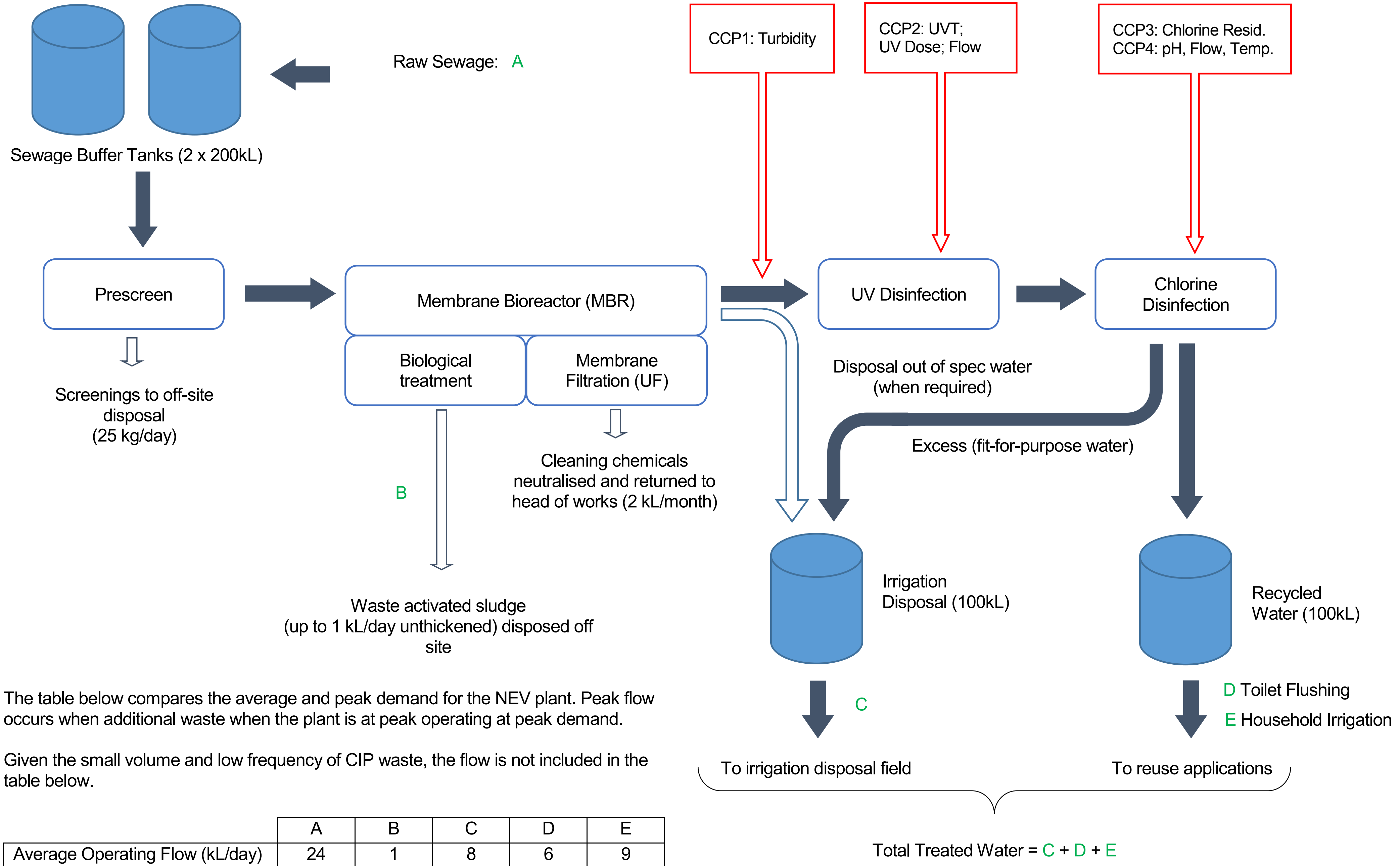
Appendix 4.2.1

Waste Water Treatment Plant – Capacity 60kL/day



Note: The table below compares the average and peak demand for the NEV plant. Peak flow occurs when additional waste when the plant is at peak operating at peak demand.

Given the small volume and low frequency of CIP waste, the flow is not included in the table below.

	A	B	C	D	E
Average Operating Flow (kL/day)	24	1	8	6	9
Peak Flow (kL/day)	24	1	23	0	0

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Appendix - 4.2.10

NEV RW Risk Assessment Output Paper v2.0

Narara Ecovillage Recycled Water System

Risk Assessment Output Paper

Narara Ecovillage Village Co-op Ltd

Date: May 2016

Version: 2.0

TECHNICAL FACILITATION SPECIALISTS

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Executive Summary

Background

- The Australian Guidelines for Water Recycling 2006 (AGWR) prescribe a holistic approach to managing health and environmental risks. This approach involves systematically assessing where and how contamination may arise and find its way to the point of use and determining how to protect consumers and the environment from such contamination.
- Central to the implementation of the AGWR is understanding and managing risks to public health and the environment.
- IPART has adopted the AGWR Framework for assessing applications for approval to treat and supply recycled water under the *Water Industry Competition Act 2006* (NSW).

Workshop purpose

The purpose of the workshop was to undertake a water quality risk assessment for Narara Ecovillage recycled water scheme and irrigation using the Narara Water Treatment Plant backwash.

Briefing paper structure

This paper documents the results of the workshop and details background information that was used within the risk assessment process for the Narara Ecovillage recycled water scheme, including:

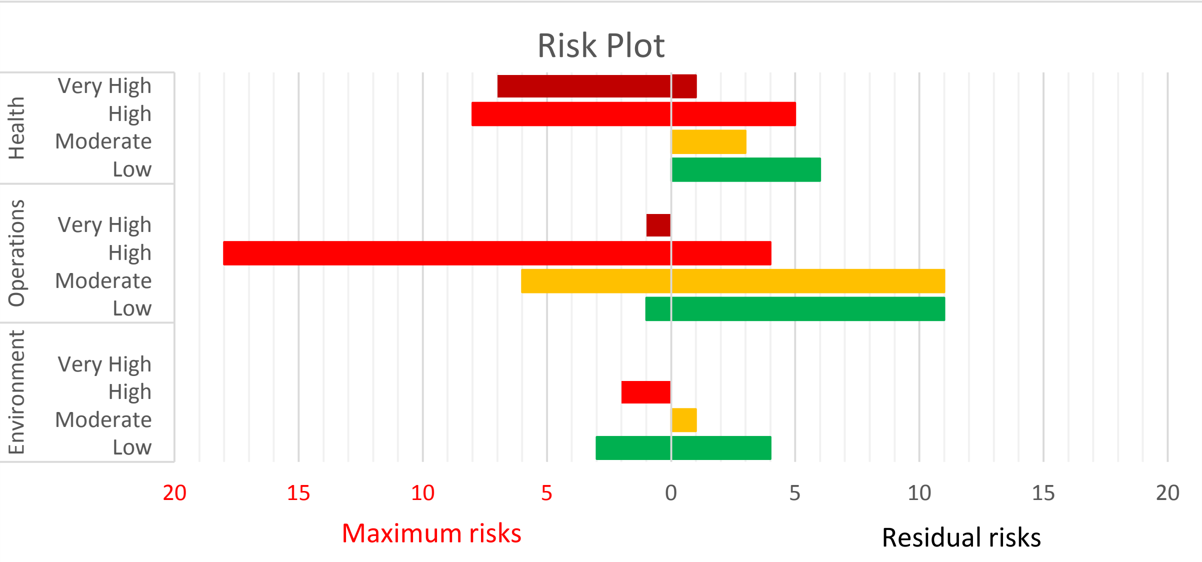
- Maps and flow diagrams of the schemes
- A description of the treatment processes
- Indicative pathogen log_{10} reduction values
- Previously identified CCPs

Risk assessment results

The risk rankings for both those without barriers (maximum risk; left) and with barriers (residual risk; right) are shown in Figure i-i for the Narara Ecovillage recycled water scheme.

Overall 46 risks were ranked as part of the risk assessment, with one very high residual risk and nine high residual risks identified.

Figure i-i Risk profile for maximum and residual risks



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Contents

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Figures

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1 Introduction

1.1 Background

Narara Ecovillage is proposing to recycle treated wastewater from home and community centre toilets, showers, hand basins and laundries. The recycled water will be supplied for toilet flushing in homes and the community centre, and irrigation of home and community gardens, lawns and landscaped areas. Backwash water from the water treatment plant will be used for field irrigation.

Atom Consulting facilitated a one day risk assessment on 18 April 2016, on the non-potable water uses for Narara Ecovillage for a *Water Industry Competition Act 2006* NSW (WICA) application.

1.2 Previous assessments

A Recycled Water Quality Management Plan (Aquacell, 2015) had previously been developed for the Narara Ecovillage recycled water scheme. A desktop preliminary risk assessment was also undertaken in March 2016.

1.3 Regulatory context

WICA establishes a licensing regime for private sector entrants to ensure the continued protection of public health, consumers and the environment. A corporation (other than a public water utility) must obtain a licence under WICA to construct, maintain or operate any water industry infrastructure or to supply water (potable or non-potable) or provide sewerage services by means of any water industry infrastructure.

The licensing principles set out in section 7 of WICA show a mandate to protect public health and the environment. WICA is supported by the *Water Industry Competition (General) Regulation 2008* (WICR). WICR sets out:

- The matters a licence application must address
- Standard licence conditions
- Information to be contained on the register of licences
- The retailer of last resort provisions

The WICR requires that applications for licences include a comprehensive statement describing how twelve elements of the Framework for Management of Recycled Water Quality and Use in the *Australian Guidelines for Water Recycling 2006* (AGWR) have been addressed and will be implemented (IPART, 2015). Before commencing to operate, a licensed network operator must submit to IPART an Infrastructure Operating Plan and a Water Quality Plan (that is consistent with the AGWR and addresses the Framework for Management of Recycled Water Quality and Use). A summary of the documents required is shown in Table 1-1.

