FUTURE WATER PLANNING

ENLARGED COTTER DAM FISH MANAGEMENT PLAN (VERSION 1)

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Prepared For:

ACTEW CORPORATION

Prepared By:

INFRASTRUCTURE DEVELOPMENT BRANCH
WATER DIVISION
12 HOSKINS STREET
MITCHELL ACT 2911

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	Position	***Name***
Prepared by:		Laslo Nagy, Lara Brunner, Kate Elliott and Mark Lintermans
ACTEW Review by:		Chris Webb
		Signature: Date:

For further information on this document, contact:

Chris Webb

Program Manager Approvals

Water Security – Major Projects

ACTEW Corporation

Phone: 02 6175 2443

Mobile: 0414 516 563

E-mail: Chris.Webb@actew.com.au

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TABLE OF CONTENTS

ABBREVIATIONS

ACT	Australian Capital Territory
ACTEW	ACTEW Corporation Ltd
ActewAGL	Public/private company operating ACT water supply under contract
DO	Dissolved Oxygen
ECD	Enlarged Cotter Dam
EHN	Epizootic Haematopoietic Necrosis
EIS	Environmental Impact Statement
EMP	Environmental Management Plans
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth of Australia)
FSL	Full supply level
FWO	Future Water Options
GL	Gigalitre (1,000,000,000 litres)
Kg	Kilogram
km	Kilometre
MDBC	Murray-Darling Basin Commission
ML	Megalitre (1,000,000 litres)
m	metre
mm	millimetre
MNES	Matter of national environmental significance
NC Act	Nature Conservation Act 1980 (ACT)
TAMS	Territory and Municipal Services
ºC	degrees Celsius

EXECUTIVE SUMMARY

Background

In October 2007, ACTEW and the ACT Government announced the commencement of detailed planning and construction of the Enlarged Cotter Dam (ECD), thereby increasing its current capacity from 3.8 gigalitres (GL) to 78 GL.

The ECD raises environmental issues regarding the management of the following four threatened fish or crayfish species:

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

The ECD triggers the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), due to the presence of Macquarie Perch and Trout Cod. Both these species are listed under the EPBC Act as "endangered" and thus enlargement requires the approval of the Commonwealth Minister for the Environment.

The ECD also triggers the ACT Nature Conservation Act 1980 (NC Act), due to the presence of Macquarie Perch (endangered status), Trout Cod (endangered status), Two-spined Blackfish (vulnerable status) and Murray River Crayfish (vulnerable status). Under this Act, ACTEW will need to obtain a licence from the ACT Conservator of Flora and Fauna before proceeding with enlargement.

The ECD poses a number of problems as well as opportunities for fish management in the Cotter River catchment (ACT Government, 2007a; Lintermans, 2005).

To obtain the relevant licences and approvals in accordance with Commonwealth and ACT legislation, ACTEW will need to provide sufficient information on how it proposes to protect the threatened fish species during the construction, filling and operational phases of the ECD.

Objective of this document

The overarching objective of the ECD Fish Management Plan is to:

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

This overarching objective is based on the visions, goals, objectives, and actions developed by the ACT Aquatic Species and Riparian Zone Conservation Strategy (ACT Government, 2007a).

The ECD Fish Management Plan needs to be:

- 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 developed as part of the overall requirements of the ECD.
- Effective in terms of resources and personnel whilst at the same time protecting threatened species.

Consequently, the ECD Fish Management Plan needs to make full use of existing relevant environmental information, but at the same time identify and address knowledge gaps.

Knowledge gaps

A number of projects have been identified to fill specific knowledge gaps. Some of these are completed or currently under investigation, whereas a number will still need to be commissioned and carried out, using appropriate resourcing to address their respective knowledge gaps.

Specific information for the ECD Fish Management Plan will be provided by several projects, designed to fill key knowledge gaps. These projects are:

- Project 1 – Artificial habitats. This project will assess the use of artificial habitats by adult Macquarie Perch (for refuge), and Two-spined Blackfish (for spawning) within the enlarged reservoir, with the aim of ensuring appropriate habitats are available for these fish while enabling flexibility of drawdown for the ECD.
- Project 2 – Swimming capacity of Macquarie Perch. This project will assess the ability of Macquarie Perch to access the river system upstream of the enlarged reservoir for spawning, with the aim of improving passage during the spawning season.
- Project 3 – Crayfish ecology. This project will assess the ecological requirements of Murray River Crayfish within the Cotter catchment.

- Project 4 – EHN virus occurrence. This project (now completed), investigated the occurrence of the Epizootic Haematopoietic Necrosis (EHN) virus in the Cotter Catchment. This virus is pathogenic to a number of fish species, including Macquarie Perch.
- Project 5 – Translocation of Macquarie Perch, Trout Cod and Two-spined Blackfish. This project aims to reduce the overall risk of extinction of Macquarie Perch, Trout Cod and Two-spined Blackfish in the ACT, by establishing new populations of these species outside the area affected by the ECD.
- Project 6 – Management program for alien fish species. This project will develop a plan to guide management of alien fish in and upstream of the ECD.
- Project 7 – Food sources for Macquarie Perch and drawdown effects. This project will investigate the current food resources of Cotter Reservoir and the diet of Macquarie Perch, the importance of macrophytes to food production, and likely scenarios of food resource availability for Macquarie Perch in the ECD.
- Project 8 – Mapping instream barriers. This project will map the barriers to Macquarie Perch in the Cotter River. The identification of possible fish barriers will help effectively target sites to restore connectivity in the rivers and streams of the Cotter catchment.
- Project 9 – Fish monitoring for ECD. This project will provide an integrated monitoring program to enable the results of mitigation actions to be assessed and to complete the adaptive management cycle.

Risks and mitigation measures

There is a range of significant risks that have been identified for the current system, as well as for the design, construction, filling and operational phases of the ECD. These risks are summarised in the table below. Some risks are common to all of the phases, whereas other risks are only present in a single phase.

Table 1: Summary of risks (CS=current situation, D=design phase, C=construction phase, FO=filling and operational phases).

Risks	CS	D	C	F O
Increased erosion resulting in increased nutrients and particulate matter in the aquatic environment (as a result of the January 2003 bushfires and subsequent storm events).	✓	✓	✓	✓
Increased nutrients resulting in oxygen depletion in Cotter Reservoir, and reducing habitat for threatened fish.	✓	✓	✓	✓
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) and increased cormorant predation through reduced refuge area.	✓	✓	✓	✓
Road crossings and other barriers reducing fish passage in Cotter River during spawning.	✓	✓	✓	✓
Releases from Bendora Reservoir providing the wrong temperature signal during the spawning season.	✓	✓	✓	✓
Insufficient or inappropriate environmental flows in the Cotter River upstream and downstream of Cotter Reservoir.	✓	✓	✓	✓
Increased chance of fuel spill, oils and other contaminants entering the aquatic environment.	✓	✓	✓	✓
Increased chance of pathogens and/or pests entering the aquatic environment.	✓	✓	✓	✓
Increased chance of devastating bushfires (due to increased human activity in the catchment, or inappropriate fire management practices which may reduce small to medium size fires but actually increase the chance of large fires).	✓	✓	✓	✓
Dam operating practices causing fish mortality or entrainment near off-take structures.	✓	✓	✓	✓
Increased chance of introducing the EHN virus into Cotter Reservoir.	✓	✓	✓	✓
Lack of sufficient information collection and monitoring to be able to compile appropriate Fish Management Plan.	✓	✓	✓	✓

Design and construction for ECD fails to incorporate fish-friendly components.		✓	✓	
Increased erosion resulting in increased nutrients and particulate matter in the aquatic environment upstream and downstream of the ECD (as a result of the construction activity).			✓	
Long-term (10-20 years) decline in fish numbers or growth rates (due to the depletion of nutrients and food sources) following the initial surge in productivity after reservoir filling.				✓
Decline or loss of Macquarie Perch population due to impoundment of reservoir waters submerging spawning areas in the river.				✓
Increased abundance of alien fish in the enlarged reservoir.				✓
Reduction in Macquarie Perch food resources (macroinvertebrates) as a result of loss of macrophytes, sedimentation and fluctuating water levels.				✓
Increased predation on Macquarie Perch in silted and shallower upstream portion of reservoir during spawning migrations.				✓
Inundation of 4 km of river may destroy suitable habitat of the Two-spined Blackfish.				✓

The ECD Fish Management Plan provides mitigation measures for each of these risks. Most of the risk mitigation measures rely on the results of continued monitoring, information from the nine key projects and adaptive management.

In most cases, the identified mitigating measures reduced the risk rating. However, in the case of devastating bushfires, mitigating measures would be unlikely to significantly reduce the risk rating.

Process for updating ECD Fish Management Plan

The ECD Fish Management Plans will be updated at key stages in the ECD process.

Version 1 of the Plan (i.e. this document), is part of the ECD Environmental Impact Statement (EIS) submission process.

Version 2 of the plan will be prepared by December 2009, using the results of completed projects, ongoing monitoring and input from regulators as well as stakeholders. This will allow some time to implement additional options, if the

abovementioned projects are unable to provide suitable results for the management of threatened fish species in the Enlarged Cotter Dam.

Version 3 of the plan will be prepared by December 2011 (when construction is completed for the Dam), once again using the results of completed projects, ongoing monitoring and input from regulators as well as stakeholders. Once again, this will allow some time to implement additional options, if the abovementioned projects are unable to provide suitable results for the management of threatened fish species in the Enlarged Cotter Dam.

Version 4 of the plan will be prepared by December 2013 (2 years after construction is completed for the Dam), using the results of ongoing monitoring and input from regulators as well as stakeholders.

1. INTRODUCTION

1.1. Background

In April 2005, ACTEW Corporation and ActewAGL completed the Future Water Options (FWO) studies (Future Water Options, 2005a and 2005b), which identified the following three main sources of additional supply for the ACT:

- Enlarged Cotter Dam (ECD) on the Cotter River (Future Water Options, 2005c).
- Naas-Gudgenby River catchment (Future Water Options, 2005d).
- Murrumbidgee River (via Tantangara Reservoir), either into Googong Reservoir via a pipeline, or into the Stromlo water treatment plant via the Cotter Pump Station (Future Water Options, 2005e).

In October 2007, ACTEW and the ACT Government announced the commencement of detailed planning and construction of the ECD, thereby increasing its current capacity from 3.8 gigalitres (GL) to 78 GL.

The ECD raises environmental issues regarding the management of the following four threatened fish or crayfish species:

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To obtain the relevant licences and approvals in accordance with Commonwealth and ACT legislation, ACTEW will need to provide sufficient information on how it proposes to protect the threatened fish species during the construction, filling and operational phases of the ECD.

The ECD poses a number of problems as well as opportunities for fish management in the Cotter River Catchment (ACT Government, 2007a; Lintermans, 2005).

The main environmental effects of enlargement will be changes in water level, water temperature, sediment distribution and nutrients, fish habitat, spawning migrations and predation by alien fish species or birds (ACT Government, 2007a; Lintermans 2005). Significant negative impacts on the threatened fish species during construction, filling and operation of the new dam will have to be avoided or mitigated as part of Commonwealth and ACT legislation regarding the protection of threatened species. This means that protective measures such as maintenance or provision of fish passage and installation of artificial fish habitats may need to be implemented to protect these species during and after the reservoir enlargement process. Potential benefits to fish management include a larger habitat for fish, and a greater ability to use environmental flows between Bendora and Cotter Reservoirs.

1.2. Objective of report

The overarching objective of the ECD Fish Management Plan is to:

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

This overarching objective is based on the visions, goals, objectives, and actions developed by the ACT Aquatic Species and Riparian Zone Conservation Strategy (ACT Government, 2007a).

The ECD Fish Management Plan needs to be:

- 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 developed as part of the overall requirements of the ECD.
- Effective in terms of resources and personnel whilst at the same time protecting threatened species.

Consequently, the ECD Fish Management Plan needs to make full use of existing relevant environmental information, but at the same time identify and address knowledge gaps.

1.3. Process for updating ECD Fish Management Plan

This document represents Version 1 of the ECD Fish Management Plan and is produced as an Appendix to the Environmental Impact Statement (EIS), submitted by ACTEW. The document provides a Fish Management Plan for the:

- Design phase.
- Construction phase.
- Filling and operational phases.

ECD Fish Management Plan (Version 2) will be produced at the start of construction (expected to be in December 2009). This will be an update on Version 1 and will incorporate:

- Results from a range of projects (currently being completed), designed to fill in knowledge gaps.
- Changes needed if the range of projects are unable to provide suitable results for the management of threatened fish species in the ECD.
- Results of ongoing monitoring (by ACTEW, ActewAGL, Ecowise, TAMS, University of Canberra and a number of other organisations).
- Input on Version 1 from regulators and stakeholders.

ECD Fish Management Plan (Version 3) will be produced at the commencement of the filling and operational phases (expected to be in December 2011). This will be an update on Version 2 and will incorporate:

- Results from a range of projects (currently being completed), designed to fill in knowledge gaps.
- Changes needed if the range of projects are unable to provide suitable results for the management of threatened fish species in the ECD.
- Results of ongoing monitoring (by ACTEW, ActewAGL, Ecowise, TAMS, University of Canberra and a number of other organisations).
- Input on Version 2 from regulators and stakeholders.

ECD Fish Management Plan (Version 4) will be produced two years into the filling and operational phases (expected to be in December 2013). This will be an update of Version 3 and will incorporate:

- Results of ongoing monitoring (by ACTEW, ActewAGL, Ecowise, TAMS, University

of Canberra and a number of other organisations).

- Input on Version 3 from regulators and stakeholders.

This timetable is summarised in Figure 1 below.

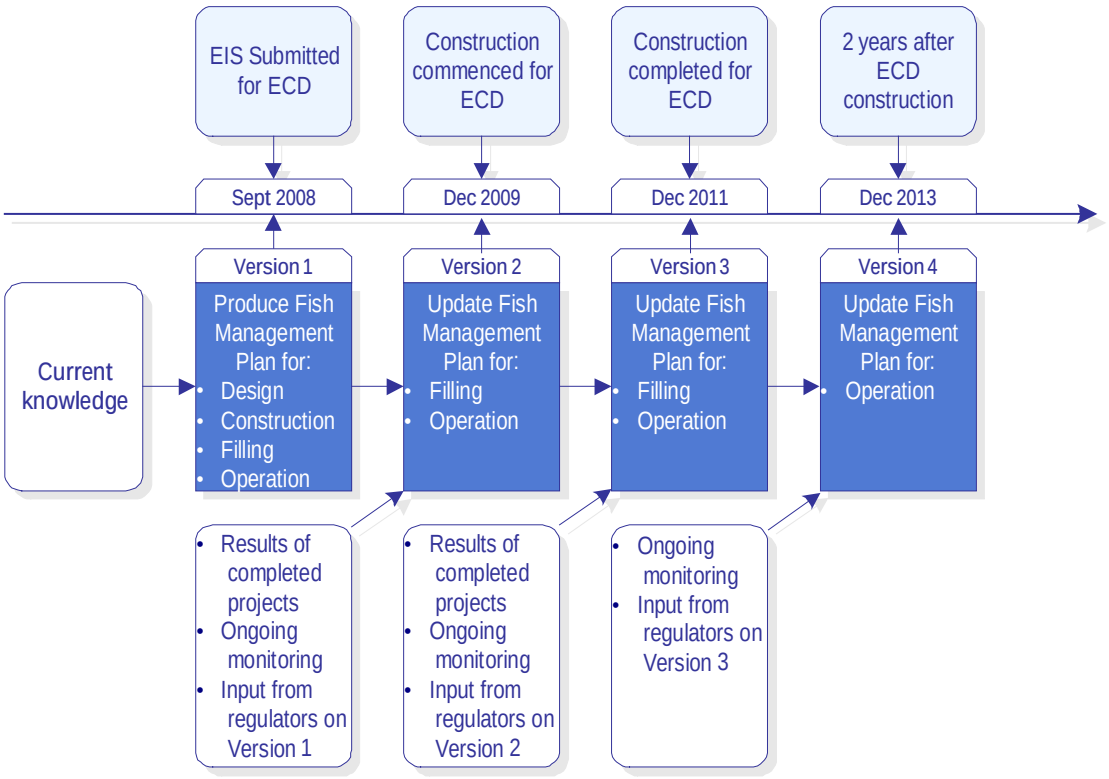

Figure 1: Process for updating ECD Fish Management Plan.

2. SUMMARY OF CURRENT MONITORING IN THE COTTER CATCHMENT

There is currently a considerable amount of ongoing monitoring within the Cotter catchment. The results of these monitoring programs have been used to compile the summary of current knowledge and to propose projects to address knowledge gaps (section 3 of the document). The results from future monitoring programs will be used to update Version 2, 3 and 4 of the ECD Fish Management Plan.

Current monitoring programs can be classified into the following broad categories (which are described further below):

- Rainfall and river flow (by Ecowise and ActewAGL).
- Water quality monitoring (by Ecowise and TAMS).
- Fish population surveys and monitoring (by TAMS).
- River health (by TAMS and University of Canberra).
- Climate change observations and projections (by Bureau of Meteorology).

2.1. Rainfall and river flow

Rainfall and river flow monitoring in the Cotter catchment is undertaken for ACTEW by Ecowise and ActewAGL. There are a number of sites:

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

There are additional sites that measure water levels within Corin, Bendora and Cotter Reservoirs. These are used to calculate storage volumes and to calibrate rainfall and runoff models.

Water quantity information has been collected on the Cotter River for the past 90 years, although only the more recent information is stored electronically.

