determine the management approach to alien fish populations both within and upstream of the Cotter Reservoir.		
	ACTEW will adopt the recommendations of Project 6 of the Fish Management Plan.	ACTEW will adopt recommendations of projects where they are relevant to ACTEW activities.	Adoption of recommendations will be undertaken in ongoing consultation with the Fish Management Program Steering Committee.

5.2 DEWHA/PER conditions/commitments

The following tables summarise the conditions stipulated by DEWHA in their approval of the Enlarged Cotter Dam project and the commitments made in the *Enlargement of the Cotter Reservoir and associated works: Public Environment Report* (ACTEW 2009b).

The actions to be undertaken to meet each condition or commitment are also documented.

Table 5.3 DEWHA conditions.

DEWHA Approval Conditions	Approval Condition	ACTEW action to meet condition	Delivery
Environmental flows			
General	The person taking the action must operate the Enlarged Cotter Dam in accordance the environmental flow requirements specified in the ACT *Environmental Flow Guidelines 2006* and the ACT Water Resources Act except for the prescriptive flow rates that are specified under other conditions in this approval.	Flows will be provided in accordance with the environmental flow requirements specified in the ACT Environmental Flow Guidelines, the ACT Water Resources Act and stipulated conditions of approval.	Environmental flows will be provided for the life of the Enlarged Cotter Dam.
Downstream flows	During construction and filling of the expanded Cotter Dam the person taking the action must: a. Release a minimum of 34 ML of water per day into the Cotter River below the dam wall (calculated over a 12 month period); b. Publish monthly reports presenting the amount of water released from the Cotter Dam; c. Undertake monitoring of baseline indicators of ecological health in the Cotter River below the dam wall and the Murrumbidgee River below the junction with the Cotter River; d. Not withstanding the requirement under a., the person taking the action	ACTEW will ensure compliance though ongoing consultation with SEWPaC (formerly DEWHA). In addition: • ACTEW has directed ActewAGL to operate the water supply infrastructure in a way that aims to provide a minimum of 34 ML d^{-1} into the Cotter River below the dam wall (12 month calculation). • The ACTEW website includes monthly reports on the amount of water provided to the Cotter River as an environmental flow. • Cotter River and Murrumbidgee River ecological monitoring programs are currently in place. The first set of monitoring to take place (after these conditions of approval were established) will be the autumn 2010 sampling round. Once the reports are finalised they will be published on the ACTEW website.	Appropriate management and monitoring of environmental flows will be conducted on an ongoing basis.

DEWHA Approval Conditions	Approval Condition	ACTEW action to meet condition	Delivery
	must provide a plan to increase the long-term flows of the Cotter River for the approval of the Minister within 4 years of the date of this approval. The plan must provide for increase in the minimum flow regime under a. to improve the ecological health of the Cotter River below the dam wall, an the Murrumbidgee River below the junction with the Cotter River; and e. Provide an annual report, demonstrating how the person taking the action has been releasing downstream flows in accordance with the advice of the Environmental Flows Technical Advisory Group established by the ACT EPA. The plan approved under d. must be implemented. All plans, reports and data required under b., c., d., and e. must be published on the ACTEW website within one month of finalisation.	• ACTEW has commenced discussions on a plan to increase long-term flows in the Cotter River. An Annual report will be provided in early 2011 detailing ACTEW's responses to advice received from the Environmental Flows Technical Advisory Group.	
Fish Management Plan			
General	Within 6 months of commencement of construction of the Enlarged Cotter Dam, the person taking the action must prepare and submit to the Minister, for approval, a Fish Management Plan. The person taking the action must consult with the ACT Government (TAMS) and the Department during the preparation and any future updating of the Plan.	Version 2 of the Fish Management Plan submitted in line with conditions of approval. Consultation with TAMS and SEWPaC (formerly DEWHA) will be primarily through the Fish Management Program Steering Committee.	Version Two of the Fish Management Plan was submitted to and endorsed by relevant stakeholders in May 2010. Consultation with the Fish Management Program Steering Committee will be ongoing