Table 1-1 Plans required under WICA/WICR (Source: IPART)

Plan	Network Operator	Retail Supplier	Network Operator/ Retail Supplier
Infrastructure operating plan	✓	×	✓
Water quality plan	✓	×	✓
Sewage management plan	✓	×	✓
Retail supply management plan	×	✓	✓

The Water Quality Plan must address all elements of the Framework and include (IPART, 2015):

- the undertaking of a comprehensive risk assessment of the recycled water supply system
- a comprehensive recycled water quality monitoring plan

- a plan to report monitoring results and any incident to NSW Health (and the Ministers and organisations required by the Regulation)

1.4 Background to the National Guidelines

In November 2006 the National Environment Protection and Heritage Council, the Natural Resource Management Ministerial Council and the Australian Health Ministers Conference released the Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) (AGWR, 2006).

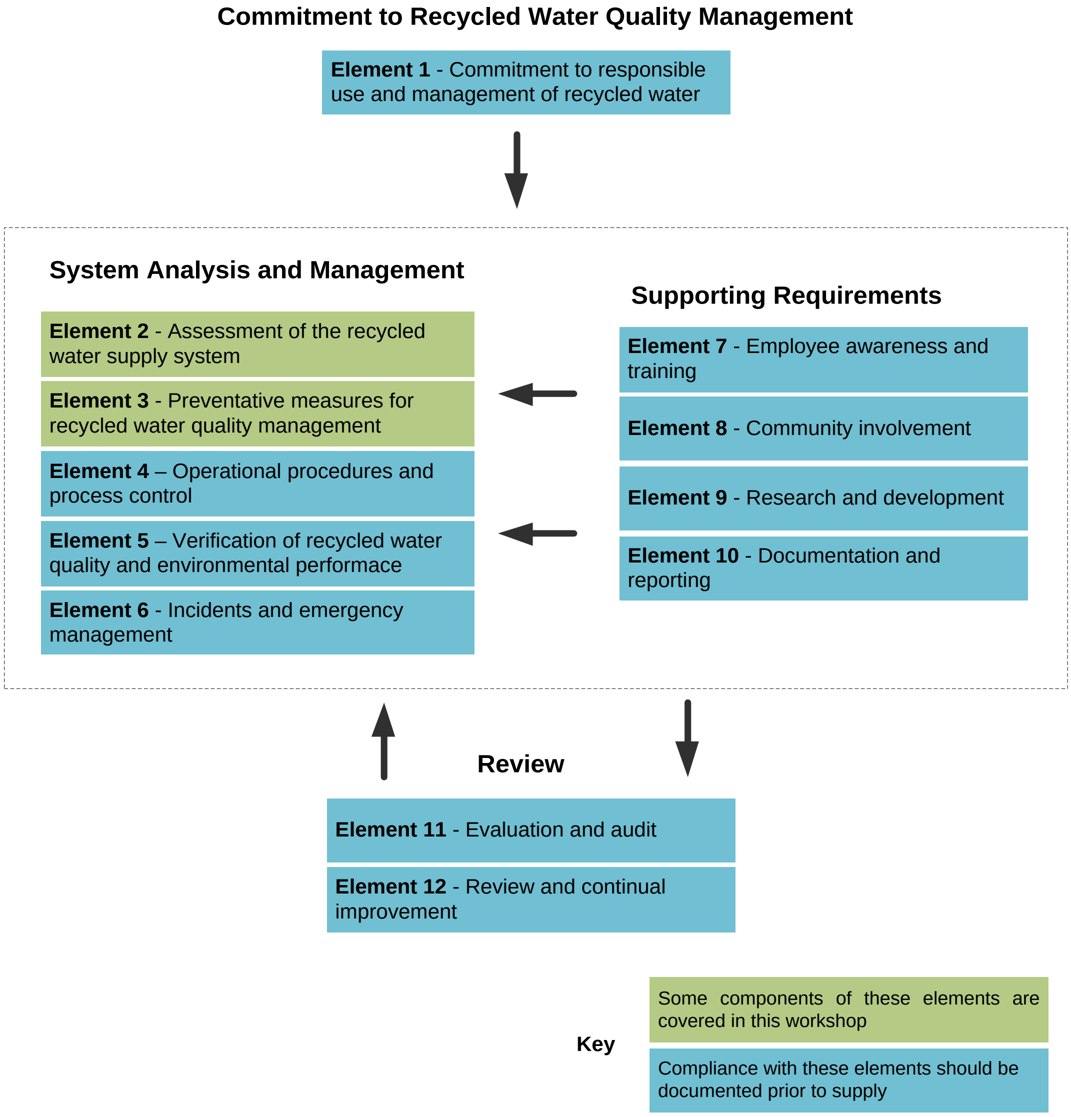
The AGWR set out a holistic approach to managing health and environmental risks. The approach involves systematically assessing where and how contamination may arise and find its way to the point of use and determining how to protect consumers and the environment from such contamination. This approach is called the *Framework for Management of Recycled Water Quality and Use* (or the “Framework”). The Framework (consisting of 12 Elements, 36 Components and 84 Actions) incorporates the principles of Hazard Analysis and Critical Control Points (HACCP) and quality assurance.

There are four general areas of the Framework:

- **Commitment to recycled water quality management** - This involves developing a commitment to recycled water quality management within the organisation. Adoption of the philosophy of the Framework is not sufficient in itself to ensure its effectiveness and continual improvement. Successful implementation requires active participation of the senior executive and a supportive organisational philosophy.
- **System analysis and management** - This involves understanding the entire recycled water supply system, the hazards and events which can compromise recycled water quality and the preventive measures and operational control necessary for ensuring safe and reliable recycled water.
- **Supporting requirements** - These requirements include basic elements of good practice such as employee training, community involvement, research and development, validation of process efficacy and systems for documentation and reporting.
- **Review** - This includes evaluation and audit processes and their review by the senior executive, to ensure that the management system is functioning satisfactorily. These components provide a basis for review and continual improvement.

These four areas are further broken down into elements, components and actions. The linkages between these four general areas and the elements are shown in Figure 1-1 over (adapted from AGWR, 2006).

Figure 1-1 Elements of the framework for the management of recycled water quality and use



Central to the provision of safe water is the identification and management of critical control points (CCPs; Element 4). A CCP is an activity, procedure or process that is essential to prevent a water quality hazard or reduce it to an acceptable level. Appropriate selection of CCPs is important, as CCPs are the focus of process control for the production of safe drinking water. Also critical for ensuring the safety of consumers are the procedures for incidents and emergencies (Element 6). Understanding the risks to drinking water and their management is essential to the development of the CCPs (Elements 2-3) and forms the basis of the current work.

1.5 Workshop context

The workshop addressed components of Elements 2 and 3 of the Framework. The components and actions for these two elements from the AGWR are listed below. A tick indicates this action was undertaken as part of the workshop and a cross that it was not considered. The section of the output paper where this action is considered is listed in brackets.

Element 2 - Assessment of the recycled water supply system

Source of recycled water, intended uses, receiving environments and routes of exposure

Summary of actions

✓ Identify source of water (Section 3)

✓ Identify intended uses, routes of exposure, receiving environments, endpoints and effects (Section 3)

✓Consider inadvertent or unauthorised uses (Section 3.2 and Appendix B)

Recycled water system analysis

Summary of actions

✓ Assemble pertinent information and document key characteristics of the recycled water system to be considered (Section 3).

✓ Assemble a team with appropriate knowledge and expertise (Workshop participants - Section 4.2 and Appendix A).

✓ Construct a flow diagram of the recycled water system from the source to the application or receiving environments (Section 3)

x Periodically review the recycled water system analysis.

Assessment of water quality data

Summary of actions

x Assemble historical data about sewage, greywater or stormwater quality as well as data from treatment plants and of recycled water supplied to users; identify gaps and assess reliability of data

x Assess data (using tools such as control charts and trends analysis) to identify trends and potential problems

Hazard identification and risk assessment

Summary of actions

✓ Define the approach to hazard identification and risk assessment, considering both public and ecological health (Section 2)

X Periodically review and update the hazard identification and risk assessment to incorporate any changes.

✓ Identify and document hazards and hazardous events for each component of the recycled water system (Section 5 and Appendix B).

✓ Estimate the level of risk for each identified hazard or hazardous event (Section 5 and Appendix B).

✓ Consider inadvertent and unauthorised use or discharge (Section 5 and Appendix B).

✓ Determine significant risks and document priorities for risk management (Section 5 and Appendix B).

✓ Evaluate the major sources of uncertainty (Section 5 and Appendix B).

Element 3 - Preventive measures for recycled water quality management

Preventive measures and multiple barriers

Summary of actions

✓ Identify existing preventive measures system-wide for each significant hazard or hazardous event and estimate the residual risk (Appendix B).

✓ Identify alternative or additional preventive measures that are required to ensure risks are reduced to acceptable levels (Section 5 and Appendix B).

✓ Document the preventive measures and strategies, addressing each significant risk (Appendix B).

Critical control points

Summary of actions

✓ Assess preventive measures throughout the recycled water system to identify critical control points (Section 5.1 and Appendix D).

✓ Establish mechanisms for operational control (Section 5.1 and Appendix D).

2 Risk assessment methodology

2.1 Risk management

Effective risk management involves identifying all potential hazards and hazardous events and assessing the level of risk they present to human and environmental health. The assessment of risk for this workshop followed standard protocols outlined in the AGWR. Table 2-1 provides definitions and examples of key words used in the risk assessment.

Table 2-1. Key words and their definitions (AGWR)

	Definition	Example
Hazard	A biological, chemical, physical or radiological agent that has the potential to cause harm to people, animals, crops or plants, other terrestrial biota, aquatic biota, soils or the general environment	The protozoan parasite *Cryptosporidium parvum* is a hazard to human health. Salinity is a hazard to soils.
Hazardous event	An incident or situation that can lead to the presence of a hazard — that is, what can happen and how	Failure at a recycled water treatment plant leading to *C. parvum* passing into the distribution system of a dual-reticulation system is a hazardous event. Bursting of a pipeline reticulating recycled water high in phosphorus is a hazardous event.
Risk	The likelihood of identified hazards causing harm in exposed populations or receiving environments in a specified timeframe, including the severity of the consequence (risk = likelihood × impact)	The likelihood of *C. parvum* being present in source water and passing through the treatment plant in sufficient numbers to cause illness in users of recycled water is a risk. The likelihood of phosphorus concentrations in the source water remaining sufficiently high to cause eutrophication (degradation of water quality due to enrichment by nutrients) in a waterway near an irrigation site is a risk.

