Review of ACT Government Proposal for use of Water Purification Plant to Augment Drinking Water Supply

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The ACTEW Corporation proposal to ACT government as a part of the Water Security Project to implement a Water Purification Plant to recycle wastewater ultimately back into the water supply requires critical analysis. The key concern for the use of reclaimed water is that of a disastrous event resulting from an unexpected output of fecal matter, viruses, bacteria or other contaminant causing harm to the consuming population. Testing must be established in order to monitor key parameters of concern to minimise the risk of such an event. The question exists if the water quality of reclaimed water can be guaranteed to a suitable standard compared to the natural water supply. In order to achieve comparison between the two sources, critical analysis of reclaimed water output from the Lower Molonglo Water Quality Control Centre (LMWQCC) is to be analysed with data from existing Membrane Filtration/Reverse Osmosis treatment plants to model achievable water quality in conjunction with the existing quality of the Cotter Reservoir. This assessment can then determine whether the Cotter water quality can be improved with this proposal and assess risk associated with the reuse of water in the ACT.

Keywords: ACTEW, Water Security Project, Reclaimed Water, LMWQCC, Contaminants, Reverse Osmosis, Membrane Filtration, Cotter Reservoir

The following paper should be read either following or in conjunction with both listed documents which describe the background information regarding the establishment of guidelines within Australia for water supplies.

Key References:
Australian Drinking Water Guidelines (NHMRC and NRMMC, 2004)
Australian Guide to Water Recycling (NRMMC, EPHC and AHMC 2006)

Key Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>LMWQCC</td>
<td>Lower Molonglo Water Quality Control Centre</td>
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<td>RO</td>
<td>Reverse Osmosis</td>
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<tr>
<td>WPP</td>
<td>Water Purification Plant</td>
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<tr>
<td>WTP</td>
<td>Water Treatment Plant</td>
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<tr>
<td>AWTP</td>
<td>Advanced Water Treatment Plants</td>
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<tr>
<td>WWTP</td>
<td>Waste Water Treatment Plant</td>
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I. Introduction to ACT Scheme

The ACT Government owned ACTEW Corporation administers the running of the Water Security Program and handles all water and wastewater schemes for the ACT. The two shareholders of the ACTEW Corporation are the Chief Minister and Deputy Chief Minister of the ACT ensuring a political outlook on all decisions.

The Lower Molonglo Water Quality Control Centre (LMWQCC) is an existing tertiary treatment plant in the ACT region where sewage and waste is collected from the ACT catchment area, treated and then released into the Molonglo River. Once into the river system, the slow flowing water is increasingly exposed to natural Ultra Violet treatment and filtration before it is drawn back out of the catchment primarily for irrigation purposes.

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The LMWQCC utilises six distinct physical treatment processes in order to provide tertiary treatment to effluent. The treatment train includes the following processes: 
- Screening
- Sedimentation Classes (Class I, II, III and IV)
- Filtration

The ACT Government through the ACTEW Corporation has proposed the construction of a Water Purification Plant (WPP) utilising membrane filtration and reverse osmosis to produce water of a quality suitable to be reintegrated back into the ACT water supply.

Currently a development application has been lodged for the design of a demonstration WPP to be constructed alongside the already existing LMWQCC. The proposal is for a display centre to be established demonstrating the reclaimed water process as an education and testing centre. Work has also begun on another three key proposals forming part of the ACTEW Water Security Project; 
- Enlarged Cotter Dam,
- Murrumbidgee to Googong Project, and
- Tantangara Transfer Project.

The Water Purification Plant forms the main part of the Water Security Project for the ACT and will be a three stage water treatment train. The plant will draw its source water from the tertiary treated output of the LMWQCC and conduct advanced water treatment utilising membrane filtration and reverse osmosis at the Molonglo site with the water then pumped to created wetlands near the Cotter Reservoir. These wetlands will be established as a buffer before the water enters the Cotter Reservoir allowing for nutrient polishing and temperature adjustment. The water will then mix into the Cotter Reservoir and this stage will be assisted by the already established destratification (mixing) program. The water will then be pumped to Mt. Stromlo WTP where it will be processed with an additional step introduced of UV sterilisation before being reintegrated into the water supply.