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

2.2. Water quality monitoring

Water quality monitoring in the Cotter catchment is undertaken for ACTEW by Ecowise.

There are a number of sites within:

- Corin Reservoir.
- Bendora Reservoir.
- Cotter Reservoir.
- Cotter River (and its tributaries).

Sites within the reservoirs are sampled at 3 m 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 (DO), pH.
- Metals (particularly iron and manganese).
- Nutrients such as nitrogen and phosphorus.
- Algae.
- Bacteria.
- Pesticides.

Water quality information has been collected on the Cotter catchment for over 50 years, although only the more recent information (last 30 years) is stored electronically. Information since 1993 can be statistically analysed as it is stored in the Ecowise Laboratory Information Management System.

There is considerable information on Bendora Reservoir, as it has been the most frequently used raw water reservoir in the catchment. Information on Cotter Reservoir is relatively comprehensive from 2002 onwards, but prior to this date information is patchy, as Cotter Reservoir was not used as a water supply source between the early 1970s and 2005.

It is expected that the Ecowise water quality monitoring program will continue in the future.

Additional water quality monitoring is undertaken by 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 AND 2008). It is expected that the TAMS water quality monitoring will also continue in the future.

2.3. Fish population surveys and monitoring

Fish population surveys and monitoring in the Cotter catchment are undertaken by TAMS, to help manage threatened fish species in the river system. The monitoring uses a number of different sampling techniques, including:

- Electro fishing.
- Fyke nets.
- Gill nets.

Recent research projects by TAMS have also used additional techniques which may be applied to monitoring programs. Such techniques include:

- Radio tracking.
- Video cameras.
- Underwater observation by snorkelling.

The monitoring program focuses on the distribution and abundance of threatened fish species and their management (ACT Government, 2008).

Data on fish distribution and abundance have been collected in the Cotter catchment for over 25 years and this information is available in reports and databases (most of which are electronically stored).

It is expected that the TAMS fish monitoring in the lower Cotter catchment will continue in the future.

2.4. River Health

Monitoring of river health is undertaken by the University of Canberra for the ACT Government. The monitoring uses the AUSRIVAS river health assessment index and results are compared to other sites in the ACT (ACT Government, 2007b and 2008).

The monitoring program has been going for about 10 years and it is expected that it will continue in the future.

2.5. Climate change observation and projections

Climate monitoring in the Cotter 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.

3. SUMMARY OF CURRENT KNOWLEDGE AND PROJECTS TO ADDRESS KNOWLEDGE GAPS

3.1. Background

Considerable work has been undertaken during the FWO studies to identify environmental issues associated with the ECD. There are no threatened plant species that would be affected by the enlargement and the potential occurrence of threatened terrestrial animal species is low (Biosis Research, 2005; CRC for Freshwater Ecology, 2004; Lintermans, 2005; Water Research Centre UC, 2005).

However, these studies identified that there are three threatened fish and one crayfish species present in the Cotter Reservoir and the Cotter River that could be potentially affected by the ECD. These are:

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

If no protective measures are taken, the proposed works could significantly impact on all or some of these species and their immediate environment.

Macquarie Perch is addressed, both in terms of Commonwealth and ACT legislation. Macquarie Perch used to be widely distributed in the ACT region, but currently the only sustainable population in the ACT is found in Cotter Reservoir and the Cotter River immediately upstream of the Reservoir. Macquarie Perch have previously been introduced to Bendora Reservoir, but their numbers are currently not sufficient to provide a detectable population (Lintermans, 2005 and 2006c).

Apart from the Cotter Reservoir, small populations of Macquarie Perch are found in a number of other locations in the ACT region, including (ACT Government, 2007a):

- Murrumbidgee River.
- Queanbeyan River immediately upstream of Googong Reservoir (although this is a remnant population).

Other populations of Macquarie Perch in the Murray-Darling Basin in Victoria and NSW are

found in the (Cadwallader, 1981; Ryan *et al*., 2003; Lintermans 2007):

- Mitta Mitta River.
- Upper reaches of Lachlan and Murrumbidgee Rivers.
- Burrinjuck Reservoir.
- Sevens Creek, Goulburn River.

Trout Cod is present in Bendora Reservoir and the Cotter River upstream from Bendora, and it is likely that at least some individuals of this species have been displaced downstream of Bendora Reservoir and are present in the downstream part of the river.

Two-spined Blackfish is present in Corin and Bendora Reservoirs in the Cotter catchment, but is absent in the Cotter Reservoir and the river system downstream of Cotter Reservoir.

Murray River Crayfish is found in the lower Cotter River below Cotter Reservoir, with isolated individuals known from immediately upstream of Cotter Reservoir (Lintermans, 2005), but numbers in the ACT have been substantially reduced over the decades.

The current available information on these species has been recently summarised by Lintermans (2005) as part of the FWO studies, and by ACT Government (2007a).

Despite the considerable information already available on these species, there are some knowledge gaps that still require additional assessments in order to provide a Fish Management Plan for the ECD. These knowledge gaps are identified in a subsequent section, along with key projects currently being conducted to address these knowledge gaps.

Based on these key projects as well as information from a range of sources such as ACT Government (2007a), Lintermans (2005) and Jones *et al*. (2007a and 2007b), a list of risks was compiled. These risks and their mitigation measures are addressed in section 6 of this document.

The ACT Aquatic Species and Riparian Zone Conservation Strategy (ACT Government, 2007a) has been a key document for the ECD Fish Management Plan, and has been used to:

- Identify available information on the four threatened species of concern.
- Assess the environmental impacts of the proposed enlargement in terms of the four threatened species.
- Indicate knowledge gaps that will need to be addressed as part of the ECD Fish Management Plan.

The Action Plan (ACT Government, 2007a) also indicates the main issues related to the introduction of pests and pathogens into the ECD (such as alien fish or pests/diseases that such alien fish may carry or transmit to the native fish population).

3.1.1. Macquarie Perch

3.1.1.1. General distribution

The preferred habitat of Macquarie Perch is cool, shaded, upland streams with deep rocky pools and substantial cover. The species will also survive well in impoundments with suitable feeder streams in which to breed. The species now seems to be confined to the upper reaches of catchments which are more pristine and less impacted by agriculture and sedimentation.

The Murray-Darling form is typically found in the cooler, upper reaches of the Murray-Darling River system in Victoria, New South Wales and the ACT. It is not known from South Australia or Queensland. The coastal form is only known from the Shoalhaven and Hawkesbury-Nepean systems in NSW (Harris and Rowland, 1996; Lintermans, 2007; Morris *et al*., 2001).

3.1.1.2. Current distribution in the Cotter system

Macquarie Perch is considered to be a key species of concern in this project since the only viable ACT population of this threatened species is found in Cotter Reservoir and upstream in the Cotter River (Lintermans, 2006c).

3.1.1.3. Ecology

Macquarie Perch are reported to live for up to 10 years (Battaglene, 1988) but some fish have been aged from otoliths and scales in excess of this age (Douglas *et al*., 2002). Males generally reach sexual maturity at two years of age and 210 mm total length, and females at three years and 300 mm total length (Lake, 1967; Harris and Rowland, 1996). However, running-ripe males have been recorded at ~140 mm in the Cotter River (Lintermans unpublished data) and at 117 mm in Lake Dartmouth (Douglas *et al*., 2002). Fish in reservoirs undertake a spawning migration into inflowing rivers. Fish gather in schools before spawning which can last several weeks (Battaglene, 1988). Spawning occurs in late spring/summer when water temperatures reach approximately 16.5°C (Cadwallader and Rogan, 1977) with fish depositing eggs above riffles or fast-flowing sections of river. The eggs are then washed downstream where they lodge in gravel or rocky areas until hatching (Cadwallader and Rogan, 1977).

Fecundity is approximately 31,000 eggs per kg of fish weight (Cadwallader and Rogan, 1977), with females carrying up to 110,000 eggs (Battaglene, 1988). Larvae hatch in 10-11 days at water temperatures of 15-17°C (Gooley, 1986) with the larvae being about 7 mm long upon

hatching (Battaglene, 1988).

The diet of Macquarie Perch consists predominantly of small benthic insect larvae, particularly mayflies, caddisflies and midges. Shrimps, yabbies, dragonfly larvae and molluscs are also eaten (McKeown, 1934; Cadwallader and Eden, 1979; Butcher, 1945 and 1947; Battaglene, 1988; Lintermans, 2006b).

Research in Cotter Reservoir indicates that young Macquarie Perch prefer edge boulder and cobble habitats with interstitial spaces (Ebner and Lintermans unpublished data), which provide protection from predators. In the Cotter Reservoir it has also been shown that fringing emergent macrophyte beds provide important daytime habitat for adult Macquarie Perch and protection from aerial predators especially cormorants (Ebner and Lintermans unpublished data).

3.1.1.4. Potential impacts of an ECD

With existing knowledge, the main potential impacts of the ECD on Macquarie Perch have been identified as:

- Loss of preferred habitat and cover for adult Macquarie Perch in the reservoir due to the enlarged reservoir inundating macrophyte beds and operating at much higher and more fluctuating water levels.
- Disruption of the breeding cycle of Macquarie Perch by obstructing spawning movements up the Cotter River, depending on water levels in the reservoir.
- Danger of spills or other unforseen events during the construction and filling of the new reservoir that could affect water quality.
- Introduction of the EHN fish virus into the Cotter Reservoir (currently considered not present).
- Expansion of populations of alien fish species as a result of increased water body size in the enlarged reservoir.
- Introduction of new, pest or alien aquatic species into the Cotter River or reservoir.
- Sedimentation during construction activity and subsequently through mobilisation of fine particles by wave action from newly inundated soils around the shoreline of the drawdown zone.
- Increased predation on Macquarie Perch by birds as a result of decreased habitat.

3.1.2. Trout Cod

3.1.2.1. General distribution

Formerly widespread in the southern Murray-Darling Basin (Murray, Murrumbidgee and Macquarie Rivers, NSW/ACT; Ovens, Goulburn, Campaspe, King, Buffalo, Mitta Mitta Rivers, Victoria; Murray River, SA), the species declined significantly in the 1970s. There are few self-sustaining populations of Trout Cod remaining in the wild. The largest is in the Murray River between Yarrawonga and Barmah (approximately 200 km of river); the other is a small translocated population present in about 15 km of the upper reaches of Sevens Creek near Euroa in Victoria. Because of early confusion regarding the identification of Trout Cod, information on the historic distribution of the species is unclear (Douglas *et al.,* 1994; Lintermans, 2007).

3.1.2.2. Current distribution in the Cotter system

Bendora Reservoir contains the only reproducing population of Trout Cod in the ACT (Lintermans, 2007). The Bendora population is the result of restocking of fingerlings in 1989 and 1990 as part of a national recovery plan (Lintermans, 1995; ACT Government, 2007a).

3.1.2.3. Ecology

Trout Cod are essentially a pool-dwelling, cover-seeking fish which is usually associated with instream cover such as fallen timber. Unlike Macquarie Perch, it has not been recorded as heavily reliant on emergent macrophyte beds for shelter.

Sexual maturity is reached at 3–5 years of age when fish are 0.75–1.5 kg and spawning occurs in late spring (mid-October to mid-November). Fecundity is ~1200–11,000 eggs per female. The eggs are large (2.5–3.6 mm diameter), adhesive, and probably deposited on hard substrates such as logs and rocks. After 5–10 days, larvae of about 6–9 mm length hatch (Douglas *et al.*, 1994; Lintermans, 2007).

The species is a carnivorous, top-order predator with diet including fish, yabbies, mudeyes, aquatic insect larvae, shrimps and freshwater prawns (Lintermans, 1995 and 2007).

3.1.2.4. Potential impacts of an ECD

Impacts are limited as Trout Cod are almost exclusively found in Bendora Reservoir. However, individuals would be expected to be displaced downstream to occur in the Cotter Reservoir or the Cotter River between Cotter and Bendora. There is potential for the ECD to provide significant habitat for this species and enhance its population size and security in the Cotter catchment.

3.1.3. Two-spined Blackfish

3.1.3.1. General distribution

This species is only known from the Murray-Darling Basin, where it has been recorded from north-east Victoria, the ACT and south-east NSW. In Victoria it is present in the upper sections of the Goulburn, Broken, Ovens, Mitta Mitta and upper Murray catchments. In the ACT it is only currently present in the Cotter catchment, although it was previously present in the Murrumbidgee and Paddys Rivers, and possibly the Naas/Gudgenby system. In NSW, it is known from the Goodradigbee, upper Murray above Lake Hume, Tumut and Goobarragandra catchments (Lintermans, 1998 and 2007).

3.1.3.2. Current distribution in the Cotter System

Two-spined Blackfish occupy the Cotter River, some permanent tributaries and Bendora and Corin Reservoirs within the Cotter River catchment. It is likely that sediment loads and consequent loss of interstitial habitat is the reason for their absence from the Cotter Reservoir and the Cotter River downstream of Cotter Reservoir (Lintermans, 2002).

3.1.3.3. Ecology

The Two-spined Blackfish is restricted to cool, clear upland or montane streams with abundant instream cover, usually in the form of boulders and cobbles. They are generally found in medium-sized streams where there is greater water depth and lower stream velocity than in the smaller headwater tributaries. They are generally found in forested catchments, where there is little sediment input to the stream from erosion (Lintermans, 2002; ACT Government, 2007a).

Movement of the species is limited, with the home-range of adults estimated at only 15 m. Home-ranges are maintained from year to year, with fish thought to avoid high velocity flows by sheltering amongst the interstitial spaces of rocks and boulders on the stream bed (Lintermans, 1998 and 2007).

The diet of Two-spined Blackfish is dominated by aquatic insect larvae, particularly mayflies, caddisflies and midges, and occasionally fish and crayfish. Adults consume proportionally more terrestrial items than juveniles, indicating the importance of intact riparian vegetation communities as a food source (Lintermans, 2002).

Importantly, Two-spined Blackfish spawn on hard structures (e.g. in rock caves) and males guard and fan the eggs (Lintermans, 2007).

3.1.3.4. Potential impacts of an ECD

Enlargement of Cotter Reservoir has the potential to destroy currently suitable habitat for the

threatened Two-spined Blackfish. Enlargement of the dam will inundate approximately 4 km of river and relocate the initial sediment deposition zone upstream, resulting in the existing suitable habitat being smothered. The rapidity and extent with which this occurs will be dependent on the sediment supply to the reservoir.

It will be important to ensure that Two-spined Blackfish has available habitat to colonise the newly inundated areas of the enlarged Cotter Reservoir. Due to the existing sediment load in the current reservoir, it is unlikely that Two-spined Blackfish would ever colonise the existing dam.

Increased water body size in the enlarged reservoir may also impact on Two-spined Blackfish as a result of increased predation and competition, from increased populations of alien fish species.

3.1.4. Murray River Crayfish

3.1.4.1. General distribution

Murray River Crayfish has the largest geographic range of any of the spiny crayfish in Australia. While most spiny crayfish are restricted to the cooler, montane streams, Murray River Crayfish have extended their range into the warmer, lower reaches of the Murray-Darling Basin. Prior to the 1950s, the species was found in the Murray River for most of its length, as well as in its major tributaries in Victoria and NSW (with the exception of the Darling River). Murray River Crayfish inhabit large and small streams in a variety of habitats including cleared pasture and dry and wet sclerophyll forests at altitudes from close to sea level to over 700 m elevation (Lintermans and Rutzou, 1991; Gilligan *et al*., 2007).

3.1.4.2. Current distribution in the Cotter system

Murray River Crayfish are present in the Cotter system, but are confined to the river below Cotter Reservoir, although occasional individuals have been observed in recent years in a short reach of river immediately upstream of the impounded waters of the Cotter Reservoir.

3.1.4.3. Ecology

Within the ACT, Murray River Crayfish are mainly found in the Murrumbidgee River (Lintermans and Rutzou, 1991). Murray River Crayfish inhabit large and small streams in a variety of habitats, but are most abundant in the main channels of rivers (ACT Government, 2007a).

In the ACT and other upland streams such as the Tumut River, the species tend to use the interstitial spaces between boulders and cobbles on the river bed for shelter, but they are known

to construct burrows in clay river banks in the lower Murrumbidgee and other lowland rivers (Lintermans and Osborne, 2002; Gilligan *et al.*, 2007).

The species feeds mainly on vegetation, scavenged fish and other animals.

Although some aspects of the species ecology are known (e.g. size at breeding), little is known of other ecological requirements, or how these requirements vary with geographic location or between life stages. There are significant knowledge gaps regarding the current population status of Murray River Crayfish in many locations (Gilligan *et al.*, 2007; Ruibal and Fulton, 2008 and 2009).

3.1.4.4. Potential impacts of an ECD

The proposed enlargement of the reservoir will lead to changes in the Cotter River upstream of the reservoir where Murray River Crayfish are present. A major change will be the inundation of a 4 km stretch of river when the reservoir is operated at full capacity.

Depending on rainfall events and water use by Canberra, water levels will fluctuate. This stretch of the Cotter River will consequently be exposed to partial drainage events when water levels in the new reservoir are low.

The flow regime downstream of the ECD will also change, affecting flow velocities and habitat conditions in both the lower Cotter River and adjacent sections of the Murrumbidgee River.

Apart from the risks to the four threatened species, the ECD may also produce some potential benefits for these species. These include:

- A substantially larger water body (and thus potential habitat) for these four threatened species. This may also provide additional food resources, refuge areas from predators and an enhanced thermal refuge from high summer water temperatures.
- Enhanced boulder habitat which could be provided as a result of the construction activity resulting from the enlargement process.
- Potential reduction in some existing movement barriers that currently limit upstream movement of native species (due to the flooding of such barriers by the enlarged reservoir).
- Enhanced stream habitat which could be provided as a result of the construction activity resulting from the enlargement process. This would involve reducing the armouring of stream beds (which may provide suitable habitat for Two-spined Blackfish).

