Indirect Potable Use and Expansion of the Cotter Reservoir, ACT

Stage 2 - Environmental Risk Assessment

August 2007

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List of Abbreviations

ACT	Australian Capital Territory
ACTEW	Australian Capital Territory Electricity and Water
BAC	Biologically activated carbon
CRC	Cooperative Research Centre
EHNV	Epizootic haematopoietic necrosis virus
EPBC	Environment Protection and Biodiversity Conservation
IPU	Indirect Potable Use
LMWQCC	Lower Molonglo Water Quality Control Centre
RO	Reverse Osmosis
UV/H_2O_2	Ultraviolet light combined with hydrogen peroxide
WPP	Water Processing Plant
WTP	Water Treatment Plant
W2W	Water2WATER project

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Executive Summary & Findings

1. Background & Methodology

The ACT Government is considering a proposal by ACTEW to augment the ACT's domestic water storages with highly-treated sewage effluent. The proposed process consists of additional treatment of effluent from the LMWQCC, using a combination of micro-filtration, reverse osmosis, and ultraviolet/peroxide oxidation. The final treated water will be pumped by pipeline to wetlands adjacent to Cotter Reservoir, and then gravitated from the wetlands to the reservoir. Residual, concentrated wastewater from the reverse osmosis unit – high in salt, some organic and inorganic compounds – will be disposed through one of three possible pathways outlined in the report (Sec. 1.4). This proposal for Indirect Potable Use (IPU) is referred to as the 'Water2WATER' (W2W) project. The W2W proposal also includes enlargement of the Cotter Reservoir from 4 GL to 78 GL.

In late April 2007, the eWater CRC was contracted by the ACT Government to provide a two stage analysis of environmental risks arising from the Water2WATER project and associated expansion of the Cotter Reservoir (public health and safety risks were to be assessed separately by an Expert Panel on Health). In May 2007, eWater CRC released an Environmental Issues Discussion Paper (Jones *et al*., 2007) which constituted stage 1 of that process. The present report completes the second and final stage of our evaluation.

In undertaking this environmental risk assessment, we have adopted a framework developed previously by the eWater CRC, which is in accordance with the Australian and New Zealand standards for risk management. The hazards/issues identified in our assessment arise from four inter-related parts of the Water 2WATER proposal:

- The water treatment plant and treatment process;
- Transfer of the treated water to the Cotter Catchment and Reservoir;
- Disposal of concentrated wastes; and
- Enlargement of the Cotter Reservoir

Under each of these headings, we first considered the likelihood and consequences for all identified environmental hazards/issues. This allowed us to reach an initial evaluation of the inherent environmental risks of the proposal. The opportunities to mitigate these risks, using engineering, technological and monitoring infrastructure and protocols available to ACTEW, were then evaluated. Finally, for all medium to high level risks, the residual risk was re-evaluated, taking into account the likely efficacy of the recommended risk mitigation strategies. As a final qualitative step, we also considered possible risks arising from 'whole of system', multiple-impact events such as bushfires, extreme storms, and climate change.

Our overall findings on the environmental risks associated with the Water2WATER proposal are based on this integrated methodology and analysis.

2. Key Findings in Summary

While there are a number of significant environmental risks associated with the Water2WATER proposal, it is our scientific judgement that these risks can be satisfactorily mitigated using known technologies and protocols. If all risk mitigations identified herein are agreed and fully included in the project design, construction and operations, we are of the opinion that the residual environmental risks are acceptable and should not, on their own, prevent the W2W project from proceeding.

In summary, these necessary risk mitigation actions are:

2.1 Environmental risks and mitigations associated with the Treatment Process

- Green energy, or suitable carbon off-sets, are used to neutralise potential greenhouse gas impacts.
- Significant reduction in nitrate concentration in treated water through denitrification at LMWQCC.
- Protection and management of threatened species habitat at, and around, the LWMQCC site as required.
- Strict real-time monitoring protocols and by-pass/failsafe provisions to ensure environmental pathogens and contaminants are removed or otherwise safely disposed.
- Strict environmental protections implemented during plant and pipeline construction.
- Appropriate water quality and ecological monitoring program in Cotter Reservoir, Cotter River downstream and Murrumbidgee River downstream of LMWQCC.

2.2. Environmental risks and mitigations associated with the transfer of water to the Cotter Catchment and Reservoir

- No discharge of treated water to Cotter catchment streams – treated water discharge to constructed wetlands, and from the wetlands to Cotter Reservoir, should be via a pipeline or constructed channel.
- Protection and management of threatened species habitat along the route of the pipeline across the Molonglo River and/or Murrumbidgee River.

2.3 Environmental risks and mitigations associated with the enlargement of the Cotter Reservoir

- Implementation of management practices that protect important fish species and other biota in Cotter Reservoir and passage upstream in the Cotter River. Specific issues include adoption of rules on the appropriate rate and extent of water-level draw-down, combined with the trialling, construction and monitoring of artificial fish habitats in Cotter Reservoir.
- Well-engineered in-reservoir mixing system to ensure good dispersal of treated-water entering the reservoir. This will also mitigate risks arising from downstream release of cold water from Cotter Reservoir.

- Alien fish species are prevented from moving upstream from below Cotter Dam during and following construction.
- Environmental flow releases downstream of Cotter Reservoir are maintained and, as required, revised for the larger dam.
- Strict environmental protections implemented during construction.
- Appropriate ecological monitoring program in, and upstream and downstream of, Cotter Reservoir.

2.4 Environmental risks and mitigations associated with disposal of wastewater

- Safe management of 'brine' waste stream from the reverse osmosis plant which, preferably, should occur on site at LMWQCC.
- Discharge of brine waste to the Murrumbidgee River during low flow periods is not recommended. Where this may be permitted to occur, such discharge should not significantly increase the salt concentration in the Murrumbidgee above that already being brought about by discharges from the existing LMWQCC plant.

3. Whole of system events and multiple-risks

As well as the specific environmental hazards/issues outlined above, we also considered, on a qualitative basis, possible risks arising from 'whole of system' events. These events, which may include bushfires, extreme storms, and climate change, act across the entire system rather than impacting only on one part. Hence, they may cause multiple environmental effects or, alternatively, act in concert on multiple parts of the system to bring about a single impact that otherwise may not have occurred. While it may be very difficult to mitigate against such system-level events, it is important to identify potential impacts and have management practices in place for when/if they occur. In particular, authorities should set in place appropriate emergency management and environmental recovery plans, so that the 'unexpected' is well planned and well prepared for, not just the day to day.

4. Recommendations for further environmental investigations

Our risk analysis and assessment has identified a number of areas where additional scientific and technical investigations are necessary for guiding further planning and design for the Water2WATER proposal. Such investigations will, if the project proceeds, also help to better manage ecological conditions and risks during routine operations. It is recommended that further investigations are carried out in the following areas:

- Identification and design of suitable non-greenhouse gas emitting energy sources to minimise net energy consumption;
- Selection of a location/route for the proposed pipeline from the LMWQCC to the Cotter Catchment and Reservoir that causes minimal impact on endemic plants and animals;

- Modelling of the potential impacts of increased nitrogen (nitrate) load on the eutrophication status of Cotter Reservoir;
- Modelling of potential changes to water chemistry (anion/cation/trace element balance) in Cotter Reservoir. If significant changes are predicted, and these changes cannot be ameliorated through chemical additions at the treatment plant, detailed studies considering the potential response of biota will also be necessary;
- For an enlarged Cotter Reservoir, hydrodynamic modelling studies to (i) select the best type, design and placement for an artificial mixing system, (ii) minimise downstream cold water releases, and (iii) to locate the treated water in-flow to ensure effective mixing within the reservoir;
- Consideration of the appropriate design and potential benefits of artificial fish habitat construction in the Cotter Reservoir as a means of mitigating deleterious ecological consequences of draw-down and reservoir height fluctuations;
- Possible expansion and control of alien fish populations in an enlarged Cotter reservoir, and potential impacts on native fish species especially Macquarie Perch;
- Detailed analysis and investigation of the various concentrated waste (brine) disposal methods are necessary before any final build decision is made. Details are currently lacking regarding the possible mechanical concentration of brine waste on site at LMWQCC, with subsequent transport and disposal of the solid salt and residual wastes elsewhere. We recommend that a detailed risk assessment be conducted if and when the on-site brine treatment is seriously considered as a part of ACTEW's W2W proposal.
- The Water2WATER proposal has drawn attention to the on-going environmental issue of salt (and nutrient) discharge from LMWQCC to the Murrumbidgee River. Given the possibility that brine discharge to the Murrumbidgee is being considered, it would be appropriate now to undertake detailed investigations of the response of endemic plants and animals to elevated salt concentrations – both to current elevated levels and those that could be experienced through the Water2WATER proposal. Sensitive life-history stages of fish and invertebrates (eg. fish eggs and larvae) should be targeted for investigation.

In addition to these investigations, regular acute and chronic ecotoxicological (biological) testing of treated water from the new plant will be important to ensure the on-going suitability of water for plants and animals in Cotter Reservoir and environs.

1 Study Background

1.1 Preamble

The ACT Government is considering a proposal by ACTEW to augment the domestic water supply by using advanced treatment of effluent from the Lower Molonglo Water Quality Control Centre (LMWQCC) and returning the water to the domestic system via the Cotter Reservoir and the Mount Stromlo water treatment plant. The proposal would also include enlargement of the Cotter Reservoir from approximately 4 GL to 78 GL. ACTEW's proposal for Indirect Potable Use (IPU) is referred to as the 'Water2WATER' project.

Major elements in the proposal are (see figure 1.1):

1. an advanced treatment facility at the Lower Molonglo plant (LMWQCC);
2. piping of treated water to a wetland system to be constructed near to the Cotter Reservoir and discharge from the wetland system – via a stream or other means – to the Cotter Reservoir;
3. treatment of the concentrated 'brine' waste from the advanced treatment facility, either on-site, by discharge to the Murrumbidgee River or by pipe-line to an area near Uriarra village where it would be discharged into evaporation ponds;
4. enlargement of the Cotter Reservoir.

Full details of the techniques used, siting, design, construction and management of the treatment plant, receiving wetlands and enlarged Cotter Reservoir will have an influence on potential impacts but are not yet available because the project is still at a conceptual stage. In late April 2007, the eWater CRC was contracted by the ACT Government (Environment & Recreation) to provide a two stage analysis of environmental risks arising from the proposed Indirect Potable Use (IPU) scheme and associated expansion of the Cotter Reservoir.

The Stage 1 report, completed in May 2007, was an environmental issues discussion paper (Jones *et al*., 2007a). The present report is a full environmental risk assessment, and it constitutes the second and final stage of the environmental evaluation for the Water2WATER project carried out by the eWater Cooperative Research Centre for the ACT Government.

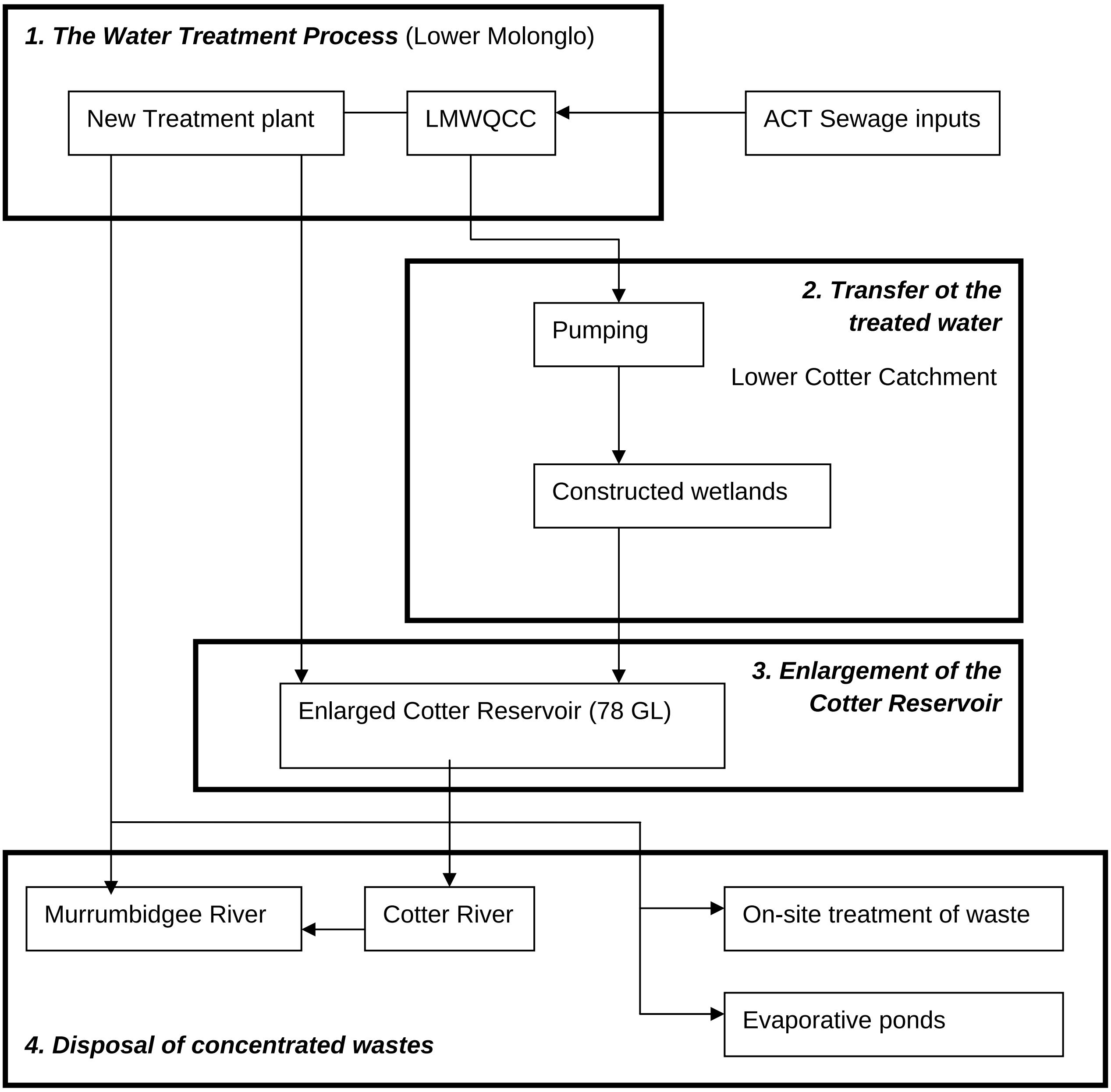

Figure 1.1 Conceptual diagram of proposed system within the Lower Molonglo Valley and Lower Cotter Catchment – basis for risk assessment (see Figure 1.2 for map).

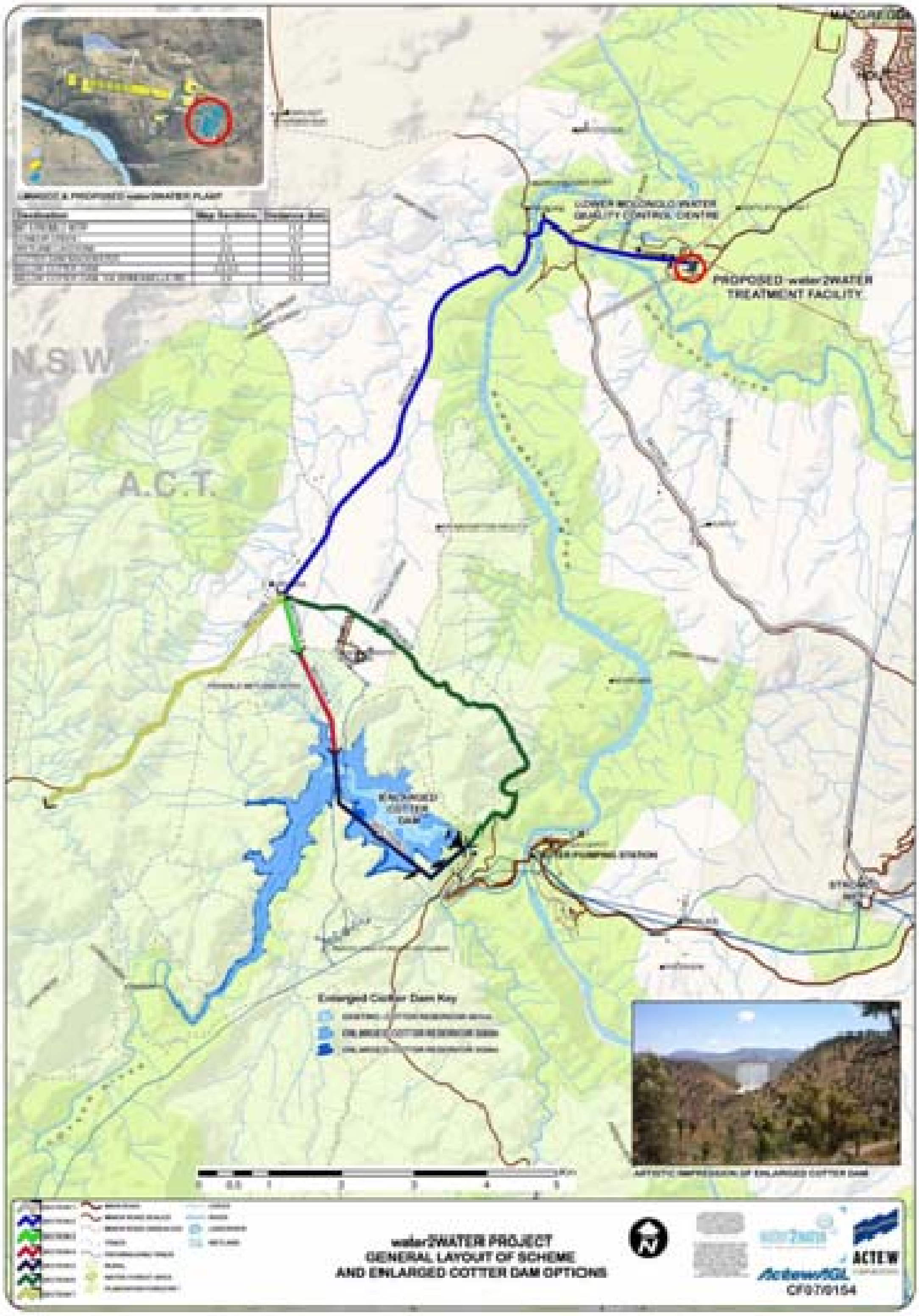

Figure 1.2 Map showing Water2WATER proposed sites and routes.