DEWHA Approval Conditions	Approval Condition	ACTEW action to meet condition	Delivery
	The Fish Management Plan must include discussion of ongoing management measures, construction management measures, the translocation program and funding and responsibilities.	Version 2 of the Fish Management Plan was prepared in consultation with the Fish Management Program Steering Committee.	Revised edition of Version Two of the Fish Management Plan incorporating comments from the Fish Management Program Steering Committee completed in September 2010.
	The person taking the action must implement the Plan. Every year the person taking the action must submit to the Minister a report covering performance against the Fish Management Plan. The date of the first report must be provided on 19 January 2011, with each subsequent report to be provided 12 months from the date of the previous report.	A report will be provided on 19 January 2011 covering performance against the Fish Management Plan. Subsequent reports will be provided annually in consultation with the Fish Management Program Steering Committee.	Reporting against the Fish Management Plan will commence in January 2011.
Ongoing Management Measures	Baseline information on population of Macquarie Perch in the Cotter River Catchment including estimates of population size, distribution and seasonal variation	Baseline information will be collated as part of Project 9 – Enlarged Cotter Dam fish monitoring.	Baseline information will be collected in the first two years of monitoring.
	A monitoring program with ability to detect at statistical power of 0.8 or greater any environmental harm to Macquarie Perch population in the Cotter River Catchment	The statistical power of the proposed monitoring program is generally capable of detecting changes to the adult Macquarie Perch population to a statistical power of at least 0.8 (Robinson 2010).	No further action
	Identification of thresholds for management intervention in relation to all measures implemented to manage and maintain a viable Macquarie Perch population in the Cotter River Catchment	Thresholds will be developed as part of Project 9 – Enlarged Cotter Dam fish monitoring.	Thresholds will be developed and modified if necessary on an ongoing basis.

DEWHA Approval Conditions	Approval Condition	ACTEW action to meet condition	Delivery
	Identification, removal and monitoring of movement barriers for the Macquarie Perch between the Enlarged Cotter Dam and Bendora Dam	Project 2 - Swimming Capacity of Macquarie Perch has provided information on the need to remediate barriers to passage of Macquarie Perch (refer to Section 4.1.2). Initial designs for remediation options are being prepared.	Project 2 was completed in July 2009. Remediation of barriers will be undertaken prior to the completion of the construction phase.
	Information collection on swimming ability of Macquarie Perch to inform the management of water levels between Bendora Dam and Cotter Dam	Project 2 - Predicted passage of native and alien freshwater fish based on swimming speed performance has provided this information. See Section 4.1.2 for findings and recommendations from Project 2.	Project 2 was completed in July 2009.
	Identification, construction and monitoring of artificial habitat for Macquarie Perch in the Enlarged Cotter Dam	The BWA Fish Management Program team has worked closely with UC to identify how much habitat to provide, where it can be located and other shelter opportunities for threatened fish. Refer to Sections 3.3.7 Provision of shelter habitat and Section 4.1.1- Constructed homes for threatened fishes.	Constructed shelter (rock reefs) will be installed prior to the completion of the construction phase. Monitoring in the enlarged Cotter Reservoir will be ongoing.

DEWHA Approval Conditions	Approval Condition	ACTEW action to meet condition	Delivery
	Identification and implementation of design features, management measures and operating controls to prevent adverse impacts on the Macquarie Perch population in the Enlarged Cotter Dam.	Specific design features to prevent adverse impacts on the Macquarie Perch include: • Measures to stop fish entering the water off-take structure. • Design of constructed habitats and identification of suitable shelter habitat. • Suitable environmental releases from Bendora Dam. • Decommission the quarry so it provides shelter habitat for threatened fish. • Design of saddle dam walls to incorporate large boulders providing shelter habitat for threatened fish. Management measures and operating controls to prevent adverse impacts on the Macquarie Perch are identified in the Aquatic Fauna and Flora Management Plan.	The Aquatic Fauna and Flora Management Plan was revised in April 2010. The implementation of measures to prevent adverse impacts on Macquarie Perch will be ongoing.
	Design, implementation and monitoring of a predator control program to protect the Macquarie Perch in Enlarged Cotter Dam.	Investigations to monitor and mitigate the predation impacts of alien fish on Macquarie Perch populations form part of the scope of works for Project 9 – Enlarged Cotter Dam fish monitoring. The design and siting of the alien fish management structure (fish trap) will be finalised as part of Project 6 – Alien fish management. ACTEW, in conjunction with UC and TAMS, has also proposed a research project to collect data on cormorant diet. This will help inform whether there is a need to implement a cormorant control program.	The monitoring conducted as part of Project 9 will be ongoing. The fish trap will be installed prior to the end of the construction period, with project expected to be completed by the end of 2011. The cormorant predation study will be completed in February 2011.

DEWHA Approval Conditions	Approval Condition	ACTEW action to meet condition	Delivery
Construction Management Measures	Identification and implementation of measures to sterilise the area between the existing Cotter Dam and the Enlarged Cotter Dam from all aquatic fauna or pathogens that would adversely impact the Macquarie Perch.	An EHN virus workshop was held in October 2009 with experts from the University of Sydney. ACTEW have applied an approach recommended by the University of Sydney experts. Measures to reduce the risk of the virus entering the Cotter Reservoir have been incorporated into the Aquatic Flora and Fauna Management Plan. Measures include disinfection for equipment and vehicles, personnel training, signage, auditing and reporting procedures.	Managing the risk of the EHN virus entering the Cotter Reservoir will be ongoing.
	Monitoring of the Cotter River Catchment for presence of EHN virus and the development of a response plan in the event that EHN virus is detected.	The EHN virus will be monitored through the presence of the known vector Redfin Perch as part of Project 9 – Enlarged Cotter Dam fish monitoring. A response plan has been prepared.	Monitoring for Redfin Perch will be ongoing. The EHN Virus Response Plan was revised in April 2010.
	Develop and implement measures to avoid chemical spills and sedimentation impacting on water quality of the Cotter River downstream during construction of the Enlarged Cotter Dam.	Measures to minimise the risk of chemical spills and sedimentation are documented in the Erosion and Sediment Control Plan and the CEMP.	Actions documented in the Erosion and Sediment Control Plan and the CEMP will be undertaken for the duration of the construction phase.
Translocation Program	Identification of suitable recipient sites in the ACT region for translocation of Macquarie Perch.	Suitable recipient sites have been identified as part of Project 5 – Research into the establishment of new populations of Macquarie Perch, Trout Cod and Two-spined Blackfish through translocation. This project is underway.	Project 5 will be completed in August 2011.