- Greater flexibility with large environmental flow releases from Bendora Reservoir (as the water could still be captured and used by the ECD).

3.2. Location specific ecological impacts

The abovementioned four threatened species are distributed over different parts of the Cotter River catchment. Thus the location specific ecological impacts of the ECD are potentially different for each of the four species. It is difficult to provide more detailed location specific information for these four threatened species, as their movement within the Cotter River catchment can depend on a number of factors including:

- Life stages.
- River flow.
- Water quality.
- Weather and season.
- Spawning migration.

Macquarie Perch is mainly found in the current Cotter Dam, and the Cotter River upstream of Bendora Dam. Thus, the location specific ecological impacts of the Enlarged Cotter Dam on Macquarie Perch cover the present and future reservoir, and the section of river upstream to Bendora Dam. This includes:

- Changes to the macrophyte beds (which currently provide daytime refuge to adult Macquarie Perch).
- Potential changes to spawning habitats available for Macquarie Perch along the Cotter River (up to Bendora Dam).
- Expansion of available water (and thus habitat) for Macquarie Perch. This may be a positive change, although care must be taken to ensure that this additional habitat is not exploited by alien fish species.

A number of projects (described below) will be undertaken to fill knowledge gaps and provide location specific risk mitigation measures for Macquarie Perch. These projects consist of:

- Project 1 – Artificial habitats.
- Project 2 – Swimming capacity of Macquarie Perch.
- Project 4 – EHN virus occurrence.
- Project 5 – Translocation of Macquarie Perch, Trout Cod and Two-spined Blackfish.

- Project 6 – Management program for alien fish species.
- Project 7 – Food sources for Macquarie Perch and drawdown effects.
- Project 8 – Mapping instream barriers.
- Project 9 – Fish monitoring for ECD.

Trout Cod is mainly found in Bendora Reservoir and the Cotter River upstream of Bendora. Thus, the location specific ecological impacts of the ECD on Trout Cod are relatively limited, and include:

- Expansion of additional habitat (in the ECD), that Trout Cod could colonise. This may be a positive change, although care must be taken to ensure that this additional habitat is not exploited by alien fish species.

A number of projects (described below) will be undertaken to fill knowledge gaps and provide location specific risk mitigation measures for Trout Cod. These projects consist of:

- Project 1 – Artificial habitats.
- Project 5 – Translocation of Macquarie Perch, Trout Cod and Two-spined Blackfish.
- Project 6 – Management program for alien fish species.
- Project 7 – Food sources for Macquarie Perch and drawdown effects.
- Project 9 – Fish monitoring for ECD.

Two-spined Blackfish is mainly found in Corin and Bendora Reservoirs and in the Cotter River upstream of Cotter Reservoir (but not Cotter Reservoir itself). Thus, the location specific ecological impacts of the ECD on Two-spined Blackfish are limited to the Cotter River between Cotter and Bendora Reservoirs. The impacts include:

- Potential loss of currently suitable habitat upstream of the present Cotter Reservoir (as the new impoundment may relocate the initial sediment deposition zone upstream, resulting in the existing river habitat being smothered by sediment).
- Expansion of additional habitat (in the ECD), that Two-spined Blackfish could colonise. This may be a positive change, although care must be taken to ensure that this additional habitat is not exploited by alien fish species.

A number of projects (described below) will be undertaken to fill knowledge gaps and provide location specific risk mitigation measures for Two-spined Blackfish. These projects consist of:

- Project 1 – Artificial habitats.

- Project 5 – Translocation of Macquarie Perch, Trout Cod and Two-spined Blackfish.
- Project 6 – Management program for alien fish species.
- Project 9 – Fish monitoring for ECD.

Murray River Crayfish are found in the Cotter River mainly below the current Cotter Reservoir (although occasional individuals have been observed in recent years immediately upstream of Cotter Reservoir). Thus, the location specific ecological impacts of the ECD on Murray River Crayfish are relatively limited. These impacts include:

- Potential loss of currently suitable habitat downstream of the ECD (depending upon the operation of the dam, habitat availability and environmental flows downstream of the dam into the Cotter River).

One project (described below) will be undertaken to fill knowledge gaps and provide location specific risk mitigation measures for Murray River Crayfish. This project is:

- Project 3 – Crayfish ecology.

3.3. Knowledge gaps

Although a substantial amount of information is available on the distribution, abundance and ecology of the four threatened species in the Cotter, a number of knowledge gaps still exist. The main knowledge gaps are identified in ACT Government (2007a) and Lintermans (2005) and are being addressed by the ECD Fish Management Plan. These knowledge gaps (based on ACT Government 2007a and Lintermans 2005) have been summarised in Table 2, along with proposed activities to address these knowledge gaps. A number of these activities consist of key projects which are described in additional detail below. Not all the knowledge gaps on fish management in Table 2 relate directly to the ECD. The knowledge gaps that are within the scope of the ECD Fish Management Plan are addressed in more detail in the Table 2, along with a description of the Key project(s) designed to fill these knowledge gaps.

A number of these projects are completed or currently under investigation. A number will still need to be commissioned and carried out, using appropriate resourcing to address their respective knowledge gaps.

Table 2: Summary of knowledge gaps (with A=from ACT Government 2007a and L=from Lintermans 2005), as well as proposed activities to address these knowledge gaps.

Source	Knowledge gap	Within scope of ECD Fish Manage-ment Plan	Comments
L1	There is little known of the movement requirements of freshwater crayfish (both Murray River Crayfish and *Euastacus crassus*).	×✓	This knowledge gap is partly related to the ECD, and some information will be obtained on this topic for Murray River Crayfish (but not for *Euastacus crassus*), from Project 3 – Crayfish ecology.
L2	There is no knowledge of the ecological requirements and little knowledge of the distribution of *Euastacus crassus* or *E. rieki*.	×	This knowledge gap is not directly related to the ECD.
L3	There is a need to determine spawning cues for Macquarie Perch (an investigation of the role of water temperature, flow and day-length).	×	This is a general knowledge gap on the ecology of Macquarie Perch, and not a direct need produced by the construction of the ECD. Ongoing work by a range of stakeholders may provide information on this in the future.
L4	There is a need to clarify the spawning season of Macquarie Perch and extent of the river being utilised for breeding (larval survey).	× ✓	Part of this knowledge gap is related to the ECD (i.e. the extent of river being utilised for breeding). This information will be provided by Project 9 – Fish monitoring for ECD.
L5	There is a need to identify location and characteristics of Macquarie Perch spawning	× ✓	This is a general knowledge gap on the ecology of Macquarie Perch and not a direct need

	sites.		produced by the construction of the ECD. However, some information will be provided by Project 9 – Fish monitoring for ECD.
L6	Impacts of fluctuating reservoir water levels and river flows on spawning movements of Macquarie Perch need investigation.	✓	Project 9 – Fish monitoring for ECD will provide information on this topic, together with information on rainfall and environmental flows in the Cotter River downstream of Bendora Dam.
L7	Swimming capacity of different life-stages of Macquarie Perch (to enable assessment of potential instream barriers) need investigation.	✓	This is directly related to the ECD. Project 2 – Swimming capacity of Macquarie Perch, and Project 8 – Mapping instream barriers will provide key information on this knowledge gap.
L8	There is a need to make an inventory of, and map potential instream barriers to Macquarie Perch movement, and the behaviour and water velocities over these barriers under different flow volumes.	✓	This is directly related to the ECD. Project 8 – Mapping instream barriers will provide key information on this knowledge gap.
L9	Movement patterns of sub-adult and juvenile Macquarie Perch in both reservoir and riverine habitats need investigation.	×✓	This is a general knowledge gap on the ecology of Macquarie Perch, and not directly due to the construction of the ECD. However, Project 9 – Fish monitoring for ECD will provide some information on this knowledge gap.
L10	There is a need to investigate and quantify cormorant predation on spawning migrations of	×✓	This is partly a general knowledge gap and partly related to the ECD (in the sense that the operation of

	Macquarie Perch.		the ECD may expose Macquarie Perch to greater predation than may be the case otherwise). This knowledge gap is being addressed by Project 1 – Artificial habitats, and by an associated project (partly funded by ACTEW) on cormorant predation.
L11	There is a need to investigate and carry out trials with habitat enhancement in reservoirs (snags and boulder habitat) to enable adequate supply of habitat across fluctuating reservoir levels.	✓	This knowledge gap is directly related to the construction of the ECD. Project 1 – Artificial habitats is designed to address this knowledge gap for Macquarie Perch, but potentially also for other species. The results of an associated project on cormorant predation will also provide information on this knowledge gap.
L12	Options for augmentation of fish passage past 'natural' barriers in the river channel caused by low flow need investigation.	✓	This knowledge gap is directly related to the construction of the ECD. Project 8 – Mapping instream barriers is designed to provide information on this knowledge gap. Additional related information will be provided by Project 2 – Swimming capacity of Macquarie Perch.
L13	Methods for restoring habitat below Cotter Dam as part of dam augmentation (if Cotter Reservoir enlargement is selected as the preferred option) need investigation.	×✓	This is not directly related to the construction of the ECD. However, Project 3 – Crayfish ecology will provide some information on the likely habit types that may enhance the

			suitability of this section of the Cotter River for Murray River Crayfish (which used to inhabit this section of the river). Additional investigations into rehabilitating this stretch of river are being investigated by ACTEW Corporation.
L14	With expanded reservoir size, changes in population levels of alien species such as Oriental Weatherloach, Goldfish, and Eastern Gambusia need investigation.	✓	This is directly related to the construction of the ECD. Project 6 – Management program for alien fish species and Project 9 – Fish monitoring for ECD will provide key information on these knowledge gaps.
L15	With expanded reservoir size, changes in population levels of predatory trout species need investigation. This includes quantification of predation levels on Macquarie Perch and the life-stages involved.	✓	This is directly related to the construction of the ECD. Project 6 – Management program for alien fish species and Project 9 – Fish monitoring for ECD will provide key information on these knowledge gaps.
L16	Techniques for facilitating rapid development of fringing macrophyte beds in new or expanded reservoirs need investigation.	✓	This is directly relevant to the construction of the ECD. It is considered unlikely that macrophytes will develop along the edge of the ECD. Project 1 – Artificial habitats is designed to provide information which will address this knowledge gap (by providing artificial habitats which will shelter Macquarie Perch, which in the current Cotter Reservoir is protected by

			macrophytes. Project 9 – Fish monitoring for ECD will provide key information on changes in macrophytes.
L17	There is a need to monitor deposition of sediment in new or expanded reservoirs and monitor changes in abundance and distribution of Two-spined Blackfish in inundated areas.	✓	This is relevant to the construction of the ECD. Project 9 – Fish monitoring for the ECD is designed to provide information related to this knowledge gap.
L18	There is a need to investigate and carry out trials of translocation strategies for establishing new sub-populations of Macquarie Perch. Such investigations should consider the numbers, timing and life-stages of fish to be used in the establishment trials.	✓	This is relevant to the construction of the ECD. Project 5 – Translocation of Macquarie Perch, Trout Cod and Two-spined Blackfish and Project 9 – Fish monitoring for ECD are designed to provide information related to this knowledge gap.
L19	Laboratory trials are required to test susceptibility of Two-spined Blackfish to EHN virus.	×✓	This is not directly related to the construction of the ECD. However, Project 4 – EHN virus occurrence will provide some information on this topic. Information will also be used from a current project (funded by the Murray-Darling Basin Commission), examining the susceptibility of a range of Murray-Darling Basin fish species to EHN virus.
L20	Field investigations are required on the exposure to and impacts of EHN virus on Macquarie Perch, in particular, to determine if there is serological evidence that ACT populations of Macquarie Perch have been exposed to the virus.	✓	This is directly related to the construction of the ECD. Project 4 – EHN virus occurrence will provide some information on this topic. Information will also be

			used from a current project (funded by the Murray- Darling Basin Commission), examining the susceptibility of a range of Murray-Darling Basin fish species to EHN virus, and development of a test to determine previous exposure to the virus.
A1	Knowledge of general ecological issues for Two-spined Blackfish such as longevity, and habitat management.	✗	These are general knowledge gaps on the ecology of Two-spined Blackfish, and not a direct need produced by the construction of the ECD. Ongoing work by a range of stakeholders may provide information on this in the future.
A2	Knowledge of general ecological issues for Two-spined Blackfish such as spawning requirements and movement ecology.	✓	Knowledge of whether this species will use artificial habitats for spawning in impoundments is required in order to adequately manage this species in the ECD. This knowledge gap is directly related to the construction of the ECD. Project 1 – Artificial habitats is designed to address this knowledge gap for spawning in Two-spined Blackfish.
A3	Knowledge of general ecological issues for Two-spined Blackfish such as effects of alien species, susceptibility to EHN virus, and establishment techniques for new populations.	✓	These issues are being addressed in Projects 4 – EHN virus occurrence, Project 5 – Translocation of Macquarie Perch, Trout Cod and Two-spined Blackfish, and Project 6 – Management program for alien fish species.

A4	Knowledge of general ecological issues for Trout Cod such as breeding requirements; effects of alien species; habitat management; susceptibility to EHN virus; movement ecology; establishment techniques for new populations.	×✓	These issues are not directly related to the construction of the ECD. Trout Cod are currently largely confined to Bendora Reservoir and this population will not be impacted by the ECD. However, some of these issues are being addressed in Projects 4 – EHN virus occurrence, Project 5 – Translocation of Macquarie Perch, Trout Cod and Two-spined Blackfish, and Project 6 – Management program for alien fish species.
A5	Investigate EHN virus impacts on threatened fish.	✓	This is directly related to the construction of the ECD. Project 4 – EHN virus occurrence will provide information on this topic. Information will also be used from a current project (funded by the Murray- Darling Basin Commission), examining the susceptibility of a range of Murray-Darling Basin fish species to EHN virus, and development of a test to determine previous exposure to the virus.
A6	Effects of alien Trout and Redfin Perch on Macquarie Perch.	✓	This is directly related to the construction of the ECD. Project 6 – Management program for alien fish species and Project 9 – Fish monitoring for ECD will provide key information on these knowledge gaps.

A7	Movement ecology of riverine populations of Macquarie Perch.	×✓	This knowledge gap was addressed by a recent NHT project to investigate movement of the Cotter riverine population of this species in relation to environmental flow releases. Project 9 – Fish monitoring for ECD and Project 2 – Swimming capacity of Macquarie Perch will provide ongoing information on how this species utilises the river and fishways. Also see L9 above.
A8	Swimming capabilities of different life stages for Macquarie Perch.	✓	See L7 above.
A9	Spawning cues and timing of spawning for Macquarie Perch.	×✓	See L3 and L4 above.
A10	Techniques to enhance adult habitat cover for Macquarie Perch during reservoir drawdown.	✓	See L11 above.
A11	Impact of bird or mammalian predation on remnant populations of Macquarie Perch.	×✓	See L10 above.
A12	Techniques to maintain pool habitat after bushfire sedimentation.	×	This is a general knowledge gap on the ecology of Macquarie Perch and not a direct need produced by the construction of the ECD. However, some information will be provided by Project 9 – Fish monitoring for ECD. Also see L17 above.
A13	Genetic structure of existing Macquarie Perch populations in the upper Murrumbidgee River.	×	This issue is not directly related to the construction of the ECD. However, a project by the ACT Government and the University of Canberra is currently addressing

			this knowledge gap.
A14	Effective adult populations size of the Cotter Reservoir Macquarie Perch population.	✓	A project by the ACT Government and the University of Canberra is currently addressing this knowledge gap (see A13 above), and Project 9 – Fish monitoring for ECD will also provide information related to this.
A15	Knowledge of general ecological issues for Murray River Crayfish such as movement ecology; effects of alien species; age at first breeding requirements; habitat requirements and usage; and juvenile ecology.	×✓	This knowledge gap is partly related to the ECD, and some information will be obtained on this topic for Murray River Crayfish (but not for *Euastacus crassus*), from Project 3 – Crayfish ecology. See L1 above.

The projects designed to address knowledge gaps related to the ECD Fish Management Plan are described below. These projects will assist with producing Version 2, 3 and 4 of the ECD Fish Management Plan.

A number of projects have been completed or will be completed by December 2009 (when Version 2 of the ECD Fish Management Plan will be produced). A number of projects have been funded, scoped and will be commencing in the near future. On most projects, consultation and collaboration will be undertaken with the ACT Research and Planning Unit of Parks, Conservation and Lands (TAMS).

3.3.1. Project 1 – Artificial habitats

The proposed enlargement of Cotter Reservoir will lead to a variety of changes both in the reservoir itself and in the Cotter River upstream of the reservoir. One of the main changes is inundation of the emergent macrophyte beds that occur predominantly in the upstream half of the existing reservoir. These fringing emergent macrophyte beds (primarily *Phragmites australis*) have been shown to provide important daytime resting habitat for adult Macquarie Perch (Ebner and Lintermans unpublished data). These reedbeds are considered to be the only available refuge for adult Macquarie Perch from predation by cormorants, and the reedbeds may also provide cover and/or feeding habitat for smaller life stages of Macquarie Perch.

Filling of the enlarged reservoir will result in the loss of these macrophyte beds, as they will be inundated by up to 50 m depth of water (Lintermans, 2005).