Taken from: ACTEW, 2007. Pumping Station and Pipeline from LMWQCC to Cotter – Preliminary Sizing and Cost Estimates, ACTEW Corporation Ltd, July 2007.

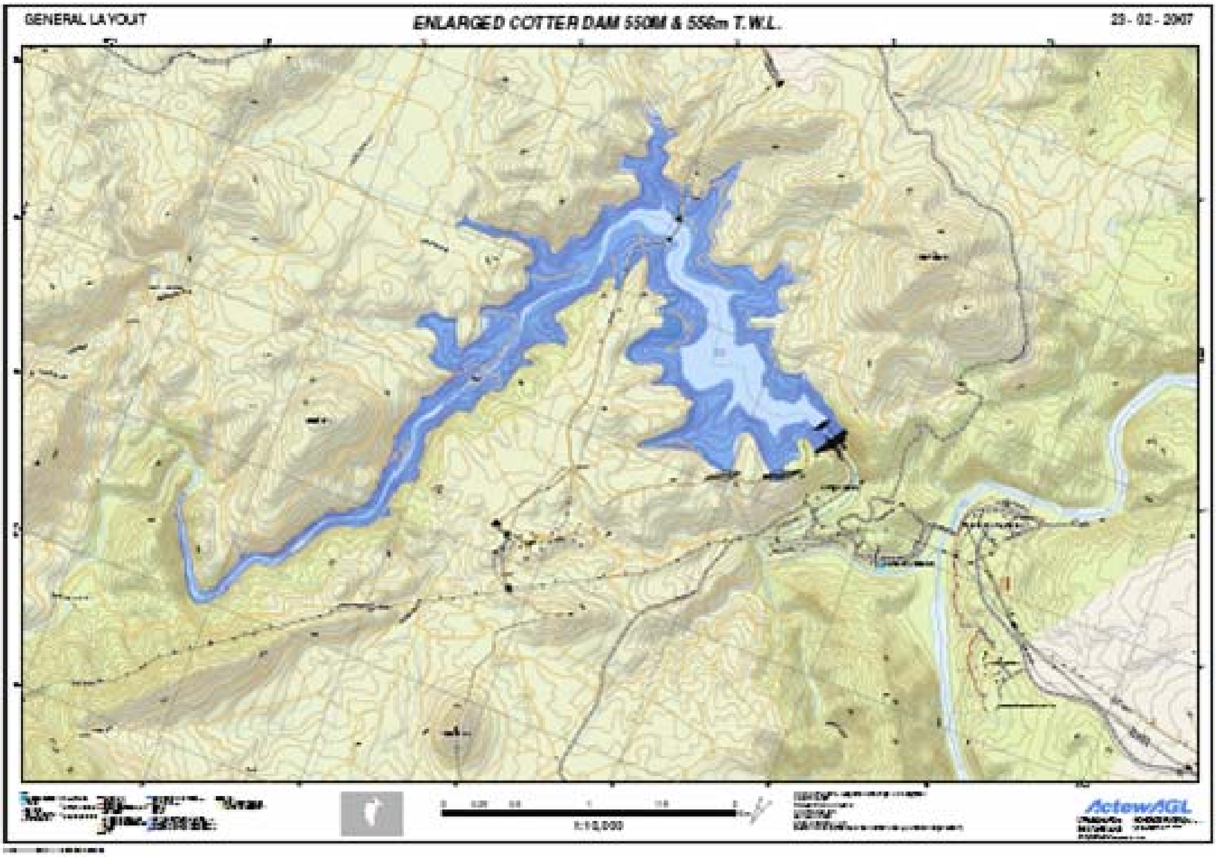

Figure 1.3 The enlarged Cotter Reservoir (78 GL) as proposed by ACTEW

1.2 Terms of Reference

The eWater CRC will assess and report on potential environmental impacts of the proposal. Assessment will focus principally on watercourses, groundwater, and aquatic ecosystems, but will also include potential impacts on terrestrial ecosystems. A preliminary listing of potential issues identified by the ACT Government and a review of these issues, and any others identified by the CRC will comprise the basis for the report. The eWater CRC will provide two reports; (1) Discussion paper on issues; (2) Technical report on issues and solutions

Stage 1. Discussion paper

The purpose of this document is to identify and provide background to the environmental issues that could arise during the course of this project. This document provides an overview of issues, based on existing documents, data and knowledge, and was prepared relatively quickly. For each potential issue, where possible, the paper discusses the likelihood that it will eventuate and the environmental consequences if it does eventuate Some issues are difficult to evaluate because we currently have insufficient understanding of the biological processes involved, and/or insufficient details of the proposed activities. For such issues eWater CRC has identified the reasons for the uncertainty surrounding the issue. The discussion paper has been used in a public consultation process to alert the community to environmental issues arising from the Water2WATER project.

Stage 2. Technical Report & Risk Assessment

The technical report is built on the discussion paper through a consideration of potential response or solutions to environmental issues. Issues considered are those included in the discussion paper, together with additional issues identified during the community consultation process. For each issue the report discusses:

- the likelihood that it will eventuate;
- the environmental consequences if it does eventuate;
- the potential for amelioration through management actions, siting or engineering solutions;
- proposed solutions.

As with the discussion paper, some issues are difficult to evaluate because we currently have insufficient understanding of the biological processes involved, and/or insufficient details of the proposed activities. For such issues eWater CRC has identified:

- the reasons for the uncertainty surrounding the issue;
- the additional investigations or information required to adequately assess the issue;
- the timing for full understanding of the issue.

The investigation of these issues has been, by necessity, be a desk top study. It is principally aimed at identifying those critical issues that have the potential to result in major environmental damage. These include those for which the ACT Government has insufficient information to make an assessment, or those for which there are no apparent amelioration measures. The report articulates the assumptions made in underpinning the assessment of issues.

It is noted that in the process of developing the report there was a need to seek further information on the proposal or to clarify anticipated management or operational procedures.

1.3 Description of receiving waters and lands

The Cotter River catchment is situated in the Brindabella Range, ACT, and occupies an area of about 483 km^2 (figure 1.2). The river flows in a northerly direction before joining the Murrumbidgee River approximately 72 km downstream at Cotter Reserve. Most of the catchment is managed to protect the quality of the water, and lies within the Namadgi National Park. The Cotter River is an upland boulder, cobble, and gravel-bed river, including bedrock outcrops. It provides habitat for several aquatic species that are listed under the Nature Conservation Act 1980 (*ACT*) as threatened with extinction.

The Cotter River catchment provides much of the drinking water supply for the ACT, with three reservoirs (Corin, Bendora and Cotter) providing water storage and regulating flows along the river. Within the upper Cotter sub-catchment, run-off has been of a high quality in the past because of good vegetation cover, soil stability, and limited human activity. However, bushfires in January 2003 burnt through 70% of the land-area within the ACT, including protected National Park areas that also cover the Cotter drinking water catchment. The future response of the Cotter catchment to the bushfires is still uncertain and further research is in progress.

The lower section of the river near Cotter Reservoir previously contained large areas of pine plantations, but most of the burnt pine debris has been cleared, and the residues burned, since the bushfires. The terrain is hilly with some steep slopes. Sandy topsoils overlay thick clay subsoils, and there is some localised soil erosion from debris removal and the extensive system of tracks and firebreaks, and possibly also some sheet erosion.

The lower Cotter catchment currently exhibits run-off having turbidity and bacteriological concentrations high enough to require water treatment before delivery to the water supply distribution system. The lower quality of water in the Cotter Reservoir is because of the more erosion-prone soils of the area, and the greater extent of pre-bushfire activities such as softwood logging and recreational pursuits, and recent debris removal. Until now, Cotter Reservoir has generally only been used for Canberra’s water supply in times of high demand, and its sub-catchment has less restricted land-use and public access, compared to the upstream reservoirs.

Land proposed for possible wetland treatment sites was formerly managed as a pine plantation. Under current ACT Government proposals for restoration of this catchment the area is to be planted with native species and allowed to revert to a predominantly native vegetation type dominated by *Eucalyptus* species, possibly reflecting its original pre-1750 woodland or forest vegetation. In 2007 the former plantation area is regenerating with some native vegetation, some dense pine wildings and other weeds, particularly along the water-courses.

The land in the immediate vicinity of the proposed area for the new treatment works is important habitat for the Pink-tailed Worm Lizard (*Aprasia parapulchella*), a species that is listed as threatened under the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999* (see Appendix D). This habitat is important as it is part of a broad link between populations to the north and to the south. This species habitat is already considerably fragmented and therefore connection between populations is important for dispersal and hence gene flow.

The fish community of the lower Cotter catchment (between Bendora and Cotter Reservoirs) contains nine species of finfish, plus three crayfish species. A further seven finfish species are known or likely to be present in the Cotter River downstream of Cotter Reservoir (Lintermans 2005). In the Reservoir or river immediately upstream, there are three threatened aquatic species present: Macquarie Perch (*Macquaria australasica*), Two-spined Blackfish (*Gadopsis bispinosus*) and Murray River Crayfish (*Euastacus armatus*), as well as five alien finfish species. Brown Trout (*Salmo trutta*) and Rainbow Trout (*Oncorhynchus mykiss*) are distributed throughout the lower Cotter, whilst Eastern Gambusia (*Gambusia holbrooki*), Oriental Weatherloach (*Misgurnus anguillicaudatus*) and Goldfish (*Carassius auratus*) are confined to the Cotter Reservoir and the river immediately upstream.

The population of Macquarie Perch in the reservoir and the river upstream (below Vanity's Crossing) is the sole remaining viable population of this species in the ACT. The previous population in the Murrumbidgee River in the ACT has declined to negligible levels; the population in Lake Burrinjuck is effectively extinct; and the translocated population above Googong Reservoir in the Queanbeyan River is now at non-detectable population size (Lintermans 2002, 2006b). Hence, sound management of the Cotter Reservoir population is critical if the species is to survive in the ACT.

Flows in the Cotter River have been closely managed under environmental flow guidelines developed as part of the ACT's commitment to COAG (Council of Australian Governments) agreements. The flow guidelines have been implemented in an adaptive management framework where sequential decisions are made based on needs and environmental information.

Adaptive management decisions following major events of fire and drought culminated in a much reduced drought-flow regime, commencing in 2003–2004, with minimum flows, variability and flushing flows. The stream ecology has been assessed using aquatic biota, ecological processes, physical features and water quality. It has been demonstrated that this regime has markedly improved and subsequently maintained the ecological condition of the Cotter River, relative to local unregulated streams. This was achieved even with stress from drought and the effects of the January 2003 bushfires (Norris *et al*., 2004).

1.4 Treatment system, supply and waste management

New treatment process

The treatment 'train' proposed by ACTEW for the advanced water treatment process is described below. The additional purification steps will be carried out in a new water purification plant to be built on the site of the existing LMWQCC.

Treatment train

(i) Feed water for the new treatment process will be tertiary treated sewage from the existing LMWQCC. Key steps in the treatment train are membrane filtration, reverse osmosis, and advanced oxidation using ultraviolet radiation combined with hydrogen peroxide, as follows:

Membrane filtration → Reverse Osmosis → UV/H_2O_2 oxidation → Wetland/Stream → Cotter Reservoir

UV/H_2O_2 = Ultraviolet light combined with hydrogen peroxide

The treatment train will also include carbon dioxide stripping and pH adjustment of treated water before transfer to the Cotter system.

(ii) Treated water will be pumped from the purification plant at LMWQCC to a site approximately 13 km from the plant and through a height differential of approximately +260m. ACTEW have advised that the treated water pumping regime currently being considered is a constant 25 ML/day for 365 days per year with the option to increase that to 50 ML/day if and when required (eg. after completion of the Cotter Reservoir enlargement).

(iii) The specific site for discharge, either to a new wetland complex or several creeks, is yet to be finalised, but is taken for the purposes of this paper to be one of the small tributaries of Condor Creek, draining from the north of Cotter Reservoir.

(iv) Water will leave the wetland complex and be transferred to the Cotter Reservoir by one of three possible options under consideration (a) surface discharge via a nearby tributary stream; (b) surface discharge via a pipe or channel; or (c) percolation through shallow groundwater to the reservoir.

(v) From Cotter Reservoir water will be pumped through the existing reticulation system to Mt Stromlo water treatment plant, diluted as appropriate with water from other reservoir sources, and then treated through the existing drinking water treatment process.

(vi) Generated from the above treatment process are waste streams arising from the membrane filtration and reverse osmosis processes. ACTEW proposes to return solid and liquid wastes from the membrane filtration process to the raw sewage inlet treatment stream at LMWQCC. However, the proposed RO Plant will generate a sperate liquid waste or ‘brine’ stream – so called because it will contain significant quantities of dissolved salts as well as nutrients, organic compounds and virus particles not removed by ultrafiltration. The RO waste stream – about 10-15% of the total volume passing through the plant - will be further treated/managed in one of three ways: (i) pumping by a separate pipeline to a site located to the north of the Uriarra Homestead and (former) Forestry settlement, (ii) concentration on-site at LMWQCC or (iii) by direct discharge to the Murrumbidgee River.

Under option 1, liquid brine waste will be dried in large evaporation ponds. The residual waste solids collected by this process will be disposed of by a method yet to be identified by ACTEW, but which may include trucking to land-fill sites outside the ACT. Under Option 2, evaporative drying will be achieved on-site by mechanical means, with subsequent disposal of the dried salt waste, as per option 1. Option 3 – direct discharge of liquid brine to the Murrumbidgee River – would not involve further treatment. Option 2 above, for brine waste disposal on-site, has been included in the planning and evaluation process by ACTEW since the stage 1 environmental issues report was prepared by the eWater CRC in May 2007.

In our stage 1 report, we also considered a second treatment train option, then being evaluated by ACTEW, based on the use of biologically activated carbon (BAC) rather than reverse osmosis. Based partly on concerns raised by the eWater CRC in our Stage 1 report, and following further evaluations, ACTEW has omitted the BAC treatment option from further planning consideration and evaluation. The main reasons for this decision are:

- the lack of salt (or total dissolved solids) removal through the BAC process. Modelling studies carried out by ACTEW indicated that there would be a very significant increase in the salinity of the water in the Cotter Reservoir, especially during the drier months of the year. These salinity increases would almost certainly have led to undesirable ecological impacts on plants and animals in Cotter Reservoir, as well as potentially affecting human water consumers; and

- the lack of nutrient removal, particularly nitrogen, through the BAC process that would result in elevated nutrient loads being imposed in the Cotter Reservoir, increasing the risk of cyanobacterial blooms and excessive plant and weed growth. It is noted here that the Expert Panel on Health (Falconer *et al*., 2007) also support the decision to opt for the Reverse Osmosis treatment process.

1.5 Enlargement of Cotter Reservoir

An integral part of the project is the enlargement of Cotter Reservoir. This will be achieved by constructing a larger dam wall immediately downstream from the existing wall. The new wall will increase the maximum storage of Cotter Reservoir from its current volume of 4.7 GL to 78 GL (GL = gigalitre = one billion litres). Enlargement of the Cotter Reservoir to 78 GL would increase the total area inundated by about 260 ha (Figure 1.3).

Enlargement of Cotter Reservoir will provide the two-fold benefit of (i) allowing a greater proportion of natural run-off from the Lower Cotter catchment to be captured in the reservoir, providing increased water supply and security for Canberra, and (ii) increasing the residence time of treated water in Cotter Reservoir, hence allowing a longer time for natural processes to diminish any residual contaminants or pathogens in the water.

1.6 Other assumptions made for this study:

Based on discussions with ACTEW the following additional assumptions have been made in compiling this issues paper:

- After dam construction – environmental flow provisions will be maintained.
- Recreational access to the reservoir will remain at current restricted levels or be even more restricted.
- Optimum performance and reliability of the proposed treatment process and waste management system.
- The catchment of the lower Cotter Reservoir that was severely damaged by the 2003 bushfires will be fully rehabilitated in favour of maintaining and enhancing water quality and environmental values (see ACT Government's 'Clean Water, Health Landscapes' Lower Cotter Catchment Draft Strategic Management Plan, May 2006).