DEWHA Approval Conditions	Approval Condition	ACTEW action to meet condition	Delivery
	Development and implementation of suitable methods to translocate Macquarie Perch.	Suitable methods to translocate Macquarie Perch have been identified and implemented as part of Project 5 – Research into the establishment of new populations of Macquarie Perch, Trout Cod and Two-spined Blackfish through translocation. This project is underway.	Project 5 will be completed in August 2011.
	Monitoring program for translocated population for a minimum of 20 years which includes a review at 5 years following commencement.	Monitoring is currently being conducted under Project 5 – Research into the establishment of new populations of Macquarie Perch, Trout Cod and Two-spined Blackfish through translocation and will be incorporated into the scope of Project 9 - Enlarged Cotter Dam fish monitoring.	Monitoring of translocated populations will be ongoing.
Funding and Responsibilities	Details of funding arrangements and the parties responsible for implementation of all aspects of Fish Management Program.	BWA and ACTEW are currently discussing and finalising these arrangements. Funding arrangements will be finalised following receipt of recommendations from each of the nine Fish Management Program projects.	Funding arrangements will be determined as recommendations become available.

Table 5.4 PER commitments.

Impact	Commitment	Action Required	Delivery
Aquatic Biodiversity	Prepare Enlarged Cotter Dam Fish Management Plans (versions 1 to 4) for each phase (design, construction and inundation/operation) of the Enlarged Cotter Dam. The plans will address the issues and their proposed management and mitigation measures to ensure there is no negative impact.	Version 2 of the Fish Management Plan was submitted in line with conditions of approval. Subsequent versions (three and four) of the Fish Management Plan will be prepared in accordance with conditions of approval.	Version Two of the Fish Management Plan was submitted to and endorsed by relevant stakeholders in May 2010. Versions three and four will be submitted in early 2012 and early 2014 respectively.

Impact	Commitment	Action Required	Delivery
	Implement Project 1 - Constructed homes for threatened fishes.	Project 1 - Constructed homes for threatened fishes has been implemented.	Project 1 will be completed by December 2010.
	Implement Project 2 - Predicted passage of native and alien freshwater fish based on swimming speed performance.	Project 2 - Predicted passage of native and alien freshwater fish based on swimming speed performance is complete. Refer to Section 4.1.2.	Project 2 was completed in July 2009.
	Implement Project 4 – EHN virus.	Project 4 – EHN virus occurrence is complete. Refer to Section 4.1.4.	Project 4 was completed in August 2008.
	Implement Project 5 - Research into the establishment of new populations of Macquarie Perch, Trout Cod and Two-spined Blackfish through translocation.	Project 5 - Research into the establishment of new populations of Macquarie Perch, Trout Cod and Two-spined Blackfish through translocation has been implemented.	Project 5 will be completed in August 2011.
	Implement Project 6 – Management program for alien fish species.	The revised scope for Project 6 – Management program for alien fish species, the design and siting of the alien fish management structure (fish trap) is still to be finalised. The monitoring component of Project 6 – Management program for alien fish species has been incorporated into the scope for Project 9 – Enlarged Cotter Dam fish monitoring.	Project 6 is expected to be completed by the end of 2011. The monitoring of alien fish will be ongoing.
	Implement Project 7 – Food sources for Macquarie Perch and drawdown effects.	Project 7 – Food sources for Macquarie Perch and drawdown effects has been implemented.	Project 7 will be completed in early to mid 2011.
	Implement Project 8 – Investigation of techniques for mapping instream barriers.	Project 8 - Investigation of techniques for mapping instream barriers has been implemented.	Project 8 will be completed in early 2011.