The new reservoir will be used as a regulatory reservoir, which means that water levels could fluctuate dramatically depending on rainfall events and water use by Canberra. Rapidly fluctuating water levels will likely result in a failure to develop fringing emergent macrophyte beds to replace those lost through inundation. The enlarged reservoir will also inundate a 4 km stretch of river when the reservoir is operated at full capacity, leading to sediment deposition in this newly inundated reach. As a result of the previously mentioned fluctuating water levels, this reach of the Cotter River will be exposed to partial drainage events when water levels in the new reservoir are low. The changing water levels in this part of the Cotter River can impose limitations on the ability of threatened fish to utilise or move through this part of the river. For example, the Macquarie Perch spawning migration from the reservoir up the Cotter River which occurs between October and December (Lintermans, 2005) could be severely impacted if fish are required to move through a featureless, sedimented river section to reach suitable spawning habitats. Such a migration would expose spawning fish to increased predation risk from avian predators such as cormorants.

The population of Macquarie Perch in the Cotter Reservoir and River is the sole remaining viable population in the ACT (Lintermans, 2006c; Jones *et al.*, 2007a and 2007b) and needs to be protected to ensure ongoing survival of this species in the ACT. Similarly, the inundation of an additional 4 km of river will impact on the population of Two-spined Blackfish in this river reach. Two-spined Blackfish are not present in the current Cotter Reservoir, presumably as a result of excessive sedimentation smothering suitable spawning sites (Lintermans 2005). It is unknown whether or how quickly this species will colonise the ECD, and whether the species will be able to breed in the new ECD. This species is absent from the existing Cotter Reservoir due to the high sediment volumes in the reservoir. Two-spined Blackfish are present in Bendora Reservoir (low sediment abundance) but it is unknown whether these fish breed in the reservoir itself or in the river upstream and then disperse.

Consequently, a project has commenced to investigate the potential use by adult Macquarie Perch of artificial refuge habitats and Two-spined Blackfish of artificial spawning habitats constructed in the reservoir.

The objectives of this project are to:

- Evaluate the suitability of artificial habitats for Macquarie Perch and Two-spined Blackfish in the current and an enlarged Cotter Reservoir.

- Provide guidelines for the construction of artificial habitats in the ECD.
- Provide information needed for the production of management procedures for the operational phase of an ECD.

Phase 1 of this project has now been completed (Lintermans *et al.*, 2008). Phase 2 will be completed in December 2012, and will complete the assessment of artificial refuge habitat use by Macquarie Perch and the assessment of artificial spawning habitat use by Two-spined Blackfish.

3.3.2. Project 2 – Swimming capacity of Macquarie Perch

Previous dam construction activities in the Canberra region have demonstrated unforeseen effects on Macquarie Perch where the newly constructed dam impounded water up to a natural barrier (such as a waterfall), preventing fish from accessing flowing waters (Lintermans, 2006b). Macquarie Perch only spawn in flowing waters and so must leave the impoundment to successfully breed. To avoid fish passage issues for Macquarie Perch moving to spawning habitats, the location of potential barriers needs to be investigated, and activities to mitigate such barriers may need to be conducted in the Cotter River upstream from the enlarged reservoir. Significant knowledge gaps exist regarding the swimming abilities of native and alien fish species and how this might influence the design of fish passages. The main knowledge gaps that need to be addressed are:

- The swimming ability of different size classes of Macquarie Perch.
- Potential mobility barriers to the passage of native fish.

ACTEW will use the results from the project (and Project 8 – Mapping instream barriers), to mitigate potential fish passage issues in the Cotter River and to provide management plans for the operational phase of the new dam. The release of (environmental) flows from Bendora Reservoir into the Cotter River will have to be controlled so that water level, temperature and flow are optimal during the time that Macquarie Perch move up the Cotter River to spawn. Similarly, operation of the ECD itself will need to take into account the requirement of operating at a high capacity during the Macquarie Perch spawning season so that fish do not have to negotiate potential barriers on their spawning migration.

The objectives of this project are to:

- Provide information on the swimming capabilities of various size classes of Macquarie Perch.
- Provide recommendations for the maintenance or enhancement of optimum fish

passage for native species.

- Provide recommendations for optimum operation of water levels in the ECD, to facilitate Macquarie Perch spawning migrations at crucial times of the year.
- Provide recommendations for optimum timing and quantity of environmental flow releases from Bendora Reservoir.

This project will be completed in July 2009, with some key results already provided (Fulton, 2008; Fulton and Cummin, 2008).

3.3.3. Project 3 – Crayfish ecology

Murray River Crayfish populations have declined dramatically in Australia due to a combination of harvesting and landscape modifications (Gilligan *et al.*, 2007). Murray River Crayfish are distributed along the length of the Murrumbidgee River in the ACT, as well as parts of the lower Paddys River (Lintermans and Rutzou, 1991; Lintermans, 2002). The geographical distribution of Murray River Crayfish in the Cotter catchment is limited to the stretch of Cotter River below the current Cotter Reservoir and a short reach of the river immediately upstream of Cotter Reservoir (Lintermans, 2005).

Significant knowledge gaps exist regarding the current population status of Murray River Crayfish and its habitat requirements over much of its range (Gilligan *et al.*, 2007). These knowledge gaps need to be addressed in order to conserve this species, which may be an important indicator of river health. The main knowledge gaps that will be addressed by the proposed project are:

- What are the main ecological requirements of Murray River Crayfish, in the Cotter and Murrumbidgee Rivers?
- What are the optimum flow speeds, water temperatures and habitat preferences for the different life-stages of Murray River Crayfish and their competitors?
- What environmental flows are likely to enhance the reproduction and survival of Murray River Crayfish?

The results from these studies will be used to design artificial habitats for Murray River Crayfish in the Cotter River. Additionally, management advice for environmental flow releases from Cotter and Bendora Reservoir will be provided based on the flow and temperature requirements of Murray River Crayfish during critical life-stages such as early development and breeding. These measures, in combination with potential translocations of individuals to suitable (artificial) habitats, will provide a comprehensive protection strategy for Murray River

Crayfish in the Cotter River.

The objective of this project is to:

- Determine the current distribution and population status of Murray River Crayfish, their likely competitors and predators in the Cotter and Murrumbidgee Rivers.
- Determine the preferred flow conditions and natural habitat requirements of Murray River Crayfish.
- Propose suitable artificial habitats for Murray River Crayfish.
- Produce recommendations for timing and quantity of environmental flow releases from Cotter Reservoir (current and enlarged) and Bendora Reservoir.

This project will be completed in December 2009, with some key results already provided (Ruibal and Fulton, 2008 and 2009),

3.3.4. Project 4 – EHN virus occurrence

This project (just recently completed) was undertaken to determine if the Epizootic Haematopoietic Necrosis (EHN) virus is present or absent in the fish population of Cotter Reservoir.

This virus, unique to Australia, was first isolated in 1985 on the alien Redfin Perch (Langdon *et al.*, 1986). It is characterised by sudden high mortalities of fish displaying necrosis of the renal haematopoietic tissue, liver spleen and pancreas (Langdon and Humphrey, 1987). Experimental work by Langdon (1989a and 1989b) demonstrated that Macquarie Perch was one of several species found to be extremely susceptible to the disease. The susceptibility of other threatened fish species in the Cotter catchment (Two-spined Blackfish and Trout Cod) has not been investigated. The EHN virus was first recorded in the Canberra region in 1986 when an outbreak occurred in Blowering Reservoir near Tumut (Langdon and Humphrey, 1987). Subsequent outbreaks have occurred in Lake Burrinjuck in late 1990, Lake Burley Griffin in 1991 and 1994, Lake Ginninderra in 1994 and Googong Reservoir, also in 1994 (Whittington *et al.*, 1996 and 1999).

The results of this project (Whittington, 2008), have indicated that the EHN virus is absent from the Cotter Reservoir and from the Murrumbidgee River immediately downstream of the Cotter River.

As the EHN virus is not present in Cotter Reservoir, then any monitoring, construction and post-construction activities must ensure that the virus continues to be excluded from the Cotter system upstream from the Cotter Dam. Efforts should centre on preventing the establishment of

the alien Redfin Perch (*Perca fluviatilis)* which acts as a major host for the virus, and may allow the virus to magnify into proportions large enough to impact on native fish species.

To obtain the necessary information, the project (Whittington, 2008):

- Sampled fish from upstream as well as downstream of Cotter Reservoir, using the available virus testing systems which relied upon:
    - Known susceptible species of fish from Cotter Reservoir (Rainbow Trout *Oncorhynchus mykiss* and Mountain Galaxias *Galaxias olidus*) or the catchment immediately upstream.
    - An antibody test for the EHN virus.

The desired outcome of this project was to:

- Determine if the EHN virus is present in the fish population of Cotter Reservoir.

3.3.5. Project 5 – Translocation of Macquarie Perch, Trout Cod and Two-spined Blackfish

This project's major aim is to reduce the overall risk of extinction of Macquarie Perch in the ACT by establishing further populations of this species outside the area potentially affected by the ECD. Currently the only sustainable population of Macquarie Perch in the ACT is in Cotter Reservoir (Lintermans, 2006c). Investigation of potential translocation needs and options for Trout Cod and Two-spined Blackfish will also be conducted.

Other projects within the fish studies program have been designed to minimise or mitigate threats to the Cotter population of Macquarie Perch, but there is still a risk of unforseen events that could endanger the population during the construction, filling and operation of the ECD. Examples of these are catastrophic spills during the construction process or other unforseen events that could destroy the existing Macquarie Perch population in the reservoir.

Since the current population in Cotter Reservoir represents the only viable population of this species in the Cotter system and the ACT, it is crucial that measures are put in place to establish additional sustainable populations of Macquarie Perch at alternative locations. As there are no government or commercial breeding programs for Macquarie Perch operating in Australia, translocation is the only available methodology to achieve this outcome, and has been used for a number of threatened freshwater species (Lintermans, 2006a).

For example, translocation of Macquarie Perch was successfully carried out from Googong Reservoir to the Queanbeyan River upstream, with an actively recruiting population present approximately 15 years after translocation in 1996-97 (Lintermans, 2006b). However, the risk

of relying on a single translocated population is highlighted by the fact that the Queanbeyan River Macquarie Perch population is currently at non-detectable population size (Jones *et al.*, 2007a and 2007b), probably as a result of the prolonged drought and the resultant repeated failure to successfully breed (Lintermans unpublished data). This clearly demonstrates the need to establish multiple additional populations.

The objectives of this project are to:

- Establish sustainable population(s) of Macquarie Perch in alternative location(s) in the Cotter system, to act as a backup for the existing population in the current Cotter Reservoir during the construction, filling and operation of the enlarged reservoir.
- Monitor the translocated populations in the new location(s).
- Investigate the need for and potential options for translocating Trout Cod and Two-spined Blackfish in the Canberra region.

The project has six main elements spread over two components. They are:

- Component 1: Hands-on translocation of Macquarie Perch:
- Identification and selection of potential translocation sites;
- Investigation of the fish fauna and habitat conditions at potential sites;
- Translocation of fish from Cotter Reservoir; and
- Monitoring success of translocation.
- Component 2: Modelling translocation strategies for Macquarie Perch:
- Modelling of potential translocation strategies for each site; and
- Investigation of the need for and translocation options for Trout Cod and Two-spined Blackfish.

The adult population size of Macquarie Perch in Cotter Reservoir is unknown, and the removal of significant numbers of adults from Cotter Reservoir may itself pose a threat to the viability of this population. Consequently, alternative translocation options need to be investigated (Lintermans, 2003). It is proposed that juvenile individuals be used in translocation programs as these fish would normally be expected to suffer high natural mortality in the first year or two of life and the removal of these fish from Cotter Reservoir should not adversely affect the donor population.

Two locations have already been selected (Cotter River above Corin Dam; Molonglo River above Molonglo Gorge) and translocation commenced to these two sites in 2006 and 2007

respectively (Lintermans, 2006c; Lintermans unpublished data). However, additional translocations sites need to be established. This project will operate over a long time-frame, for a number of reasons. The use of juvenile fish means that these fish will be unable to immediately reproduce at reintroduction sites, and so the establishment of reproducing populations will take longer than if adult fish were used. To minimise potential impacts on the donor population, only small numbers of fish will be translocated each year. It is expected that translocations will occur over several years at each location to establish sufficient individuals to provide reproducing populations. As monitoring programs to detect the establishment of viable populations have taken in excess of 10 years in other translocation projects (Lintermans, 2003 and 2006b), evidence of the successful establishment of viable populations will take many years.

A similar contingency approach of establishing populations of threatened species elsewhere was used during maintenance work on the Waroona Dam in Western Australia (Molony *et al.*, 2005).

3.3.6. Project 6 – Management program for alien fish species

The proposed enlargement of Cotter Reservoir is expected to result in a number of changes to alien fish abundance, distribution and impacts on native fish species in and upstream of the new impoundment (Lintermans 2005; Jones *et al.*, 2007a and 2007b). Preferred lentic environments of some species (Goldfish, Eastern Gambusia, and Oriental Weatherloach) will significantly increase in area, and the establishment of a large thermal refuge in the expanded reservoir may enhance Trout populations. New reservoirs are usually characterised by increased food resources in the short-term, leading to dramatic increases in average size and growth rates of species such as Trout.

Potential biotic changes include:

- Within the reservoir:
    - Expansion of distribution and abundance of existing alien species such as Eastern Gambusia, Oriental Weatherloach, Goldfish and Trout.
    - Introduction of new alien species such as Carp and Redfin Perch (and associated diseases).
    - Increased predation of Macquarie Perch and Two-spined Blackfish by Trout.
- Upstream of the reservoir:
    - Seasonal increases in Trout abundance (as a result of expanded thermal refuge

within the reservoir).

- Increased predation of Macquarie Perch and Two-spined Blackfish by Trout.

A coordinated management program to investigate, mitigate and/or monitor these changes and their associated impacts is required. The objectives of the program are to:

- Scope the potential changes to alien fish populations.
- Establish baselines against which future changes can be measured.
- Identify, prioritise and address relevant information gaps.
- Identify, design and implement management interventions to mitigate threats to native fish in the reservoir and upstream river reaches.

The upstream invasion of alien fish species, from the Cotter River below the existing dam into the enlarged reservoir, will be prevented through careful design of the construction methodology. To minimise the risk of transfer, no water from below the existing dam wall will be used for construction purposes, and the space between the old and the new dams will be thoroughly dried out prior to commissioning the new dam.

This project will work closely with Project 9 – Fish monitoring for ECD.

3.3.7. Project 7 – Food sources for Macquarie Perch and drawdown effects

The proposed enlargement of Cotter Reservoir and it subsequent operation will lead to a variety of changes to the productive habitats that provide the major food resource for all species of the resident fish populations. Emergent macrophytes, submerged macrophytes and large woody debris (post fire) all provide shelter and are the primary structural habitat for macroinvertebrates. Indications from preliminary work are that most of the biomass and numbers of invertebrates that provide fish food are freshwater shrimp that are most common in the submerged and emergent macrophyte beds.

Evidence from other studies is that newly filled reservoirs can be highly productive after initial filling. However, subsequent operation with frequent drawdown can lead to the normally productive littoral zones losing emergent and submerged macrophytes and losing much invertebrate production on which the fish rely.

The objectives of the project are to assess:

- The main food of Macquarie Perch and the other resident fish species.
- The habitat features that support invertebrate production as food items.

- By comparison with other local reservoirs with drawdown characteristics (e.g. Corin and Googong, possibly Tantangara) establish the availability of food items and the effects of drawdown.
- Whether sufficient food will be available in the long term to support the fish population and consider if competition for food within is likely to limit the Macquarie Perch population.
- Whether habitats may be provided, or enhanced to promote the production of fish food.

3.3.8. Project 8 – Mapping instream barriers

Macquarie Perch are the only native fish known to make regular river-reach or local migratory movements in the Cotter catchment (Lintermans, 2005). Due to this migratory nature and the requirement for adequate riverine spawning habitat, Macquarie Perch is susceptible to in-stream barriers. The lack of access to suitable spawning habitat can lead to the extinction of populations, as has been seen in Googong Reservoir (Lintermans, 2002, 2005 and 2006b).

This project (partly funded by ACTEW Corporation), is designed to map and investigate barriers to fish passage in the Cotter River upstream of Cotter Reservoir.

The intention of this work is to map accessibility of the Cotter catchment's stream network by mapping the barriers to Macquarie Perch. The identification of possible fish barriers will help effectively target sites to restore connectivity in the rivers and streams of the Cotter catchment.

The objectives of the project are to:

- Identify barriers to fish dispersal, specifically for Macquarie Perch (*Macquaria australasica*) from Cotter Reservoir.
- To test whether digital elevation models and geographic information systems can be used to identify physical fish barriers.
- Determine the best resolution of the digital elevation models to identify the natural and anthropogenic barriers to fish dispersal.

This project will be completed in March 2009, and will use information provided by Project 2 – Swimming Capacity of Macquarie Perch.

3.3.9. Project 9 – Fish monitoring for ECD

An integrated monitoring program is required to enable the results of mitigation actions to be assessed and to complete the adaptive management cycle.

Many monitoring programs fail because the programs were not rigorously designed

(statistically), were conducted on an ad-hoc basis, failed to identify the questions to be answered by the monitoring, or failed to adequately address the questions that were expected to be answered by the monitoring. This is especially so for organisms that are rare and/or threatened because of problems in collecting or measuring enough individuals to achieve sufficient statistical power combined with the practical and ethical problems of the risks associated with handling them.

The monitoring program must contain a number of essential elements if there is to be confidence that the correct information is being collected.