2 Risk Assessment Methodology

2.1 Evaluating Consequence & Likelihood

The following risk assessment is based on the framework developed by eWater CRC (Blackmore *et al*. 2007) which is in accordance with the following Australian and New Zealand standards:

- Risk Management, AS/NZS 4360:2004;
- Environmental Risk Management – Principle and Process, HB 203:2004;
- Risk Analysis of Technological Systems – Application Guide, AS/NZS 3931:1998

Risk management is defined in AS/NZS 4260:2004 as :
'The culture, processes and structures that are directed towards realizing potential opportunities whilst managing adverse effects'

And the risk management process as:
'The systematic application of management policies, procedures and practices to the tasks of communicating, establishing the context, identifying, analysing, evaluating, treating, monitoring and reviewing risk'.

Risk assessments are usually based on the consequences of a given event and the likelihood of those consequences occurring. The consequence of an event is its impact on a vulnerable population or community – in this case an ecological population or community. The likelihood of an event having an impact will not only depend on the likelihood of the event occurring, but also on the likelihood of the population being in a vulnerable state at the time the event occurs (Blackmore *et al*., 2007). The 'issues' identified in the following risk assessment refer to events that may result in the environmental risks identified.

Following on from the topics outlined in the Stage 1 Environmental Issues Report by the eWater CRC (Jones *et al*., 2007), the environmental risks arising from the following components of the Water2WATER proposal were considered under four headings:

- Construction and operations of the advanced water treatment plant;
- Transfer of the treated water to the Cotter Catchment and Reservoir;
- Enlargement of the Cotter Reservoir; and
- Disposal of concentrated wastes.

We also briefly evaluated risks arising from potential whole of system events such as bushfires and sever storms.

The present risk assessment follows the general steps outlined in figure 2.1, as adopted from Blackmore *et al's*. (2007) framework. The scaling of the consequences of risks in this assessment was conducted for worst case scenarios. In reaching our initial findings, we first considered the inherent risks for each identified environmental hazard/issue. The opportunities to mitigate the assessed risks using engineering, technological and monitoring infrastructure and protocols available to ACTEW were then evaluated, and these were combined with the initial risk analysis in reaching our final assessment of the acceptability or otherwise of the residual risk.

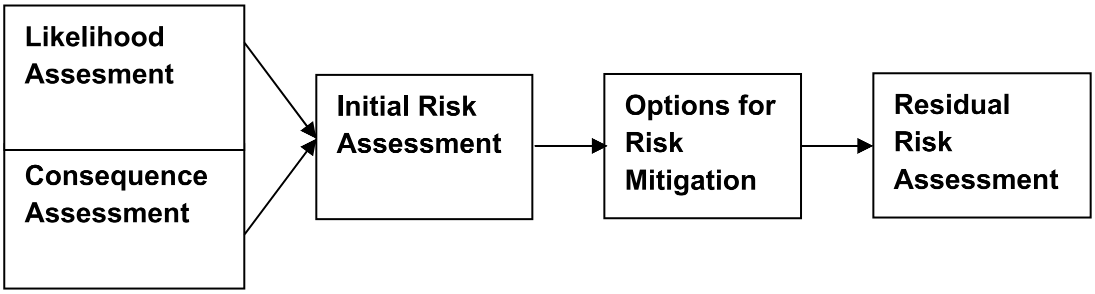

Figure 2.1 General Steps in Risk Management Process (modified from Blackmore et al., 2007).

Evaluating Environmental Consequence

In order to give a value to each environmental consequence in this risk assessment, it was necessary to identify the extent and intensity of each consequence. The extent of each consequence was identified using a two-way matrix (Table 3.1). Firstly identifying the spatial extent, i.e. how large an area will be affected, and secondly identifying the temporal extent, i.e. how long the said effect will last for.

Extent

Spatial:
1. Reach
2. Multiple reaches
3. Basin/Region

Temporal:
1. Short-term effect (affects current generation only)
2. Long-term effect (may affect future generations)
3. Permanent effect

The two ‘scores’ are combined to give a single overall score for ‘extent’ (table 2.1)

Table 2.1 Extent score-table for risk assessment.

Extent table		**Spatial**		
		1	**2**	**3**
Temporal	**1**	1	1	2
	2	1	2	3
	3	2	3	3

The intensity of a consequence refers to the level of the effect on a population or ecosystem. For example, a consequence of an event could be lethal to a population or ecosystem, or, it could simply result in behavioural changes. The intensity of each consequence was calculated using the scale below.

Intensity - 1. Chronic/low level (behavioural, lifespan or condition effect)
2. Acute/moderate (impact on growth, recruitment or survival rates)
3. Lethal/extreme (for individuals or communities)

A two-way matrix for extent and intensity of consequences was used to identify an overall consequence ratings for each consequence (Table 2.2).

Table 2.2 Consequence table for risk assessment

Consequence table		**Intensity**		
		1	**2**	**3**
Extent	**1**	1	1	2
	2	1	3	4
	3	2	4	5

It is necessary to have a description for each level of consequence that applies to the proposal at hand. In a descriptive sense, the consequence rating obtained for each risk correlates to the following consequence scale.

Consequence scale:

1. Minor or transient effect (eg. behavioural changes).
2. Noticeable decline in ecosystem function, population, receiving land or water quality with no action required for recovery.
3. Noticeable decline in ecosystem function, population, receiving land or water quality with action required for recovery.
4. Long term loss of ecosystem function, population, receiving land or water quality with difficulty in recovery.
5. Total loss of ecosystem function, population, receiving land or water quality with no possibility of recovery.

Evaluating Consequential Likelihood

The likelihood of each consequence occurring was assessed using table 2.3, adopted from Blackmore *et al*. (2007). Likelihoods were assessed based on the assumption that, within the range of design options provided to us, ACTEW will implement the best available system and monitoring ie. their choice will not be limited by cost. Even allowing for failure of such systems, the response will be quick and mitigation activities will be rapidly implemented.

Table 2.3 Likelihood scaling for risk assessment.

Risk Likelihood Level		Definition	Likelihood Range
1	Highly unlikely	May occur only in very exceptional circumstances.	<1%
2	Unlikely	Unlikely to occur in most circumstances.	1-20%
3	Possible	May occur in some circumstances.	21-49%
4	Very likely	May occur in most circumstances.	50-85%
5	Almost certain	Expected to occur in most circumstances.	>85%

2.2 Evaluating Levels of Environmental Risks

Once a consequence value and a likelihood value had been established for each risk it was then possible to identify overall risk ratings (Table 2.4) and, hence, identify the risks of greatest concern. This was done using a two-way matrix for consequence and likelihood based on the premise that a frequent event of low consequence is equivalent to an infrequent event of high consequence. For example, if the consequence of a given event is rated high, but the likelihood of that event occurring is low, the overall risk rating will be low to intermediate. Only when a consequence is rated high and the likelihood of that consequence occurring is also high will the risk become a high level risk and therefore a high priority for mitigation. This rating helps to scale the different risks against one another in order to identify those of greatest concern.

Table 2.4 Risk values table for risk assessment.

Risk Table		Consequence Value				
Likelihood Value		**1**	**2**	**3**	**4**	**5**
	1	1	1	1	2	2
	2	1	2	2	3	3
	3	1	2	3	4	4
	4	2	3	4	4	5
	5	2	3	4	5	5

Risk Scale:

1. Very low level risk, consequences unlikely or very easily mitigated.
2. Low level risk, consequences unlikely or easily mitigated.
3. Medium level risk, mitigation of consequences necessary.
4. High level risk, mitigation of consequences imperative, monitoring required.
5. Very high level risk, mitigation of consequences imperative, close monitoring essential.

2.3 Establishing risk prevention/mitigation

Once risks have been identified and evaluated, risk management involves the selection and implementation of appropriate prevention/mitigation measures and ongoing monitoring in an ever changing environment. It is a dynamic and iterative process as monitoring identifies the effectiveness of implemented mitigation measures and the need for ongoing revision of risks. The context should not be limited to preventative measures; mitigation and emergency response are equally important. For example, the ability of the community to respond to emergencies might influence suitability of alternative control measures (Blackmore *et al*., 2007).

In cases like this one, where risk assessment is being used to inform planning and decision-making, risk management procedures can be used to adjust the design of a given proposal to reduce risks, identify common causes of failure and to ascertain the ease with which areas of high risk can be managed (Blackmore *et al*., 2007).

Management of risk events may cover three stages:

1. Risk management implemented *before* the occurrence of events;
2. Emergency response management *during* the occurrence of events;
3. Recovery management *after* the occurrence of events (Blackmore *et al*., 2007).

Our environmental risk assessment of the W2W Project focuses primarily on risk management implemented before the occurrence of events (1), as further assessment is outside our terms of reference.

2.4 Assessment of residual risks

A residual risk assessment has been conducted for any risks that were initially identified as being a level 3 risk (‘Medium’) or above, and hence requiring *a priori* risk mitigation. Risks identified as level 1 or 2 are considered of an acceptable level, though still requiring close monitoring and vigilance. The residual risk assessment was conducted using the same framework outlined above, but assuming that the recommended mitigation measures are implemented.

3 Environmental Risk Assessment and Mitigation Measures

Using the framework outlined in Section 2 above, the following risk assessment focuses on identifying the environmental risks posed by ACTEW's Water2WATER proposal and outlines mitigation measures for those risks. The assessment is divided into four sections as outlined in figure 1.1. The first deals with risks associated with construction and operations of the advanced water treatment plant, the second deals with risks associated with the transfer of the treated water, the third deals with risks associated with enlarging the Cotter Reservoir and the fourth deals with risks associated with the disposal of waste and waste water.

For a complete breakdown of likelihood and consequence scores, as assessed by the authors, refer to Appendix B (initial risk assessment) and Appendix C (residual risk assessment).

3.1 Construction and operations of the advanced water treatment plant.

3.1.1 Issue – High energy consumption and greenhouse gas emissions.

Advanced water treatment is an energy intensive process. Internationally, the major energy consuming and, consequently, greenhouse gas-emitting parts of the process tend to be reverse osmosis and pumping. At the time of writing this report, very limited information was available to us regarding the specific energy requirements of the Water2WATER project. Consequently we have relied on published information for similar plants elsewhere in the world, and also, on a draft energy and emissions analysis provided to us by the ACT Government (AETF Consulting, 2007).

International experience suggests that energy consumption for the proposed processes could be in the order of:

Dual membrane filtration (MF/UF)	400 kWhr/ML
UV treatment	200 kWhr/ML
Reverse osmosis	800 kWhr/ML
Pumping to discharge site	3000-5000 kWhr/ML (estimate only).

A similar plant to that proposed under Option A operating in Singapore uses 700-900 kWhr/ML. The contribution, if any, of pumping to that energy use is presently unknown. Preliminary estimates of the power requirements for the new treatment process, provided to us in May by ACTEW's consulting engineers, were about 6000 kW (kilowatts). Based on an estimated greenhouse gas emission rate of 1.08 kg CO_2/kWhr, and assuming 24 hours a day, 365 days per year operations, this level of energy consumption translates to a minimum greenhouse gas emission rate of about 57,000 tonnes of carbon dioxide per year from plant operations. Analysis provided in the AETF Consulting (2007) draft report, provided to us only in early August, indicates that the new water treatment and pumping plant will contribute a lower level of 16,000-17,000 tonnes of additional carbon dioxide emissions per year. Further, the draft analysis indicates that this figure could be reduced to about 10,000 tonnes per year through energy offsets from a mini-hydroelectricity installation (presumably in-pipe on the downhill side of the Cotter Catchment, though this was not stated in the report).

Environmental risks

Contribution to global warming (changed weather, reduced flows).

Consequence rating: 2 – Noticeable decline in ecosystem function, population, receiving land or water quality with no action required for recovery.

Likelihood rating: 5 – Almost certain, expected to occur in most circumstances (50-85%).

Risk rating: 3 – Medium level risk, mitigation of consequences necessary.

Mitigation

Mitigating against green-house gas production should be reasonably straight forward, and there appear to be no obvious non-financial reasons, given the right planning and regulatory incentives, why the Water2WATER process could not be greenhouse neutral. Green energy sources are available to ACTEW and should easily be incorporated. ACTEW is also able to participate in the NSW/ACT Greenhouse Gas Abatement Scheme (GGAS). There may also be opportunities to reduce net energy consumption and greenhouse gas emission by using in-pipe hydro-electricity options or through heat generated from the treatment plant itself.

Residual risk: 2

Given that the above energy-offset and green-energy mitigations should be reasonably straight forward to implement, we feel that the risks will be reduced to an acceptable level. A low level risk, with consequences unlikely or easily mitigated. One caveat is that we would take a very cautious view of a hydro-scheme being built on the new Cotter Dam itself (rather than on the LMWQCC to Cotter pipeline). This option has not been proposed to us by ACTEW, nor have we analysed it in any detail. We note the concern here only for precautionary reasons. Experience elsewhere in Australia suggests that hydro-schemes can bring about ecological impacts downstream due to the wildly varying flow regimes that can result due to the need to supplement peak electricity demands at certain times of the day

3.1.2 Issue – New works at LMWQCC posing potential impacts on the Pink-tailed Worm Lizard which is listed as a threatened species under the Commonwealth EPBC Act.

Any new works required at and around the LMWQCC site pose potential impacts on the Pink-tailed Worm Lizard (*Aprasia parapulchella*). This species is listed as threatened under the Commonwealth's *Environment Protection and Biodiversity Conservation ACT 1999*, and has Special Protection Status (SPS) under the ACT's *Nature Conservation Act 1980*.

The ACT is the only known stronghold for the species which occupies rocky grassland habitat that is largely confined to rocky river slopes and nearby hills (eg. Mt. Taylor) (ACT Government 2007) and is of considerable regional importance (Osborne, 2006). The population located along the Lower Molonglo River is probably the most extensive population of the species recorded to date. Extensive Pink-tailed Worm Lizard habitat found along the Lower Molonglo and Murrumbidgee Rivers potentially allows for dispersal and hence gene flow between localised populations and every effort should be made not to further isolate the remaining patches of Pink-tailed Worm Lizard habitat (Osborne, 2006).

The lizard habitat within the LMWQCC boundary is important because it is part of a broad link between populations to the north along the Murrumbidgee River and to the south along the north bank of the Molonglo River (Osborne and Coghlan, 2004) and patches of suitable habitat provide an important part of a semi-continuous link between Pink-tailed Worm Lizard west of Shepherds Lookout and the Molonglo River corridor (Osborne, 2006).

The location of the works required for the Water2Water project (as indicated on the feasibility concept plan supplied by ACTEW) is likely to eliminate a small area of moderate quality habitat identified by Osborne (2006), however this is not likely to be a significant loss (see Appendix E). Of greater importance is the potential for loss of habitat immediately around any new pipeline that leaves the LMWQCC and crosses the Molonglo River and/or Murrumbidgee River. This may result in fragmentation of the lizard population that is found on the northern/eastern banks of the Molonglo/Murrumbidgee up to and beyond the ACT/NSW border. It is noted that the route of the pipeline across the rivers has not yet been defined, hence, the extent of the potential impact on lizard habitat is unknown at this time.

Environmental risks

Decline in or loss of the Pink-tailed Worm Lizard (*Aprasia parapulchella*) population.

Consequence rating: 4 – Long term loss of ecosystem function, population, receiving land or water quality with difficulty in recovery.

Likelihood rating: 5 – Almost certain, expected to occur in most circumstances (>85%).

Risk rating: 5 – Very high level risk, mitigation of consequences imperative, close monitoring essential.

Mitigation

Impacts can be mitigated by careful planning and execution of construction. In the context of his assessment of the proposed works within the LMWQCC boundary, Osborne (2006) suggested the following guidelines:

- Maintain a buffer zone of at least 20 metres around the edges of each designated area of Pink-tailed Worm Lizard habitat (i.e. mapped patches with a moderate or high quality habitat ranking).
- Keep all forms of disturbance, such as heavy earth-moving equipment and other construction activity away from the designated habitat areas.
- Ensure that vehicles do not drive over these habitat areas, as they may dislodge rocks.
- Prevent construction activity from occurring up-slope of the mapped Pink-tailed Worm Lizard habitat areas in order to ensure that site drainage properties remain the same.
- Prevent the spread (or planting) of trees, shrubs or woody weeds (e.g. blackberry) into Pink-tailed Worm Lizard habitat

Planning, design and construction of the W2W Project must incorporate these guidelines and the remaining Pink-tailed Worm Lizard habitat at the LMWQCC should be protected from further disturbance. Locating the precise route for the pipeline that must cross the Molonglo River and/or Murrumbidgee River and its construction must be based on a plan that:

- includes a detailed appraisal and mapping of suitable Pink-tailed Worm Lizard habitat to determine the optimum route for the pipeline

- avoids any known habitat (a buffer zone of at least 20 metres around the edges of each habitat area)
- establishes construction protocols (based on those identified above for the works within the LMWQCC boundary) that will ensure connectivity along the river margins is restored, and
- monitors of the success or otherwise of the mitigating measures put in place to protect the habitat for the Pink-tailed Worm Lizard and connectivity along the river to enable dispersal of lizards.

Residual Risk: 2

Given that the above mitigation measures are implemented, and monitoring is used to assess the ongoing state of the population, we feel that the risk will be reduced to an acceptable level. A low level risk, with consequences unlikely or easily mitigated.

3.1.3 Issue – Introduction of environmental pathogens from treated water (especially Epizootic haematopoietic necrosis virus (EHNV)).