Impact	Commitment	Action Required	Delivery
	Implement Project 9 – Enlarged Cotter Dam fish monitoring.	The scope for Project 9 – Enlarged Cotter Dam fish monitoring has been reviewed by Steering Committee.	The monitoring undertaken for Project 9 will be ongoing.
	Manage the impact of changes to the management of water resources (and the Trout Cod population) in Bendora Reservoir following construction of the Enlarged Cotter Dam.	The management of water resources (including Bendora Reservoir) will be in accordance with ACTEW's Licence To Take Water. Where appropriate, findings and recommendations from the Fish Management Program projects will be provided to the Environmental Flows Technical Advisory Group to inform future review of the management of ACT water resources.	The management of water resources will be ongoing.
	Manage the impact of reduced flows on Murray Cod in the Murrumbidgee River.	The management of this issue will be undertaken in consultation with SEWPaC (formally DEWHA) and the ACT EPA.	The management of water resources will be ongoing.
Ongoing monitoring and reporting	Monitor change in population numbers of Macquarie Perch following construction.	Included in the scope for Project 9 – Enlarged Cotter Dam fish monitoring.	The monitoring undertaken for Project 9 will be ongoing.
	Monitor annual recruitment of Macquarie Perch in the enlarged Cotter Reservoir.	Included in the scope for Project 9 – Enlarged Cotter Dam fish monitoring.	The monitoring undertaken for Project 9 will be ongoing.
	Monitor changes in the abundance and size composition of trout population in enlarged Cotter Reservoir.	Included in the scope for Project 9 – Enlarged Cotter Dam fish monitoring.	The monitoring undertaken for Project 9 will be ongoing.
	Monitor changes in the abundance, distribution or species composition of piscivorous birds in the enlarged Cotter Reservoir.	Included in the scope for Project 9 – Enlarged Cotter Dam fish monitoring.	The monitoring undertaken for Project 9 will be ongoing.

Impact	Commitment	Action Required	Delivery
	Monitor changes in the abundance and size composition of trout population in the Cotter River upstream of the enlarged Cotter Reservoir.	Included in the scope for Project 9 – Enlarged Cotter Dam fish monitoring.	The monitoring undertaken for Project 9 will be ongoing.
	Monitor changes in the abundance and size structure of Macquarie Perch in the Cotter River above and below Vanity's Crossing.	Included in the scope for Project 9 – Enlarged Cotter Dam fish monitoring.	The monitoring undertaken for Project 9 will be ongoing.

5.3 Fish Management Plan Version 1 commitments

The commitments shown in the following table have been extracted from Version One of the Fish Management Plan.

Table 5.5 Fish Management Plan Version 1 commitments.

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
Executive Summary, page vi	ACTEW will provide sufficient information (documented in the Fish Management Plan and associated management plans) on how it proposes to protect the threatened fish species during the construction, filling and operational phases of the Enlarged Cotter Dam.	ACTEW has been working closely with the University of Canberra, to ensure protection of threatened fish species. Protection of fish during the construction phase will be documented in Version 2 of the Fish Management Plan. Protection measures during filling and operational phases will be documented in subsequent versions of the Fish Management Plan.	Version Two of the Fish Management Plan was submitted to and endorsed by relevant stakeholders in May 2010. Versions three and four will be submitted in early 2012 and early 2014 respectively.
Section1.3, page 3	Version 2 of the Fish Management Plan will be produced at the start of construction and will incorporate: • Results from a range of projects (currently being completed), designed to fill knowledge gaps. • Changes needed if the range of projects is unable to provide suitable results for the	Version 2 of the Fish Management Plan was submitted in line with conditions of approval in consultation with the Fish Management Program Steering Committee and covers the Enlarged Cotter Dam construction period (from late 2009 to late 2011).	Version Two of the Fish Management Plan was submitted to and endorsed by relevant stakeholders in May 2010.

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
	management of threatened fish species in the Enlarged Cotter Dam. • Results of ongoing monitoring (by ACTEW, ActewAGL, Ecowise Environmental, TAMS, University of Canberra and a number of other organisations). • Input on Version 1 from regulators and stakeholders.		
Section 1.3, page 3	Version 3 of the Fish Management Plan will be produced at the commencement of filling and operational phases and will incorporate: • Results from a range of projects (currently being completed), designed to fill knowledge gaps. • Changes needed if the range of projects is unable to provide suitable results for the adaptive management of threatened fish species in the Enlarged Cotter Dam. • Results of ongoing monitoring (by ACTEW, ActewAGL, Ecowise Environmental, TAMS, University of Canberra and a number of other organisations). • Input on Version 2 from regulators and stakeholders.	Version 3 of the Fish Management Plan will be submitted in accordance with conditions of approval.	Version Three will be submitted in early 2012.
Section 1.3, page 3	Version 4 of the Fish Management Plan will be produced two years into the filling and operations phases and will incorporate: • Results of ongoing monitoring (by ACTEW, ActewAGL, Ecowise Environmental, TAMS, University of Canberra and a number of other organisations). • Input on Version 3 from regulators and stakeholders.	Version 4 of the Fish Management Plan will be submitted in accordance with conditions of approval.	Version Four will be submitted in early 2014.