For a recycled water scheme the primary focus is on the health and environmental hazards associated with the scheme.

2.1.1 Health hazards

The most significant human health hazards in recycled water are those microorganisms which cause enteric illness. Such microorganisms are found at high concentrations in untreated sewage, although numbers of individual pathogens will vary depending on rates of illness in the humans and animals contributing faecal waste.

Chemical hazards also need to be considered, particularly for uses of recycled water involving potential for direct contact or ingestion.

While there are many pathogens associated with waterborne disease, with each having a slightly different combination of sources, treatment sensitivity and effect on health, to simplify matters the World Health Organisation's (WHO) concept of 'reference pathogens' (2004 and 2006) can be adopted.

The concept of a 'reference pathogen' is that if the more problematic organisms are under control, risk from the hundreds of other waterborne pathogens should also be largely under control. A summary of reference pathogens is given in Table 2-2.

Table 2-2. List of reference pathogens for health

Reference Pathogen	Representative Of
Rotavirus	Enteric viruses
Cryptosporidium	Protozoan parasites and human helminthic parasites
Campylobacter	Enteric bacteria
Taenia saginata	Severe parasites borne by cattle
Taenia solium	Severe parasites borne by pigs

2.2 Log reduction requirements

Water quality requirements for recycled water are based on the likely exposure volumes that can be ingested. The AGWR expresses the reduction in pathogen concentration using logarithms (logs) to the base 10, with each $\log_{10}$ reduction value representing an order of magnitude decrease in pathogen concentration. The higher the number of log reductions, the lower the concentration of pathogens. For example, a 1 log reduction means the concentration is reduced to 1/10, a 2 $\log_{10}$ reduction means 1/100.

Logarithm Reduction (base 10)	% Removal	% Original Number of Pathogens
1 log	90% removal	10%
2 log	99% removal	1%
3 log	99.9% removal	0.1%

The AGWR $\log_{10}$ reductions for dual reticulation and municipal irrigation are shown in Table 2-3. The municipal irrigation requirements cover end uses including open spaces, sports grounds, golf courses, dust suppression and truck washing. The dual reticulation covers internal uses (toilet use, washing machine & the possibility of cross connections) and home garden use.

Table 2-3. Water quality requirements ($\log_{10}$ reductions) for the intended use

Pathogen	Dual reticulation (garden + internal)	Municipal irrigation
Bacteria (*Campylobacter*)	5.0	4.0
Virus (rotavirus)	6.5	5.0
Protozoa (*Cryptosporidium*)	5.0	3.5

Source: *Data from AGWR (2006) Table 3.8.*

2.3 Environmental hazards

The most significant environmental hazards in recycled water are generally chemical and physical. Chemical and physical hazards generally pose a greater potential threat to the environment than to humans, although major incidents such as spills or unauthorised chemical discharges may be hazardous to both environmental and human health. The most significant environmental hazards (key hazards) in recycled water have been identified and are given in the AGWR (Box 1). For the purposes of the workshop, this list was used to identify the key environmental hazards.

Box 1. Key environmental hazards (AGWR, 2006)

Boron
Cadmium
Chlorine disinfection residuals
Hydraulic load (water)
Nitrogen
Phosphorus
Salinity
Chloride
Sodium

2.4 Risk workshop methodology

The risk assessment workshop consisted of a number of different components. The facilitator guided workshop attendees through each of these workshop components.

For the purposes of this workshop the attendees are referred to as 'the team'. Each of the components and the role of the team in the workshop are outlined below:

1. Achievement of team consensus on the flow diagram and system description.
2. Verification of the intended uses for the recycled water.
3. Identification of hazards associated with supplying recycled water that is fit for purpose (both health and environmental risks).
4. Identification of process failures that can lead to environmental and health impacts.
5. Identification of additional control measures (apart from those already proposed) that may be required to reduce risks to acceptable levels.

Risks were assessed as Likelihood (Table 2-4) x Consequence (Table 2-5). A risk assessment matrix (AGWR, 2006) was used to assess risks for maximum and residual risk (Table 2-6).

Table 2-4. Likelihood table

Level	Descriptor	Example description
A	Rare	May occur only in exceptional circumstances. May occur once in 100 years
B	Unlikely	Could occur within 20 years or in unusual circumstances
C	Possible	Might occur or should be expected to occur within a 5- to 10-year period
D	Likely	Will probably occur within a 1- to 5-year period
E	Almost certain	Is expected to occur with a probability of multiple occurrences within a year

Source: *AGWR (2006)*

Table 2-5. Consequence table

Level	Descriptor	Example description
1	Insignificant	Insignificant impact or not detectable
2	Minor	**Health** - Minor impact for small population **Environment** – Potentially harmful to local ecosystem with local impacts contained to site **Operations** – Operational impact results in unscheduled visits by Aquacell
3	Moderate	**Health** - Minor impact for large population **Environment** – Potential harmful to a regional ecosystem with local impacts primarily contained to on-site **Operations** – Process is unavailable for a couple of days or associated costs are in the order of $5,000
4	Major	Health - Major impact for small population **Environment** – Potentially lethal to local ecosystem; predominately local but potential for off-site impacts

Level	Descriptor	Example description
		Operations - Process is unavailable for a week or associated costs are between $10,000 and $50,00
5	Catastrophic	**Health** - Major impact for large population **Environment** – Potentially lethal to regional ecosystem or threatened species; wide-spread onsite and off-site impacts **Operations** - Process is unavailable for more than two weeks or associated costs are greater than $50,000

Source: *AGWR (2006), Operations added as agreed as part of risk assessment workshop process*

Table 2-6. Risk matrix

	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
A (rare)	Low	Low	Low	High	High
B (unlikely)	Low	Low	Moderate	High	Very high
C (possible)	Low	Moderate	High	Very high	Very high
D (likely)	Low	Moderate	High	Very high	Very high
E (almost certain)	Low	Moderate	High	Very high	Very high

Source: *AGWR (2006)*

3 Systems description

3.1 Recycled water scheme overview

The Narara Ecovillage site is located on Research Rd, Narara on the NSW central coast.

The Narara Ecovillage development has two proposed phases:

- First phase: a maximum of 46 dwelling houses and a maximum of 18 other housing types.
- Full development with an indicative mix of 75 free dwelling houses and 75 other housing types.

The development will include a café and areas for eco-activities including short courses on sustainable production and well-being.

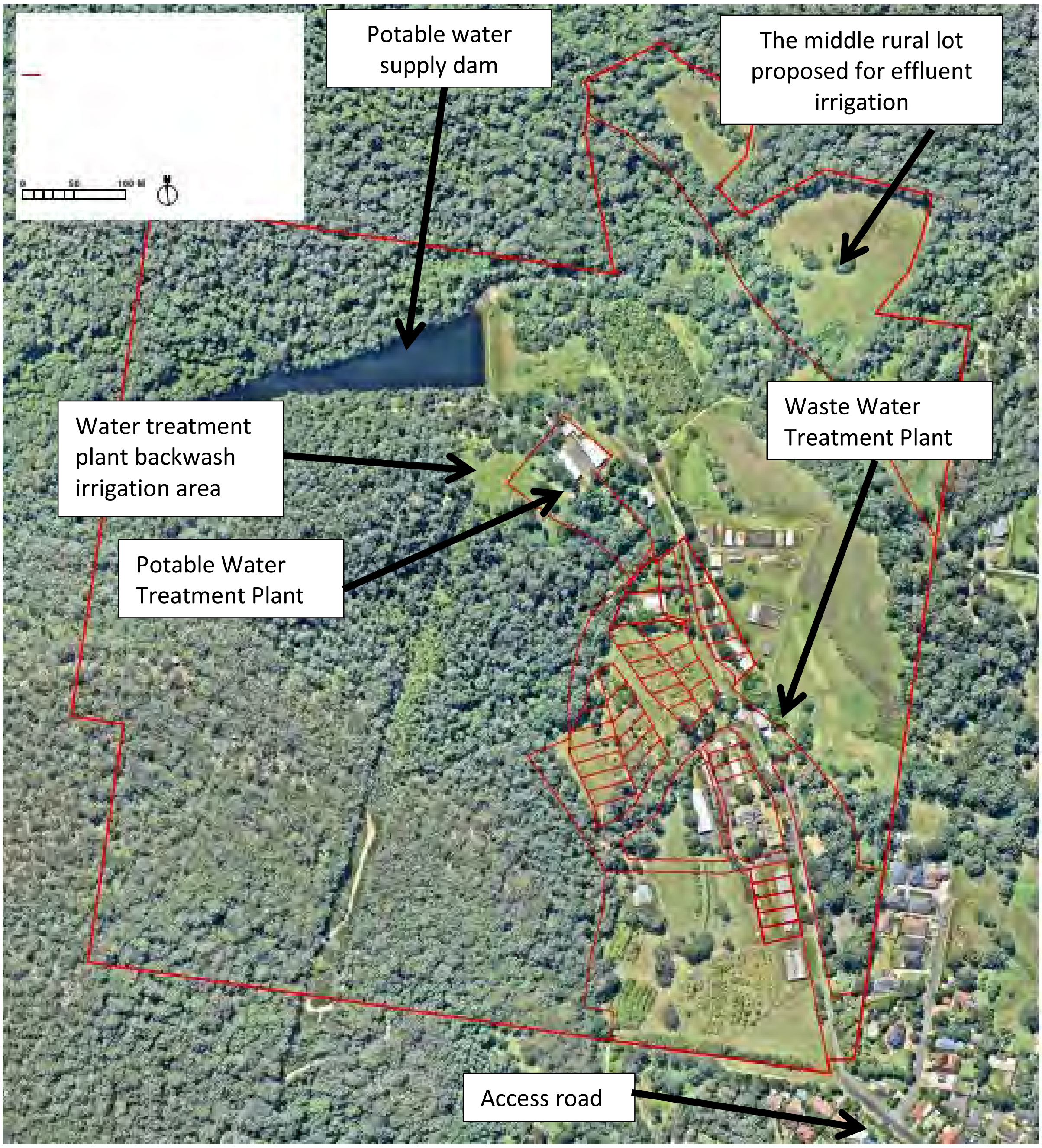
The first phase of the project will include construction of a temporary waste water treatment plant (WWTP) of 25 kl/day capacity. The second phase, with construction of a permanent WTP will have an ultimate design capacity of 60 kL/day. The biological reactor will be constructed to enable the plant capacity to be ramped up as development occurs.