Pathogens may enter the sewerage system in a number of ways, including from the disposal of liquid waste or cage washings from household pets, including fish, reptiles, amphibians and mammals and waste water, including from hand washing, in medical, veterinary, food and agricultural premises. Although some information is known about the survivability of human pathogens, little, if anything, is known about the survival of aquatic animal pathogens (Aquaculture Development and Veterinary Services Pty. Ltd. 1999). Some pathogens may have no or limited effects, whereas others may be lethal to individual animals. However, populations usually evolve to coexist with their pathogens. It should be noted that there is little known about the range of pathogens that may be found in Australian native animals unless they cause disease in livestock or a zoonotic (a disease that can be transmitted between animals and humans). For a detailed discussion of potential pathogens see Appendix A.

The major concern for the introduction of disease organisms relates to the potential spread of *Epizootic haematopoietic necrosis virus* (EHNV). 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 damage to the renal haematopoietic tissue, liver spleen and pancreas (Langdon and Humphrey, 1987). The threatened Macquarie Perch found in the Cotter Catchment is one of several species known to be extremely susceptible to the disease (Langdon, 1989 a, b). The Cotter Reservoir population of Macquarie Perch is the last remaining viable population of this species in the ACT (Lintermans, 2006b). EHNV was first recorded from the Canberra region in 1986 when an outbreak occurred in Blowering Reservoir near Tumut. 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). The EHNV has not been recorded from the Cotter system and the presence of a healthy population of Macquarie Perch in Cotter Reservoir suggest that the virus is currently not present (Lintermans, 2005). It is assumed that the W2W treatment process, designed to eliminate any potential disease organisms relevant to human health, would also remove EHNV. Consequently, the likelihood of this virus being introduced into the Cotter system through discharge of recycled water is considered to be low, assuming the W2W treatment process is working effectively.

Nevertheless, an accidental introduction could lead to severe consequences for Cotter fish populations especially Macquarie Perch. Further investigation of issues surrounding EHNV (including the design of a monitoring system and testing of the susceptibility of other threatened fish species such as Trout Cod and Two-spined Blackfish) will be necessary.

Environmental risks

Impacts on biota due to pathogen contamination.

Consequence rating: 4 – Long term loss of ecosystem function, population, receiving land or water quality with difficulty in recovery.

Likelihood rating: 1 – Highly unlikely, may occur only in very exceptional circumstances (<1%).

Risk rating: 2 – Low level risk, consequences unlikely of easily mitigated.

Mitigation

The Expert Panel on Health found that the multiple barriers of the proposed purification plant would remove from 11 to 28 Logs of the pathogens (where a single Log reduction is a 10 fold decrease and a 2 Log reduction removes 99% of the pathogen) (See Table 3.1). The table shows that greater than 11 Log removal can be expected, which is far in excess of the minimum log removals recommended in the draft Australian Guidelines for Water Recycling (AGWR) (NRMMC and EPHC, 2007), namely 8 Log for the protozoan parasite *Cryptosporidium,* 9.5 Log for enteric viruses and 8.1 Log for the bacterium *Campylobacter* in drinking water augmentation applications.

Table 3.1: Reduction of water contaminants due to treatment

Microbiological agents	Overall Log removal
Parasites	14 to 23
Bacteria	14.5 to 28
Viruses	11.5 to 24
Phages	11 to 23.5
Helminths	16 to 24

In summary, the Expert Panel on Health found that, 'with the treatment train proposed by ACTEW and with appropriate levels of operational monitoring and management, along with operator training and skills at the level recommended by the Panel, the quality of purified water that is transferred to the Cotter Reservoir will comply with all the health related guidelines of both the 2004 Australian Drinking Water Guidelines (ADWG) and the draft 2007 AGWR' (including the level of human pathogens) (Falconer *et al*., 2007). While little work has been done on the effects of water-borne plant pathogens on crops and even less on effects on native plants, treatment with ultraviolet radiation is an effective treatment for controlling *P. cinnamomi, F. oxysporum* and *Alternaria zinniae* (Mebalds *et al*. 1996). Ultraviolet disinfection facilities are currently being constructed at the Mt Stromlo Water Treatment Plant (expected to be operational by the end of 2007) and the proposal includes this treatment of all water by this method at the LMWQCC. Introduction of EHNV into Cotter Reservoir may lead to the loss of the lower Cotter population of Macquarie Perch. Establishment of other secure Macquarie Perch populations in the ACT would mitigate against such loss. A translocation program to establish such populations is required (ACT Government, 2007). As this issue is a low likelihood, high consequence issue, it is important that mitigation measures are implemented. In the unlikely event that such circumstances did occur, the consequences could be severe if not catastrophic for threatened species such as Macquarie Perch, and it is therefore imperative that the best possible treatment measures and monitoring are in place.

3.1.4 Issue – Transfer of poor-quality water due to failure of the advanced water treatment process.

If any of the system/process was to fail, there would be detrimental impacts on the receiving land and waterways and in turn on the biota of the area. The processes involved must be well researched and trialled to ensure that they are safe and reliable. ACTEW has not outlined it's proposed staffing levels for the new treatment plant, nor the level of training that the plant operators will have undergone. It is noted that details of this should be outlined and assessed before the project goes ahead.

Environmental risks

Impacts of biota/environment due to contamination.

Consequence rating: 4 - Long term loss of ecosystem function, population, receiving land or water quality with difficulty in recovery.

Likelihood rating: 1 – Highly unlikely, may occur in very exceptional circumstances (<1%).

Risk rating: 2 – Low level risk, consequences unlikely or easily mitigated.

Mitigation

Well researched and trialled treatment and water transfer processes must only be implemented. The Expert Panel on Health have recommended that the new water processing plant be staffed for 24 hours/day for at least the first 5 years, whereafter experience will dictate whether or not the plant can operate unmanned for periods of the day (Falconer *et al*, 2007). Real-time or near-real time monitoring must be included in the treatment process design. For the RO system, highly sensitive real-time conductivity sensors will be an important component of a fail-safe detection system. These should be coupled with an automatic by-pass system that would automatically re-route water back to the sewage treatment plant if treated water conductivity exceeds the regulated limits.

3.1.5 Issue – Undetected ecosystem change - appropriate and comprehensive monitoring and assessment.

It is essential that the monitoring and assessment regimes implemented are thorough and based on the best knowledge to date. Environmental problems are unlikely to go unnoticed with a comprehensive monitoring system in place. All aspects of system performance should also be monitored.

Environmental risks

Undetected loss of discharge water quality and/or quantity, leading to ecosystem impacts; undetected ecosystem impacts.

Consequence rating: 3 – Noticeable decline in ecosystem function, population, receiving land or water quality with action required for recovery.

Likelihood rating: 2 – Unlikely to occur in most circumstances (1-20%).

Risk rating: 2 – Low level risk, consequences unlikely or easily mitigated.

Mitigation

As identified by the Expert Panel on Health, at present there are individual monitoring programmes in place at LMWQCC, Cotter Reservoir and Mt Stromlo Water Treatment

Plant. It will be necessary to combine these with those included in the Recycled Water Management Plan to produce a system wide Monitoring Programme that can be used to gauge the overall system performance (Falconer *et al*., 2007). It is important that environmental monitoring protocols are based on the best available scientific knowledge and well-directed hypotheses of potential ecological responses. Physical, chemical and biological barriers all require monitoring and ecotoxicological testing must also be carried out. The timing and spatial coverage of monitoring should be carefully considered for each particular organism, community or chemical being monitored, not simply on the basis of history or convenience.

3.1.6 Issue - Changes to the flow regime in the Murrumbidgee River below LMWQCC.

The effects downstream of the Cotter confluence in the Murrumbidgee River will largely be related to the decreased discharges from the LMWQCC (equivalent to the amount of water transferred to the Cotter Catchment). The current discharge of treated water significantly increases the flows in the Murrumbidgee River in the summer months, relative to natural conditions. Consequently, the W2W process may mitigate the harm from return flows during summer. At other times of the year, lessening of flow may exacerbate the fragmenting effect of natural low flow barriers to fish movement such as small chutes, waterfalls or riffles. For the Murrumbidgee River downstream of the LMWQCC plant, there may be a small ecological benefit in reducing the volume of discharge from the plant. Discharged treated effluent is suspected of forming a ‘barrier’ to fish migration from the Murrumbidgee River, possibly as a result of an aversion response by fish to some constituent of the discharge. Fish sampling in 1994, 1996, 1997 and 2003 demonstrated the absence of Golden Perch and Murray River Crayfish from a site immediately below the discharge point, but that they were present 5 km downstream in the Murrumbidgee River.

Environmental risks

Alteration to aquatic ecosystems (loss of organic matter processing, barriers to fish migration).

Consequence rating: 1 – Minor or transient effect.

Likelihood rating: 5 – Almost certain, expected to occur in most circumstances (>85%).

Risk rating: 2 - Low level risk, consequences unlikely or easily mitigated.

Mitigation

No specific actions required other than ensuring appropriate monitoring protocols are included for the Murrumbidgee River downstream of LMWQCC.

3.1.7 Issue - Construction impacts resulting in aquatic habitat loss due to sedimentation.

With land being cleared to make way for construction, plant root systems that are important stabilisers for the ground are likely to be removed. This results in quicker and easier erosion of the ground and sedimentation of the waterways. This will result in changed aquatic habitats and changed aquatic ecosystems.

Environmental risks

Impacts on aquatic biota.

Consequence rating: 2 - Noticeable decline in ecosystem function, population, receiving land or water quality with no action required for recovery.

Likelihood rating: 3 – Possible, may occur in some circumstances (21-49%).
Risk rating: 2 - Low level risk, consequences unlikely or easily mitigated.
Mitigation
Careful planning and assessment of construction activities that minimises the amount of vegetation removed during construction. Erosion and sedimentation control barriers to be maintained throughout the construction phase. Careful disposal of construction waste where it will not affect waterways.

3.1.8 Issue - Increase in the amount of nitrate entering the Cotter Reservoir.

There is some evidence that RO systems may not provide highly efficient removal of nitrate ions from waste water. This could potentially lead to an increased risk of algal blooms and uncontrolled aquatic plant growth in the receiving waterways, especially in Cotter Reservoir.
Environmental risks
Eutrophication of receiving waters, algal blooms.
Consequence rating: 1 – Minor or transient effect.
Likelihood rating: 3 - Possible, may occur in some circumstances (21-49%).
Risk rating: 1 – Very low level risk, consequences unlikely or very easily mitigated.
Mitigation
Modelling of likely nitrate concentrations in Cotter Reservoir, combined with regular monitoring of nitrate loads and concentration in, and entering, Cotter Reservoir. Preferably, denitrification of the treated water should occur at the treatment plant, prior to transfer to the wetlands and Cotter Reservoir.

3.1.9 Issue – Changes to water chemistry due to a new water source to the Cotter Reservoir (product of the treatment plant).

The transfer of treated water from the proposed new treatment plant into the Cotter Reservoir means the reservoir will be receiving a new source of water of different chemical composition to the water received from catchment run-off. The water coming from the treatment plant will have a very low level of major and minor cations and anions, trace metals and natural organic matter (close to distilled water quality). While it is unlikely that when mixed with the reservoir waters it will have any impact on the aquatic ecosystems, the potential effects are very difficult to estimate. Any effects of discharging treated water to the Cotter Reservoir are also likely to be more significant in the early stages before the enlarged reservoir has been filled.
Environmental risks
Changes to water chemistry with possible impacts on aquatic ecosystems.
Consequence rating: 1 – Minor or transient effect.
Likelihood rating: 3 - Possible, may occur in some circumstances (21-49%).
Risk rating: 1 – Very low level risk, consequences unlikely or very easily mitigated.
Mitigation
Regular monitoring of water chemistry of Cotter Reservoir. Extra consideration may need to be given to the rate of input of treated water from the new treatment plant until the enlarged reservoir is reasonably full. Some rebalancing of the cation and anion content of the treated water may be necessary before discharge to Cotter Reservoir. ACTEW have already

advised that pH will be adjusted as a final treatment step and LMWQCC. It is recommended that further investigations be carried out in this area in the future.

3.1.10 Issue - Introduction of endocrine disruptors to the Cotter Reservoir.

The addition of endocrine-disrupting chemicals to waterways is a only recently recognised threat in Australia. These chemicals either disrupt normal hormone function, or mimic hormones to give an unnatural response. One group of endocrine disruptors is the environmental oestrogens which can mimic the female hormone, oestrogen. International research has demonstrated impacts of endocrine disruptors on aquatic vertebrates such as frogs, mussels and fish, with oestrogenic substance often found in discharges from sewage treatment plants or industrial discharges (Sonnenschein and Soto, 1998; Jobling *et al*, 1998; Matthiessen *et al*, 2002; Quinn *et al*, 2004). Environmental oestrogens have been demonstrated to cause changes in reproductive behaviour in fish (Bjerselius *et al*, 2001), changed sexual ratios, intersex individuals, or altered gonadal development (Solé *et al*, 2002; Rodgers-Gray *et al*, 2000; Jobling *et al*, 1998; Panter *et al*, 1998; Lye *et al*, 1996), with feminisation of genetically male fish a demonstrated outcome. This can have severe impacts on the ability of the species to successfully reproduce. Little research has been conducted in Australia on this problem, but it represents a potential threat to Australia's streams, and further investigation may be required in the future. The likelihood of endocrine disruptors being introduced into the Cotter system through discharge of recycled water is considered to be very low, because the RO and advanced oxidation treatment should form a highly effective physical and chemical barriers to all organic compounds respectively.

Environmental risks

Effects on the reproductive ability of fish species.

Consequence rating: 1 – Minor or transient effect.

Likelihood rating: 1 – Highly unlikely, may occur only in very exceptional circumstances (<1%).

Risk rating: 1 – Very low level risk, consequences unlikely or very easily mitigated.

Mitigation

When operating effectively under normal conditions the RO and oxidation treatment processes should eliminate all hormone mimics. However, regular testing of treated water using both chemical and biological assay methods is essential to ensure the on-going environmental safety of the treated water to be discharged to Cotter Reservoir.

3.2 Transfer of the treated water to Cotter Catchment.

3.2.1 Issue – Impacts on Condor Creek or other small streams used to transfer treated water to or from the proposed constructed wetland and the Cotter Reservoir.

Water from the wetland is likely to be discharged into a smaller stream of a nearby subcatchment before reaching the Cotter Reservoir. ACTEW has proposed using Condor Creek, or other nearby streams, as a means of transferring the water from the wetlands to the reservoir (and possibly in transferring to the wetland). No detail on the design of the proposed wetlands and their ecological characteristics has been available to assess for this report. We had proposed to carry out detailed hydrological modelling during this stage 2 technical study, but have had insufficient information provided to us to allow this to happen.

Nevertheless, it is reasonable to expect that if water is discharged at rates approaching 25-50 ML/day, as indicated, major ecological impacts on the stream used will occur. Scouring, incision and enlargement of the stream channel would be expected, with consequent loss of in-stream, and possibly riparian, plant and animal habitat.

Environmental risks

Destruction of river ecology and morphology (souring and incision, changed biota).

Consequence rating: 4 – Long term loss of ecosystem function, population, receiving land or water quality with difficulty in recovery.

Likelihood rating: 5 – Almost certain, expected to occur in most circumstances (>85%).

Risk rating: 5 – Very high level risk, mitigation of consequences imperative, close monitoring essential.

Mitigation

Use of more than one stream to 'share' the treated water flow may mitigate these consequences. However, it would be less environmentally damaging to deliver the water via a pipeline or channel from the wetlands to the reservoir in order to avoid any impacts on the stream (Condor Creek) and the ecosystems within it. The use of a pipe may also assist with the effective mixing of treated water as it enters the Cotter Reservoir – the pipe-end can be placed at a depth deemed most suitable based on hydrodynamic modelling. This depth may vary during the year as the surface mixed-layer depth changes. In addition, a diffuser could be added to the pipe-end if hydrodynamic modelling showed that this would be beneficial. In contrast, surface in-flows to the Cotter Reservoir from a stream or channel may be difficult to mix with the water already in Cotter Reservoir at certain times of the year, due to thermal stratification. See issue 3.3.5 for further information on the management of thermal stratification.

Residual Risk: 1

If a pipeline or channel is used, rather than a natural stream, and careful planning of the construction and route of the pipeline is implemented we consider the risk to reduced to that of an acceptable level. Very low level risk, consequences unlikely or very easily mitigated.

3.2.2 Issue – Water quality and ecological impacts of the artificial wetlands.

The location proposed for discharge of the treated effluent to new artificial wetlands to be constructed is in an area of moderately steep slope with soils that are prone to erosion. With the information to hand it is not possible to assess how effectively the proposed wetlands will perform in terms of flow, erosivity, residence time, and vegetation growth. Largely because of the previous land use for this area there will be a need for detailed study of slope, soil and drainage characteristics on which to base the design of a system of wetlands suitable to receive the quantity of recycled water (25-50 ML/day) expected for the project. Evaporative and infiltration losses to groundwater in wetlands may also be significant, which would appear to be counter-productive to the major W2W project objective of maximising water availability in the Cotter Reservoir.