Essential elements of any monitoring program that must be addressed are:

- A clear statement of the objectives of the monitoring program.
- What statistical techniques will be used, to analyse data from the monitoring program (This will influence the program design). Also, what statistical power or confidence in the conclusion is deemed appropriate for the study?
- What species and life stages are to be targeted (this will influence the sampling methods used)?
- What temporal sampling strategy is required (number of samples, seasons, and years)?
- What spatial sampling strategy is required (number of intervention sites, control sites, within or outside catchment)?
- Are there existing monitoring data that can be built upon (i.e. common methods and sampling framework)?

Issues in the ECD project that will require monitoring programs include:

- Changes in Macquarie Perch and Two-spined Blackfish populations in the ECD (juveniles, sub-adults and adults).
- Annual recruitment in Macquarie Perch and Two-spined Blackfish populations in the ECD.
- Changes in the abundance, distribution and size composition of Trout in the ECD.
- Levels of predation on Macquarie Perch and Two-spined Blackfish larvae and juveniles by Trout in the ECD.
- Changes in the abundance, distribution and species composition of piscivorous birds in the ECD.

- Changes in the abundance and size composition of Trout in the river upstream of the ECD.
- Changes in the abundance and distribution of Macquarie Perch and Two-spined Blackfish populations in the Cotter River above and below Vanity's Crossing.
- Changes in the abundance, and species composition of submerged and emergent macrophytes in the ECD.
- Survival and reproduction of translocated populations.
- Relationships between operation (drawdown regimes) of the ECD and the Macquarie Perch population in terms of:
    - Effects on habitat use and available habitat types.
    - Predation.
    - Food sources.
    - Limiting factors.

Synergies between existing monitoring programs and the abovementioned information will be explored, in order to share resources and information.

3.4. Associated Projects

A number of associated projects will also provide information to address knowledge gaps. These include:

- A study on the use of macrophyte beds by adult Macquarie Perch in Cotter Reservoir and the impact of these macrophyte beds on the predation of Macquarie Perch by cormorants. This project is currently being conducted at the University of Canberra (with partial funding from ACTEW Corporation).
- A study on the susceptibility of selected Murray-Darling Basin fish species to the EHN virus, and the development of a diagnostic test to determine previous exposure of fish to the EHN virus. This project is currently being conducted with funding from the Murray-Darling Basin Commission, by a team from the University of Sydney, which recently completed EHN monitoring in Cotter Reservoir (Project 4).
- Other projects and/or research by stakeholder organisations, particularly the ACT Research and Planning Unit of Parks, Conservation and Lands (TAMS).

3.5. Summary Risks

A number of risks have been identified for fish management in an ECD (ACT Government, 2007a; Lintermans, 2005; Jones *et al*. 2007a and 2007b). These risks, plus a number of additional risks that have been identified since, are summarised in Table 3 below, and addressed in detail in section 6 of this document. Risks have been categorised for the different phases of the ECD project (with a number of risks present in all phases).

Table 3: Summary of risks (CS=current situation, D=design phase, C=construction phase, FO=filling and operational phases).

Risks	CS	D	C	F O
Increased erosion resulting in increased nutrients and particulate matter in the aquatic environment (as a result of the January 2003 bushfires and subsequent storm events).	✓	✓	✓	✓
Increased nutrients resulting in oxygen depletion in Cotter Reservoir, and reducing habitat for threatened fish.	✓	✓	✓	✓
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) and increased cormorant predation through reduced refuge area.	✓	✓	✓	✓
Road crossings and other barriers reducing fish passage in Cotter River during spawning.	✓	✓	✓	✓
Releases from Bendora Reservoir providing the wrong temperature signal during the spawning season.	✓	✓	✓	✓
Insufficient or inappropriate environmental flows in the Cotter River upstream and downstream of Cotter Reservoir.	✓	✓	✓	✓
Increased chance of fuel spill, oils and other contaminants entering the aquatic environment.	✓	✓	✓	✓
Increased chance of pathogens and/or pests entering the aquatic environment.	✓	✓	✓	✓
Increased chance of devastating bushfires (due to increased human activity in the catchment, or inappropriate fire management practices	✓	✓	✓	✓

which may reduce small to medium size fires but actually increase the chance of large fires).				
Dam operating practices causing fish mortality or entrainment near off-take structures.	✓	✓	✓	✓
Increased chance of introducing the EHN virus into Cotter Reservoir.	✓	✓	✓	✓
Lack of sufficient information collection and monitoring to be able to compile appropriate Fish Management Plan.	✓	✓	✓	✓
Design and construction for ECD fails to incorporate fish-friendly components.		✓	✓	
Increased erosion resulting in increased nutrients and particulate matter in the aquatic environment upstream and downstream of the ECD (as a result of the construction activity).			✓	
Long-term (10-20 years) decline in fish numbers or growth rates (due to the depletion of nutrients and food sources) following the initial surge in productivity after reservoir filling.				✓
Decline or loss of Macquarie Perch population due to impoundment of reservoir waters submerging spawning areas in the river.				✓
Increased abundance of alien fish in the enlarged reservoir.				✓
Reduction in Macquarie Perch food resources (macroinvertebrates) as a result of loss of macrophytes, sedimentation and fluctuating water levels.				✓
Increased predation on Macquarie Perch in silted and shallower upstream portion of reservoir during spawning migrations.				✓
Inundation of 4 km of river may destroy suitable habitat of the Two-spined Blackfish.				✓

4. LEGISLATIVE REQUIREMENTS

4.1. Commonwealth legislation

The *Environment Protection and Biodiversity Conservation Act* 1999 is the Australian Government's principal piece of national environmental legislation.

Since its implementation, the EPBC Act has transformed environmental management and planning, particularly in relation to large infrastructure projects. The EPBC Act has increased the:

- Requirements for environmental assessment.
- Profile of nationally significant environmental issues.
- Need for considering environmental matters at the project design phase.
- Ability of organisations and individuals to be involved in the decision making process.

Generally, projects have a higher chance of approval if the proponents make use of available scientific information and formulate well-considered management procedures which minimise, mitigate or eliminate negative impacts on threatened species. This approach has tended to:

- Increase the chance of an approval by the Minister for the Environment.
- Reduce the chance of legal challenges from organisations or individual (which can occur even after an approval has been granted by the Minister for the Environment).
- Increase support for the project in the courtroom of public opinion.

4.1.1. EPBC Act requirements

The *EPBC Act* prescribes the Commonwealth's role in environmental assessment, biodiversity conservation and the management of protected areas.

Under provisions of the *EPBC Act*, actions that are likely to have a *significant impact* on a matter of national environmental significance (MNES) are subject to a rigorous assessment and approval process.

Part 3 Division 1 of the *EPBC Act* identifies one of these MNES as nationally 'listed threatened species or endangered ecological communities'. Under s18 of the Act any action that has, or is likely to have, a significant impact on a threatened species becomes a 'controlled action' and requires assessment and approval by the Commonwealth Minister for the Environment, if the species is:

- extinct in the wild;
- critically endangered;
- endangered; or
- vulnerable.

4.1.2. Assessment of what is a 'significant impact' on a Matter of National Environmental Significance

Administrative guidelines, namely *EPBC Act–Principal Significant Impact Guidelines 1.1: Matters of National Environmental* Significance (Department of Environment and Heritage, 2006) sets out a range of criteria to assist in assessing the potential for impact on listed threatened species.

These guidelines outline criteria for endangered species for an action that has, or is likely to have a significant impact if it does, or is likely to:

- lead to a long-term decrease in the size of a population; or
- reduce the area of occupancy of the species; or
- fragment an existing population into two or more populations; or
- adversely affect habitat critical to the survival of a species; or
- disrupt the breeding cycle of a population; or
- modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline; or
- result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species´ habitat1; or
- interfere with the recovery of the species.

Habitat critical to the survival of a species or ecological community may include areas that are necessary:

- for activities such as foraging, breeding, roosting, or dispersal;

[1] Introducing an invasive species into a habitat may result in that species becoming established. An invasive species may harm a critically endangered or endangered species by direct competition, modification of habitat, or predation.

- for succession;
- to maintain genetic diversity and long term evolutionary development; or
- for the reintroduction of populations or recovery of the species/community.

4.1.3. Description of nationally listed threatened species

Considerable work was undertaken during FWO to identify key environmental considerations that would potentially affect the enlargement of Cotter Reservoir.

Studies identified two fish species present in the Cotter Reservoir and the Cotter River that are listed as endangered under the *EPBC Act* (Lintermans, 2005).These are:

- Macquarie Perch (*Macquaria australasica*).
- Trout Cod (*Maccullochella macquariensis*).

It is anticipated that the enlargement works therefore trigger the requirement for a referral to the Commonwealth Minister for the Environment under the *EPBC Act*.

4.1.4. National Recovery Plans for threatened species

Section 268 of the *EPBC Act* requires that a Commonwealth agency must not take any action that contravenes a species recovery or threat abatement plan. For the Minister to approve the action, he/she must consider any approved conservation advice for a threatened species.

The Commonwealth therefore prepares National Recovery Plans for species and ecological communities listed as endangered under the *EPBC Act*.

A National Recovery Plan has been in operation for several years for the endangered Trout Cod (Brown *et al*., 1998; Trout Cod Recovery Team 2004, and 2008). A National recovery plan is currently being drafted for Macquarie Perch, but will not be completed before the ECD commences.

In addition, there were Territory Action Plans (ACT Government, 1999a and 1999b) for the recovery of these species under the ACT's *Nature Conservation Act* 1980. These Action Plans have now been reviewed and incorporated into a multi-species Conservation Strategy (ACT Government, 2007a).

4.1.5. Referral and assessment process

Advice was sought from Department of the Environment, on the need to refer the ECD proposal to the Minister under the EPBC Act, and in particular what issues would need attention in an EIS.

Advice confirmed that the enlargement works trigger the requirement for a referral to the Minister due to the anticipated impact on endangered fish species and their habitat, specifically the Macquarie Perch.

Based on the referral, within 20 days the Minister will deem the ECD proposal as:

- unacceptable action – action not allowed; or
- controlled action – approval required; or
- approval not required – manner specified.

If the action is deemed *unacceptable*, the proposed enlargement of the ECD will not be allowed to take place.

A *controlled action* means that the proposal will pass to the next stage of the process, the assessment and approval stage. An environmental assessment and impact statement will be required by the Commonwealth Minister, who will then either approve the proposal with or without constraints, or not approve the proposal.

If the information provided in the referral sufficiently explains what measures will be put into place to avoid significant impacts on the endangered fish species, the Commonwealth Minister may deem the proposal as *approval not required manner specified*[2]. This means the EPBC Act is not triggered, and the action does not need to go through the assessment process on the condition that the action is undertaken in the manner prescribed.

The studies and management advice that are proposed in the ECD Fish Management Plan address the protective measures that will be put into place to avoid significant impact on the endangered species under the *EPBC Act*. Therefore, these studies and management advice are crucial in obtaining a successful *EPBC Act* approval outcome.

4.1.6. Environmental impact statement

If the Minister declares the enlargement works a 'controlled action', an assessment must be carried out on the relevant impacts of the enlargement works. Guidelines for the assessment process are determined by the relevant controlling provisions of the Act. It is expected that an EIS will be required.

Section 5.04 of the *EPBC Regulations* 2000 stipulates that a draft environmental impact statement must address the matters mentioned in Schedule 4 of the Regulations.

[2] To qualify for a manner specified decision, the action cannot simply compensate for a significant impact, but must directly avoid or mitigate the physical impacts of the action.

4.2. Territory legislation

Territory legislation directly relevant to threatened fish management in the ECD consists of the following two Acts (which are described in more detail below):

- *Nature Conservation Act* 1980; and
- *Fisheries Act* 2000.

4.2.1. Nature Conservation Act

The *Nature Conservation Act* 1980 provides a mechanism for the protection and conservation of native plants and animals in the ACT with specified activities managed via a licensing system.

Three fish and one crayfish species that are present in the Cotter catchment are listed as threatened under the *Nature Conservation Act* 1980:

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

It is an offence under the Act to disturb or destroy a nest of an animal, which would extend to the destruction of spawning sites of threatened fish. It is also an offence under the Act to take or kill a native animal without a permit.

This therefore triggers the requirement to apply for a licence from the Conservator of Flora and Fauna to carry out the proposed action.

Under the legislation, any action affecting an endangered species is subject to special scrutiny. Conservation requirements are a paramount consideration and only activities relevant to conservation of the species or serving a special purpose are permissible.

Native plants and animals are declared as protected under Sections 16 and 17 of the Act. Species declared as endangered under the Act are also given ‘special protection status’, the highest level of statutory protection that can be conferred on a species in the ACT (ACT Government, 2007a).

Vulnerable fish or invertebrate species are not automatically protected, however the Murray River Crayfish and Two-spined Blackfish have been declared protected fish or invertebrates and their taking from the wild is prohibited without a permit.

The Conservator of Flora and Fauna may only grant a licence for activities affecting a species with special protection status where satisfied that the activity specified in the licence meets a range of stringent conditions.

The Act provides for the preparation of Action Plans for the conservation of threatened or endangered species or ecological communities. The threats to native fish species are outlined in the *ACT Aquatic Species and Riparian Zone Conservation Strategy* (ACT Government, 2007a) and can be broadly summarised as: habitat destruction or modification (including the effects of dams and weirs), sedimentation, thermal pollution, altered river flows, recreational fishing, introduction of alien species, and impacts on the riparian zone.

Section 42 of the *Nature Conservation Act* 1980 requires that the ACT Conservator of Flora and Fauna prepare Action Plans for declared threatened species or ecological communities.

Any Action Plan is required to include proposals for the identification, protection and survival of a species or a community, so as to inform decision-making with regard to conservation of threatened species by outlining principles on which to base management decisions.

The Aquatic Species and Riparian Zone Conservation Strategy: Action Plan 29 (ACT Government, 2007a) now supersedes separate Action Plans previously published for the four threatened fish and crayfish species described above.

4.2.2. Fisheries Act 2000

The *Fisheries Act 2000* provides a mechanism for the conservation of native fish species and their habitat in the ACT. The legislation also aims to sustainably manage ACT fisheries, provide high quality and viable recreation fishing, and cooperate with other Australian governments to protect native fish species.

The legislation requires the Conservator to prepare a management plan for fish species and their habitats in the ACT. The plan (which is open to community consultation and comment), must include:

- A description of fish species and their habitats in the ACT.
- A description of current and potential threats to fish species and their habitats.
- Measures taken to achieve the objectives of the ACT (including performance indicators and monitoring methods).
- Guidelines that the Conservator needs to fulfil its functions under the ACT.

The abovementioned fish management plan under the *Fisheries Act 2000* is produced by the

Conservator and covers the ACT. Consequently it is different in its nature and scope to the fish management plan in this document, which is produced by ACTEW as a subset of the Environmental Management Plan for the ECD.

5. ECD AND INTENDED OPERATIONAL REGIME

5.1. Introduction

To obtain the relevant licences and approvals in accordance with Commonwealth and ACT legislation, ACTEW will need to provide sufficient information on how it proposes to protect the threatened species during design, construction, filling and operation of the ECD.

To assess the potential impact of an ECD on the habitat and ecology of threatened species and subsequently plan, implement and manage adequate programs to mitigate anticipated impacts, the intended likely operational regime of the ECD is summarised below from modelling provided by ActewAGL (2008).

This information is crucial given potential negative impacts of dam operation on threatened species. Lintermans (2005) identified some of the potentially negative impacts as:

- Projected maximum storage level of the enlarged reservoir may end in areas containing minor barriers to fish movement which may prevent Macquarie Perch spawning (manipulation of drown-out flows, fishways or stream-bed modifications may be able to alleviate this problem).
- Fluctuating or prolonged lowering of water levels once the reservoir is established will adversely impact on fringing macrophyte beds.
- Fluctuating or prolonged lowering of water levels once the reservoir is established will adversely impact on edge-boulder habitat (important habitat for juvenile Macquarie Perch).
- Reduction in flows downstream of the dam may impact on the small population of Macquarie Perch in the lower Cotter and lower Paddys Rivers.
- Reduction in flows below Cotter Dam may compromise program of re-establishing connectivity between Murrumbidgee River and Paddys River fish communities.
- Reduction in flows will compromise attempts to re-introduce Two-spined Blackfish populations below Cotter Dam.

The current dam is 3.8 GL in volume with a dam wall of about 30 m in height. The ECD is expected to have a capacity of 78 GL, and a dam wall height of about 80 m. This provides a number of problems as well as opportunities for fish management in the Cotter River

catchment (ACT Government, 2007a; Lintermans 2005). For example, the ECD will substantially increase the volume of water in the dam, but also the depth of the water column. This will create a larger habitat for aquatic wildlife, but may increase the volume of cold water within the dam, which may benefit coldwater alien species such as Trout.

5.2. Modelling and anticipated operational regime

In order to provide an accurate indication of likely operating levels, modelling (ActewAGL, 2008), assumed that:

- The inflow inputs are based on current worse-case 2030 climate change and yield reduction due to the 2003 bushfires and potential future bushfire events.
- The demand inputs are based on high population growth forecast sourced from the Australian Bureau of Statistics with 25% demand reduction by 2023.
- The base scenario is based on existing system and supply optimisation rules.
- The ECD scenario is based on the addition of 78 GL Cotter Dam and existing system and supply optimisation rules.
- Both scenarios use the existing Cotter Pump Station, with an anticipated capacity of 100 ML/day (this assumption was specified in the modelling request).
- Both scenarios include the supply of Murrumbidgee River water for the purposes of satisfying environmental flows downstream of Cotter Dam after June 2009.
- The proposed Murrumbidgee to Googong pipeline is not included (this assumption was specified in the modelling request).
- The modelling period is 1st August 2008 to 31st March 2057.
- Initial storages in all dams have been set to the level at 28 July 2008.