Wastewater will be collected from home and community centre toilets, showers, hand basins, and laundries.

A dual reticulation system will supply recycled water for:

- toilet flushing in homes and the community centre
- irrigation of home and community gardens, lawns and landscaped areas.

Figure 3-1. The site plan (Plan courtesy of e8urban).

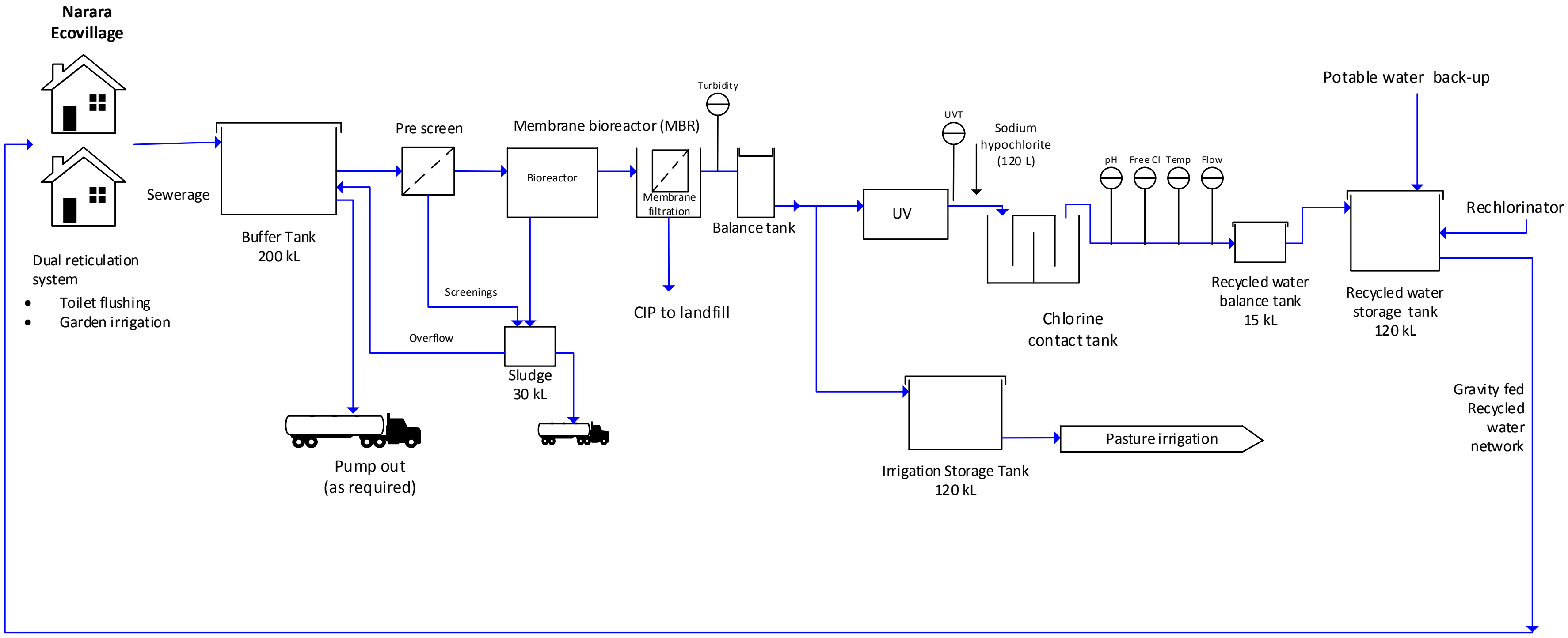


The proposed sewage treatment system will have the following treatment components:

- A buffer tank for collection of wastewater from the site
- Pre-screen
- Biological treatment and ultrafiltration zone (together forming the Membrane Bioreactor or MBR).
- Ultraviolet light disinfection
- Chlorine disinfection
- Recycled Water Storage (120 kL)
- Irrigation recycled water storage (120 kL)
- Overflows and drains to pump out (back to buffer tank)
- Sludge collection tank (off-site disposal)
- Chemical neutralisation and recycle tank.

A process flow diagram for the system is shown in Table 3-1.

Figure 3-2. Narara recycled water scheme process flow diagram (phase 1)



3.2 Potential Misuses of Water

The risk assessment considered potential misuses of the water. Potential misuses are listed in Table 3-1.

Table 3-1. Potential misuse description.

Category	Specific details
Chronic exposure risks	Cross connection so that recycled water flows into a potable supply system Tap in of a single potable connection to the recycled water
Acute exposure risks	Drinking from recycled water system Dermal exposure to recycled water (e.g. swimming pools, car wash, boat washing, dog washing, cleaning fish, washing furniture and walls). Inhalation.
Environmental impact	Scouring Sodicity Chlorine release Nutrient release Over-application

3.3 Log_{10} reductions

Dual reticulation

Theoretical log reduction values for the treatment process and the log reductions claimed in the Recycled Water Quality Management Plan (Aquacell, 2015) are shown in Table 3-2. The overall log reduction values are compared to the log reduction requirements for dual reticulation in Table 3-3.

Chlorine disinfection has been used to achieve a 4 log reduction value for virus and bacteria (Aquacell, 2015). This has been calculated based on using a minimum pipe length of 24 m at a diameter of 289 mm; max peak design flow (Q) of 0.05 m3/min, with a calculated residence time of 31 minutes. A concentration of 0.75 mg/L of free chlorine has been set as the minimum required for a residence time of 29 minutes for a C.t of 21.75 mg.min/L (Aquacell, 2015).

Table 3-2. Dual reticulation theoretical log_{10} reduction values

Treatment barrier	Protozoa		Viruses		Bacteria	
	Indicative reduction	Claimed reduction[1]	Indicative reduction	Claimed reduction[1]	Indicative reduction	Claimed reduction[1]
Primary treatment	0 - 0.5	0	0 – 0.1	0	0 – 0.5	0
Membrane filtration	>6.0	3.0	2.5 – 4.0	2.0	3.5 – 4.0	3.0
UV	3.0 - 4.0	3.0	1.0 – 3.0	0.5	2.0 – 4.0	3.0
Chlorination	0 - 0.5	0	1.0 – 4.0	4.0	2.0 – 4.0	4.0
Overall LRV	**9.0 – 11.0**	**6.0**	**4.5 – 11.1**	**6.5**	**7.5 – 12.5**	**10.0**

Note [1] *Total log reduction based on average with a maximum of 4 per treatment barrier (Aquacell, 2015 Table 3.2)*

Table 3-3. Dual reticulation theoretical log_{10} reduction values compared to LRV requirements

Treatment barrier	Protozoa		Viruses		Bacteria	
	Indicative reduction	Claimed reduction[1]	Indicative reduction	Claimed reduction[1]	Indicative reduction	Claimed reduction[1]
Overall LRV	9.0 – 11.0	6.0	4.5 – 11.1	6.5	7.5 – 12.5	10.0
Dual reticulation LRV requirements[2]	5.0	5.0	6.5	6.5	5.0	5.0
Difference	**4.0 – 6.0**	**1.0**	**-2.0 – 4.6**	**0.0**	**2.5 – 7.5**	**5.0**

Note [1] *Total log reduction based on average with a maximum of 4 per treatment barrier (Aquacell, 2015)*
[2] *LRV requirements AGWR Table 3.8*

Irrigation

Water that does not meet the water quality requirements for dual reticulation may be used to irrigate the field shown in Figure 3-1. Recycled water to be used for this irrigation end use will be treated by the MBR.

Claimed theoretical log reduction values for the MBR process (Aquacell, 2015) are shown in Table 3-2. End use control barriers for the irrigation area will include no public access and a minimum buffer zone of 30 m. Overall log reduction values are compared to log reduction requirements for municipal irrigation in in Table 3-3.

Table 3-4. Municipal irrigation theoretical log_{10} reduction values

Treatment barrier	Protozoa		Viruses		Bacteria	
	Indicative reduction	Claimed reduction[1]	Indicative reduction	Claimed reduction[1]	Indicative reduction	Claimed reduction[1]
Primary treatment	0 - 0.5	0	0 – 0.1	0	0 – 0.5	0
Membrane filtration	>6.0	3.0	2.5 – 4.0	2.0	3.5 – 4.0	3.0
Overall LRV	**6.0 – 6.5**	**3.0**	**2.5 – 4.1**	**2.0**	**3.5 – 4.5**	**3.0**

Note: *[1] Total log reduction based on average with a maximum of 4 per treatment barrier (Aquacell, 2015 Table 3.2)*

Table 3-5. Municipal irrigation theoretical log_{10} reduction values compared to LRV requirements

Treatment barrier	Protozoa		Viruses		Bacteria	
	Indicative reduction	Claimed reduction[1]	Indicative reduction	Claimed reduction[1]	Indicative reduction	Claimed reduction[1]
Overall LRV	**6.0 – 6.5**	**3.0**	**2.5 – 4.1**	**2.0**	**3.5 – 4.5**	**3.0**
End use controls[2] • No public access • Buffer zone	3.0	3.0	3.0	3.0	3.0	3.0
Municipal irrigation LRV requirements[3]	3.5	3.5	5.0	5.0	4.0	4.0
Difference	**5.5 – 6.0**	**2.5**	**0.5 – 2.1**	**0**	**2.5 – 3.5**	**2.0**

Note: *[1] Total log reduction based on average with a maximum of 4 per treatment barrier (Aquacell, 2015)*
[2] AGWR Table 3.5, with a total maximum used of 3 log
[3] LRV requirements AGWR Table 3.8