It has been noted by the Expert Panel on Health and is supported here, that with the level of treatment built into the water purification plant and with the quality of water that will be produced, there will be little to no advantage achieved, from a purification point of view, by passage through the proposed wetlands. Indeed, the wetlands will need to be carefully managed to avoid introduction of pest species, pathogens and parasites by birds and animals that will be attracted to the wetlands. Moreover, birds and animals will also defecate in or around the wetlands with likely affects on nutrient concentrations in the treated water. Birds have been associated with the spread of pathogens that may infect other species or other birds. For example, Whittington *et al*. (1996) recorded Silver Gulls (*Larus novaehollandiae*) and Great Cormorants (*Phalocrocorax carbo*) eating sick and dying juvenile Redfin Perch (*Perca fluviatilis*) suspected of being infected with EHNV in Lake Burley Griffin in 1991. In this case, the virus did not survive the passage through the gastrointestinal tract but it is thought that birds have the potential to spread EHNV, possibly due to regurgitation of ingested material within a few hours of feeding or through mechanical transfer on feathers, feet and bills. Another possible pathogen is avian influenza, which has a history of being introduced into commercial chicken farms from migratory water birds (eg. Lockwood near Bendigo, Victoria in 1985 (Cross, 2003) and three outbreaks in Australia in the 1990s (Alexander, 2000).

There may be incidental ecological benefits of the constructed wetlands, such as provision of year round habitat for animals and birds or as a refuge during drought or fires. Whether these incidental benefits are sufficient to justify the use of constructed wetlands in the W2W project is impossible for us to assess at the present time. It has been suggested by ACTEW that the wetlands would assist with removal of residual nitrate in the treated water. However, it is our view that nitrate is better managed through controlled denitrification facilities at LWMQCC . We have been advised that ACTEW believes one of the main functions of the wetlands is to equilibrate the temperature of the treated water, in order to ensure that temperature-driven short-circuiting is minimised in the Cotter Reservoir (Expert Panel on Health, 2007). However, without detailed hydrodynamic modelling, across a full annual cycle, it is very difficult to assess the validity of this proposition.

Environmental risks

Contamination of the treated water by birds and animal excreta; plant die off and release of nutrients downstream (algal blooms, ecosystem impacts); introduction of exotic pests by wetland biota; emissions of greenhouse gases.

Consequence rating: 1 – Minor or transient effect.

Likelihood ratings: 4 – Highly likely, may occur in most circumstances (50-85%)

Risk rating: 2 – Low level risk, consequences unlikely or easily mitigated.

Mitigation

Design and construction of wetlands will need to be integrated with the ACT Government's plans for restoration of the Lower Cotter Catchment set out in the draft report 'Clean water, Healthy landscapes'. The location of the proposed wetland is on land formerly planted to pines that were destroyed in the 2003 bushfires, but is now showing varying degrees of recovery, some with dense regeneration of pines, some native vegetation, and some weed infestations (often blackberries). Design and construction of the wetlands may assist restoration of the landscape damaged by the bushfires. However, the nutrient removal ability of constructed wetlands is highly variable, and may be unreliable especially during winter. Nitrate removal at LMWQCC seems like a more controllable and more efficient option. Regular monitoring of the water quality entering and leaving the wetlands will need to be undertaken. If *in situ* contamination with nutrients and pathogens from bird and animal excreta is deemed to be problematic, these biota will need to be excluded from the wetlands using nets or other barriers

3.3 Enlargement of the Cotter Reservoir.

3.3.1 Issue – Impacts on endangered fish species due to operations of an enlarged reservoir.

The flooding of more land to enlarge the current Cotter Reservoir storage will affect various terrestrial and aquatic habitats and the animals that utilise those habitats, if only on a transient basis. Rapidly fluctuating, or excessive range of, drawdown of water levels will impact aquatic biota, especially fish. While noting that such seasonal fluctuations will be dampened in an enlarged reservoir, with drawdown likely to be less rapid and less extreme (except during prolonged dry periods when reservoir levels may be very low), care must be taken to avoid unnecessary impacts on habitats of endangered species such as Macquarie Perch.

Environmental risks

(i) Flooding will submerge and destroy existing fringing macrophyte (water plant) beds, although new fringing macrophyte beds should develop as the new reservoir water level stabilises. Fluctuating water levels will delay establishment of new macrophyte beds, as well as influencing the availability of other fish habitat (cobble banks, riparian litter fall areas, fallen timber around reservoir margins). As noted above, such fluctuations are likely to be dampened in a larger dam than presently. There is currently a drawdown limit of 1m in the Cotter Reservoir, this risk assessment assumes that there will be no limitations to the extent of drawdown in the enlarged Cotter Reservoir.

(ii) Drawdown of the reservoir during fish spawning season (Oct-Dec) may create a long inlet run of shallow, exposed water which can act as a barrier to fish leaving the reservoir to spawn. (iii) Recent research on Macquarie Perch in Cotter Reservoir has indicated that predation by cormorants may be a significant impact on the adult spawning stock. The increase in the abundance of alien fish species (see issue 3.3.4) may attract an increase in cormorant numbers. As Macquarie Perch move out of the reservoir to access shallow riverine spawning habitats, the only protection from such aerial predation would have been the presence of submerged and emergent macrophyte beds, as well as shade-dappling provided by riparian vegetation. It will take some years for the riparian vegetation and macrophyte beds to establish around the new waters edge of an expanded reservoir. Consequently, cover will be limited and predation risk will be increased. Both issues (i) and (ii) could lead to a decline in the Macquarie Perch population.

Consequence ratings: 4 – Long term loss of ecosystem function, population, receiving land and water quality with difficulty in recovery.

Likelihood ratings: 4 – Very likely, may occur in most circumstances.

Risk rating: 4– High level risk, mitigation of consequences imperative, monitoring required.

Mitigation

A reservoir operating plan that takes into account required water levels to maximise access to important habitats could greatly reduce the potential for habitat-related fish population impacts. Similarly, management of drawdown levels during the Macquarie Perch spawning season could mitigate shallow water barriers, this will require imposing a limit on the extent of drawdown permissible during the spawning season. A monitoring program would be required to allow adaptive management of reservoir filling and operations. ACT fisheries scientists suggest that provision of strategically placed artificial habitat structures could ameliorate the impacts of reduced natural habitat availability caused by reservoir

drawdown. Provision of strategically placed artificial habitat structures for Macquarie Perch could also reduce the likelihood of significant cormorant predation. Establishment of other Macquarie Perch populations where refuge habitat is not limited would lessen the overall impact of cormorant predation on the species. Direct or indirect control of Cotter Reservoir cormorant population may also be an option worth investigating. Further comment on this possibility as a mitigation strategy is difficult for us due to a prospective conflict of interest for one of the report authors. However, we strongly suggest that ACTEW seeks advice on the potential benefits of artificial fish habitat construction in the Cotter Reservoir as a means of mitigating deleterious ecological consequences of draw-down and reservoir height fluctuations.
Residual risk: 2 If water drawn-down is properly managed in conjunction with artificial habitat for endangered fish species, the risk is considered to be at an acceptable level. Low level risk, consequences unlikely or easily mitigated.

3.3.2 Issue – Introduction of pests or pathogens through recreational use of an enlarged Cotter Reservoir.

It is almost certain that people will be attracted to an enlarged Cotter Reservoir for the intentions of recreational use such as fishing. In the past recreational use of the reservoir has been regulated, and recreational use control may need to be even more stringent than in previous years to prevent impacts on native fish and other biota.

Environmental risks

Possible introduction of EHNV virus and/or Redfin Perch from using infected Redfin Perch as bait when fishing in the reservoir. Impacts on threatened native fish species.

Consequence rating: 4 – Long term loss of ecosystem function, population, receiving land or water quality with difficulty in recovery.

Likelihood rating: 3 – Possible, may occur in some circumstances (21-49%).

Risk: 4 – High level risk, mitigation of consequences imperative, monitoring required.

Mitigation

Strict recreational access restrictions, especially no fishing, within the Cotter Reservoir. Monitoring and strict regulation of recreational use within the reservoir.

Residual Risk: 2

If strict recreational access restrictions apply within the reservoir or, better still, if access is prevented all together, the risk is considered to be that of an acceptable level. Low level risk, consequences unlikely or easily mitigated.

3.3.3 Issue - Inundation and destruction of Macquarie Perch spawning habitat.

Macquarie Perch are currently thought to spawn in a short stretch of river immediately upstream of Cotter Reservoir, between the impounded waters and Bracks Hole. The enlarging of Cotter Reservoir will inundate these and other potential spawning habitats, rendering them unsuitable for Macquarie Perch. This is not considered a major issue as long as the enlarged reservoir does not impound waters up to the base of an impenetrable barrier to fish movement (ie there is new spawning habitat available and accessible). The situation that occurred as a result of constructing Googong Reservoir must be avoided. In this situation the impounded waters extended to the base of a natural barrier (Curleys Falls), that prevented Macquarie Perch accessing spawning habitats. The population of

Macquarie Perch ceased to recruit, and faced certain extinction if remedial actions (a controlled translocation beyond the barrier) had not been undertaken (Lintermans, 2006a).

Environmental risks

Decline in or loss of the Macquarie perch population.

Consequence rating: 4 – Long term loss of ecosystem function, population, receiving land or water quality with difficulty in recovery.

Likelihood rating: 3 – possible, may occur in some circumstances (21-49%).

Risk rating: 4 – High level risk, mitigation of consequences imperative, monitoring required.

Mitigation

Detailed mapping of natural instream barriers and their position in relation to full capacity and expected reservoir operating capacity, and remediation of passage past critical barriers can avoid loss of access to spawning habitats. A reservoir operating plan that takes into account and closely monitors required water levels to maximise access to spawning habitats during the spawning season (Oct-Dec) will also minimise impacts on spawning.

Residual Risk: 1

If water level management ensures that fish passage past critical in-stream barriers is maintained at all times, this risk is considered to be of an acceptable level. Very low level risk, consequences unlikely or very easily mitigated.

3.3.4 Issue – Impacts of expanded populations of alien fish species.

The alien fish species Goldfish, Eastern Gambusia and Oriental Weatherloach generally prefer slow-flowing or still water habitats. The expansion of the capacity of Cotter Reservoir from 4 GL to approximately 78 GL will significantly increase the available habitat for these alien species. There are no feasible management options to prevent the expansion of these alien fish populations. The impacts of increased population sizes of two of these species (Goldfish and Oriental Weatherloach) on existing aquatic communities are not likely to be severe, as they are not generally aggressive or predatory species, and few detrimental impacts have been attributed to them in Australia. However, Eastern Gambusia is known to be a seriously aggressive species that will chase, harass and fin-nibble both small and large individuals of other species. The species is also known to have a detrimental impact on invertebrate structure, which is important for ecosystem function. The increase in volume of an expanded Cotter Reservoir is likely to facilitate the expansion of the population of the two trout species (Brown Trout and Rainbow Trout) in the reservoir. There are few feasible management options to prevent the expansion of trout populations in the reservoir. An enlarged reservoir will provide both an enlarged area of open water for these species, as well as an enlarged thermal refuge from high seasonal water temperatures. Trout are a known predator of native fish species including the threatened species present in the Cotter Reservoir.

Environmental risks

Decline in or loss of native fish species due to increase competition for resources and increased predation.

Consequence rating: 3 – Noticeable decline in ecosystem function, population, receiving land or water quality with action required for recovery.

Likelihood rating: 4 – Very likely, may occur in most circumstances (50-85%).

Risk rating: 4 – High level risk, mitigation of consequences imperative, monitoring required.

Mitigation

There is a limited range of mitigation techniques possible. However, prevention of reservoir stratification (see below) will reduce potential for cool water refuge for trout species. Establishment of other Macquarie Perch populations in areas where alien fish species (particularly trout) are less abundant or absent (e.g. above Corin dam) will reduce regional impact on this species. Other less threatened aquatic species (Two-spined Blackfish, Murray River Crayfish) are already more widely distributed. It is recommended that further investigations are directed toward obtaining a greater understanding of to what extent the that alien fish populations will expand and the consequential impacts on native species.

Residual Risk: 2

If populations of Macquarie Perch are established in other areas where alien fish species are less abundant or absent, the risk to the overall regional population of this species is considered to be lowered to that of an acceptable level. Stratification of the reservoir will also contribute to keeping this risk at an acceptable level. Nevertheless, these controls are not perfect, and careful monitoring of native and exotic fish populations will be very important. Low level risk, consequences unlikely or easily mitigated.

3.3.5 Issue – Cold-water pollution due to stratification of the Cotter Reservoir.

Unless carefully managed, ecologically damaging cold-water releases are likely from a larger and deeper Cotter Reservoir. It is also important to ensure that there is effective mixing of treated water entering the Cotter Reservoir with water already *in situ*.

Environmental risks

Downstream cold-water pollution and effects on downstream river ecosystems; incompletely mixed water leading to 'lenses' of poorer quality water in the reservoir

Consequence rating: 3 – Noticeable decline in ecosystem function, population, receiving land or water quality with action required for recovery.

Likelihood rating: 3 – Possible, may occur in some circumstances (21-49%).

Risk rating: 3 – Medium level risk, mitigation of consequences necessary.

Mitigation

Destratification (artificial mixing) of the reservoir is essential, and a very effective form of thermal pollution risk mitigation, especially if combined with an automatically-controlled variable depth off-take tower linked to real-time in-reservoir temperature profiling. ACTEW is already factoring in artificial mixers in its dam design planning, and have advised us that mixers are likely to be pods of WEARS type pump mixers (5m diam impellers with 12m draft pipe) pumping water from surface and discharging at depth. This system will also help to mitigate against the risks of toxic cyanobacterial blooms, and the off-take of poor water quality plumes arising from storm events.

Residual Risk: 1

With effective destratification of the reservoir in place, combined with a variable depth off-take tower, this risk is considered to be of an acceptable level. Very low level risk, consequences unlikely or very easily mitigated.

3.3.6 Issue – Ecosystem impacts caused by a changed flow regime below the Cotter Reservoir.

Previous studies by the University of Canberra indicate an enlarged Cotter Reservoir will lead to variable impacts on the current flow regime downstream of Cotter Reservoir — which is already significantly modified from natural conditions. There will be some hydrological disturbances, most notably in the trapping of high flows. This is because a large Cotter dam will capture significant volumes of peak flood flows that the current dam is too small to retain. Such changes could have significant ecological consequences downstream. There will also be changes to flow variability and seasonality but, unlike high flows, these flow characteristics are already affected by the existing dam. The current Cotter dam traps all coarse sediment; therefore, any changes to sediment transport capacity caused by the enlarged Cotter dam will have little impact on sand transport or deposition. There may be a small increase in silting, but the larger reservoir capacity may partly offset this effect because of increased trapping of fine sediments. The effects on silting will depend largely on management through construction, reservoir operation and maintenance of medium/low flow regime, because the system is already regulated. There are small populations of Murray River Crayfish and Macquarie Perch below the Cotter Reservoir. While the habitat in this area is already degraded from years of flow reduction, reduced river flows may lead to increased sedimentation which may prevent recovery/expansion of these populations. Previous studies have shown that macro-invertebrate communities are impaired downstream of all three existing dams on the Cotter River. As already noted, increasing storage capacity in the lower Cotter River will reduce high flow events, and it is possible that macroinvertebrates will show some further impairment.

Environmental risks

Changed river flow regime downstream of the reservoir. Impacts on crayfish and Macquarie Perch populations and on the aquatic ecology of the river downstream of the Reservoir.

Consequence rating: 2 – Noticeable decline in ecosystem function, population, receiving land or water quality with no action required for recovery.

Likelihood rating: 5 – Almost certain, expected to occur in most circumstances (50-85%)

Risk rating: 3 – medium level risk, mitigation of consequences necessary.

Mitigation

An appropriate environmental flow regime must be maintained below a new enlarged Cotter Reservoir including during the reservoir filling phase. The existing rules for Cotter Reservoir may need to be modified to take into account the impact of the larger dam on peak flows. For example, increased provision may need to be made for semi-regular downstream flushing flows.

Residual Risk: 2

With the establishment of an appropriate environmental flow regime along with a monitoring program, the risk is reduced to an acceptable level. Nevertheless, vigilance will be required. Low level risk, consequences unlikely or easily mitigated. While not currently part of the proposal, we also recommend that no hydro-electricity system should be constructed on the new dam (due to potential impacts on flow regime) without detailed environmental investigations and risk assessment.

3.3.7 Issue – Upstream invasion of alien fish species during construction of a new dam wall.

There is a number of fish species that are present immediately downstream but not upstream of the existing Cotter dam. These species could potentially colonise water upstream of the existing wall during or following construction of the new dam. Of particular concern are two alien species Redfin Perch and Carp. The introduction of these species would result in increased levels of competition or predation on native species, and the introduction of Redfin Perch in particular would provide a host and vector for the establishment of EHN virus (see issue 3.1.3).

Environmental risks

Decline in or loss of native fish species due to increase competition for resources and increased predation. Establishment of host for EHNV and associated impacts on Macquarie Perch

Consequence rating: 4 – Long term loss of ecosystem function, population, receiving land or water quality with difficulty in recovery.

Likelihood rating: 3 – Possible, may occur in some circumstances (21-49%).

Risk rating: 4 – High level risk, mitigation of consequences imperative, monitoring required.

Mitigation

During construction of new Cotter dam wall, integrity of existing barrier to fish invasion from downstream must be maintained. After completion of new dam wall and prior to flooding of existing dam, waters between the two structures need to be treated to remove all living fish.

Residual Risk: 1

With the above mitigation measures implemented, the risk is considered to be of an acceptable level. Very low level risk, consequences unlikely or very easily mitigated.