The ACT Water Cycle including the proposed Water Security Project is displayed as Figure 1 with the proposed WPP and wetlands highlighted in yellow and the current sewerage path in brown.
II. Review of Existing Water Purification Plants

The Water Purification Plant process of water recycling and the following augmentation into the drinking supply has an inherently high risk due to the high level of exposure to the population. Based on the plan to reinforce Cotter Reservoir with reclaimed water the key risk can be identified as illness suffered by consumers following exposure to parameters of concern or pathogens in the output of the treatment process. In order to minimise this risk appropriate monitoring schemes must be put in place based upon experience gained from similar treatment processes already in operation. Worldwide examples of treatment plants along with any relevant managing documentation or organisations are discussed in more detail as follows.5

A. Singapore.

Singapore utilises Water Purification Plants under the management of the Public Utilities Board and the project title of NEWater. NEWater was identified as an essential alternative for water supply by the Singapore government which sees the introduction of desalinated water and recycled water by the year 2012. The initiative is crucial in order to cope with increased demand coupled with lessened supply due to the end of the water trade agreement with Malaysia. The NEWater Water Purification Plant has been set up as a trial scheme to conduct real time testing on quality output as well as increase public awareness through tours and open displays.

The NEWater plant uses a multi stage process in order to produce clean filter output of drinking quality water. The initial stage uses microfiltration to remove impurities and additives from the water. The water then goes through the reverse osmosis process to remove bacteria, pharmaceuticals and viruses. The final stage includes UV Sterilisation producing a water quality higher than local tap water. This model can be seen as the closest comparison in design to the proposed model for the ACT.

The Public Utilities Board utilises the World Health Organisation (WHO) Guidelines as well as its own higher standard internal product water quality.6

B. United States.

The governing body for the monitoring of water reuse quality control is The United States Environmental Protection Agency (EPA). There are varied levels of water reuse programs currently in use in the United States however only four states have regulations or guidelines for indirect potable reuse.7 Information with regards to monitoring programs from US facilities will be utilised by ACTEW in order to establish the ACT program. United States facilities utilise the following treatment processes;8

- Gwinnett County Department of Public Utilities, Lawrenceville, GA, USA.
  - Secondary treated wastewater is passed through a microfiltration system followed by granular activated carbon absorption and ozonation before release into natural waterways. These waterways are used as drinking water supply sources.
- Clayton County Water Authority, Morrow, GA, USA.
  - Secondary treated wastewater from an extended aeration plant is discharged to land for land-filtration. This water is discharged to a reservoir which is the source water for a WPP.
- West Basin Municipal Water District, Fountain Valley, CA, USA.
  - WPP discharges water to groundwater (to combat seawater intrusion) and commerce and industry non-potable applications. The plant is capable of producing separate outputs of water quality depending on the expected use. Treatment processes include, microfiltration, RO (single and dual pass) and advanced oxidation using ultraviolet/hydrogen peroxide.
- Upper Occoquan Sewage Authority, Centreville, VA, USA.
  - The plant discharges into a river system which is the source for a WTP. Treatment includes; lime precipitation softening, two stage recarbonation, granular media filtration, granular activated carbon, chlorination and dechlorination.
- Orange County Water District, Fountain Valley, CA, USA.
  - Used a system under the project name of Water Factory 21 discharging water to the groundwater system and some other irrigation uses. The plant was reconstructed to utilise microfiltration, reverse osmosis and advanced oxidation using ultraviolet and hydrogen peroxide.
C. Africa.
Namibia is currently the only African country that utilises recycled water with the direct potable treatment plant at Windhoek established in 1968 and the Gorangab Reclamation Plant which began operation in 2002. The Windhoek plant discharges treated water to a reservoir which is the source for a WTP. The treatment process includes ozonation, dissolved air flotation, sand filtration, biologically active carbon, ultrafiltration and chlorination.