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
Table 2, Section 3.3, pages 19-28	The projects detailed in the Fish Management Program will address those knowledge gaps directly related to the construction of the Enlarged Cotter Dam.	Knowledge gaps related to the construction of the Enlarged Cotter Dam will be addressed by the projects identified in the Fish Management Program.	Knowledge gaps will be addressed on an ongoing basis.
Section 3.3, page 28	On most projects, consultation and collaboration will be undertaken with the ACT Research and Planning Unit of PCL.	ACTEW maintains communication with ACT Research and Planning Unit of PCL via the Fish Management Program Steering Committee.	Consultation with the Fish Management Program Steering Committee will be ongoing.
Section 4.1.4, page 44	Actions detailed in the Fish Management Plan are to be in accordance with National Recovery Plans for Trout Cod and Macquarie Perch (when available).	ACTEW will work with their Fish Advisor and the Fish Management Program Steering Committee to meet these commitments.	Consultation with the Fish Advisor will be ongoing.
Section 4.2.1, page 47	Actions detailed in the Fish Management Plan are to be in accordance with *The Aquatic Species and Riparian Zone Conservation Strategy: Action Plan 29*.		
Section 4.2.2, page 47	Actions detailed in the Fish Management Plan are to be in accordance with the fish management plan prepared by the ACT Conservator under the ACT *Fisheries Act 2000.*		
Section 5.3, page 51	Provision of artificial shelter habitat for adult fish whilst the reservoir fills and the reedbeds establish	Constructed shelter habitat will be provided. Habitat is being designed by the Fish Management Program team in consultation with ACTEW and the University of Canberra.	Constructed shelter habitat (rocks reefs) will be installed prior to the completion of the construction phase.
Section 5.3, page 51	Provision of artificial shelter habitat for adult fish suitable when the reservoir is drawn down greater than 1.5 m (from FSL).	Constructed shelter habitat will be provided. Habitat is being designed by the Fish Management Program team in consultation with ACTEW and the University of Canberra.	Constructed shelter habitat (rocks reefs) will be installed prior to the completion of the construction phase.

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
Section 5.3, page 51	Survey of potential fish habitat structures at a range of depth transects before the reservoir fills to identify the need for artificial habitats across the full drawdown range.	Survey is being undertaken by Fish Management Program team in consultation with Biosis and the University of Canberra.	Survey will be completed by September 2010.
Section 5.3, page 52	Investigate measures to provide shelter, or to mitigate cormorant predation including potential management solutions prior to the reservoir filling.	Habitat is being designed by the BWA in consultation with ACTEW and the University of Canberra. Measures to monitor changes in the distribution and abundance of cormorants are included in the scope for Project 9 – Enlarged Cotter Dam fish monitoring.	Constructed shelter habitat (rocks reefs) will be installed prior to the completion of the construction phase. Monitoring of cormorants will be ongoing.
Section 5.3, page 52	Investigate the impacts of the Enlarged Cotter Dam on Two-spined Blackfish breeding.	Spawning habitat enhancements and recruitment of Two-spined Blackfish within Bendora Reservoir are being investigated as part of Project 1 - Constructed homes for threatened fishes. Monitoring of potential Enlarged Cotter Dam impacts are included in scope of Project 9 – Enlarged Cotter Dam fish monitoring.	Project 1 will be completed in December 2010. Monitoring of Two-spined Blackfish recruitment will be ongoing.
Table 4, Section 6.6, page 69			
Monitoring	Continue monitoring water quantity and quality in Cotter Reservoir and provide this information on a regular basis to ACTEW, TAMS and ActewAGL.	Monitoring will be in accordance with ACTEW's Licence To Take Water.	Monitoring will be ongoing.
	Continue to monitor nutrient concentrations and algal numbers in Cotter Reservoir and provide this information on a regular basis to ACTEW and ActewAGL.	Monitoring will be in accordance with ACTEW's Licence To Take Water.	Monitoring will be ongoing.

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
	Continue monitoring the recovery of the catchment and provide this information on a regular basis to TAMS, ACTEW and ActewAGL.	Monitoring will be in accordance with ACTEW's Licence To Take Water.	Monitoring will be ongoing.
	Continue to monitor fish numbers in Cotter Reservoir and the Cotter River upstream of the reservoir and provide this information to TAMS.	Monitoring is included in the scope of Project 9 – Enlarged Cotter Dam fish monitoring.	Monitoring will be ongoing.
	Occasionally monitor storm events to estimate sediment transport.	Monitoring will be in accordance with ACTEW's Licence To Take Water.	Monitoring will be ongoing.
	Continue to monitor the presence of Macquarie Perch and reproductive success upstream of Vanity's Crossing.	Monitoring is included in the scope of Project 9 – Enlarged Cotter Dam fish monitoring.	Monitoring will be ongoing.
	Monitor annual recruitment or spawning in the Macquarie Perch population.	Monitoring is included in the scope of Project 9 – Enlarged Cotter Dam fish monitoring.	Monitoring will be ongoing.
	Monitor potential adverse water-quality changes (DO and pH) in the water trapped between the two dam walls (if overlapping construction and filling phases).	Monitoring will be in accordance with ACTEW's Licence To Take Water.	Monitoring will be ongoing.
	Monitor fishing use of the Cotter River between Bendora and Cotter Reservoir.	The responsibility for this commitment will be discussed with the ACT Government.	Monitoring will be ongoing.
	Regularly monitor food resources available to fish.	ACTEW will undertake monitoring in accordance with recommendations of Project 7 – Food sources for Macquarie Perch and drawdown effects.	Timing of monitoring to be as recommended.