The following scenarios were examined during the modelling process for the ECD (ActewAGL, 2008):

- Time taken to fill.
- Percentage time spent at various drawdown levels after initial filling.

Modelling indicated that the ECD is likely to fill within 2.5-6 years of becoming operational.

Modelling also indicated that after being initially filled, the ECD is likely to be at:

- Full service level (FSL) 53% of the time.

- Within 1.5 m of FSL 63% of the time (with an average recurrence interval of 3 years).
- Within 4 m of FSL 81% of the time (with an average recurrence interval of 4 years).
- Within 10 m of FSL 96% of the time (with an average recurrence interval of 13 years).
- Within 13 m of FSL 98% of the time (with an average recurrence interval of 20 years).
- Within 20 m of FSL 99.6% of the time (with an average recurrence interval of 36 years).

5.3. Implications for aquatic habitat and habitat mitigation measures

The extent and frequency of drawdowns will significantly impact on critical Macquarie Perch habitat and potential passage from the reservoir to spawning habitats. Critical habitat affected will be daytime shelter (assuming emergent macrophytes will re-establish around the perimeter of the reservoir at FSL). If the reservoir is expected (on average) to remain within 1.5 m of FSL for 63 % of the time, it is reasonable to expect that some fringing emergent macrophytes beds will establish. However the timeframe until such reedbeds establish is unknown (but expected to be lengthy, and cannot occur until the Reservoir fills), given that there will be no natural seed source for these macrophytes in the inundated soil (~50 m elevation above existing macrophyte beds). Consequently, there is a need to provide alternative shelter habitat for adult fish whilst the reservoir fills and the reedbeds establish. Similarly, when the reservoir is drawn down greater than 1.5 m, the macrophyte beds are likely to become isolated from the water body, and artificial shelter habitats will be required. Project 1 (artificial habitats) is designed to provide information to guide the installation of artificial habitats. The percent frequency of the various levels of drawdown and the time that the reservoir may remain at certain levels of drawdown will guide the extent (depth profile) of the artificial shelter habitats required. For example, if the reservoir is expected to be drawn down by >13 m for approximately 2 % of the time, then artificial habitats need to be built to at least 13 m depth, as even though such drawdown levels are relatively rare, when they occur fish may be extremely vulnerable to predation if no alternative cover is available. A survey of potential fish habitat structures is required at a range of depth transects before the reservoir fills. This information will be used to identify the need for artificial habitats across the full drawdown range.

After the reservoir initially fills, access by Macquarie Perch out of the reservoir to breeding habitats in the river is also likely to be compromised by drawdown. Sedimentation of the newly inundated 4 km stretch of river and subsequent partial drainage events as a result of drawdown, are likely to destroy existing spawning sites, requiring fish to move through this occasionally inundated area to access clean spawning beds further upstream. Although fish in healthy non-

fragmented populations may not need to successfully breed every year, the risk of losing an annual recruitment pulse in a small fragmented population may be significant. The annual spawning migration of Macquarie Perch from Cotter Reservoir in search of suitable spawning sites will expose fish to increased levels of predation as they pass through this relatively featureless section of the previously inundated river/reservoir. Measures to provide shelter to migrating fish, or to mitigate cormorant predation will be investigated, and further research into potential management solutions will be carried out before the reservoir fills.

Similarly, the inundation of an additional 4 km of river will impact on the population of Two-spined Blackfish in this river reach. Two-spined Blackfish are not present in the current Cotter Reservoir, presumably as a result of excessive sedimentation smothering suitable spawning sites (Lintermans, 2005). It is unknown whether or how quickly this species will colonise the ECD, and whether the species will be able to breed in the new ECD. Investigation of the impacts of the ECD on breeding of the Two-spined Blackfish is required.

6. FISH MANAGEMENT PLANS

The Fish Management Plan for each phase of the ECD development has been compiled in Table 4.

For each management plan representing the different phases of the ECD project there will be overlap in risks and risk mitigation, as many of these risks to fish will carry through from the design phase to the filling and operational phases. The plan has been written as a stand-alone document, therefore there is some repetition between the descriptions for each of the phases.

Management plans and mitigation measures are provided for the:

- Design phase;
- Construction phase; and
- Filling and operational phases.

6.1. Current System

Whilst a formalised fish management plan representing collective input from all stakeholders is not in place, there are key actions currently undertaken within the Cotter catchment to reduce impacts on threatened fish species. ACT Government (2007a) provides a useful overview of current knowledge and understanding of fish management in the system.

Current fish management within the existing Cotter Reservoir and lower Cotter catchment aims to conserve existing populations of threatened fish in the current Cotter Reservoir, whilst ensuring consistent supply of water to the ACT.

The scope of fish management in the existing Cotter Reservoir identifies the impacts that current human activities (e.g. water supply, forestry, land management) and natural events (e.g. bushfire, drought) create, and any impacts that are influenced by the operation of Cotter Reservoir (see Table 4). In particular, it:

- indicates actions that minimise adverse impacts on threatened species within Cotter Reservoir; and
- facilitates compliance with relevant legislation.

6.1.1. Background

The current catchment has been managed for the past 20 years by the ACT Government (which commenced management following self-government in 1987).

Cotter Reservoir was Canberra's first water supply, but by the 1970s it was only used intermittently, due to high concentrations of iron and manganese in the water column (particularly during the summer months). Consequently, water levels in Cotter Reservoir were relatively constant (near the FSL of 500.7 m), which allowed a fringe of emergent macrophytes (primarily *Phragmites*, *Typha* and *Eleocharis*) to develop along its edges, particularly in the upstream half of the reservoir. These macrophytes have provided fish with protective cover from avian predation.

The reservoir system was relatively stable until the January 2003 bushfires. These bushfires and the subsequent storms washed a considerable amount of nutrients and particulate material into Cotter Reservoir. As a result of these extra nutrients, microbial activity depleted dissolved oxygen, such that by April 2004 Cotter Reservoir was anoxic from about two metres down. Anoxia at the lower water levels of the reservoir had been noted as a feature of the reservoir in previous years, when the reservoir stratified over the summer months, often resulting in high iron and manganese concentrations (Nagy and Hure, 2005).

Most fish need at least 4 mg/L dissolved oxygen in the water column for oxygen exchange through their gills, and the seasonal lack of oxygen in Cotter Reservoir would have significantly reduced their available habitat.

A de-stratifying mixer was installed in December 2004 which has increased dissolved oxygen levels in Cotter Reservoir, particularly within the top 12 m of the water column (which represents about 87% of the water volume in the reservoir).

Since early 2005, Cotter Reservoir has once again been used as one of Canberra's raw water sources. This was partly due to the ongoing drought and partly to the success of the mixer, which increased oxygen levels in the water column, and at the same time decreased iron and manganese concentrations (Nagy *et al.*, 2007). The enhancement of the Stromlo Water Treatment Plant following the bushfires has also allowed Cotter Reservoir water to be used for raw water supply.

In 2006, the ACT Government decided to phase out forestry operations in the lower Cotter catchment and return land use to 'Water Catchment' (Environment ACT, 2006).

The management and protection of threatened fish species in the current system relies on:

- a drawdown limit of 1.5 m to protect adult Macquarie Perch which use the emergent macrophytes for daytime shelter;
- environmental flows in the Cotter River to provide a healthy river and suitable spawning opportunities for Macquarie Perch;

- restrictions on fishing in Cotter Reservoir to reduce the chance of introducing alien fish or pathogens; and
- monitoring of fish populations by TAMS.

6.1.2. Description of activity

Activities in the current reservoir and immediate catchment are undertaken by a number of stakeholders, including:

- ACT Government agencies;
- ACTEW;
- ActewAGL;
- Commonwealth Government agencies;
- Universities and CSIRO;
- community organisations; and
- individual members of the public.

Activities include recreation, research, catchment management and water supply operations. Key stakeholder activities that may impact on the threatened fish include:

- managing river flows by providing environmental releases from Bendora Reservoir along the Cotter River into Cotter Reservoir (this is undertaken by ACTEW and ActewAGL);
- managing river flows by providing environmental releases from Cotter Reservoir into the Cotter River downstream of the dam (this is undertaken by ACTEW, ActewAGL and the EPA);
- managing the catchment around Cotter Reservoir (this is undertaken by TAMS);
- managing water abstraction from Cotter Reservoir for water supply (this is undertaken by ACTEW and ActewAGL and regulated by the EPA);
- monitoring of environmental conditions and threatened fish species (for example; Ecowise monitors river flow and water quality on behalf of ACTEW and ActewAGL, University of Canberra monitors environmental flow impacts and TAMS monitors threatened fish numbers in Cotter Reservoir and the Cotter River);
- management of monitoring and/or communications sites (for example; Air Services Australia has a monitoring site in the Brindabella Mountains);

- research into a range of water quality, ecological and environmental issues (for example; University of Canberra has regular field trips to Cotter Reservoir);
- tree planting (for example; Greening Australia has a number of re-forestation activities around Cotter Reservoir);
- bushwalking (the area around Cotter Reservoir is open for bushwalking);
- cycling (the area around Cotter Reservoir is open for cycling); and
- recreational fishing (the area between the junction of the Cotter River and Pierces Creek to Bendora Dam is open for fishing as long as only artificial lures or flies are used as bait fishing is prohibited).

6.1.3. Current fish management within the existing Cotter Reservoir

The issues associated with threatened fish, including risks and mitigating measures for the current system are indicated in Table 4 below.

6.1.4. Auditing requirements and reporting

The management of threatened fish in the current system:

- is guided by The *Aquatic Species and Riparian Zone Conservation Strategy* (ACT Government, 2007a) and the *Fish Stocking Plan for the Australian Capital Territory*;
- has regular review and reporting requirements to the ACT Flora and Fauna Committee; and
- involves regular and ad-hoc monitoring programs funded from both ACT Government and ACTEW.

Although reporting and review processes exist, there are no formal auditing processes.

Current threatened fish management has evolved gradually over the past two decades.

6.2. Design Phase

This section describes the Fish Management Plan for the design phase (i.e. Cotter Reservoir at 3.8 GL capacity, while the design work is being completed for the ECD).

6.2.1. Background

The design phase will cover a duration of about one year, from approximately December 2007 to December 2008.

During this period there will be a significant increase in the extent of activity in the Cotter

catchment, as a range of consultants will be making assessments or conducting research on:

- hydrology and hydrodynamics;
- geotechnics;
- flora and fauna; and
- cultural heritage.

6.2.2. Purpose

The main purpose of the Fish Management Plan for the design phase is to ensure that all potential environmental impacts that could reasonably be expected to occur during the design phase of the ECD project are minimised and fall within acceptable and agreed limits. This will be achieved through pro-active environmental management. Accordingly, emphasis is placed upon integrating the environmental management planning with design, construction, filling and operational phases.

The requirements of these plans are applicable to all on-site work carried out. All subcontractors and suppliers will be bound to comply with the requirements of this plan, in so far as they are applicable to the nature and scope of their work.

The scope of these plans embraces the impacts that the work will create and any impacts that are influenced by the operation of Cotter Reservoir. In particular, it:

- establishes procedures that will minimise adverse impacts on threatened species within Cotter Reservoir;
- facilitates compliance with the relevant legislation;
- provides evidence of practical and achievable plans for managing the ECD Project to ensure that environmental requirements are complied with, by providing an integrated planning framework for comprehensive monitoring and control of design impacts; and
- provides documented evidence that the design phase of the project is being managed in an environmentally acceptable manner.

6.2.3. Description of activity

Activities during the design phase will be undertaken by a number of stakeholders, including:

- ACT Government agencies;
- ACTEW;
- ActewAGL;
- consultants involved in a range of activities on the design phase of ECD;

- Commonwealth Government agencies;
- Universities and CSIRO;
- community organisations; and
- individual members of the public.

These stakeholders may be involved in a number of activities, including:

- managing river flows by providing environmental releases from Bendora Reservoir along the Cotter River into Cotter Reservoir (this is undertaken by ACTEW and ActewAGL);
- managing the catchment around Cotter Reservoir (this is undertaken by TAMS);
- managing water abstraction from Cotter Reservoir for water supply (this is undertaken by ACTEW and ActewAGL);
- managing river flows by providing environmental releases from Cotter Reservoir into the Cotter River downstream of the dam (this is undertaken by ACTEW and ActewAGL and regulated by the EPA);
- consulting to ACT Government, ACTEW and/or ActewAGL on a range of issues associated with ECD (such as geotechnical investigations, hydrological and hydrodynamic studies, flora and fauna assessments and cultural heritage surveys);
- monitoring of environmental conditions and threatened fish species (for example; Ecowise monitors river flow and water quality on behalf of ACTEW and ActewAGL, and TAMS monitors threatened fish numbers in Cotter Reservoir and the Cotter River);
- management of monitoring and/or communications sites (for example; Air Services Australia has a monitoring site in the Brindabella Mountains);
- research into a range of issues (for example; University of Canberra has regular field trips to Cotter Reservoir);
- tree planting (for example; Greening Australia has a number of re-forestation activities around Cotter Reservoir);
- bushwalking (the area around Cotter Reservoir is open for bushwalking);
- cycling (the area around Cotter Reservoir is open for cycling); and
- recreational fishing (the area between the junction of the Cotter River and Pierces Creek to Bendora Dam is open for fishing as long as only artificial lures or flies are

used as bait fishing is prohibited).

6.2.4. Fish Management Plan for the Design Phase

The Fish Management Plan for the design phase is indicated in Table 4.

The same risks are present during the design phase as during the current situation. However, a number of risks present during the current situation increase during the design phase. These are:

- Increased chance of fuel spills, oils and other contaminants entering the aquatic environment.
- Increased chance of pathogens and/or pests entering the aquatic environment.
- Increased chance of introducing the EHN virus into Cotter Reservoir.
- Lack of sufficient information collection and monitoring to be able to compile appropriate Fish Management Plan.

There is one new risk during the design phase which was not present during the current situation:

- Design and construction for ECD fails to incorporate fish-friendly components.

6.2.5. Auditing requirements and reporting

The Fish Management Plan for the design phase will be audited prior to the commencement of the construction phase and any updates will be then incorporated into the Fish Management Plan for the construction phase.

6.3. Construction Phase

This section describes the Fish Management Plan for the construction phase (i.e. Cotter Reservoir at 3.8 GL capacity, while the construction work is being completed for the ECD).

6.3.1. Background

The construction phase will cover a duration of about three years, from approximately December 2008 to December 2011. Based on the exact construction methods used, the filling phase may partially overlap with the dam construction phase. This is because the new dam wall may be:

- built to its total height, and then used as the main water retaining structure (in this case the gap between the old and new walls will remain unflooded during construction, and the filling phase would start after the end of the construction phase); or

- built and used as the main water retaining structure once it is higher than the current dam wall (in this case the gap between the old and new walls will be flooded, and the filling phase would overlap with the construction phase).

During this period there will be a further significant increase in the extent of activity in the Cotter catchment, as a range of consultants and contractors will be engaged in:

- dam wall construction;
- saddle dam construction;
- additional geotechnical tests;
- roadway construction;
- extractive operations;
- materials transport;
- project management;
- public consultation and liaison; and
- other infrastructure construction (such as pipelines, substations, offices, visitor centre).

6.3.2. Purpose

The main purpose of the Fish Management Plan for the construction phase is to ensure that all potential environmental impacts that could reasonably be expected to occur during the construction phase of the ECD project are minimised and fall within acceptable and agreed limits. This will be achieved through pro-active environmental management. Accordingly, emphasis is placed upon integrating the environmental management planning with design, construction, filling and operational phases.

The requirements of this plan is applicable to all on-site work carried out. All subcontractors and suppliers will be bound to comply with the requirements of this plan, in so far as they are applicable to the nature and scope of their work.

The scope of this plan embraces the impacts that the work will create and any impacts that are influenced by the operation of Cotter Reservoir. In particular, it:

- establishes procedures that will minimise adverse impacts on threatened species within and downstream of the Cotter Reservoir;
- facilitates compliance with the relevant legislation;
- provides evidence of practical and achievable plans for managing the ECD Project to

ensure that environmental requirements are complied with, by providing an integrated planning framework for comprehensive monitoring and control of construction impacts; and

- provides documented evidence that the construction phase of the project is being managed in an environmentally acceptable manner.

6.3.3. Description of activity

Activities during the construction phase will be undertaken by a number of stakeholders, including:

- ACT Government agencies;
- ACTEW;
- ActewAGL;
- consultants and contractors involved in a range of activities on construction phase of ECD;
- Commonwealth Government agencies;
- Universities and CSIRO;
- community organisations; and
- individual members of the public.