III. Domestic Water Recycling
Water recycling within Australia at least directly is currently limited to only non potable reuse options. The water reuse schemes that currently exist may lead to some indirect ingestion based upon water pumped back into water courses however no direct planned water recycling is used as a potable source. Schemes which exist within Australia are based primarily upon commercial/industrial reuse with a recent push towards dual reticulation programs for new domestic developments.

A. Sydney - Rouse Hill.
The Rouse Hill dual reticulation scheme has been established to lower the overall demand placed upon Sydney’s drinking water supplies. Dual reticulation refers to the establishment of dual water supplies, one of drinking quality water for domestic use and the other of recycled waste water primarily for outdoor use. Recycled waste water in the Rouse Hill project is supplied via separate pipe systems and houses are fitted with a separate ‘purple’ meter to monitor household use. The water is produced to a suitable standard for human use however taps are colour coded and marked ‘Recycled waste water – do not drink’. Water in this form can be used for flushing toilets, watering gardens, washing cars and other outdoor uses.

This concept is becoming increasingly attractive to water conservationists especially as an option to be installed in new developments. The main step required from a government point of view would be to establish an Australian Standard with regards to dual reticulation and empower local government to enforce new subdivisions to establish dual reticulation infrastructure.9

B. NSW - Port Macquarie
The Port Macquarie-Hastings council has developed a program which will utilise dual reticulation to both existing urban areas and the proposal for recycled water schemes to be included in all new developments. The Port Macquarie Sewage Treatment Plant produces tertiary treated effluent that is pumped to the Hastings River and now also treated with Advanced Water Treatment processes including ultra-filtration, reverse osmosis and UV disinfection. This currently active project is very similar in process to the ACT proposal with the exception that the use remains non-potable and water being supplied through a new dual reticulation network.10 Data from this project if available may be utilised to model the proposed ACT treatment train.

C. South East Queensland
The Western Corridor Recycled Water Project (WCRWP) is the Queensland Government initiative to reclaim water from municipal effluent for reuse primarily by industrial applications as an effort to lower demand on source water. There are plans mentioned for modification of the plan to recharge source water dependant on risk management with regards to drinking water. The project will include micro/ultra filtration, reverse osmosis and other processes. Plans exist to construct three new AWTPs to reclaim water from an existing six WWTPs. The project will also require the construction of approximately 200km of pipes to distribute the treated product.11

IV. Concern Parameters
The monitoring of certain parameters can be used to create safeguards for the quality of reclaimed water output. Monitoring can be simplified based on the principle that it is more effective to test for a narrow range of key characteristics as frequently as possible rather than a lengthy analysis less often. A possible approach demonstrates monitoring limits for turbidity, chlorine residual and coliform bacteria to indicate the removal of;12

- Viruses (Turbidity and Chlorine Residual)
- Protozoa (Turbidity)
- Bacteria (Turbidity, Chlorine Residual and Coliforms)

Hazard concentrations will be decreased based on the combination of treatments provided through the process. The effectiveness of pathogen reduction will be influenced by design factors such as;13

- Pore sizes of membranes,
Disinfectant doses and detention times, and
detention times in lagoons and wetlands.
A more general outlook can be to consider specific characteristics within drinking water. By considering the
different concern parameters the review can focus on which aspects are of major concern. These characteristics are
split into the following fields which will be covered in detail:¹⁴

- Microbial Indicators
- Physical and Chemical Characteristics
- Non Conventional Threats

A. Microbial Indicators

In order for risk management to be achieved with regards to the use of reclaimed water, quality control must be
established in a cost effective and timely manner. Microorganisms are conventionally used as indicators of the
presence of fecal contamination. With the increasing quality of advanced water treatment, fecal contamination is
becoming of lower concern however must still be considered to ensure health and safety.

Box 1 outlines the ideal microorganism indicator traits when considering the correct parameter to
measure/monitor water quality.