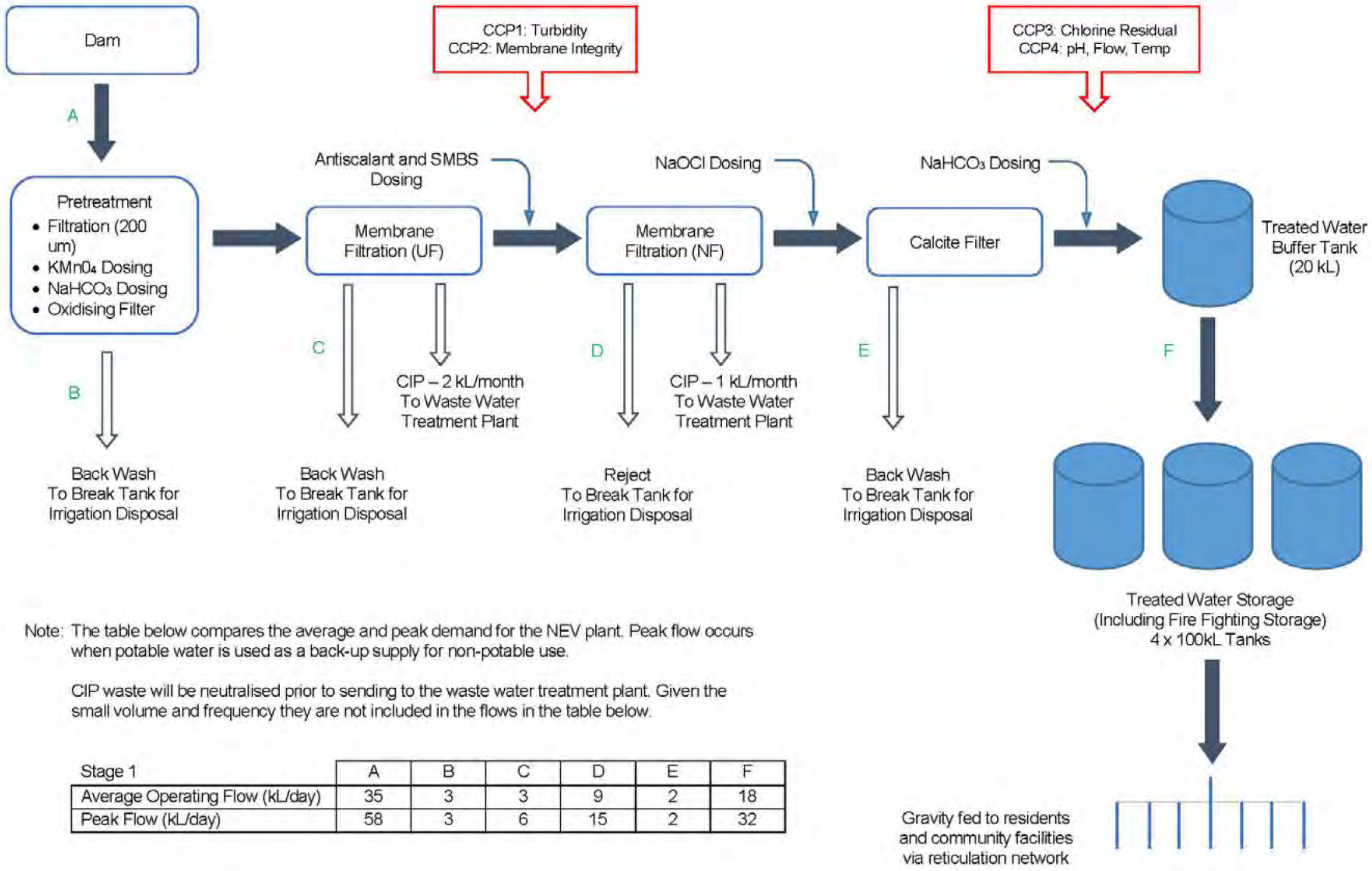
3.4 Water Treatment Plant backwash reuse

The Narara Water Treatment Plant backwash is proposed to be used for irrigation. To ensure that the water treatment plant backwash meets municipal irrigation water quality requirements, a high level analysis of log reduction value requirement has been calculated using the *Manual for the Application of Health Based Targets* (WSA, 2015) and the AGWR (2006), details of these calculations are included in Appendix C.

Using the conservative estimate with an assumption of an unprotected catchment a maximum of 2.5 log reduction requirement value has been calculated for municipal irrigation reuse of the backwash water, which can be met through end use control barriers (total 3 LRV from no public access and minimum 30 m buffer zone).

If a partially protected catchment is assumed, which is likely to be the case for the area, no log reduction is required for public health when using the backwash for irrigation.

Figure 3-3. Narara potable water treatment plant diagram



Stage 1	A	B	C	D	E	F
Average Operating Flow (kL/day)	35	3	3	9	2	18
Peak Flow (kL/day)	58	3	6	15	2	32

Source: *Narara Ecovillage, WTP block plan*

3.5 Governance

The scheme manager will be Narara Ecovillage and the supplier of recycled water will be Aquacell. Aquacell will remotely monitor the operation of the WWTP and NEV will undertake surveillance monitoring activities. The users are the residents and visitors to the ecovillage. Details of the governance responsibilities as identified in the scheme Recycled Water Management Plan (Aquacell, 2015) are shown in Table 3-6.

Table 3-6. Scheme governance

Role/ Assignment		NEV	Aquacell
Non-Potable and Sewerage Scheme	WICA License Holder - Network	X	
	WICA License Holder - Retail	X	
Waste Water Treatment Plant	Design		X
	Installation and Commissioning		X
	Operation		X
	On site testing and monitoring	X	X
	Completing daily site log	X	
	Maintenance – Daily	X	
	Maintenance – Weekly	X	X
	Maintenance - Monthly		X
	Maintenance – 6 Monthly		X
	Asset Management Plan		X
	Infrastructure Operating Plan		X
	Instrument Calibrations		X
	Training		X
	Water sampling and forwarding as per RWQMP	X	
	Management of water quality testing		X
	Review of sampling results and identification of appropriate actions		X
Non-Potable Sewerage Network	Design – scope and specification	X	
	Preparation of tender specification	X	
	Coordination of tendering process	X	
	Construction	X	
	Construction Supervision	X	
	Plumbing in accordance with AS/NZS 3500:2003	X	
	Testing and Commissioning	X	
	Repair and Maintenance of sewerage and non-potable network	X	
Infrastructure Operating Plan	Preparation and approval	X	
	Statutory reporting	X	
	System audit	X	
	Review		X
Incidents and Emergencies	Development of protocols, response actions, responsibilities and communications	X	
	Identification of non-compliances and incidents	X	X
	Statutory reporting of non-compliances and incidents	X	
	Emergency repairs to waste water treatment plant		X
	Emergency repairs to sewerage network	X	
	Coordinating emergency pump out via tanker when necessary	X	
Administrative	Monthly reporting of treatment plant performance to owner		X
	Billing of retail customers	X	
	Annual reporting as per WICA license requirements	X	
	Audits as required for WICA license	X	

Source: Aquacell 2015

3.6 Proposed verification monitoring

Aquacell's proposed verification monitoring plan is shown in Table 3-7. The period of sampling is for 6 weeks. Ongoing monitoring will be undertaken as shown in Table 3-8.

Table 3-7. Verification monitoring

Location	Parameter	Units	Monitoring Frequency	Compliance Value
Influent	*E. coli*	cfu/100 mL	Weekly	NA
	BOD	mg/L	Weekly	NA
	Coliphages	pfu/100 mL	Fortnightly	NA
	Clostridia	cfu/100 mL	Fortnightly	NA
Effluent	*E. coli*	cfu/100 mL	2 times/week	< 1
	BOD	mg/L	2 times/week	< 10
	SS	mg/L	2 times/week	< 5
	pH	NA	Continuous online	6.0 – 9.0
	Turbidity	NTU	Continuous online	< 2 (95%ile) & 5 (maximum)
	UVI	mJ/cm^2	Continuous online	> 65
	Residual Chlorine	mg/L	Continuous online	1.0 – 5.0
	Coliphage	pfu/100 mL	2 times/week	< 1
	Clostridia	cfu/100 mL	2 times/week	< 1

Source: Aquacell 2015

Table 3-8. Ongoing monitoring

Location	Parameter	Unit	Monitoring Frequency	Compliance Value
Effluent	*E. coli*	cfu/100ml	Weekly	< 1cfu/100ml

Source: Aquacell 2015

4 Risk assessment workshop

The risk assessment was undertaken as a facilitated workshop, as recommended by the NSW Guidelines. The risk assessment workshop focussed on phase one of the development on the construction of a temporary WWTP.

4.1 Workshop Purpose

The purpose of the workshop was to carry out a risk assessment of Narara Ecovillage recycled water scheme, phase one. Consideration was also given to irrigation of backwash water from the Narara Water Treatment Plant.

4.2 Workshop Details

The AGWR requires that the recycled water system is analysed by a team with appropriate knowledge and expertise.

The team should include management and operations staff from the recycled water supplier and regulatory agencies. A list of workshop participants is shown in Table 4-1 . A workshop agenda and sign in sheet is included in Appendix A.

Table 4-1. Workshop attendees

Organisation	Name	Role
Narara Ecovillage Co-op Ltd	Geoff Cameron	Director
	Mark Fisher	Project Manager
Aquacell Pty Ltd	Warren Johnson	Technical Manager
IPART*	Shweta Shrestha	Senior Analyst
NSW Health	Kerry Spratt	Central Coast Public Health Unit
Atom Consulting	Annalisa Contos	Facilitator
	Natalie Crawford	Recorder

Note: *Attendance by an IPART representative should not be taken as approval for the workshop process or outcomes

5 Risk assessment results

Table 5-1 provides an overview of the number and degree of maximum and residual risks with respect to process steps for the Narara Ecovillage recycled water scheme. The risk rankings are for both those without barriers (maximum risk; left) and with barriers (residual risk; right).

The maximum and residual risk profile is shown in Figure 5-1. 46 risks were ranked as part of the risk assessment, with one very high residual risk and nine high residual risks identified.

The very high health risk was identified for cross connections in households leading to illness from chronic exposure to recycled water. While ranked as very high, this rank relates to the significant volumes of water that would be consumed from chronic exposure from cross connections. This risk may be reviewed once there is verification data for the plant.