3.3.8 Issue - Destruction of suitable habitat for the threatened Two-spined black fish.

Enlargement of the reservoir has the potential to destroy currently suitable habitat for the threatened Two-spined Blackfish above the reservoir. Enlargement of the dam will relocate upstream the initial sediment deposition zone, resulting in the existing suitable habitat being smothered. The rapidity with which this occurs will be dependant on the sediment supply to the reservoir. In the low sediment-supply Bendora Reservoir, blackfish are still abundant, although their numbers appear to have declined since the 2003 bushfires (none are present in Cotter Reservoir).

Environmental risks

Decline in Two-spined Blackfish populations.

Consequence rating: 2 – Noticeable decline in ecosystem function, population, receiving land or water quality with no action required for recovery.

Likelihood rating: 3 – Possible, may occur in some circumstances (21-49%).

Risk rating: 2 –Low level risk, consequences unlikely or easily mitigated.

Mitigation

This potential impact will be manageable through sound planning during the construction/building phase and improved catchment management reducing sediment delivery to streams. Ecological risk mitigation provisions included in the reservoir build stage, and good adaptive management practices.

3.3.9 Issue – Downstream impacts caused by catastrophic dam failure or emergency release of reservoir water.

There is always a risk of catastrophic failure of a dam wall or even the requirement to release large amounts of water if the structural integrity of a dam wall becomes questionable. For example, in October 1996, the floodgates of the Hume Dam were opened due to the discovery of a structural fault. The water was released as a safety measure and as a result farmland and meadows were flooded along the Murray River all the way to South Australia.

Environmental Risks

Scouring of river bed downstream; temporary loss of habitat and vegetation.

Consequence rating: 1 – Minor or Transient effect (eg. behavioural changes).

Likelihood rating: 1 – Highly unlikely, may occur only in very exceptional circumstances (<1%).

Risk: 1 – Very low level risk, consequences unlikely or very easily mitigated.

Mitigation

While monitoring of the structural integrity and movement of the dam wall will identify any problems, the risk of such an event occurring will be extremely difficult to mitigate in advance. The ecological consequences are major short-term habitat destruction and temporary loss of species from the river reach immediately downstream. Recovery plans will be needed to ensure that habitat is resorted and biota receiver as soon as possible after the event. Ongoing monitoring is required to ensure dam wall integrity is maintained appropriately..

3.4 Disposal of concentrated wastes.

As noted in section 1 of this report, the proposed reverse osmosis (RO) plant will generate a sperate concentrated liquid waste or 'brine' stream – so called because it will contain significant quantities of dissolved salts as well as nutrients, organic compounds and virus particles not removed by membrane filtration. The volumes of RO liquid waste will be quite high – estimated to be about 10-15% of the total volume of water passing through the new plant - about 3 – 4 ML/day initially and more than double that volume at full capacity.
The waste stream will be further treated/managed in one of three ways: (i) pumping by a separate pipeline to a site located to the north of the Uriarra Homestead and Forestry settlement for concentration by evaporation in large 'brine' ponds , (ii) concentration on-site at LMWQCC or (iii) by direct discharge to the Murrumbidgee River. Under options (i) and (ii) the dried waste must be trucked off-site to a site elsewhere (probably outside the ACT) for permanent disposal. There may also be off-site re-use options. The risk associated with each of these waste management options is evaluated below.

Issue 3.4.1 Pumping to evaporative (brine) ponds – energy consumption and greenhouse gas emissions.

The concentrated waste water from LMWQCC will need to be pumped uphill (over 200 m rise) to reach the site of the proposed evaporation ponds. Information on the energy required for this additional pumping stage is not yet available, but it expected to be significant – probably of the order of 10-15% of that required to pump the treated water to

Cotter Reservoir. As we do not have quantitative information on the energy costs for pumping, it is difficult to undertake a detailed risk assessment. Nevertheless, it seems reasonable, assuming direct additive effects of each additional energy-consuming stage of the W2W proposal, to apply the risk evaluation carried out for the treated water energy consumption, under issue 3.1.1.

Environmental risks

Contribution to global warming (changed weather, reduced flows).

Consequence rating: 2 – Noticeable decline in ecosystem function, population, receiving land or water quality with no action required for recovery.

Likelihood rating: 5 – Almost certain, expected to occur in most circumstances (50-85%).

Risk rating: 3 – Medium level risk, mitigation of consequences necessary.

Mitigation

Mitigating against green-house gas production should be reasonably straight forward, and there appear to be no obvious non-financial reasons, given the right planning and regulatory incentives, why the Water2WATER process could not be greenhouse neutral . Green energy sources are available to ACTEW and should be easily be incorporated. ACTEW is also able to participate in the NSW /ACT Greenhouse Gas Abatement Scheme (GGAS). There may also be opportunities to reduce net energy consumption and greenhouse gas production by using heat generated from the treatment plant itself or through in-pipe hydro-electricity generation.

Residual risk: 2

Given that the above energy-offset and green-energy mitigations should be reasonably straight forward to implement, we feel that the risks will be reduced to an acceptable level. A low level risk, with consequences unlikely or easily mitigated.

3.4.2 Issue – Ecosystem impacts of brine waste discharge to the Murrumbidgee River.

Treated waste water is presently discharged from LMWQCC to the Murrumbidgee River. Raw and treated sewage is relatively high in salt concentration due to the addition of salts to household washing powders, as well as being discharged by many industrial processes. Recent modelling by ACTEW indicates that the existing LMWQCC discharges increase summer-time (low flow) salt concentrations in the downstream reach of the Murrumbidgee River from about 100-150 EC to 550-650 EC. An increase above these already elevated concentrations is highly undesirable from an ecological perspective. ACTEW modelling also shows that discharge of the brine waste stream from the new W2W treatment plant at LMWQCC would further increase peak summer salt concentrations in the Murrumbidgee River up to around 650-800 EC, with the plant operating at a through-put of 25 ML/day, up to 1200 EC when operating at 50 ML/day, and up to 1500 EC when operating at 60 ML/day. These highest salt concentrations are above or close to the threshold where impacts on sensitive aquatic plants and animals can be expected (Dunlop *et al.,* 2005). Indeed, Horrigan *et al* (2005) reported changes to stream macroinvertebrate communities in Queensland at salinities as low as 300 EC. There is also evidence that elevated salinities may affect critical life-stages of native fish, with pre-hardened eggs significantly more susceptible than juvenile or adult fish (Clunie *et al*., 2002).

Environmental risks

Elevated concentrations of salt (electrical conductivity) in the Murrumbidgee River downstream of LMWQCC leading to impacts on sensitive aquatic plants and animals.

Consequence rating: 2 - Noticeable decline in ecosystem function, population, receiving land or water quality with no action required for recovery.
Likelihood rating: 5 – Almost certain, expected to occur in most circumstances (>85%).
Risk rating: 3 – Medium level risk, mitigation of consequences necessary.
Mitigation
Discharge of concentrated brine waste to the Murrumbidgee River during low-flow periods is undesirable and should be avoided. Some small elevation over current low-flow maxima may be permissible, in some periods. But any such agreement would need to, first, be carefully investigated from an ecotoxicology perspective and, second, guarantee that agreed concentration threshold maxima are strictly adhered to. Storage of brine waste may be feasible during low-flow periods, for subsequent discharge during higher flows.
Residual Risk 3:
It is noted here that brine discharge to the Murrumbidgee River is an undesirable option and it is recommended that other options are considered in place of this. Medium level risk, mitigation of consequences necessary.

Issue 3.4.3 Contamination of biota using waste water (brine) evaporative ponds.
There are unlikely to be any significant construction impacts on native vegetation at the proposed site of the 'brine' ponds because it is largely rural land with scattered trees and exotic pasture grasses. The management of concentrated liquid wastes is a well understood and generally well managed process internationally (at least in advanced economies). With appropriate design and operational planning, salt and other concentrated wastes should be retained on site with little or no local environmental impacts. Nevertheless, there are many examples of failures around the world that have led to significant and even catastrophic environmental consequences (analysed further below – issues 3.4.4, 3.4.5 and 3.4.6). The potentially significant ecological issue raised here is the attraction of birds and other animals to the brine ponds, and their subsequent contamination by organic and inorganic contaminants present in evaporating liquid waste.
Environmental risks
Contamination of birds and other animals that are attracted to the ponds.
Consequence rating: 1 – Minor or transient effect.
Likelihood rating: 2 – Unlikely to occur in most circumstances (1-20%).
Risk: 1 – Very low level risk, consequences unlikely or very easily mitigated.
Mitigation
Annual or bi-annual monitoring of contaminant bioaccumulation in birds and other animals inhabiting or frequenting the brine ponds should be carried out (using non-lethal techniques). The use of the ponds by birds could be monitored and discouraged using nets, or by finding alternative roosting sites in the area and the use of deterrents such as pyrotechnics and taped distress calls. Other barriers could be constructed to exclude mammals, reptiles and amphibians if contamination of these animals was found to be an issue.

3.4.4 Issue – Waste water (brine) evaporative ponds – pipeline leak or failure and contamination of adjacent streams and groundwater.

Notwithstanding the comments above about the efficacy of evaporative (brine) ponds for managing liquid wastes, the possibility of leakage or catastrophic failure must be evaluated. Failure could occur as a consequence of structural failure of pond walls or through over-topping in the event of a very large, intense rainfall event (storms). Inadequate design or design failure could also lead to sub-surface leakage and contamination of groundwater. Due to the close proximity to streams, this would lead inevitably to impact on stream ecosystems. Rupture, leakage, or even sabotage of the pipeline delivering the wastewater to the ponds must also be considered, especially given that this pipeline will pass directly over (or under) the Murrumbidgee River *en route*. The ecological consequences of such a rupture event could be, in the short term, very severe especially if not detected quickly and cut-off.

Environmental risks

Contamination of local surface- and ground-waters and the ecosystems within them.

Consequence rating: 2 – Noticeable decline in ecosystem function, population, receiving land or water quality with no action required for recovery.

Likelihood rating: 1 – Highly unlikely, may occur only in very exceptional circumstances (<1%).

Risk: 1 – Very low level risk, consequences unlikely or very easily mitigated.

Mitigation

Sound site maintenance and safety monitoring program in place, including monitoring of adjacent streams and groundwaters for contamination. For the brine pipe-line, automatic pressure-loss detection systems with real-time connection to flow cut-off valves *en route* and at LMWQCC. Well managed, routine pipe-line inspection and maintenance program. Other protective structures should be included as required, for example, bunding.

3.4.5 Issue - Wind dispersal of dried waste accumulated on site.

The dried salt and trace contaminants will be subject to wind dispersal, if precautions are not taken on-site to manage accumulations of dried material. Severe wind events are uncommon but they must be taken into account with the on-site waste management plan.

Environmental risks

Contamination of local environment by wind dispersed salt and residual contaminants.

Consequence rating: 1 – minor or transient effect.

Likelihood rating: 3 – possible, may occur in some circumstances (21-49%).

Risk: 1 – Very low level risk, consequences unlikely or very easily mitigated.

Mitigation

Appropriate stock-piling of dried material under covers when ever possible, careful handling of dried material on-site, in particular during loading onto trucks.

3.4.6 Issue – Land or water contamination due to vehicular accident during transport of dried waste.

In a relative sense, one of the highest risk areas in the management of contaminated wastes is that accidents may occur during transport of the wastes to the final disposal location. Consequential discharges to adjacent lands and streams are not unknown following such events in Australia.

Environmental risks
Contamination of the environment where accident occurs.
Consequence rating: 2 – Noticeable decline in ecosystem function, population, receiving land or water quality with no action required for recovery.
Likelihood rating: 1 – Highly unlikely, may occur only in very exceptional circumstances (<1%).
Risk: 1 – Very low level risk, consequences unlikely or very easily mitigated.
Mitigation
Safe transport guidelines established by ACTEW and to be followed by all waste transport contractors. Appropriate spill emergency response plans in place in the ACT and notification of relevant state and local authorities in other states along the transport route.

3.4.7 Issue – Concentration of brine wastes on site at LMWQCC.

As an alternative to pumping to evaporative ponds in the Lower Cotter Catchment, or to direct discharge to the Murrumbidgee River, ACTEW have recently been evaluating the possible mechanical concentration of brine waste on site at LMWQCC, with subsequent transport and disposal of the solid salt and residual wastes elsewhere (probably outside the ACT). No details have been provided of the mechanical techniques to be used, though it is understood that the process is expensive and energy intensive.

It is not possible with this limited information to carry out more detailed risk assessment. No doubt environmental issues covered in other issue above (eg. greenhouse gases, risks of road transport) will be highly relevant. We recommend that a detailed risk assessment be done if and when the on-site brine treatment process is considered to be a likely part of the final treatment train proposed by ACTEW.

4 Whole of system events & multiple-risks

As well as the specific environmental hazards/issues evaluated in Section 3 above, we also considered, on a qualitative, descriptive basis, possible risks arising from 'whole of system' events. These events, which by their nature often tend to be 'extreme', include bushfires, severe storms, and climate change. They act across the entire system, or at several points, rather than impacting only on one part. Hence, they may cause multiple environmental impacts or, alternatively, act in concert on multiple parts of the system to bring about a single impact that otherwise may not have occurred. Generally speaking, these tend to be low likelihood-high consequence events (although among these, climate change is certainly more likely). The potential issues arising, and their consequences, are reasonably clear in some cases, while being quite speculative in others. This is the consequence of such, comparatively rare, events.

While it may be very difficult to fully mitigate against 'whole of system' or extreme events, it is important to identify their potential impacts and have management practices in place for when/if they occur. In particular, emergency management and environmental restoration plans are fundamental to minimising long-term environmental damage.

Below we have identified a selection of possible extreme events, and outlined the likely effects on the entire system and implications for management. Those events listed should be considered as examples of the possibilities that could arise, rather than being an exhaustive analysis. In many cases, the issues raised will apply equally to human, as well as to environmental, health and risk management.

4.1 Extreme storms

Flash flooding

- Intense run off to reservoir and other receiving waters, increased sedimentation. This poses a short-term risk to aquatic ecosystems, although this may be buffered in an enlarged reservoir.
- Implications for environmental flow releases for the Cotter River and Murrumbidgee River.
- Potential effects on a small streams already effected by increased flow from new treatment plant (if this option is chosen).
- Implications for wetland function – vegetation scouring, short-circuiting and surcharge of dirty water and sediment to reservoir
- Possible implications for waste disposal in evaporative (brine) ponds.- uncontrolled over-flow and contamination of adjacent streams and groundwaters
- During construction phase, could lead to failure of containment mechanisms and massive sediment/dirty water event and habitat damage.
- Overflow of incompletely treated sewage to Murrumbidgee River from LMWQCC (noting that a storm detention dam is already in place)

Gale force winds

- Power lines down, loss of power to water treatment plant, and pump station. Cease in water being delivered to the wetlands and reservoir. This holds implications for wetland function and reservoir water levels, which in turn may affect aquatic habitats
- Tree down across pipelines – spillage of wastewater to adjacent lands and streams

Vehicular accident

- Increased risk for road transporting of dried or concentrated waste.

Damage to communications systems

- Implications for effective management during the storm and immediately after.

4.2 Protracted drought

Extended drawdown of reservoir

- Poses the risk of barriers to fish migration upstream. May require extra treated water input to mitigate loss of spawning habitat.
- Implications for environmental flow regimes in the Cotter River and Murrumbidgee River.
- Implications for routine operations of an enlarged reservoir (Sydney experience with 'deep draw' down option for Warragamba Dam).
- Exposure and oxidation of deeper sediments, possibly leading to nutrient release and algal blooms upon re-filling.

Low flows in Murrumbidgee River

- Would seriously impact on timing and volumes of brine that could be discharged to Murrumbidgee River (due to necessary dilution to maintain salt concentrations below agreed maxima)

Low rainfall in catchment

- May impact on vegetation condition in the constructed wetlands, leading to die-off, particularly if, for any reason, in-flows of treated water are restricted or cut-off during hot periods.

4.3 Climate change

Higher temperatures

- May affect functioning of treatment plant or constructed wetlands (in a positive or negative way)
- Combined with possible increased nitrogen load from treated water, may lead to increased risk of toxic algal blooms in enlarged Cotter Reservoirs (noting the mitigating effect of artificial destratification, discussed in Section 3.3.5)
- Increased bushfire risk (see below)

Reduced in-flows

- Implications for barriers to fish migration. May require extra input of treated water from LMWQCC.

- Impacts on environmental flows provisions – possible consequences for downstream biota.

Extended drawdown of reservoir due to decreased rainfall

- Poses the risk of barriers to upstream fish migration. May require extra treated water input to mitigate loss of spawning habitat.
- Implications for operation of an enlarged reservoir.

Increased severe storm frequency

- See section 4.1 above

4.4 Bushfire

Destruction of infrastructure

- Destruction or damage to LMWQCC plant could lead to discharges of poor quality water to Murrumbidgee River
- Fire damage to constructed wetland - Implications for water quality entering the reservoir and effects on the ecosystems with in it.
- Fire damage to waste evaporative ponds – could force shut-down of treatment process unless safe, alternative means of waste disposal available

Increased sediment and organic load in receiving waterways

- Poses a risk to aquatic ecosystems in reservoir and downstream
- Effects on water quality such as lowered dissolved oxygen and a change in nutrient levels, leading to possible ecosystem alterations.

Loss of riparian cover

- Loss of protective habitat for native fish species

4.5 Human error or malicious act

Treatment plant misoperation or undetected malfunction

- Incompletely treated waste water pumped to Cotter Reservoir – potential ecosystem (and human) health impacts. Automatic detection and failsafe systems will help mitigate these risks.