These stakeholders may be involved in a number of activities, including:

- managing river flows by providing environmental releases from Bendora Reservoir along the Cotter River into Cotter Reservoir (this would be undertaken by ACTEW and ActewAGL);
- managing the catchment around Cotter Reservoir (this would be undertaken by TAMS);
- managing water abstraction from Cotter Reservoir for water supply (this would be undertaken by ACTEW and ActewAGL);
- managing river flows by providing environmental releases from Cotter Reservoir into the Cotter River downstream of the dam (this would be undertaken by ACTEW and ActewAGL);
- consulting to ACT Government, ACTEW and/or ActewAGL on a range of issues associated with ECD (such as geotechnical investigations, hydrological and

hydrodynamic studies, flora and fauna assessments and cultural heritage surveys);

- constructing the ECD project;
- monitoring of environmental conditions and threatened fish species (for example; Ecowise would be monitoring river flow and water quality on behalf of ACTEW and ActewAGL, and TAMS would be monitoring threatened fish numbers in Cotter Reservoir and the Cotter River);
- management of monitoring and/or communications sites (for example; Air Services Australia would be monitoring site in the Brindabella Mountains);
- research into a range of issues (for example; University of Canberra would have regular field trips to Cotter Reservoir);
- tree planting (for example; Greening Australia would be involved in a number of re-forestation activities around Cotter Reservoir);
- bushwalking (the area around Cotter Reservoir would be open for bushwalking);
- cycling (the area around Cotter Reservoir would be open for cycling); and
- recreational fishing (the area between the junction of the Cotter River and Pierces Creek to Bendora Dam may be open for fishing as long as only artificial lures or flies are used as bait fishing is prohibited).

6.3.4. Fish Management Plan for the construction phase

The Fish Management Plan for the construction phase is indicated in Table 4.

Generally the same risks are present during the construction phase as during the design phase. Five existing risks from the design phase increase in importance due to the additional construction activity. These are:

- Increased chance of fuel spills, oils and other contaminants, entering the aquatic environment.
- Increased chance of pathogens and/or pests entering the aquatic environment.
- Increased chance of introducing the EHN virus into Cotter Reservoir.
- Lack of sufficient information collection and monitoring to be able to compile appropriate Fish Management Plan.
- Design and construction for ECD fails to incorporate fish-friendly components.

One new risk is added to the previously existing list of risks, due specifically to the additional

construction activity. This risk is:

- Increased erosion resulting in increased nutrients and particulate matter in the aquatic environment upstream and downstream of the ECD (as a result of the construction activity).

6.3.5. Auditing requirements and reporting

The Fish Management Plan for the construction phase will be audited prior to the commencement of the filling and operational phases and any updates will be then incorporated into the Fish Management Plan for the filling and operational phases. Based on the exact construction methods used, the filling phase may effectively overlap with the dam construction phase. This is because the new dam wall may be:

- built to its total height, and then used as the main water retaining structure (in this case the gap between the old and new walls will remain unflooded during construction, and the filling phase would start after the end of the construction phase); or
- built and used as the main water retaining structure once it is higher than the current dam wall (in this case the gap between the old and new walls will be flooded, and the filling phase would overlap with the construction phase).

6.4. Filling and Operational Phases

This section describes the Fish Management Plan for the filling and operational phases (i.e. the ECD at up to 78 GL capacity).

6.4.1. Background

The filling and operational phases may cover a number of years (ActewAGL, 2008) from approximately December 2011. The exact period of time will be influenced by:

- rainfall in the Cotter catchment;
- releases from upstream systems (such as Corin and Bendora Reservoirs);
- water extractions from Cotter Reservoir; and
- use of water from the Murrumbidgee River and/or Googong Reservoir.

During this period there will be a reduction in construction activity, but a potential increase in visits by members of the public.

It is generally agreed that the Fish Management Plan for the filling and operational phases will be more complex than for the other phases.

6.4.2. Purpose

The main purpose of the Fish Management Plan for the filling and operational phases is to ensure that all potential environmental impacts that could reasonably be expected to occur during the filling and operational phases of the ECD project are minimised and fall within acceptable and agreed limits. This will be achieved through pro-active environmental management. Accordingly, emphasis is placed upon integrating the environmental management planning with design, construction, filling and operational phases.

The requirements of this plan is applicable to all on-site work carried out. All subcontractors and suppliers will be bound to comply with the requirements of this plan, in so far as they are applicable to the nature and scope of their work.

The scope of this plan embraces the impacts that the work will create and any impacts that are influenced by the operation of Cotter Reservoir. In particular, it:

- establishes procedures that will minimise adverse impacts on threatened species within and downstream of the Cotter Reservoir;
- facilitates compliance with the relevant legislation;
- provides evidence of practical and achievable plans for managing the ECD Project to ensure that environmental requirements are complied with, by providing an integrated planning framework for comprehensive monitoring and control of filling and operational impacts; and
- provides documented evidence that the filling and operational phases of the project is being managed in an environmentally acceptable manner.

6.4.3. Description of activity

Activities during the filling and operational phases will be undertaken by a number of stakeholders, including:

- ACT Government agencies;
- ACTEW;
- ActewAGL;
- consultants and contractors involved in a range of activities on filling and operational phases of ECD;
- Commonwealth Government agencies;

- Universities and CSIRO;
- community organisations; and
- individual members of the public.

These stakeholders may be involved in a number of activities, including:

- managing river flows by providing environmental releases from Bendora Reservoir along the Cotter River into ECD (this would be undertaken by ACTEW and ActewAGL);
- managing the catchment around ECD (this would be undertaken by TAMS);
- managing water abstraction from ECD for water supply (this would be undertaken by ACTEW and ActewAGL);
- managing river flows by providing environmental releases from ECD into the Cotter River downstream of the ECD (this would be undertaken by ACTEW and ActewAGL);
- consulting to ACT Government, ACTEW and/or ActewAGL on a range of issues associated with filling and operating the ECD;
- monitoring of environmental conditions and threatened fish species (for example; Ecowise would be monitoring river flow and water quality on behalf of ACTEW and ActewAGL, and TAMS would be monitoring threatened fish numbers in ECD and the Cotter River);
- management of monitoring and/or communications sites (for example; Air Services Australia would be monitoring site in the Brindabella Mountains);
- research into a range of issues (for example; University of Canberra would be having regular field trips to Cotter Reservoir);
- tree planting (for example; Greening Australia would be involved in a number of re-forestation activities around Cotter Reservoir);
- bushwalking (the area around ECD would be open for bushwalking);
- cycling (the area around ECD would be open for cycling); and
- recreational fishing (the area between the junction of the Cotter River and Pierces Creek to Bendora Dam is currently open for fishing as long as only artificial lures or flies are used as bait fishing is prohibited).

6.4.4. Fish Management Plan for the filling and operational phase

The Fish Management Plan for the filling and operational phases is indicated in Table 4.

Generally the same risks are present during the filling and operational phases as during the construction phase. However, a number of risks present during the construction phase increase in importance during the filling and operational phases. These are:

- 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) and increased cormorant predation through reduced refuge areas.
- Road crossings and other barriers reducing fish passage in the Cotter River during spawning.
- Insufficient or inappropriate environmental flows in the Cotter River upstream and downstream of the Cotter Reservoir.
- Increased chance of pathogens and/or pests entering the aquatic environment.
- Increased chance of introducing the EHN virus into Cotter Reservoir.
- Lack of sufficient information collection and monitoring to be able to compile appropriate Fish Management Plan.

The following new risks are added to the previously existing list of risks:

- Long-term (10-20 years) decline in fish numbers or growth rates (due to the depletion of nutrients and food sources) following the initial surge in productivity after reservoir filling.
- Decline or loss of Macquarie Perch population due to impoundment of reservoir waters submerging spawning areas in the river.
- Increased abundance of alien fish species in the enlarged reservoir.
- Reduction in Macquarie Perch food resources (macroinvertebrates) as a result of loss of macrophytes, sedimentation and fluctuating water levels.
- Increased predation on Macquarie Perch in silted and shallower upstream portions of reservoir during spawning migrations.
- Inundation of 4 km of river may destroy suitable habitat of the Two-spined Blackfish.

6.4.5. Auditing requirements and reporting

The Fish Management Plan for the filling and operational phases will be audited two years

after the commencement of filling (expected in December 2011) and any updates will be then incorporated into the next version of the Fish Management Plan for the filling and operational phases.

6.5. Risk assessment process

The following risk assessment at Table 4 is based on the framework developed by ActewAGL Water Division which is in accordance with the Australian and New Zealand Standard *AS/NZS4360.*

The level and score for each risk identified in Table 4 was determined based on the matrix below (Figure 2) once the likelihood and consequences of each risk were determined. The risk level description is based on the likelihood multiplied by the highest consequence score.

Table 4 sets out the risk assessment for each phase of the ECD and residual risk following the implementation of mitigation measures.

LIKELIHOODS					
Almost Certain (5)	Moderate (5)	High (10)	Very High (15)	Extreme (20)	Extreme (25)
Likely (4)	Moderate (4)	High (8)	Very High (12)	Very High (16)	Extreme (20)
Probable (3)	Low (3)	Moderate (6)	High (9)	Very High (12)	Very High (15)
Unlikely (2)	Low (2)	Moderate (4)	Moderate (6)	High (8)	High (10)
Rare (1)	Low (1)	Low (2)	Low (3)	Moderate (4)	Moderate (5)
	Insignificant (1)	**Minor (2)**	**Moderate (3)**	**Major (4)**	**Catastrophic (5)**
	CONSEQUENCE				

Figure 2: Risk management matrix developed and used by ActewAGL.

6.6. Risks and mitigation measures

The risks and their mitigation measures are summarised in Table 4 below, together with their current and post-mitigation residual risk assessments.

In most cases, the identified mitigating measures reduced the risk rating. However, in the case of devastating bushfires, mitigating measures would be unlikely to significantly reduce the risk rating for the ECD Fish Management Plan.

Table 4: Fish Management Plan risks and mitigation measures (CS = Current Situation, D = Design, C = Construction, FO = Filling and Operational Phases).

No.	Risk	Mitigation Measures – Fish and aquatic ecosystem management	Project Phase				Current Risk Assessment			Residual Risk Assessment		
			CS	D	C	FO	Likeli-hood	Conse-quence	Risks	Likeli-hood	Conse-quence	Risks
1	**Increased erosion resulting in increased nutrients and particulate matter in the aquatic environment (as a result of the January 2003 bushfires and subsequent storm events).** This has increased siltation in the river and reservoir, thus reducing available habitat for threatened fish species. However, over the past two years a decision has been made to phase out forestry operations in the Cotter catchment. This has resulted in a number of (forestry) road closures which have reduced erosion in the catchment. Tree-planting activities have also further reduced erosion in the catchment, as has the natural re-vegetation process (which has increased ground cover).	Continue monitoring water quantity and quality in Cotter Reservoir and provide this information on a regular basis to ACTEW, TAMS and ActewAGL. Continue to monitor nutrient concentrations and algal numbers in Cotter Reservoir and provide this information on a regular basis to ACTEW and ActewAGL. Continue monitoring the recovery of the catchment and provide this information on a regular basis to TAMS, ACTEW and ActewAGL. Continue to monitor fish numbers in Cotter Reservoir and the Cotter River upstream of the reservoir and provide this information to TAMS. Occasionally monitor storm events to estimate sediment transport. Occasionally undertake catchment erosion assessment. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.	✓				Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
				✓			Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
					✓		Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
						✓	Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
2	**Increased nutrients resulting in oxygen depletion in Cotter Reservoir, and reducing habitat for threatened fish.** This was a problem especially during the summer months between December 2003 and April 2004. However, by December 2004, a solar powered mixer was installed into Cotter Reservoir by ACTEW and ActewAGL. This mixing system has significantly improved the amount of dissolved oxygen in the water column of Cotter Reservoir, which in turn has increased available habitat for threatened fish.	Continue to monitor water quality in Cotter Reservoir (particularly dissolved oxygen through the profile) and provide this information on a regular basis to ACTEW, TAMS and ActewAGL. Continue to monitor nutrient concentrations and algal numbers in Cotter Reservoir and provide this information on a regular basis to ACTEW, TAMS and ActewAGL. Continue to operate the mixer in the present reservoir, and install a mixer into the enlarged reservoir. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.	✓				Likely (4)	Moderate (3)	Very High (12)	Unlikely (2)	Moderate (3)	Moderate (6)
				✓			Likely (4)	Moderate (3)	Very High (12)	Unlikely (2)	Moderate (3)	Moderate (6)
					✓		Likely (4)	Moderate (3)	Very High (12)	Unlikely (2)	Moderate (3)	Moderate (6)
						✓	Likely (4)	Moderate (3)	Very High (12)	Unlikely (2)	Moderate (3)	Moderate (6)

3	**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) and increased cormorant predation through reduced refuge areas.** Cotter Reservoir has a fringe of emergent macrophytes which provide protection for Macquarie Perch. Using the existing Cotter Reservoir for water supply increases water level fluctuations, which in turn removes or isolates the fringe of emergent macrophytes and/or edge-boulder environments. Construction of the ECD will inundate and destroy the existing macrophyte beds. This in turn removes protective habitat for fish species and will likely result in greater cormorant predation. To reduce this risk, the current maximum drawdown for Cotter Reservoir is 1.5 m below full service level, with zero drawdown over the Macquarie Perch spawning season (Oct-Dec).	Continue monitoring water quantity and quality in Cotter Reservoir and provide this information on a regular basis to ACTEW, TAMS and ActewAGL. Continue to monitor nutrient concentrations and algal numbers in Cotter Reservoir and provide this information on a regular basis to ACTEW, TAMS and ActewAGL. Continue to monitor fish numbers in Cotter Reservoir and the Cotter River upstream of the Reservoir and provide this information to TAMS. Use the findings of Project 1 - Artificial habitats to provide additional information specifically on the suitability of some form of artificial habitat as a replacement for the current macrophyte beds. Then use this information to provide such habitats at the operational levels expected for the ECD. If Project 1 does not find suitable artificial habitats, then an alternative research program will be required to develop other mitigation options. Survey ECD basin to determine whether suitable refuge habitats, especially boulder, cobble and rock areas, and timber, will be submerged down to maximum operating level. Examine the possibility of providing additional edge-boulder habitat (for juvenile and sub-adult Macquarie Perch), within the new dam. Examine the possibility of providing additional boulder habitat (for juvenile, sub-adult and adult Macquarie Perch), within the quarry site for the ECD (which will be within the flooded area of the ECD). Review proposals for managing vegetation within the inundation area, seek to maximise amounts of submerged timber at all depths. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.	✓				Unlikely (2)	Major (4)	High (8)	Unlikely (2)	Major (4)	High (8)
				✓				Unlikely (2)	Major (4)	High (8)	Unlikely (2)	Major (4)	High (8)
					✓			Unlikely (2)	Major (4)	High (8)	Unlikely (2)	Major (4)	High (8)
						✓		Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)

4	**Road crossings and other barriers reducing fish passage in Cotter River during spawning.** There are a number of road crossings over the Cotter River upstream of Cotter Reservoir. The most frequently used of these is Vanitys Crossing, which is located about 5 km upstream of Cotter Reservoir. This crossing was a barrier to the passage of Macquarie Perch, but it was changed in 2001 to incorporate a rock-ramp fishway. Since then, Macquarie Perch have been observed upstream of Vanitys Crossing during the spawning season.	Continue to monitor the presence of Macquarie Perch and reproductive success upstream of Vanitys Crossing. Use the findings of Project 2 – Swimming capacity of Macquarie Perch to provide additional information specifically on improving the passage of fish (particularly Macquarie Perch) along the Cotter River upstream of the ECD. Use the findings of Project 8 – Mapping instream barriers. Reduce or eliminate remaining instream barriers (if any). Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.	✓				Likely (4)	Major (4)	Very High (16)	Unlikely (2)	Major (4)	High (8)
				✓				Likely (4)	Major (4)	Very High (16)	Unlikely (2)	Major (4)	High (8)
					✓			Likely (4)	Major (4)	Very High (16)	Unlikely (2)	Major (4)	High (8)
						✓		Likely (4)	Major (4)	Very High (16)	Unlikely (2)	Major (4)	High (8)
5	**Releases from Bendora Reservoir providing the wrong temperature signal during the spawning season.** Macquarie Perch may use a number of environmental signals for their spawning. One of these may be water temperature (coldwater pollution, if water is released from the bottom layers of Bendora Reservoir). It is important to ensure that releases from Bendora Reservoir (as much as possible) have a temperature profile similar to that which would have occurred if the river was unregulated. This is important most of the time but particularly important during the spawning season for Macquarie Perch (which is generally between mid-October to mid-November).	Continue to use the ACT Environmental Flows Committee to determine the quantity and temperature of releases from Bendora Reservoir, including flushing flows. 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). Monitor annual recruitment or spawning in the Macquarie Perch population. Occasionally review the impact of environmental flows on the system. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.	✓				Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
				✓				Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
					✓			Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
						✓		Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)

6	**Insufficient or inappropriate environmental flows in the Cotter River upstream and downstream of Cotter Reservoir.** This can result in insufficient water in the river, especially during the spawning migration (during mid-October to mid-November), or unseasonal flow patterns. To reduce this risk, the ACT Environmental Flows Committee has produced and updated a range of management rules for the Cotter Reservoir. This specifies the volume of water for environmental flows, as well as for flushing flows (which try and mimic storm flows). This is particularly important for Macquarie Perch and Two-spined Blackfish.	Continue to monitor water quality (especially temperature) in Bendora Reservoir to determine the temperature of releases from Bendora Reservoir. Monitor annual recruitment or spawning in the Macquarie Perch population. Use the findings of Project 3 - Crayfish ecology to provide additional information specifically on improving of the Cotter River downstream of the ECD for crayfish. Use the findings of Project 8 – Mapping instream barriers. Reduce or eliminate remaining barriers (if any). Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.	✓				Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
				✓				Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
					✓			Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
						✓		Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)