<table>
<thead>
<tr>
<th>Ideal Indicator Microorganisms Traits</th>
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<tr>
<td>1. The microorganism should only originate in the digestion tract of humans and warm-blooded animals.</td>
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<td>2. The microorganism should be easily, rapidly, and reliably identified and enumerated.</td>
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<tr>
<td>3. The analysis should be inexpensive.</td>
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<td>4. The indicator should survive longer than pathogens in the extra-intestinal environment.</td>
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<td>5. The indicator should occur in high numbers.</td>
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<td>6. The indicator should not be pathogenic itself.</td>
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Box 1 Ideal Microorganism Indicator Traits

These considerations cover the basic overview for establishing a suitable requirement to choose microorganisms
for testing on a short term basis. This level of testing is essential to be able to monitor both incoming and outgoing
water to identify spikes in fecal matter.

Microorganisms within sewage exist predominantly as Bacteria, Viruses, Protozoas and Helminths. Indicator
organisms can include the following with their type listed in brackets:¹⁶

- Escherichia Coli (Bacteria)
- Enterococci (Bacteria)
- Clostridium Perfringens (Bacteria)
- Somatic Coliphages (Virus)
- F-RNA Coliphages (Virus)

The two main forms of microorganism applicable as indicator organisms are coliforms and viruses.

1. Coliforms

Two groups of coliforms exist, total and fecal and are the most commonly used indicators. The total coliform
group is commonly used as an indicator for drinking water however due to the fact that some of its members are
widely distributed throughout the environment a safety factor is required to be applied to measurements.

The fecal coliform group, a subgroup of the total coliforms and can provide a much more specific indicator of
fecal contamination. Approximately 96.4% of coliforms in human feces are fecal coliforms and the percentage for
warm blooded animals is 93-98%.¹⁵ Due to this high concentration of fecal coliforms within feces coupled with the
lower ability for these coliforms to exist in the extra-intestinal environment can allow researchers to achieve a more
specific indication of the fecal contamination of the sample water.

The preferred test parameter for fecal contamination is Escherichia Coli (E. Coli) as some environmentally
occurring coliforms are thermotolerant. It is recommended testing for E. Coli be utilized as it exists as the most
common thermotolerant coliform within feces at over 90%. A presence of E. Coli indicates recent fecal
contamination as E. Coli does not generally multiply in the drinking water system.¹⁸

2. Viruses

Phages are viruses and can be excreted at high concentrations. A main concern of viruses is that they remain
persistent for much longer than the bacterial pathogens. The test methods for Coliphages involve taking a sample
and adding it to an E. Coli active medium. The result can be the forming of a plaque (Virus Colony) and
measurements are taken in PFU (Plaque Forming Units). Results for Plaque detection can be established within 4-6 hours and 12-14 hours for full plaque development.19

B. Physical and Chemical Characteristics

Health and environmental risks are associated with the use of reclaimed water and the effects cannot simply be measured at the output of the plant. Factors affecting the final output of the water quality received by the consumer is influenced by the inflow of effluent to the tertiary treatment facility at LMWQCC to the treated effluent that will be treated at the WPP. The reclaimed water can then have environmental impacts on the Cotter Reservoir both with regards to water quality and also the sustainability of natural species and their eco system.

Cotter reservoir itself has issues with regards to water quality predominantly caused by the bushfires and the area being cleared of trees leading to impact from erosion following heavy rainfall. Of particular concern is the threat of algal bloom in the form of Cyanophyta (Blue green algae) which is already a threat to the reservoir. A mixing program has been implemented within the reservoir to attempt to ensure mixing to a depth of 12m to manage water quality, specifically iron and manganese.20

It is essential that water quality is such that it remains suitable for both environmental discharge and supply to the Canberra water system. The key environmental issues as identified by the ACTEW Corporation are included in Box 2.21

In selecting the Water Purification Plant design necessary to achieve water suitable for both environmental discharge and supply to the Canberra water supply system it was necessary to consider the impacts of different processes on water quality as outlined below:

- consideration of nutrient loading on the Cotter Reservoir and to nuisance algal blooms;
- consideration of physical changes in water quality due to changes in salinity, temperature or nitrates which can impact adversely on the aquatic ecosystem; and
- consideration of salinity changes in any discharges to the Murrumbidgee River and the water supply system;