Failure to set, or comply with, appropriate environmental safeguards and guidelines

- Multiple ecosystem risks depending on nature of failure
- Impacts may go undetected for some years, especially if poor monitoring is part of the problem, leading to problems for restoration and recovery

5 Conclusions and recommendations

5.1 Conclusions

Following the protocol outlined in figure 1.1, we carried out an initial risk assessment based on the likelihood and consequences of a range of environmental hazards arising from the proposed Water2WATER project. This initial environmental risk assessment identified several issues considered to be of medium to high level risk, and which would require satisfactory mitigation before the environmental risks could be considered acceptable.

Those areas that were identified as requiring appropriate *a priori* mitigation were:

- High energy use and greenhouse gas emissions;
- New works at LMWQCC posing potential impacts on the Pink-tailed Worm Lizard which is listed as a threatened species under the Commonwealth EPBC Act;
- Impacts on Condor Creek or other small streams used to transfer treated water to or from the proposed constructed wetlands and the Cotter Reservoir;
- Impacts on endangered fish species due to operations of an enlarged reservoir;
- Introduction of pests or pathogens through recreational use of an enlarged Cotter Reservoir;
- Inundation and destruction of Macquarie Perch spawning habitat;
- Impacts of expanded populations of alien fish species;
- Cold-water pollution due to stratification of the Cotter Reservoir;
- Ecosystem impacts caused by a changed flow regime below the Cotter Reservoir;
- Upstream invasion of alien fish species during construction of a new dam wall;
- Pumping to evaporative (brine) ponds – energy consumption and greenhouse gas emissions;
- Ecosystem impacts of brine waste discharge to the Murrumbidgee River.
- .

If the mitigation measures outlined in our risk assessment are implemented effectively and thoroughly, it is our scientific judgement that the residual environmental risks (after mitigation) are considered to be of an acceptable level ie, low or very low level risk. Consequently, we are of the opinion that the residual (mitigated) environmental risks should not, on their own, prevent the Water2WATER project from proceeding.

5.2 Recommendations for further investigations

Our risk assessment has identified a number of areas where additional scientific and technical investigations are necessary for guiding on-going planning and design for the Water2WATER proposal. Such investigations will, if the project proceeds, also help to better manage ecological conditions and risks during the operational phase. It is recommended that further investigations are carried out in the following areas:

- Identification and design of suitable non-greenhouse gas emitting energy sources to minimise net energy consumption for the entire process. These may include thermal capture techniques from the treatment plant, solar and wind energy generation, as well as their integration with hydro-electricity generation.

- Selection of a location/route for the proposed pipeline from the LMWQCC to the Cotter Catchment and Reservoir that causes little or no impact on endemic plants and animals. ACTEW should provide an exact location/route for the proposed pipeline from the LMWQCC to the wetlands and from the wetlands to the Cotter Reservoir. The location/route of this pipeline must be carefully planned to ensure no further impact on the already fragmented Pink-Tailed Worm Lizard habitat occurs.

- Modelling of the potential impacts of increased nitrogen (nitrate) load on the eutrophication status of Cotter Reservoir. Investigation is recommended into the additional nitrate load arising from the treated water, and appropriate safe thresholds loads for nitrogen in Cotter Reservoir. Further, the nitrate removal efficiency of denitrification techniques at the treatment plant, possibly combined with nitrogen removal in the constructed wetlands, should be evaluated

- For an enlarged Cotter Reservoir, hydrodynamic modelling studies to (i) select the best type, design and placement for an artificial mixing system, (ii) minimise downstream cold water releases, and (iii) to locate the treated water in-flow to ensure effective mixing within the reservoir.

- Modelling of potential changes to water chemistry (anion/cation/trace element balance) in Cotter Reservoir. Will depend on the ratio of treated water to natural catchment inflow (which will vary both seasonally, and on an inter-annual basis, with changing climatic conditions), and on the extent to which cations, anions and trace elements are removed during the treatment process. If significant changes are predicted, and these changes cannot be ameliorated through chemical additions at the treatment plant, detailed studies considering the potential response of biota will also be necessary;

- Investigation of the appropriate design and potential benefits of artificial fish habitat construction in the Cotter Reservoir as a means of mitigating deleterious ecological consequences of draw-down and reservoir height fluctuations.
.
- Possible expansion and control of alien fish populations in an enlarged Cotter reservoir, and potential impacts on native fish species, especially Macquarie Perch. It would be advantageous to direct further investigations towards obtaining a greater understanding of to what extent alien fish populations may expand in an enlarged reservoir and to the impact this may impose on native fish species.

- More research is required regarding the design of the proposed constructed wetlands and how effective they will be in terms of flow, erosivity, residence time and vegetation growth. Further, it would be helpful to consider how their location and management might be integrated into broader restoration objectives for the Lower Cotter catchment.

- The Water2WATER proposal has drawn attention to the on-going environmental issue of salt (and nutrient) discharge from LMWQCC to the Murrumbidgee River. It would be appropriate now to undertake detailed investigations of the response of endemic plants and animals to elevated salt concentrations – both to current elevated levels and those that could be experienced through the Water2WATER proposal. Sensitive life-history stages of fish and invertebrates (eg. fish eggs and larvae) should be targeted for ecotoxicological investigations.

- Detailed analysis and investigation of the various concentrated waste (brine) disposal methods are necessary before any final build decision is made. Details are currently lacking regarding the possible mechanical concentration of brine waste on site at LMWQCC, with subsequent transport and disposal of the solid salt and residual wastes elsewhere. We recommend that a proper risk assessment be conducted if and when the on-site brine treatment is seriously considered as a part of the Water2WATER proposal.

In addition to these special investigations, regular acute and chronic ecotoxicological testing of treated water from the new plant will be important to ensure the on-going suitability of water for plants and animals in Cotter Reservoir and environs, along with the required routine biological and chemical monitoring programs discussed in Section 3 of this report..

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7 Appendices

Appendix A Overview of environmental pathogens

Associate Professor Suresh Mahalingam (University of Canberra) became involved in this project after the release of the initial 'issues' paper (May, 2007). Provided here is his input of initial issues regarding viral and bacterial environmental pathogens.

Water2WATER project - Consideration of adverse effects of pathogens on the environment

The Water2WATER proposal entails the construction of a Water Purification Plant (WPP) at the Lower Molonglo Water Quality Control Centre (LMWQCC). This new WPP will treat the water from LMWQCC that is currently released to the Molonglo River, to produce high quality water that is then transported to the Cotter Reservoir via a series of created wetlands. The Cotter Reservoir will be enlarged and the resulting blend of water from this reservoir will then be transported to the Mt Stromlo Water Treatment Plant (WTP) for further treatment to produce drinking water that is then reticulated into Canberra City.

System inputs

The input for the water treatment system will be derived from the LMWQCC and will consist of treated domestic, commercial and industrial wastewater and raw sewage containing pathogens, hormones, pharmaceuticals etc, other chemicals and a high nutrient load. Discharge of trade waste into the Canberra sewer system is controlled by regulations and permits to discharge. Canberra has no major toxic waste-generating industry, however there are several smaller commercial operators in the ACT who are licensed for waste discharge. Canberra's hospitals, universities and private laboratories also have licences to discharge trade waste into the sewer system that are relevant to wastewater quality, particularly with respect to pathogens. ACT Health has advised the Expert Panel on Health that clinical wastes (predominantly blood) are not discharged to sewer but are handled separately and are disposed of to landfill after autoclaving. However, pathogens may enter the sewer system in a number of ways, including from the disposal of liquid waste or cage washings from household pets, including fish, reptiles, amphibians and mammals and waste water, including from hand washing, in medical, veterinary, food and agricultural premises.

Pathogen removal

Consideration of the effectiveness of treatment for the removal of human pathogens is relevant to the consideration of the effectiveness of treatment of pathogens that may have environmental impacts, since the organisms are of similar types and are susceptible to the same disinfection treatments.

The Expert Panel on Health found that the multiple barriers of the proposed purification plant would remove from 11 to 28 logs of the pathogens (where a single Log reduction is a 10 fold decrease and a 2 Log reduction removes 99% of the pathogen) (See Table 1). The table shows that greater than 11 Log removal can be expected, which is far in excess of the minimum log removals recommended in the draft Australian Guidelines for Water Recycling (AGWR) (NRMMC and EPHC, 2007), namely 8 Log for the parasite *Cryptosporidium*, 9.5 Log for enteric viruses and 8.1 Log for the bacteria *Campylobacter* in drinking water augmentation applications.

Table 1: Reduction of water contaminants due to treatment

Microbiological agents	Overall log removal
Parasites	14 to 23
Bacteria	14.5 to 28
Viruses	11.5 to 24
Phages	11 to 23.5
Helminths	16 to 24

In summary, the Expert Panel on Health found that, 'with the treatment train proposed by ACTEW and with appropriate levels of operational monitoring and management, along with operator training and skills at the level recommended by the Panel, the quality of purified water that is transferred to the Cotter Reservoir will comply with all the health related guidelines of both the 2004 Australian Drinking Water Guidelines (ADWG) and the draft 2007 AGWR' (including the level of human pathogens) (Falconer *et al*., 2007).

However, the disinfection of prions from waste water was not specifically examined. Exposure of susceptible species to infected animal tissues containing prions (e.g. in transmissible mink encephalopathy, bovine spongiform encephalopathy, spongiform encephalopathy in domestic cats and a variety of captive zoo animals and variant Creutzfeldt- Jakob disease transmitted to humans by the ingestion of bovine spongiform encephalopathy (BSE) affected cattle) can transmit the encephalopathies. The disease agents exhibit an unusual resistance to conventional chemical and physical decontamination methods and are not adequately inactivated by most common disinfectants and some infectivity may persist under standard hospital or healthcare facility autoclaving conditions (e.g. 121°C for 15 minutes). They are also extremely resistant to high doses of ionizing and ultra-violet radiation and some residual activity has been shown to survive for long periods in the environment (WHO 1999).

Pathogens

The pathogens that need to be considered include the following types of infectious agents: parasites, including protozoa and Helminths; bacteria; viruses; and prions. The pathogens could affect fish and other aquatic species, birds, reptiles, native or introduced mammal species or plant pathogens. This report is assessing only the environmental impacts of pathogens because health and public safety issues have been considered by the Expert Panel on Health.

Plant pathogens

Agricultural crops, pastures and native plants can be affected by various plant pathogens transmitted through a number of different pathways including water, although it is believed that the risk from pathogens in irrigation water is low under most circumstances. However, plant pathogens in irrigation water used for intensive agricultural and horticultural industries (particularly where wastewaters are reused) can potentially lead to crop damage and economic loss (ANZECC and ARMCANZ 2000) and can also affect other plant species. Many disease-causing organisms are easily transported in irrigation water from diseased plants to healthy ones, for example, Fusarium and root rot causing fungi, such as Phytophthora, are readily spread in water. Little work has been done on the effects of water-borne plant pathogens on crops and even less on effects on native plants, treatment with ultraviolet radiation is an effective and treatment for controlling *P. cinnamomi*, *F. oxysporum* and *Alternaria zinniae (*Mebalds *et al.* 1996). Ultraviolet disinfection facilities are currently being constructed at the Mt Stromlo Water Treatment Plant (expected to be operational by the end of 2007) and the proposal includes this treatment of all water by this method at the LMWQCC.

Aquatic animal pathogens
Aquatic diseases or parasites have frequently been spread throughout the world by the translocation of fish (Environment Australia,1993). Whether the pathogens survive in the sewer system is dependent on several factors such as the nature of the pathogen, mean residence time in the system, the availability of host organisms (in some cases) and the treatment systems. Although some information is known about the survivability of human pathogens, little, if anything, is known about the survival of aquatic animal pathogens (Aquaculture Development and Veterinary Services Pty. Ltd. 1999).

Aquatic pathogens not endemic to a particular region are frequently more dangerous to the new hosts (the endemic fish) than the original carrier. Even the translocation of native species within their natural range poses the risk of spreading taxon specific pathogens (Langdon, 1989b). Supposedly species specific diseases have been shown to be capable of infecting other non-related species, for example, Redfin Perch (*Perca fluviatilis*) carries a pathogenic virus (*Epizootic haematopoietic necrosis virus*, EHNV) which has been shown to be highly pathogenic for Silver Perch, Mountain Galaxias, Macquarie Perch and, to a lesser extent, Murray Cod (Langdon, 1989b), with many other fish also likely to be susceptible. This may be the most serious disease threat to native fish. The virus is unique to Australia and was first isolated in 1985 on Redfin Perch (Langdon *et al*. 1986) and also affects trout species, which may spread the disease. The virus is robust, can easily be transmitted between locations and is considered impossible to eradicate.

EHNV was first recorded from 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 (1990), Lake Burley Griffin (1991 and 1994), Lake Ginninderra (1994) and Googong Reservoir (1994) (Lintermans 2000; Whittington *et al*. 1996). The Murrumbidgee River and Googong Reservoir populations of Silver Perch and Macquarie Perch have been exposed to the virus. It is highly likely the Queanbeyan River population of Macquarie Perch (upstream of Googong Reservoir) has been exposed through the movement of infected adult trout between the reservoir and the river. The Cotter River and reservoirs above Cotter Dam are not affected by EHNV (ACT Government, 2007).

A lethal disease of Murray Cod (*Maccullochella peeli peeli*) is identical to the exotic Gourami iridovirus and is believed to now be endemic in the Murray-Darling Basin (Chong and Whittington, 1995). The four other viruses known to exist in Australian fish are four viruses isolated from Australian estuarine finfish (Munday and Owens, 1998; Munday 2002), whereas there are a large number (34) of viruses of finfish identified overseas but not in Australia (see Munday 2002).

A wide range of bacterial pathogens have been reported from Australian finfish Humphrey (1995). For example, *Lactococcus garviae* (*Enterococcus seriolicida, Streptococcus sp. biovar 1*) caused significant disease in Rainbow Trout, Oncorhynchus mykiss in Tasmania for a number of years but had not been seen for a decade until an outbreak was reported from Victoria (Kessel *et al*. 2000).

One serious bacterial pathogen affecting a wide range of fish species that causes a range of diseases, including furunculosis, septicaemia, erythrodermatitis and ulcerative syndromes, atypical *Aeromonas salmonicida*, has been imported in Goldfish and subsequently spread throughout Australia and causes disease in Goldfish (*Carassius auratus*), Carp (*Cyprinus carpio*), Roach (*Rutilis rutilis*) and Silver Perch (*Bidyanus bidyanus*) (Humphrey and Ashburnern 1993; Humphrey 1995). An endemic strain produces ulceration of captive Greenback Flounder, *Rhombosolea tapirina* (AQIS 1999) and another atypical strain of unknown origin has produced significant disease in Atlantic Salmon (*Salmo salar*), and Rainbow Trout (*Onchorhynchus mykiss*) in Tasmania (Munday 2002). *Aeromonas. salmonicida* is easily transmitted horizontally by natural routes such as water, contaminated equipment, by fish to fish contact, and food (McCarthy 1977; Austin and Austin 1993).

Edwardsiella tarda is endemic and has been isolated from eels, *Anguilla sp*. and Rainbow Trout (AQIS 1999). Similarly, vibriosis due to *Vibrio anguillarum* and yersiniosis due to *Yersinia ruckeri* are endemic. Epitheliocystis has been reported in Silver Perch in freshwater (Frances *et al*. 1997).

Carp or Redfin Perch are considered to be the source of the Australian populations of the parasitic copepod (anchor worm) *Lernaea cyprinacea* (Langdon 1989a). In the Victorian Tambo River, some Australian Grayling (*Prototroctes maraena*) have been found to be infected with *Lernaea*, which depletes fish populations overseas (Hall, 1988). Anchor worm is known to infect other native species including River Blackfish, Golden Perch, Silver Perch, Murray Cod (Langdon, 1989a) and Macquarie Perch, and Mountain Galaxias (M. Lintermans. unpubl. data). Lernaea has been recorded on Peron’s Tree Frog (*Litoria peroni*) in the Cotter River (Lintermans unpubl. data) and may infect other stream-dwelling frog species in the ACT.

Carp, Goldfish or Eastern Gambusia are probably implicated as the source of the Asian fish tapeworm *Bothriocephalus acheilognathi*, which has been recorded in native fish species in the ACT (Dove *et al*. 1997). This tapeworm causes widespread mortality in juvenile fish overseas and may have similar effects on local native species. The tapeworm has low host specificity at both stages of its life cycle with the adult stage recorded from at least 50 species of fish in five taxonomic orders (Dove *et al*. 1997; ACT Government 2007).

A large number of protozoan infections of Australian freshwater and estuarine finfish have been identified (O'Donoghue and Adlard 2000). Many of these parasites have not been identified beyond genus level. Some fish pathogens such as *Acanthomoeba sp*. have not been reported from fish in Australia but they have recorded from mammals and the environment (O'Donoghue and Adlard 2000).

The third disease of fish thought to be derived from imported fish and has become established in native Australian fish populations – the protozoan parasite, *Ichthyophthirius multifiliis*, that causes gill and skin diseases in all freshwater fish (Humphrey 1995). At least 19 species of pathogens and parasites have been imported into Australia in ornamental fish species (Humphrey 1995; Chong and Whittington 2005). If these disease agents are released from quarantine in ornamental fish, there is the potential for the agents to enter the sewer system by the disposal of fish tank contents into the system. The local distribution of many of the endemic disease agents, i.e. if they are already endemic in the Cotter dam region or not, is not known, whilst it is more likely that the exotic agents are not present in the Cotter dam region.