7	**Increased chance of fuel spill, oils and other contaminants entering the aquatic environment.** This can introduce chemicals that may be harmful to some threatened fish species, or harmful to particular life-stages of some threatened fish species. This risk has been mitigated by fuel and chemical handling arrangements by organisations involved in the catchment. For example Forestry ACT has removed fuel storage sites from the catchment. Furthermore, pesticide use (primarily for forestry operations) has been curtailed in the catchment, partly because the catchment is now once again used for water supply and partly because forestry operations (run by the ACT Government) are being phased out in the catchment. This risk is heightened during the construction phase.	Decommission existing fuel or chemical storages in the catchment (such as pesticides for forestry operations). Prohibit establishment of any new fuel or chemical storages in the catchment. Phase out forestry operations in catchment. Continue monitoring water quality in Cotter Reservoir (including hydrocarbons and pesticides) and provide this information on a regular basis to ACTEW and ActewAGL. Require all consultants undertaking activities in catchment to have EMPs for their activities. Require all consultants to have necessary approvals (such as a waterways permit) in place. Require all consultants to notify the Bulk Water Alliance of their activities in the catchment. Also require that key personnel are trained in mitigation measures to reduce the change of introducing contaminants into Cotter Reservoir. 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). Monitor potential adverse water-quality changes (DO and pH) in the water trapped between the two dam walls (if overlapping construction and filling phases). Use the findings of Project 9 – Fish monitoring for ECD. Liaise with ACT Government to promote a program of public education about the various risks. Ensure that Uriarra development does not increase this risk. Use above information in adaptive management.	✓				Unlikely (2)	Moderate (3)	Moderate (6)	Rare (1)	Moderate (3)	Low (3)
				✓				Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
					✓			Unlikely (2)	Moderate (3)	Moderate (6)	Rare (1)	Moderate (3)	Low (3)
						✓		Unlikely (2)	Moderate (3)	Moderate (6)	Rare (1)	Moderate (3)	Low (3)

8	**Increased chance of pathogens and/or pests entering the aquatic environment.** This can occur through human activity such as the introduction of infected fish, or the use of infected bait or fishing equipment by anglers. It can also occur via other species, such as cormorants (which may use several river systems to catch and consume their prey). This risk has been partly mitigated by requirements on anglers to only use lures (instead of live bait), and general restrictions on access. However, enforcement of such requirements is always difficult (due to the resources required). Furthermore, the movement of birds (such as cormorants), or animals is not possible to control. This risk is present in the current Cotter Reservoir, although it is heightened during the construction phase. The intentional introduction of pathogens and/or pests is a risk also present in the current Cotter Reservoir.	Continue to use existing decontamination measures by ACT Government agencies, ACTEW, ActewAGL and contractors. Require all consultants undertaking activities in catchment to have EMPs for their activities. Require all consultants to have necessary approvals (such as a waterways permit) in place. Require all consultants to notify the Bulk Water Alliance of their activities in the catchment. Also require that key personnel are trained in mitigation measures to reduce the change of introducing pathogens and /or pests into Cotter Reservoir. 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 into the new reservoir. This will require fish eradication techniques (e.g. drying, poisoning, netting etc). Liaise with ACT Government to promote a program of public education about the various risks. Ensure that Uriarra development does not increase this risk. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.	✓				Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
				✓				Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
					✓			Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
						✓		Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)

9	**Increased chance of devastating bushfires (due to increased human activity in the catchment, or inappropriate fire management practices which may reduce small to medium size fires but actually increase the chance of large fires).** The risk has been partly mitigated by regular reviews of access and bushfire management practices. For example, following the decision to phase out forestry operations in the catchment, some of the tracks previously used for these operations have been decommissioned, but those needed for fire management have been retained. However, as with a number of other risks, it is not possible to provide mitigation measures to fully reduce bushfire risks. As a consequence of the January 2003 bushfires, threatened fish in the current system have experienced (and survived) a number of severe shocks, including increased sedimentation and oxygen depletion. Although some risks are difficult (or impossible) to control, when they do occur it is important to collect information on recovery rates. The collection and use of such information can then help reduce the consequence of future similar risks.	Continue to incorporate fire management practices into overall catchment management. Occasionally evaluate location and use of fire trails. Use the findings of Project 9 – Fish monitoring for ECD. Liaise with ACT Government to promote a program of public education about the various risks. Use above information in adaptive management.	✓				Probable (3)	Major (4)	Very High (12)	Probable (3)	Major (4)	Very High (12)
				✓				Probable (3)	Major (4)	Very High (12)	Probable (3)	Major (4)	Very High (12)
					✓			Probable (3)	Major (4)	Very High (12)	Probable (3)	Major (4)	Very High (12)
						✓		Probable (3)	Major (4)	Very High (12)	Probable (3)	Major (4)	Very High (12)
10	**Dam operating practices causing fish mortality or entrainment near off-take structures.** Adult Macquarie Perch appear to congregate in the wet-well (around the off-take tower). Procedures have been implemented to capture these fish (if present in sufficient numbers) in the wet-well and return them to the reservoir prior to the wet-well being drained.	Continue to monitor adult Macquarie Perch in wet-well. Compile protocol(s) for trapping these fish and releasing them. This is to be undertaken jointly by TAMS, ACTEW and ActewAGL. Investigate screening to prevent fish access or entrainment. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.	✓				Probable (3)	Minor (2)	Moderate (6)	Unlikely (2)	Minor (2)	Moderate (4)
				✓				Probable (3)	Minor (2)	Moderate (6)	Unlikely (2)	Minor (2)	Moderate (4)
					✓			Probable (3)	Minor (2)	Moderate (6)	Unlikely (2)	Minor (2)	Moderate (4)
						✓		Probable (3)	Minor (2)	Moderate (6)	Unlikely (2)	Minor (2)	Moderate (4)

11	**Increased chance of introducing the EHN virus into Cotter Reservoir.** Such an introduction could occur via human sources (such as anglers using infected live bait, or fishing gear, deliberate introductions), or via other sources (such as cormorants catching infected fish in the Murrumbidgee River and then carrying it into Cotter Reservoir). This risk can be only partially mitigated. Based on the Fisheries Act 2000 (ACT), it is illegal to use live bait in the Cotter catchment, with only artificial bait allowed (lures and flies). However, not all anglers may be familiar with these rules for the Cotter catchment, or the rules may only have partial enforcement. Furthermore, it is not possible to control the actions of cormorants (and other wildlife) in the catchment. However, current stakeholders with activities in the catchment have been educated about the need to reduce the risk of EHN virus introduction into the Cotter Reservoir. ACTEW and ActewAGL have configured pipes and pumps at the Cotter Pump Station and the Murrumbidgee Pump Station to prevent the possible pumping of Murrumbidgee River water into Cotter Reservoir. TAMS have equipment segregation protocols to ensure that items used in the Cotter catchment have not been used elsewhere. Ecowise have wash-down rules for their equipment (including boats) to reduce the chance of cross-contamination between catchments (primarily due to blue-green algae, but also applicable to other organisms) This risk is present in the current reservoir.	Continue with current fishing restrictions and requirements in the Cotter River between Bendora and Cotter Reservoirs (i.e. prohibiting the use of live bait). Continue enforcement of current fishing restrictions and requirements in the Cotter River between Bendora and Cotter Reservoir. Monitor fishing use of the Cotter River between Bendora and Cotter Reservoir. Require all consultants undertaking activities in catchment to have EMPs for their activities. Require all consultants to have necessary approvals (such as a waterways permit) in place. Require all consultants to notify the Bulk Water Alliance of their activities in the catchment. Also require that key personnel are trained in mitigation measures to reduce the change of introducing the EHN virus into Cotter Reservoir. 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. 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 into the new reservoir. This will need fish eradication (drying, poisoning, netting etc). Use the findings of Project 4 - EHN virus occurrence to provide additional information. Use the findings of Project 9 – Fish monitoring for ECD. Liaise with ACT Government to promote a program of public education about the various risks. Use above information in adaptive management.	✓				Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
				✓				Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
					✓			Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
						✓		Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
							✓	Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)

12	**Lack of sufficient information collection and monitoring to be able to compile appropriate Fish Management Plan.** A considerable amount of information has been collected and this has been compiled into the ECD Fish Management Plan. However, there is always the possibility that information is insufficient or is insufficiently used. To reduce this risk, there are ongoing monitoring programs for a range of water and environmental characteristics.	Continue with current monitoring programs (for a range of water and environmental characteristics). Have regular stakeholder assessments of management requirements. Continue to translocate Macquarie Perch, Trout Cod and Two-spined Blackfish to other potentially suitable habitats and monitor populations(s) in new habitat(s). 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. Require close consultation between ACT government agencies, ACTEW and ActewAGL, to recognise additional risks due to lack of sufficient information. Require peer reviews of information collection and monitoring. Carry out and complete Projects 1-9. Require peer reviews of Projects 1-9. Use the findings of Project 5 – Translocation of Macquarie Perch, Trout Cod and Two-spined Blackfish to reduce the potential impact of this risk. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.	✓				Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
				✓				Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
					✓			Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
						✓		Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)

13	**Design and construction of ECD fails to incorporate fish-friendly components.**	Ensure frequent meetings between fish management personnel and design/construction team members to discuss fish management requirements. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.		✓	✓		Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
14	**Increased erosion resulting in increased nutrients and particulate matter in the aquatic environment upstream and downstream of the ECD (as a result of construction activity).** This risk is largely due to the substantial construction activities, and the ground disturbance resulting from this activity within the Cotter catchment, both upstream and downstream of the ECD.	Monitor sediment movement during filling phase. Require all consultants undertaking activities in catchment to have EMPs for their activities. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.			✓		Probable (3)	Moderate (3)	High (9)	Unlikely (2)	Moderate (3)	Moderate (6)
15	**Long-term (10-20 years) decline in fish numbers or growth rates (due to the depletion of nutrients and food sources) following the initial surge in productivity after reservoir filling.** Most newly filled reservoirs undergo a significant increase in trophic activity, due to the addition of new nutrients. This increases the food-web at all levels, which then increases the population of organisms in the reservoir, including the fish population. The process can take many years, following which the food-web can drop dramatically, which then results in a drop in the fish population.	Continue to monitor water quality in Cotter Reservoir and provide this information on a regular basis to ACTEW, TAMS and ActewAGL. Continue to monitor nutrient concentrations and algal numbers in Cotter Reservoir and provide this information on a regular basis to ACTEW, TAMS and ActewAGL. Continue to monitor fish numbers in Cotter Reservoir and the Cotter River upstream of the Reservoir. Regularly monitor food resources available to fish. Use the findings of Project 7 – Food sources for Macquarie Perch and drawdown effects. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.				✓	Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)

16	**Decline or loss of Macquarie Perch population due to impoundment of reservoir waters submerging spawning areas in the river.** The new dam wall may impound water up to the base of a natural fish passage barrier, preventing Macquarie Perch from accessing spawning areas in the river. This risk is more likely during the operational phase than at any other time. After the reservoir initially fills, access by Macquarie Perch out of the reservoir to breeding habitats in the river is also likely to be compromised by drawdown. Sedimentation of the newly inundated 4 km stretch of river and subsequent partial drainage events as a result of drawdown, are likely to destroy existing spawning sites,	Utilise the results of Project 2 – Swimming capacity of Macquarie Perch to determine what constitutes a barrier to Macquarie Perch movement. Use the findings of Project 8 – Mapping instream barriers. Ensure in design phase that impounded water FSL does not end up adjacent to a natural fish passage barrier. Ensure substantial areas of suitable spawning habitats are available at all storage levels. Ensure that natural fish passage barriers do not become operational at a range of projected drawdown levels. Provide uninterrupted passage at any problem barriers, either by modifying stream bed structure or building fishways. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.				✓	Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
17	**Increased abundance of alien fish species in the enlarged reservoir.** An increased abundance of alien fish in the enlarged reservoir could lead to increased competition for resources (Goldfish, Oriental Weatherloach, Gambusia, Trout) and increased risk of predation of Macquarie Perch and Two-spined Blackfish by Trout (as a result of increased coldwater refuge at depth in ECD).	Continue to translocate Macquarie Perch, Trout Cod and Two-spined Blackfish to additional locations to establish new populations. Monitor alien fish numbers in reservoir and river immediately upstream. Investigate levels of Trout predation and what life stages of threatened fish are most affected. Investigate control techniques to reduce impacts of predation (barriers, trapping etc). Use the findings of Project 6 – Management program for alien fish. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.				✓	Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)

18	**Reduction in Macquarie Perch food resources (macroinvertebrates) as a result of loss of macrophytes, sedimentation and fluctuating water levels.**	Use the findings of Project 7 – Food sources for Macquarie Perch and drawdown effects. Use the findings of Project 9 – Fish monitoring for ECD. Use the abovementioned information in adaptive management.				✓	Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
19	**Increased predation on Macquarie Perch in silted and shallowed upstream portion of reservoir during spawning runs.** Sedimentation of the newly inundated 4 km stretch of river and subsequent partial drainage events as a result of drawdown, are likely to destroy existing spawning sites, requiring fish to move through this occasionally inundated area to access clean spawning beds further upstream. There may be increased predation of Macquarie Perch (by cormorants), in shallow, sedimented sections at the head of the enlarged reservoir, particularly during the spawning part of the year (Oct-Dec) each year.	Minimise drawdown during Macquarie Perch spawning season (Oct-Dec). Monitor cormorant activity during such events. Investigate temporary and permanent provision of artificial cover during such events. Investigate temporary bird management options to mitigate predation during such events. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.				✓	Probable (3)	Major (4)	Very High (12)	Unlikely (2)	Major (4)	High (8)
20	**Inundation of 4 km of river may destroy suitable habitat of the Two-spined Blackfish** Sedimentation of the newly inundated 4 km stretch of river and subsequent partial drainage events as a result of drawdown, are likely to destroy existing habitat and spawning sites for Two-spined Blackfish. This species is absent from the existing Cotter Reservoir due to the high sediment volumes in the reservoir. Two-spined Blackfish are present in Bendora Reservoir (low sediment abundance) but it is unknown whether these fish breed in the reservoir itself or in the river upstream and then disperse	Investigate whether the species will breed in reservoir habitats. Investigate provision of artificial spawning habitats. Use the findings of Project 1 – Artificial habitats to provide additional information specifically on the suitability of artificial spawning habitat as an alternative spawning site for Two-spined Blackfish Then use this information to provide such habitats in the 4 km river-inundation zone for the ECD. Use the findings of Project 9 – Fish monitoring for ECD. Use above information in adaptive management.				✓	Likely (4)	Moderate (3)	Very High (12)	Probable (3)	Moderate (3)	High (9)

7. PROCESS FOR UPDATING ECD FISH MANAGEMENT PLANS

At the completion of the main ECD phases, the Fish Management Plan will be updated. Furthermore, as indicated previously, the Fish Management Plan will also be updated two years after the commencement of the filling and operational phases (expected to be in December 2013).

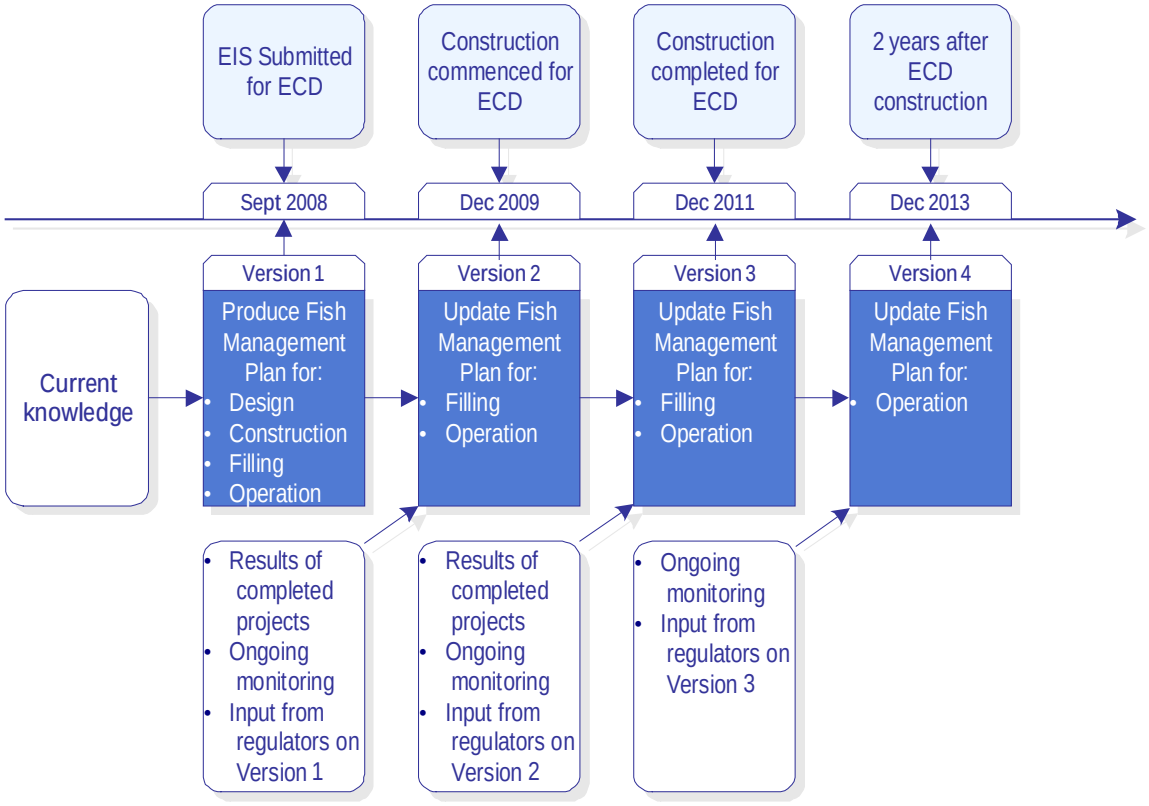

Figure 3: Process for updating ECD Fish Management Plan.

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