<table>
<thead>
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<th>Box 2 Environmental Considerations</th>
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<tr>
<td>1. Nutrients</td>
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<td>Target nutrient levels must be set and ACTEW has outlined that for the project the target levels will be based upon the Australian and New Zealand Guidelines for Fresh and Marine Water (ANZECC and ARMCANZ 2000).22 Nutrients of particular concern are nitrates (NO$_3$N), ammonia (NH$_4$N) and ortho-phosphorus (PO$_4$P). Although these nutrients are removed to some degree the residual may have an effect on the environmental balance. The nutrient targets for water discharging to the Cotter reservoir are included as Table 1.23</td>
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<table>
<thead>
<tr>
<th>Table 1 Nutrient Targets from ACTEW Corporation</th>
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<tr>
<td><strong>Parameter</strong></td>
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<tr>
<td>Effluent from LMWQCC (Target)</td>
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<tr>
<td>Water quality Cotter Reservoir (Target)</td>
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<tr>
<td>Total additional removal required</td>
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The ratio of Nitrogen to Phosphorus must be controlled in order to avoid algal blooms by maintaining Phosphorus limiting conditions. Assessment of the conditions of the Cotter reservoir and the required nutrient levels will be required to determine the level of denitrification that is to occur as a part of the waste water treatment process. The nutrient polishing wetlands proposed will also aim to level out this effect however control of the plant output can be achieved by comparison of the nutrient levels for nitrate, ammonia and ortho-phosphorus for effluent before and after LMWQCC treatment and the required WPP output.

2. Temperature

The temperature of the inflow into the Cotter Reservoir can produce a large temperature gradient especially in the winter months where the reservoir temperature will be much lower than the WPP output. Temperature of output from the WPP will be required to be compared to the temperature of the reservoir and systems considered to decrease the temperature gradient (through ponds, wetlands or other resting areas).
C. Non Conventional Threats

Organic Microcontaminants such as Pharmaceuticals, Hormones and Personal Care Products that can be introduced to effluent through domestic waste, hospitals and some industrial applications are of serious concern to the safety of both the human consumer and the environment. A pilot study released on estrogen in wastewater described the impact of endocrine disrupting chemicals (EDCs) on aquatic fauna causing endocrine disruption including feminization and masculinisation.\textsuperscript{24} The conclusion of the study was that steroidal estrogen removal was not well predicted for the WWTPs and research was currently being undertaken into advanced treatment technology.

The proposal is to utilise Membrane Filtration coupled with Reverse Osmosis which has produced good results overseas at removal of organic microcontaminants. It has been demonstrated that tertiary treatment of reclaimed wastewater by membrane filtration followed by reverse osmosis is the most efficient combination of filtration against microcontaminants at this stage.\textsuperscript{25} The monitoring of these parameters within the test samples remains of high importance in order to protect aquatic flora and fauna including endangered fish species existing in the Cotter Reservoir.

V. Testing Parameters

The ADWG 2004 provides a summary of guideline values which have been established for Microbial Quality (Table 10.9), Physical and Chemical Characteristics (Table 10.10), Pesticides (Table 10.11) and Radiological Quality (Table 10.12). During this study these values will be utilised as standards also with ACTEW supplied specific product quality guidelines (if to a higher level).

Within the scope of this study the water quality will be considered from varied sources throughout the treatment process in order to identify problematic trends or seasonal fluctuations. Two main monitoring programs have been identified by ACTEW being the Baseline Monitoring Program (BMP) and the Ongoing Sampling and Monitoring Program (SAMP).

A. Baseline Monitoring Program

The key objective of the ACTEW program is to obtain baseline information across the existing sewerage collection system and treatment plant effluent.\textsuperscript{26} Data collected from raw sewerage, LMWQCC treated effluent, Cotter Reservoir water quality and Mt. Stromlo WTP inflows will be used in the study. The gathering of baseline information for both the source of recycled water and the receiving environment is essential to determine characteristics for both areas.\textsuperscript{27} Data from Ecowise has already been collected and will form the source of information for this assessment by mathematical modeling to identify any dangerous trends or fluctuations.