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
	Continue to monitor adult Macquarie Perch in wet-well.	The design of the intake structure for the enlarged Cotter Reservoir will prohibit the entrainment of adult Macquarie Perch, therefore monitoring of the wet well is not required.	No further action.
	Monitor alien fish numbers in reservoir and river immediately upstream.	Monitoring is included in the scope of Project 9 – Enlarged Cotter Dam fish monitoring.	Monitoring will be ongoing.
	Monitor cormorant activity during spawning events.	Monitoring will be conducted by the University of Canberra as part of the associated project Cormorant predation of Macquarie Perch and ongoing monitoring of cormorant activity in spring, during spawning events. Long-term monitoring is included in the scope of Project 9 – Enlarged Cotter Dam fish monitoring	The cormorant predation study will be completed in February 2011. Monitoring conducted as part of Project 9 will be ongoing.
Operating Regime	Continue to use the ACT Environmental Flows Technical Advisory Group to determine the quantity and temperature of releases from Bendora Reservoir, including flushing flows.	ACTEW will operate the enlarged reservoir in accordance with their operating licence, including the provision of stipulated environmental flows and drawdown limits. The quantity and quality of environmental flows required in the Cotter River Catchment will continue to be determined by the ACT EPA.	Appropriate management of water resources will be ongoing.
	Ensure that releases from Bendora Reservoir have a temperature similar to that of river water during the Macquarie Perch spawning season (mid-October to mid-November).		
	Minimise drawdown during Macquarie Perch spawning season (Oct-Dec).		

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
Construction Environmental Management	Require all consultants undertaking activities in catchment to have EMPs for their activities.	All consultants will undertake activities in accordance with BWA environmental management requirements.	Ongoing for the duration of the construction phase.
	Require all consultants to have necessary approvals (such as a waterways permit) in place.	All consultants will have necessary approvals and permits in place.	Ongoing for the duration of the construction phase.
	Require all consultants to notify the BWA of their activities in the catchment. Also require that key personnel are trained in mitigation measures to reduce the chance of introducing contaminants into Cotter Reservoir.	All consultants will undertake activities in accordance with BWA environmental management requirements.	Ongoing for the duration of the construction phase.
	Ensure that no water from below the existing dam wall is used for construction purposes, and ensure that the space between the old and the new dams is thoroughly dried out prior to commissioning the new dam.	Procedures for the management of the area between the new and existing dam walls and onsite water use, to minimise the risk of the EHN virus entering the existing or enlarged Cotter Reservoir, are documented in the CEMP and Aquatic Flora and Fauna Management Plan.	Ongoing for the duration of the construction phase.
	Ensure that appropriate measures are employed to eliminate the possibility of transferring biological material from the river section between the old and the new walls in the new reservoir. This will require fish eradication techniques (e.g. drying, poisoning, netting etc).	Procedures for the management of the area between the new and existing dam walls, to minimise the risk of the EHN virus entering the enlarged Cotter Reservoir, are documented in the CEMP and Aquatic Flora and Fauna Management Plan.	Ongoing for the duration of the construction phase.
Shelter Habitat	Use the findings of Project 1 to provide additional information specifically on the suitability of some form of artificial habitat as a replacement for the current macrophyte beds.	Suitable constructed habitats (rock reefs) have been identified through Project 1 – Construction homes for threatened fishes.	Constructed shelter habitat (rocks reefs) will be installed prior to the completion of the construction phase.