Of the nine high residual risks identified, 5 were health risks and 4 were operational risks.

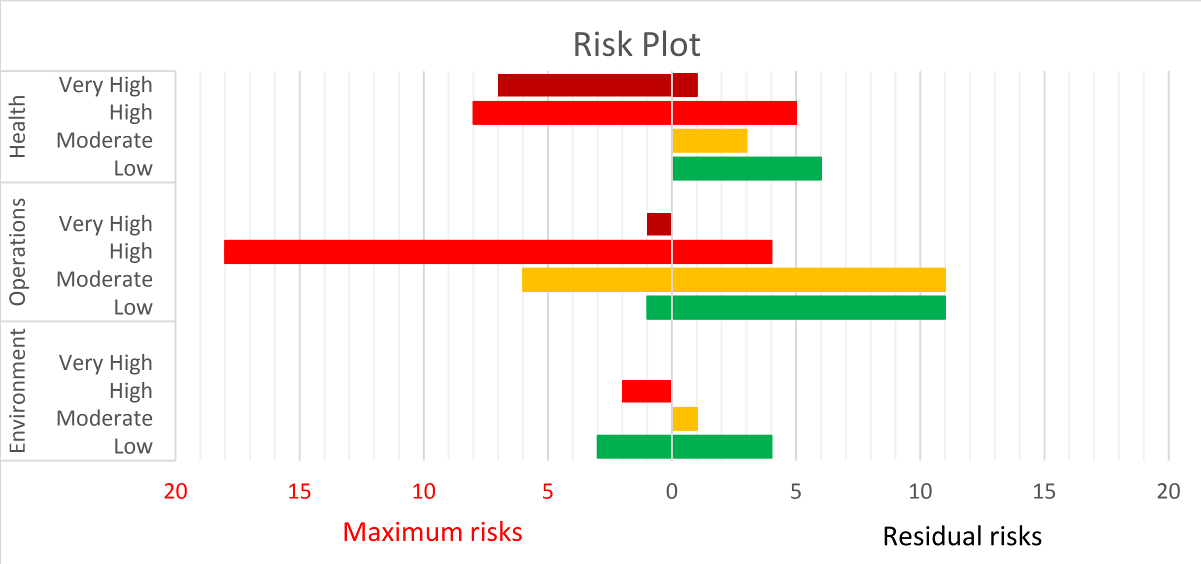
- Operational risks;
  - Mechanical failure of the blower leads to loss of biological process in the treatment plant
  - Longer term power failure (greater than two days) leads to loss of biological process in the treatment plant
  - Loss of membrane performance leads to reduced flow rate, requiring an enhanced chemical clean or membrane replacement
  - Loss of air scour blower leads to severely limited production
- Health risks;
  - Failure in the chlorination system leads to water supplied to dual reticulation that hasn't achieved required primary kill
  - During chlorination, pH is too high, leading to Illness from pathogens as primary kill is not achieved
  - Low pH results in acute or chronic illness from metals as result of corroding plumbing
  - Illness from acute exposure to recycled water (higher exposure levels than considered in the LRV requirements)
  - Illness from chronic exposure to recycled water (higher exposure levels than considered in the LRV requirements)

Details of all risks assessed as part of the workshop are included in the risk assessment tables in Appendix B

Table 5-1 Summary of maximum and residual risks

	Maximum risk				Residual risk			
Process step	Low	Moderate	High	Very high	Low	Moderate	High	Very high
Catchment	1	2	6		6	3		
Secondary treatment		2	8	2	2	7	3	
UV		1	4		4	1		
Chlorination		1	4	2	4	1	2	
Treatment plant			1				1	
Reticulation and distribution			2	1	1		2	
End uses	1		2	3	1	3	1	1
Potable backwash reuse	2		1		3			
Number of risks out of total of 46 risks	**4**	**6**	**28**	**8**	**21**	**15**	**9**	**1**

Figure 5-1 Risk profile for maximum and residual risks



5.1 Critical control points

Choice of critical control points were reviewed as part of the risk assessment and included:

- MBR
- UV disinfection
- Chlorination

Proposed critical control limits identified as part of the scheme's Recycled Quality Management Plan (Aquacell, 2015) are documented in Appendix D. These limits and the monitoring points were not assessed within this workshop.

6 Actions

The workshop identified 17 actions shown in Table 6-1. These actions should be assigned to the appropriate staff member, the action undertaken and the effectiveness of the action reviewed to ensure the issue has been addressed.

Table 6-1. Summary of workshop actions

Action number	Action	Issue
1	Set up mechanisms in the buffering tank to monitor level increases in relation to stormwater	Unable to treat excessive hydraulic load at the WWTP
2	Ensure NEV has the power to access/audit/rectify, including for future owners	Excessive flows from stormwater to WWTP and cross connections in households
3	Develop procedures for large events to ensure that there are sufficient portable toilets	Temporary population increases lead to difficulties in treating population load
4	Develop and maintain a knowledge database of allowed chemicals that are to be used and how these are to be disposed of	Future trade waste sources impact on biological process
5	Develop a process for trade waste	Future trade waste sources impact on biological process
6	Prohibit use of food insinkerators	Food waste from households impact operation of plant
7	Ensure replacement components can be quickly requisitioned following equipment failure. Consider having duty standby in temporary plant and in stock spares, with consideration given to timeframes and associated risk	Mechanical failure leads to biological treatment failure
8	Consider longer term power failure in incident and emergency processes; including temporary power supply to maintain biological process.	Longer term power failure (greater than two days) leads to loss of biological process
9	Review CCP limit for sub surface irrigation requirements	Membrane failure leads to loss of membrane integrity
10	Aquacell to provide Health with information on proposed UV unit and Health to advise if NWRI validated unit is acceptable	UVT outside validation limits
11	Consider UV automatic sleeve cleaning	UV sleeve fouling
12	Develop procedures around purchasing and stock rotation of chlorine to ensure first in and first out scenarios	Changes in chlorine strength from storage or procurement
13	Develop procedures to ensure that recycled water with high levels of chlorine isn't used for irrigation for too long a period (consider environmental discharge ramifications)	Overdosing of chlorine
14	Develop ongoing verification monitoring program for reticulation monitoring	Loss of chlorine residual in recycled water storage tank
15	Develop pipe repair procedures to manage recontamination risk	Recontamination in mains from pipe repairs
16	Ensure Stage 2 has adequate wet weather storage to prevent overwater of the receiving environment	Hydraulic load insufficient for extended wet weather
17	Consider use of lime instead of sodium bicarbonate at the WTP	Potassium permanganate, sodium bicarbonate in potable backwash to be used for irrigation reuse

7 References

ADWG see *Australian Drinking Water Guidelines* - Natural Resource Management Ministerial Council

AGWQMR see *Australian Guidelines for Water Quality Monitoring and Reporting* - Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand

Aquacell, March 2015, *Narara Ecovillage Recycled Water Scheme - Recycled Water Quality Management Plan*, Aquacell Project A0072.

AS/NZS ISO, 2009, AS/NZS *ISO 31000: Risk management - Principles and guidelines*

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Health and Safety Executive, 1999, *HSG48 Reducing error and influencing behaviour*, UK, ISBN 978 0 7176 2452 2

IPART, 2008, *Water Recycling – Public Health Requirements*, WICA Fact Sheet, NSW Government.

ISO/IEC, 2009, ISO/IEC 31010 *Management – Risk Assessment Techniques*, Geneva, Switzerland

Natural Resource Management Ministerial Council, 2011, *Australian Drinking Water Guidelines 6*, National Health and Medical Research Council, Canberra

WHO (2004). Guidelines for Drinking-Water Quality. Third Edition. World Health Organization.

Water Services Association of Australia (WSA), 2015, *Drinking Water Source Assessment and Treatment Requirements, Manual for the Application of Health-Based Targets*, WSA 202-2015-1.2.

Appendix A Workshop Details

A.1 Workshop Details

A one day risk assessment workshop was held on 18 April 2016. Workshop information is shown in Table A-1 and an agenda in Table A-2.

Table A-1. Workshop information

Item	Detail
Date	Monday 18 April 2016
Time	9:00 am
Venues	MGSM CBD Executive Conference Centre, 37 Pitt Street, Sydney

Table A-2. Agenda for risk assessment workshop

Time	Item	Who
9:00	Arrival, who's who and welcome	Atom Consulting
9:05	Overview of WICA process	IPART
9:10	Scheme overview, confirm intended use, incidental use and end users	Narara Ecovillage Aquacell
9:20	Confirm flow diagram at high level	Aquacell
9:50	Risk assessment (health and environment) and identification of control measures for Recycled Water Scheme	Facilitated by Atom Consulting
10:15	Morning tea	All
10:30	Continue risk assessment and identification of control measures for Recycled Water Scheme	Facilitated by Atom Consulting
12:00	Lunch	All
12:30	Continue risk assessment and identification of control measures for Recycled Water Scheme	Facilitated by Atom Consulting
15:30	Risk assessment (health and environment) and identification of control measures for WTP backwash for pasture irrigation	Facilitated by Atom Consulting
16:00	Meeting Close	Atom Consulting

A.2 Sign in sheet

Narara Ecovillage

Recycled Water Scheme Risk Assessment

List of Attendees, 18 April 2016

Name:	Warren Johnson	
Organisation:	Aquacell	
Role	Technical Manager	
Name:	Geoff Cameron	
Organisation:	Narara Ecovillage	
Role	Director	
Name:	Kerry Spratt	
Organisation:	Coffey	
Role	Head IR Rep	
Name:	Shweta Shrestha	
Organisation:	IPART	
Role	Senior Analyst	
Name:	MARK FISHER	
Organisation:	Narara Ecovillage	
Role	Director	
Name:	Annalisa Contos	
Organisation:	Atom Consulting	
Role	Facilitator	
Name:	Natalie Crawford	Natalie Crawford
Organisation:	Atom Consulting	
Role	Recorder	
Name:		
Organisation:		
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Appendix B Risk Assessment Tables