B. Validation Monitoring

Validation monitoring is used to determine whether treatment processes are capable of adequately controlling water quality and exposure levels to meet target criteria.\textsuperscript{28} Information from existing WPPs, preferably the NEWater scheme from Singapore and the Port Macquarie council as previously mentioned if available will be used to form a treatment model for the proposed process. Modeling of the treatment process, the environmental interaction within the to be created wetlands, and the already existing Cotter Reservoir mixing process will outline any key concerns or shortcomings of the proposal.

C. Ongoing Sampling and Monitoring Program

For an established system further data collection points would be required to establish a safe control system for monitoring output to the consumer. If possible a variety of sampling practices should be established in order to monitor sudden fluctuations as well as diurnal and seasonal variations. The establishment of operational monitoring ensuring that the system processes remain under control as well as verification monitoring to confirm compliance with the water quality management plan is essential.\textsuperscript{29}

Data gathered from baseline monitoring will be utilised with a mathematical model of the proposed treatment train to aim to predict issues with the proposal.

The main parameters to be considered in this study are;

- Microbial
  - Escherichia Coli
Physical and Chemical
- Nitrogen
- Phosphorus
- Ammonia
- pH
- Iron
- Manganese
- Temperature
- Oxygen
- Salinity

Monitoring of microcontaminants will not be conducted however further study of existing WPPs with membrane filtration and RO will be considered. Existing data collected through Ecowise will be utilised as well as more current data within these parameters requested from ACTEW in order to conduct the review of the proposed treatment process through comparison of data.

Sampling Locations within the LMWQCC are identified in Figure 2.³⁰

Four sampling locations exist that have been utilised in the data collection provided by Ecowise for this study with the points relating to the following:
- Point LM3003 (3)
  - Final effluent
- Point LM3005 (5)
  - Following final clarification
- Point LM3006 (6)
  - Following primary sedimentation
- Point LM3007 (7)
  - Sewage at plant inlet

The Data collection points required for further analysis of the suitability of the program are identified in Figure 3.

At this stage required data collection is not complete however this information has been requested through ACTEW in order for analysis to be conducted.
- Point A
  - Inlet to LMWQCC (LM3007)
- Point B
  - Tertiary treated water (LM3003)
- Point C
  - Cotter Reservoir Water Quality
- Point D
  - Water supply to Mt. Stromlo WTP
- Point E
  - Canberra Water Supply *(WTP Output)
VI. Summary

The background information provided within this initial report outlines the key issues with regards to the ACTEW Proposal to the ACT Government for the development of the Water Purification Plant to recycle water from LMWQCC to the Cotter Reservoir. The main issues are concerned with the monitoring of key parameters to ensure that the water supplied to the reservoir is of a suitable standard avoiding illness among the consumer population.

Data from Ecowise has been gathered and utilising this information in addition to data requested from the NEWater and Port Macquarie programs, a validation assessment will be conducted. The concern parameters identified will be required to be assessed for both the consumer population and the aquatic flora and fauna of the Cotter Reservoir.

References

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5ACTEW Corporation, Water Purification Scheme for the ACT, Document No: 313952, July 2007, pp. 18 - 20
6ACTEW Corporation, Water Purification Scheme for the ACT, Document No: 313952, July 2007, p. 19
7ACTEW Corporation, Water Purification Scheme for the ACT, Document No: 313952, July 2007, p. 16
8ACTEW Corporation, Water Purification Scheme for the ACT, Document No: 313952, July 2007, pp. 16 - 19
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21ACTEW Corporation, Water Purification Scheme for the ACT, Document No: 313952, July 2007, p. 33
22ACTEW Corporation, Water Purification Scheme for the ACT, Document No: 313952, July 2007, p. 33
23ACTEW Corporation, Water Purification Scheme for the ACT, Document No: 313952, July 2007, p. 34

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Appendices

Appendix A – Management Documentation