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
	Survey Enlarged Cotter Dam basin to determine whether suitable shelter habitats, especially boulder, cobble and rock areas, and timber, will be submerged down to maximum operating level.	Survey has been undertaken by Biosis in consultation with the Fish Management Program team and the University of Canberra.	Survey will be completed in September 2010.
	Examine the possibility of providing additional edge-boulder habitat (for juvenile and sub-adult Macquarie Perch), within the new dam.	Treatment of final quarry and surfaces of saddle dams and provision of rock reefs will provide suitable juvenile and sub-adult Macquarie Perch habitat.	Treatment will be undertaken prior to completion of construction phase.
	Examine the possibility of providing additional boulder habitat (for juvenile, sub-adult and adult Macquarie Perch), within the quarry site for the Enlarged Cotter Dam (which will be within the flooded area of the Enlarged Cotter Dam).	Treatment of final quarry to provide suitable fish habitat.	Treatment will be undertaken prior to completion of construction phase.
	Seek to maximise amounts of submerged timber at all depths.	Timber within the inundation zone will be left in situ in accordance with approval conditions.	No further action.
Fish Passage	Use the findings of Project 2 to provide additional information specifically on improving the passage of fish (particularly Macquarie Perch) along the Cotter River upstream of the Enlarged Cotter Dam.	Project 2 - Predicted passage of native and alien freshwater fish based on swimming speed performance recommends that existing pipe culverts at Pipeline Road Crossing and Bourke's Creek Crossing be modified to reduce flow velocity and allow passage by Macquarie Perch. Repairs to Vanity's Crossing are also proposed.	Remediation will be undertaken prior to the completion of the construction phase.
	Use the findings of Project 8 to reduce or eliminate remaining instream barriers (if any).	Project 8 – Investigation of techniques for mapping instream barriers is currently underway.	Project 8 will be completed by early 2011.

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
	Provide uninterrupted passage at any problem barriers, either by modifying stream bed structure or building fishways.	Project 2 - Predicted passage of native and alien freshwater fish based on swimming speed performance recommends that existing pipe culverts at Pipeline Road Crossing and Bourke's Creek Crossing be modified to reduce flow velocity and allow passage by Macquarie Perch. Repairs to Vanity's Crossing are also proposed.	Remediation will be undertaken prior to the completion of the construction phase.
Crayfish	Use the findings of Project 3 to provide additional information specifically on improving of the Cotter River downstream of the Enlarged Cotter Dam for crayfish.	Project 3 - Crayfish ecology recommends that flows be investigated to improve the quality and availability of Murray River Crayfish habitat.	The investigation and modification of environmental flows will be ongoing.
Design	Investigate screening to prevent fish access or entrainment in intake structure.	The design of the intake structure has mitigated this risk.	No further action.
Stakeholder Management	Require close consultation between ACT government agencies, ACTEW and ActewAGL, to recognise additional risks due to lack of sufficient information.	The Fish Management Program Steering Committee will meet regularly to guide the provision of mitigation strategies for the protection of threatened native aquatic species. Represented organisations include SEWPaC (formerly DEWHA), the ACT Government, the ACT EPA, the University of Canberra, ACTEW and the BWA The Community Engagement and Stakeholder Management Team will keep the ACT community informed of fish management activities.	Consultation with the Fish Management Program Steering Committee will be ongoing.
	Ensure frequent meetings between fish management personnel and design/construction team members to discuss fish management requirements.		
	Have regular stakeholder assessments of management requirements.		
	Liaise with ACT Government to promote a program of public education about the various risks.		

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
	Involve relevant stakeholders including ACTEW, ActewAGL, the ACT Government and the ACT community.		
	Compile protocol(s) for recovery and release of any fish which become trapped in intake infrastructure. This is to be undertaken jointly by TAMS, ACTEW and ActewAGL.		
Translocation	Continue to translocate Macquarie Perch, Trout Cod and Two-spined Blackfish to other potentially suitable habitats and monitor populations(s) in new habitat(s).	Project 5 - Research into the establishment of new populations of Macquarie Perch, Trout Cod and Two-spined Blackfish through translocation is currently underway.	Project 5 will be completed in August 2011.
Fish Management Plan and adaptive management	Review Fish Management Plan on a regular basis; for example, at end of design phase, at end of construction phase and then at intervals of once every two years for the filling and operational phases.	Update of the Fish Management Plan has been developed in accordance with Territory and Commonwealth conditions of approval. This process will be overseen by the Fish Management Program Steering Committee.	Version Two of the Fish Management Plan was submitted to and endorsed by relevant stakeholders in May 2010. Versions three and four will be submitted in early 2012 and early 2014 respectively.
	Require peer reviews of information collection and monitoring.	Peer reviews will be conducted as required.	Peer review will be ongoing.
	Ensure substantial areas of suitable spawning habitats are available at all storage levels.	The remediation of Pipeline Road Crossing and Burke's Creek Crossing, will allow Macquarie Perch to access a further 13 km of suitable spawning habitat in the Cotter River upstream of the enlarged inundation zone.	Remediation will be implemented prior to the completion of the construction phase.