Pathogens of amphibians
Ranaviruses are one genus of the *Iridoviridae* capable of infecting and causing lethal diseases in amphibians. Some ranaviruses can infect amphibians, reptiles and fish. Two ranaviruses are endemic in Australia, *Epizootic haematopoietic necrosis virus* (see aquatic animal pathogens) and *Bohle iridovirus*, which has been identified in the Ornate Burrowing Frog (*Limnodynastes ornatus*), native and introduced fresh water fish, freshwater turtles and snakes (Speare and Smith 1992; Moody and Owens 1994; Ariel 1997). Some other ranaviruses not found in Australia are capable of infecting native Australian species, for example, *Guatapo* virus can infect the green tree frog, *Litoria caerulea* (Zupanovich *et al*. 1998). No epidemic of ranaviral disease has been identified in wild amphibians in Australia. At least 6 other groups of viruses have been reported from amphibians overseas. These viruses can cause disease but their impact on wild populations are not well studied (Berger and Speare 2003a).

The only bacterial disease associated with significant mortality in wild amphibians is bacterial septicaemia, with a variety of bacterial species associated with septicaemia. However, bacterial infections may be secondary to other factors such as environmental stressors (Berger and Speare 2003b).

Pathogenic fungi are important pathogens of amphibian species. *Batrachochytrium dendrobatidis* is one which causes the disease chytridiomycosis. It can cause a high incidence of morbidity and mortality in some species of amphibians in the wild and is transmitted via a zoospore that requires water as a medium. The fungus was initially detected in southeast Queensland and northern New South Wales, Western Australia, South Australia , with a possible finding in the Kimberleys. It is now thought to be present in all States/Territories except the Northern Territory. Epidemics of chytridiomycosis in wild amphibians occur in Australia and appear to be continuing, with strong seasonal cycles in some climates. One infected amphibian, the Northern Corroboree frog (*Pseudophryne pengilleyi*) has been found in the ACT (Spear 2007). Infection with the amphibian chytrid resulting in chytridiomycosos was listed in July 2002 as a key threatening process under the Environment Protection and Biodiversity Conservation Act 1999 and a Threat Abatement Plan published in 2006.

Another major fungal infection of amphibians is *Mucor amphibiorum*, which has not been detected in the ACT region. The fungus has yet to be shown to have a significant impact on wild amphibian populations (Speare 2002). Amphibians have a large range of protozoa, many of which are commensals and appear to do no harm to the amphibians. However, *Myxobolus hylae* was found in Green and Golden Bell Frogs (*Litoria aurea*) in Sydney, associated with sick animals (Johnston and Bancroft 1918). Many Helminth species can infect amphibians and some cause disease with heavy burdens, however, none have been reported to cause disease in the wild (Berger and Spear 2003c).

Pathogens of reptiles

Pathogens also affect a number of reptilian species. These include viruses, bacteria, fungi and parasites, including protozoa and nematodes. Reptiles may have a number of ectoparasites but infestations are not usually associated with disease. Reptiles may also have endoparasites, including nematodes (worms), cestodes (tapeworms), trematodes (flukes), acanthocephalans (spiny-headed worms), pentastomes (respiratory worms). Reports of fungal disease in reptiles are rare compared to reports from higher vertebrates (Migaki et al 1984).

A number of viruses can infect reptiles, including a retrovirus causing Inclusion Body Disease (IBD) of boid snakes (pythons and boas), that has been recognised since the mid 1970’s (Schumacher et al., 1994). The first occurrence of IBD was documented in Australia in 1998 in a Carpet Python (*Morelia spilota variegata*) and a Diamond Python (*M. s. spilota*) from Queensland (Carlisle-Nowak *et al*., 1998), although it is thought to have been present much longer. A ranavirus has also been identified in Green Tree Pythons (*Chondropython viridis*) (Hyatt *et al*. 2002).

Bacteria can also infect reptiles, many of which do not cause disease (e.g. *Hafnia alvei*, which is pathogenic to fish but not snakes), or contribute to diseases such as infectious stomatitis (where a number of bacteria are involved). A number of protozoa infect reptiles, including *Cryptosysporidia spp.*, which causes cryptosporidiosis and for which there is not treatment and *Entamoebe invadens* causes amoebiasis in Australian snakes. Other protozoan species can be isolated but are not conclusively associated with disease (AQIS 2003).

Mammalian pathogens

There are a number of mammalian pathogens present in Australian mammals and livestock, however, little is known about their distribution in native animals. One pathogen which may be of concern is Johne's disease, caused by *Mycobacterium paratuberculosis*. The bacteria is shed in large numbers in faeces from infected animals and can be spread by contaminated water and survive for several months in the environment. The prevalence of Ovine Johne’s Disease in the ACT is medium, compared to high prevalence in the adjacent districts of Goulbourn and Yass (NSW DPI 2004).

Cyanobacteria in water has long been recognised as a cause of taste and odour problems in drinking water but they can also contain or release toxins which, if ingested, can cause illness in humans and other mammalian species.

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Appendix B – Initial risk assessment table: Break-down of individual scores

Process	Driver	Description of ecological consequences	Spatial value	Temporal value	Extent value	Intensity value	Consequence value	Likelihood Value	Risk Value
Water treatment process	High energy consumption and greenhouse gas emissions.	Contribution to global warming (changed weather, reduced flows).	3	2	3	1	2	5	3
	Increase in the amount of nitrate entering the Cotter Reservoir.	Eutrophication of receiving waters (algal blooms).	1	3	2	1	1	3	1
`	Change to flow regime in the Murrumbidgee River below LMWQCC.	Alteration to aquatic ecosystems (loss of organic matter processing, barriers to fish migration, loss of Murray River Crayfish).	1	1	1	2	1	5	2
	Construction impacts resulting in aquatic habitat loss due to sedimentation.	Impacts on aquatic biota.	1	1	1	3	2	3	2
	Loss of terrestrial habitat due to Construction impacts at the LMWQCC and Murrumbidgee River.	Impacts on Pink-Tailed Worm Lizard population.	2	3	3	3	4	5	5

Process	Driver	Description of ecological consequences	Spatial value	Temporal value	Extent value	Intensity value	Conseque nce value	Likelihood Value	Risk Value
	Transfer of poor quality water due to failure of the advanced water treatment process.	Impacts on biota due to contamination.	1	3	2	3	4	1	2
	Introduction of environmental pathogens from treated water (especially EHNV).	Impacts on biota due to contamination.	1	3	2	3	4	1	2
	Appropriate and comprehensive monitoring and assessment.	Undetected ecosystem impacts.	2	2	2	2	3	2	2
	New water source to Cotter Reservoir (product of the treatment plant).	Changes to water chemistry leading to impacts on aquatic ecosystems.	1	2	1	1	1	3	1
	Introduction of endocrine disruptors to Cotter Reservoir.	Effect on reproductive ability of fish species.	1	2	1	2	1	1	1
Transfer of the treated water	Use of a smaller stream to direct the treated water from the proposed wetlands to Cotter Catchment.	Destruction of river ecology and morphology (scouring and incision, changed biota).	1	3	2	3	4	5	5

Process	Driver	Description of ecological consequences	Spatial value	Temporal value	Extent value	Intensity value	Consequence value	Likelihood Value	Risk Value
	Construction and use of a wetland.	Emissions of N_2O, N_2, CH_4 and CO_2 (contribution to global warming) Contamination of the treated water by pests and bird excreta. Plant die off and release of nutrients downstream (change of ecosystems, algal blooms). Introduction of exotic pests by wetland biota.	1	3	2	1	1	4	2
Enlarging the Cotter reservoir	Operation of an enlarged reservoir.	Destruction of fringing macrophyte beds. Draw down during fish spawning season. Significant predation on Macquarie Perch by cormorants Decline in or loss of Macquarie Perch population.	1	3	2	3	4	4	4

Process	Driver	Description of ecological consequences	Spatial value	Temporal value	Extent value	Intensity value	Consequence value	Likelihood Value	Risk Value
	Catastrophic failure or emergency release of reservoir water due to safety concerns.	Flooding of land and homes downstream of the reservoir.	2	1	1	2	1	1	1
	Human recreational use of enlarged Cotter Reservoir.	Possible introduction of EHNV virus from using infected Redfin Perch as bait when fishing in the reservoir.	1	3	2	3	4	3	4
	Inundation and destruction of Macquarie perch spawning habitat.	Decline in or loss of Macquarie Perch populations.	1	2	1	2	4	3	4
	Destruction of suitable habitat for the threatened Two-Spined Blackfish.	Decline in Two-Spined Blackfish populations.	1	2	1	3	2	3	2
	Cold water pollution due to stratification of the Cotter Reservoir in warmer months.	Cold water pollution and effects on downstream ecosystems. Release of treated effluent only (lens effect).	1	3	2	2	3	3	3
	Increased impacts of expanded populations of alien fish species.	Competition with native fish, predation of native fish,	1	3	2	2	3	4	4

Process	Driver	Description of ecological consequences	Spatial value	Temporal value	Extent value	Intensity value	Consequence value	Likelihood Value	Risk Value
	Changed flow regime below the Cotter Reservoir.	Decline in or loss of populations of crayfish (*E. crassus* and *E. armatus*	2	3	3	1	2	5	3
	Invasion of alien fish species during construction of dam wall.	Decline in or loss of native fish species. Establishment of hosts for EHN virus.	2	3	3	2	4	3	4
Disposal of waste water	Evaporative (brine) ponds – energy consumption.	Energy consumption	3	2	3	1	2	5	3
	Evaporative (brine) ponds – construction and normal operation.	Construction impacts on environment. Failure of the ponds.	2	2	2	1	1	2	1
	Evaporative brine ponds – leaks or failure.	Contamination of adjacent streams and ground water.	1	1	1	3	2	1	1
	Wind dispersal of dried waste accumulated on site.	Contamination of land, water, flora and fauna.	3	1	2	1	1	3	1
	Brine waste discharge to the Murrumbidgee River.	Ecosystem impacts.	2	2	2	2	2	5	3
	Vehicular accident during transport of dried waste.	Contamination of land, water, flora and fauna.	1	1	1	3	2	1	1

Appendix C - Residual Risk Assessment Table – Conducted for issues initially identified as requiring mitigation, and assuming the recommended mitigation measures will be implemented.

Process	Driver	Ecological consequences	Spatial value	Temporal value	Extent value	Intensity value	Consequence value	Likelihood value	Residual Risk value
Water treatment process	Energy consumption and greenhouse gas emissions.	Contribution to global warming (changed weather, reduced flows).	3	2	3	1	2	2	2
	Loss of terrestrial habitat due to Construction impacts at the LMWQCC and Murrumbidgee River.	Impacts on Pink-Tailed Worm Lizard population.	1	3	2	2	3	2	2
Transfer of the treated water	Use of a smaller stream to direct the treated water from the proposed wetlands to Cotter Catchment.	Destruction of river ecology and morphology (scouring and incision, changed biota).	1	1	1	1	1	1	1

Process	Driver	Ecological consequences	Spatial value	Temporal value	Extent value	Intensity value	Consequence value	Likelihood value	Residual Risk value
Enlarging Cotter Reservoir	Operation of an enlarged reservoir.	Destruction of fringing macrophyte beds. Draw down during fish spawning season. Significant predation on Macquarie Perch by cormorants Decline in or loss of Macquarie Perch population	1	3	2	2	3	2	2
	Human recreational use of enlarged Cotter Reservoir.	Possible introduction of EHNV virus from using infected Redfin Perch as bait when fishing in the reservoir.	1	3	2	3	4	1	2
	Inundation and destruction of Macquarie perch spawning habitat.	Decline in or loss of Macquarie Perch populations.	1	1	1	1	1	2	1
	Increased impacts of expanded populations of alien fish species.	Competition with native fish, predation of native fish,.	1	3	2	2	3	2	2

Process	Driver	Ecological consequences	Spatial value	Temporal value	Extent value	Intensity value	Conseque nce value	Likelihood value	Residual Risk value
	Cold water pollution due to stratification of the Cotter Reservoir in warmer months.	Cold water pollution and effects on downstream ecosystems. Release of treated effluent only (lens effect).	1	1	1	1	1	1	1
	Changed flow regime below the Cotter Reservoir.	Decline in or loss of populations of crayfish (*E. crassus* and *E. armatus*	2	3	3	1	2	2	2
	Invasion of alien fish species during construction of dam wall.	Decline in or loss of native fish species. Establishment of hosts for EHN virus.	1	2	1	2	1	2	1
Disposal of concentrat ed wastes	Brine waste discharge to the Murrumbidgee River	Ecosystem impacts	2	2	2	2	2	5	3
	Evaporative (brine) ponds – energy consumption.	Energy consumption	3	2	3	1	2	2	2

Appendix D – Distribution of Pink-Tailed Worm lizard habitat and proposed location of new treatment works.

BLUE AREAS = Moderate Quality Pink-Tailed Worm-Lizard habitat.

PINK AREAS = High quality Pink-Tailed Worm-Lizard habitat.

Proposed location of new treatment works.

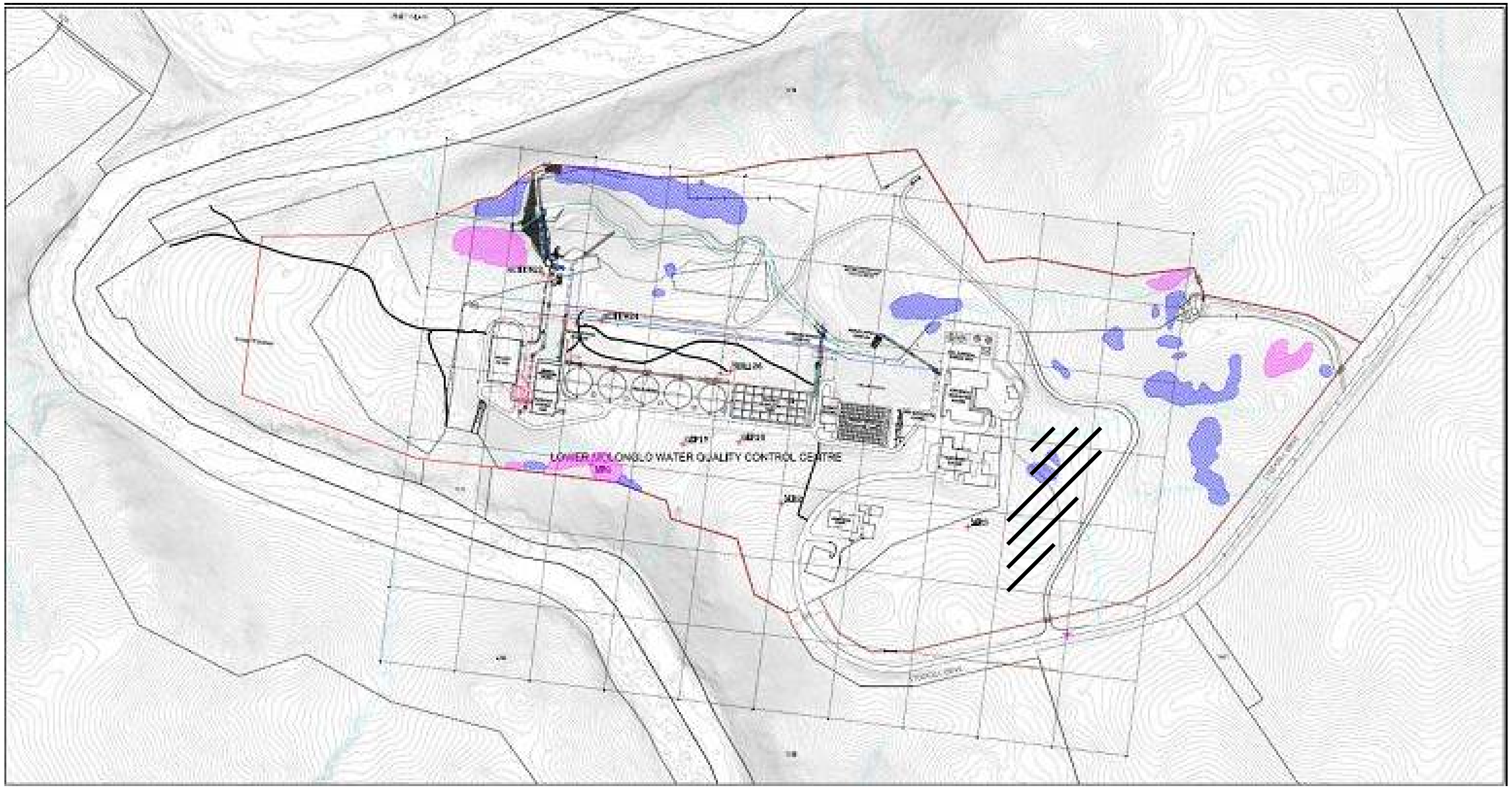

Figure 7.1 Distribution of Pink-Tailed Worm Lizard habitat and proposed site of new treatment works. Drawing No. LM8G0-0912. This drawing was sourced from Figure 5 in: Osborne, 2006, Habitat mapping and regional conservation considerations for the Pink-Tailed Worm Lizard (*Aprasia parapulchella*) population at the Lower Molonglo Water Quality Control Centre, Institute for Applied Ecology, University of Canberra, prepared for ActewAGL, December 2006.