No.	Process Step	How can the hazard be introduced? (cause)	Contaminants (hazards)	Risk	E/ H/ O	Control measures	Barrier Effectiv-eness	Responsib-ility	Likelihood (Maximum)	Consequ-ence (Maximum)	Maximum Risk	Likelihood (Residual)	Consequ-ence (Residual)	Residual Risk	Follow up actions	Act-ion No.	Comment
1	Catchment	Household chemicals from residential properties	Chemicals	Impact of chemicals on the biological process; membranes and chlorination (pH)	O	Education, policy. Controlled population - member owned utility. Procedures to enforce binding community management statement (CMS)	Procedural	Community association, NEV, householders	Likely	Moderate	High	Possible	Minor	Moderate			
2	Catchment	Localised outbreak of illness within community	Pathogens	Insufficient barriers to treat a higher pathogen load	O	Conservative log reduction claimed. Potable water backup.	Good	Aquacell (Design), NEV (surveillance)	Likely	Moderate	High	Likely	Minor	Moderate			Consequence is lower for residual risk due to the additional treatment barriers that haven't been claimed in log reduction value calculations.
3	Catchment	Normal pathogen load	Pathogens	Treatment barriers are unable to treat the normal pathogen load	O	Flexibility in process, through buffering and alternate pathways Treatment train Maintenance contract Asset management	Very good	Aquacell (Design & Operation), NEV (surveillance)	Almost certain	Moderate	High	Unlikely	Minor	Low			
4	Catchment	Excessive flows from stormwater	Hydraulic load, chemicals, pathogens	Unable to treat excessive hydraulic load at the WWTP	O	Flexibility in process through buffering and alternate pathways. Treatment train Verification at installation Private certifier inspections Pump out when necessary	Good	Aquacell (Design & Operation), Council	Possible	Moderate	High	Unlikely	Minor	Low	Set up mechanisms in the buffering tank to monitor level increases in relation to stormwater	1	Consequence is based on assessment of pump out costs
															Ensure NEV has the power to access/audit/rectify, including for future owners	2	
5	Catchment	Temporary population increases e.g. conference, events etc. Sporadic peak loadings	Hydraulic load, pathogens	Unable to treat hydraulic load at the WWTP	O	Flexibility in process, through buffering and alternate pathways. Treatment train Pump out when necessary. Potable backup. Modelling allows	Good	Aquacell (Design & Operation), NEV (surveillance)	Possible	Minor	Moderate	Unlikely	Minor	Low			Consequence based on pump out costs Modelling of loads includes 5 residents / day / household and 70 visitors / week

No.	Process Step	How can the hazard be introduced? (cause)	Contaminants (hazards)	Risk	E/ H/ O	Control measures	Barrier Effectiv-eness	Responsib-ility	Likelihood (Maximum)	Consequ-ence (Maximum)	Maximum Risk	Likelihood (Residual)	Consequ-ence (Residual)	Residual Risk	Follow up actions	Act-ion No.	Comment
						for conservative loads											
6	Catchment	Temporary population increases e.g. conference, events etc. Sporadic peak loadings	Biological	Difficulties in treating biological load; possibly leading to failures meeting treated water quality targets for dual reticulation.	O	Flexibility in process, through buffering and alternate pathways. Treatment train Pump out when necessary. Potable backup. Modelling allows for conservative loads	Good	Aquacell (Design & Operation), NEV (surveillance)	Possible	Moderate	High	Unlikely	Minor	Low	Develop procedures for large events to ensure that there is sufficient portable toilets.	3	Modelling of loads includes 5 residents / day / household and 70 visitors / week
7	Catchment	Future trade waste sources	Chemicals, grease and oils, biological load	Impact on biological process; membranes; chlorination (pH)	O	Education, policy. Controlled population, with a member owned utility. Procedures to enforce binding community management statement (CMS). Trade waste process. Onsite controls, such as grease arresters. Composting of food waste	Procedural	Aquacell (Design & Operation), NEV (surveillance)	Possible	Moderate	High	Unlikely	Minor	Low	Develop and maintain a knowledge database of allowed chemical that are to be used and how these are to be disposed of. Develop a trade waste process.	4 5	
8	Catchment	Food waste from households	biological load	Impact operation of plant with a need to derate plant	O	Education, policy. Controlled population, with a member owned utility. Procedures to enforce binding CMS. Flexibility in process, through buffering and alternate pathways. Treatment train. Active composting.	Good	Aquacell (Design & Operation), NEV (surveillance)	Likely	Insignificant	Low	Possible	Insignificant	Low	Prohibit use of food insinkerators	6	
9	Catchment	Change in strength of domestic sewage (actual water usage per	Biological	Impact operation of plant with a need to derate plant. Plant will not be able to simultaneously	O	Staged development. Flexibility in process, through buffering and alternate	Very good	Aquacell (Design), NEV (surveillance)	Possible	Minor	Moderate	Possible	Minor	Moderate			

No.	Process Step	How can the hazard be introduced? (cause)	Contaminants (hazards)	Risk	E/ H/ O	Control measures	Barrier Effectiv-eness	Responsib-ility	Likelihood (Maximum)	Consequ-ence (Maximum)	Maximum Risk	Likelihood (Residual)	Consequ-ence (Residual)	Residual Risk	Follow up actions	Act-ion No.	Comment
		resident is less than predicted)		achieve desired flow and water quality.		pathways. Treatment train											
10	Secondary treatment	Chemicals from catchment. Mechanical failure or operator error leads to CIP chemicals being returned to the bio reactor	Chemicals	Loss of process in the bio reactor.	O	Buffering in buffer tank pH monitor in buffer tank Training	Poor	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Unlikely	Moderate	Moderate			
11	Secondary treatment (temporary plant)	Mechanical failure of the blower	Pathogens, BOD	Biological treatment failure	O	DO probe (alarmed) Blowers (low pressure alarm, failure alarm)	Procedural	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Possible	Moderate	High	Ensure replacement components can be found quickly Consider having duty standby in temporary plant, in relation to timeframes and risk	7	Consequence based on temporary plant not having duty standby
12	Secondary treatment (permanent plant)	Mechanical failure of the blower	Pathogens, BOD	Biological treatment failure	O	DO probe (alarmed) Blowers (low pressure alarm, failure alarm) Duty standby	Good	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Possible	Insignificant	Low			Consequence based on permanent plant having duty standby
13	Bioreactor	Failure of online instrumentation (DO probe on bioreactor, pH of filtrate)	Pathogens, BOD	Insufficient biological treatment	O	Automatic default to time based operation of blower (alarmed)	Good	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Possible	Minor	Moderate			
14	Treatment plant	Power failure less than two days	Pathogens, BOD	Loss of biological process	O	Buffer tank for influent. Supply is gravity fed (15 days supply).	Poor	Aquacell (Design), NEV (surveillance)	Likely	Minor	Moderate	Likely	Minor	Moderate			While barrier effectiveness for collection and supply is good; barrier effectiveness was ranked as poor for maintaining process
15	Treatment plant	Longer term power failure (greater than two days)	Pathogens, BOD	Loss of biological process	O	Buffer tank for influent. Supply is gravity fed (15 days supply).	Poor	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Possible	Moderate	High	Consider longer term power failure in incident and emergency processes; including temporary power supply to maintain biological process.	8	Consequence was assessed based on costs associated with use of temporary generators. While barrier effectiveness for collection and supply is good; barrier effectiveness was ranked as poor for maintaining process

No.	Process Step	How can the hazard be introduced? (cause)	Contaminants (hazards)	Risk	E/ H/ O	Control measures	Barrier Effectiv-eness	Responsib-ility	Likelihood (Maximum)	Consequ-ence (Maximum)	Maximum Risk	Likelihood (Residual)	Consequ-ence (Residual)	Residual Risk	Follow up actions	Act-ion No.	Comment
16	Secondary treatment (temporary plant)	Mechanical equipment failure (transfer pumps)	Pathogens, BOD	Loss of process	O	Duty standby for buffer tank & recirculation	Poor	Aquacell (Design), NEV (surveillance)	Likely	Moderate	High	Likely	Minor	Moderate	Ensure replacement components can be quickly requisitioned following equipment failure. Consider keeping in stock spares	7	Duty standby is limited in temporary plant
17	Secondary treatment (permanent plant)	Mechanical equipment failure (transfer pumps)	Pathogens, BOD	Loss of process	O	Duty stand by	Good	Aquacell (Design), NEV (surveillance)	Likely	Moderate	High	Likely	Minor	Moderate			
18	Membranes	Membrane failure	Pathogens, turbidity	Loss of membrane performance leading to reduced flow rate, requiring an enhanced chemical clean or membrane replacement	O	Monitoring TMP (alarmed) Routine chemical clean Membrane replacement (worst case) Enhanced chemical cleaning	Good	Aquacell (Design), NEV (surveillance)	Possible	Major	Very high	Possible	Moderate	High			
19	Membranes	Membrane failure	Pathogens, turbidity	Loss of membrane integrity	H	Turbidity online monitoring (CCP) Cease production of recycled water and potable water top up. Pump outs (water would not be suitable for irrigation)	Very good	Aquacell (Design), NEV (surveillance)	Possible	Major	Very high	Possible	Insignificant	Low	Review CCP limit for sub surface irrigation requirements	9	Residual risk ranking is based on assumption that the plant has shut down and water has not been supplied. Maximum risk assumes water has been supplied.
20	Membranes	Failure of turbidity monitor	Pathogens, turbidity	Cannot operate plant	O	Buffer tank for influent. Gravity fed for supply (15 days supply). Potable water top up. Instrument signal monitoring Maintenance contract Flow switch (alarm) Monthly verification and recalibrations if required	Very poor	Aquacell (Design & Operation), NEV (surveillance)	Possible	Minor	Moderate	Possible	Minor	Moderate			While the barriers are effective for public health and raising awareness that an event has happened, the barriers were assessed as very poor for maintaining process
21	Membranes (temporary)	Loss of air scour blower	Pathogens, turbidity	Severely limited production	O	Buffer tank Potable water back up Pump out	Poor	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Possible	Moderate	High	Ensure replacement components can be quickly requisitioned following equipment	7	