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
	Use findings of each of the Fish Management Plan projects to inform actions.	The results of the Fish Management Program and associated projects will be used to inform the adaptive management approach and will be guided by the Fish Management Program Steering Committee.	Adoption of recommendations will be undertaken in ongoing consultation with the Fish Management Program Steering Committee.
	Audit, review and update Fish Management Plan	The audit, review and update of the Fish Management Plan will be in accordance with Territory and Commonwealth conditions of approval and will be overseen by the Fish Management Program Steering Committee.	Version Two of the Fish Management Plan was submitted to and endorsed by relevant stakeholders in May 2010. Versions three and four will be submitted in early 2012 and early 2014 respectively. Consultation with the Fish Management Program Steering Committee will be ongoing
Predation	Investigate levels of Trout predation and what life stages of threatened fish are most affected.	Included in the scope of Project 9 – Enlarged Cotter Dam fish monitoring.	Monitoring will be ongoing.
	Investigate control techniques to reduce impacts of predation (barriers, trapping etc).	The design and siting of the alien fish management structure (fish trap) will be finalised as part of the scope of Project 6 – Alien fish management.	Project 6 is expected to be completed by the end of 2011.
	Investigate temporary and permanent provision of artificial cover during spawning events.	Project 9 - Enlarged Cotter Dam fish monitoring for Enlarged Cotter Dam will determine the need for constructed habitat based on Macquarie Perch and cormorant behaviours.	Monitoring will be ongoing.

Fish Management Plan reference	Commitment	ACTEW action to meet commitment	Delivery
	Investigate temporary bird management options to mitigate predation during spawning events.	This will be investigated by the University of Canberra as part of the proposed project Research into the potential predation by cormorants of Macquarie Perch in the Cotter Reservoir which is planned to commence in late 2010 and culminate in early 2011.	The cormorant predation study will be completed in February 2011.
Spawning Habitat	Investigate whether Two-spined Blackfish will breed in reservoir habitats.	The spawning behaviour of Two-spined Blackfish in Bendora Reservoir is included in the scope of Project 1 - Constructed homes for threatened fishes.	Project 1 will be completed in December 2010.
	Investigate provision of artificial spawning habitats for Two-spined Blackfish.	The spawning habitat requirements for Two-spined Blackfish, including their use of spawning tubes is included in the scope of Project 1 - Constructed homes for threatened fishes.	Project 1 will be completed in December 2010.

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7 Glossary and abbreviations

Term	Definition
ACT	Australian Capital Territory.
ACT EPA	ACT Environment Protection Authority.
ACTEW	ACTEW Corporation Pty Ltd.
ACTPLA	ACT Planning and Land Authority.
Biosis	Biosis Research Pty Ltd.
BRUV	Baited Remote Underwater Video.
BWA	Bulk Water Alliance. A partnership between ACTEW and ActewAGL, GHD, Abigroup and John Holland Group, formed for the delivery of water security projects.
CEMP	Construction Environmental Management Plan.
Chironomidae	Taxomonic family informally referred to as non-biting midges.
Coleoptera	Taxonomix order of the beetle.
CPUE	Catch per unit effort, the number of target individuals caught for each sampling period.
d^{-1}	Per day.
DA	Development Application.
Decapoda	Taxonomic order of crustaceans including freshwater shrimp *Paratya australiensis* and freshwater prawns *Macrobrachium australiens.*
DEWHA	The Commonwealth Department of the Environment, Water, Heritage and the Arts.
Diel	24 hour period.
Diel range	Length of shoreline used by an individual in a complete diel period.
Diel mobility	Sum of all movements of an individual in a complete diel period.
Diel activity	Mean percentage of distance covered by an individual for each interval between tracks for each diel period.
Diptera	Taxonomic order of flies and midges.
EHN virus	Epizootic Haematopoietic Necrosis virus.
EIS	Environmental Impact Statement.
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*
Ephemeroptera	Taxonomic order of the mayfly.
FSL	Full Supply Level.

Term	Definition
GIS	Geographic Information System.
GL	Gigalitres.
GPS	Global Positioning System. A system which enables a mobile receiver to determine its precise location based on signals received from satellites orbiting the Earth.
Home range (daily only)	The total length of shoreline used by an individual based on daily tracks only.
Home range (total)	The total length of shoreline used by an individual for all tracks.
Mesohabitat	Medium scale patches of habitat in which an organism can live. Measured over a 10 to 100 m scale.
Microhabitat	A small, specific habitat type within a mesohabitat patch where an organism resides, for example under and between boulders in a river. Measured at a 1-10 m scale.
ML	Megalitre.
NSW	New South Wales.
OCL	Occipital carapace length. The length of the hard shell which forms the exoskeleton of the crayfish. Does not include the tail segments.
PCL	Parks, Conservation and Lands, a branch within the ACT Government Department of Territory and Municipal Services.
PER	Public Environment Report.
pH	A measure of the acidity or basicity of a solution.
Piscivorous	Feeds on fish.
PIT	Passive Integrated Transponder.
Quadrat	A quadrat is a measured and marked rectangle used in ecology to isolate a sample.
s^{-1}	Per second.
SEWPaC	The Commonwealth Department of Sustainability, Environment, Water, Population and Communities (formally DEWHA).
TAMS	Territory and Municipal Services, a department within the ACT Government.
TL	Total length, a common measure of fish and crayfish size.