No.	Process Step	How can the hazard be introduced? (cause)	Contaminants (hazards)	Risk	E/ H/ O	Control measures	Barrier Effectiv-eness	Responsib-ility	Likelihood (Maximum)	Consequ-ence (Maximum)	Maximum Risk	Likelihood (Residual)	Consequ-ence (Residual)	Residual Risk	Follow up actions	Act-ion No.	Comment
															failure. Consider keeping in stock spares		
22	Membranes (permanent)	Loss of air scour blower	Pathogens, turbidity	Severely limited production	O	Buffer tank Potable water back up Pump out Duty standby	Good	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Possible	Minor	Moderate			
23	UV	UVT outside validation limits	Pathogens	Water is supplied not meeting dual reticulation water quality requirements	H	Online UVT and UVI monitoring Internationally validated UV unit Lowered UVT limit (~50%) Adequate cross connection controls Education	Good	Aquacell (Design), NEV (surveillance)	Unlikely	Major	High	Unlikely	Moderate	Moderate	Aquacell to provide Health with information on proposed UV unit and Health to advise if NWRI validated unit is acceptable	10	Assumed UV unit is NWRI validated, with lower UVT bounds, assumed for risk assessment ranking Consequence assumes end users unlikely to consumer supplies water
24	UV	UVT outside validation limits	Pathogens	Water leaving plant does not meet dual reticulation water quality requirements and cannot be supplied	O	Online UVT and UVI monitoring Internationally validated UV unit with Lowered UVT limit (~50%)	Poor	Aquacell (Design), NEV (surveillance)	Likely	Minor	Moderate	Unlikely	Minor	Low	Aquacell to provide Health with information on proposed UV unit and Health to advise if NWRI validated unit is acceptable	10	For risk assessment ranking it was assumed that the UV unit is NWRI validated, with lower UVT bounds
25	UV	UV unit is hydraulically undersized	Pathogens	Design UV dose cannot be achieved	H	Flow is critical limit associated Knowledgeable designers/peer review as part of audit	Good	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Rare	Moderate	Low			
26	UV	UV lamp failure	Pathogens	Supply of water that has inadequate disinfection (outside AGWR dual reticulation water quality requirements)	H	Lamp failure alarm Maintenance program CCP (cease to supply dual reticulation and irrigate to pasture)	Very good	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Rare	Moderate	Low			
27	UV	UV sleeve fouling	Pathogens	Supply of water that has inadequate disinfection (outside AGWR dual reticulation water quality requirements)	H	Maintenance program UVI monitoring (alarmed) CCP (cease to supply to dual reticulation and divert to pasture irrigation)	Very good	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Rare	Moderate	Low	Consider UV automatic sleeve cleaning	11	Current assessment doesn't assume automatic cleaning
28	Chlorination	Changes in chlorine strength from storage or	Pathogens	Unable to add enough chlorine to meet disinfection requirements	O	Free chlorine monitoring (alarmed) CCP (cease to	Very good	Aquacell (Design), NEV (surveillance)	Unlikely	Moderate	Moderate	Rare	Moderate	Low	Develop procedures around purchasing and stock rotation of chlorine to ensure first	12	

No.	Process Step	How can the hazard be introduced? (cause)	Contaminants (hazards)	Risk	E/ H/ O	Control measures	Barrier Effectiv-eness	Responsib-ility	Likelihood (Maximum)	Consequ-ence (Maximum)	Maximum Risk	Likelihood (Residual)	Consequ-ence (Residual)	Residual Risk	Follow up actions	Act-ion No.	Comment
		procurement issues				supply to dual reticulation and divert to pasture irrigation)									in and first out scenarios		
29	Chlorination	High chlorine demand	Pathogens	Unable to add enough chlorine to meet disinfection requirements	O	Free chlorine monitoring (alarmed) CCP (cease to supply to dual reticulation and divert to pasture irrigation)	Good	Aquacell (Design), NEV (surveillance)	Possible	Moderate	High	Rare	Moderate	Low			
30	Chlorination	Unable to demonstrating achieved C.t	Pathogens	Water leaving plant does not meet dual reticulation water quality requirements and cannot be supplied	O	Water that doesn't meet chlorine critical limit is sent to irrigation (automatic)	Very good	Aquacell (Design & Operation), NEV (surveillance)	Possible	Moderate	High	Rare	Moderate	Low			
31	Chlorination	Failure in chlorination system operation	Pathogens	Water supplied to dual reticulation that hasn't achieved required primary kill	H	Free chlorine monitoring (alarmed) CCP (cease to supply to dual reticulation and divert to pasture irrigation) Cross connection controls	Very good	Aquacell (Design & Operation), NEV (surveillance)	Possible	Major	Very high	Rare	Major	High			Residual risk ranking assumes cross connection controls are in place
32	Chlorination	No chlorine available for dosing	Pathogens	Water does not meet water quality requirements, dual retic recycled water cannot be supplied	O	Level switch in hypo tank (automatic shut off) and divert to irrigation Potable water top up	Very good	Aquacell (Design & Operation), NEV (surveillance)	Possible	Moderate	High	Unlikely	Moderate	Moderate			
33	Chlorination	Overdosing of chlorine	Pathogens	Dermal and health impacts from water supplied exceeding AGWR limits	H	Free chlorine monitoring CCP (cease to supply to dual reticulation and divert to pasture irrigation) Cross connection controls	Very good	Aquacell (Design & Operation), NEV (surveillance)	Possible	Moderate	High	Rare	Moderate	Low	Develop procedures to ensure that recycled water with high levels of chlorine levels isn't used for irrigation for too long a period (consider environmental discharge ramifications)	13	Residual risk ranking assumes cross connection controls are in place
34	Chlorination	pH is too high	Pathogens	Illness from pathogens as primary kill is not achieved, with a high pH	H	Online pH monitoring CCP (cease to supply to dual reticulation and divert to pasture irrigation)	Very good	Aquacell (Design & Operation), NEV (surveillance)	Possible	Major	Very high	Rare	Major	High			

No.	Process Step	How can the hazard be introduced? (cause)	Contaminants (hazards)	Risk	E/ H/ O	Control measures	Barrier Effectiv-eness	Responsib-ility	Likelihood (Maximum)	Consequ-ence (Maximum)	Maximum Risk	Likelihood (Residual)	Consequ-ence (Residual)	Residual Risk	Follow up actions	Act-ion No.	Comment
35	End uses	pH is too low	Metals	Acute or chronic illness from metals as result of corroding plumbing	H	Online pH monitoring CCP (cease to supply to dual reticulation and divert to pasture irrigation) Cross connection controls	Very good	Aquacell (Design & Operation), NEV (surveillance)	Unlikely	Major	High	Rare	Major	High			Residual risk ranking assumes cross connection controls are in place
36	Reticulation and distribution	Loss of chlorine residual in recycled water storage tank	Pathogens	Illness from recontamination or opportunistic pathogens	H	Cross connection controls Recycled water tank rechlorinator	Good	NEV (surveillance)	Possible	Moderate	High	Rare	Moderate	Low	Develop ongoing verification monitoring program for reticulation monitoring	14	
37	Reticulation and distribution	Recontamination in mains from pipe repairs	Pathogens	Illness from acute exposure to recycled water (higher exposure levels than considered in the LRV requirements)	H	Cross connection controls	Procedural	NEV (surveillance)	Possible	Moderate	High	Possible	Moderate	High	Develop pipe repair procedures to manage recontamination risk	15	
38	Reticulation and distribution	Cross connections in distribution	Pathogens	Illness from chronic exposure to recycled water (higher exposure levels than considered in the LRV requirements)	H	Recycled water 8 m lower Infrastructure audit Treatment process	Unknown	NEV	Unlikely	Catastrophic	Very high	Rare	Catastrophic	High	Ensure that testing for cross connections is considered as part of the commisioining as part of the dual reticulation scheme, and following any reticulation augmentation.		
39	End use - dual reticulation	Cross connections in households	Pathogens	Illness from chronic exposure to recycled water (higher exposure levels than considered in the LRV requirements)	H	New connection audit process Plumbing certificates Ongoing education Treatment process	Procedural	Aquacell (Design & Operation), NEV (surveillance)	Almost certain	Major	Very high	Possible	Major	Very high	Ensure NEV has the power to access/audit/rectify, including for future owners	2	Consequence assessed on barriers being in place, including treatment process, but consumption in cross connection is higher than would be considered by the LRV requirements, hence consequence is major because the DALY would be higher than the acceptable level of risk. Based on the plant achieving its LRV requirements.
40	End use - dual reticulation	Inappropriate use of dual reticulated water outside e.g. children	Pathogens	Illness from acute exposure to recycled water (higher exposure levels than	H	Education Plumbing Code (signage & colours) Treatment process	Procedural	Aquacell (Design & Operation), NEV (surveillance)	Likely	Major	Very high	Possible	Minor	Moderate			Consequence assessed on barriers being in place, including treatment process, with LRV requirements

No.	Process Step	How can the hazard be introduced? (cause)	Contaminants (hazards)	Risk	E/ H/ O	Control measures	Barrier Effectiv-eness	Responsib-ility	Likelihood (Maximum)	Consequ-ence (Maximum)	Maximum Risk	Likelihood (Residual)	Consequ-ence (Residual)	Residual Risk	Follow up actions	Act-ion No.	Comment
		playing, car washing		considered in the LRV requirements)													include a 1L/year exposure through e.g. cross connections. Consequence assessed as minor as the exposures are likely to still to be within the levels of DALY acceptable
41	End use - dual reticulation	Inappropriate use of dual reticulated water inside e.g. diversion of laundry water for other uses	Pathogens	Illness from acute exposure to recycled water (higher exposure levels than considered in the LRV requirements)	H	Education Plumbing Code (signage & colours) Treatment process	Procedural	Aquacell (Design & Operation), NEV (surveillance)	Likely	Major	Very high	Possible	Minor	Moderate			Consequence assessed on barriers being in place, including treatment process, with LRV requirements include a 1L/year exposure through e.g. cross connections. Consequence assessed as minor as the exposures are likely to still to be within the levels of DALY acceptable
45	End use - irrigation quality water	Salts in the water from CIP and people	CIP chemicals, salt	Environmental impact of increasing salinity levels	E	Modelling	Procedural	NEV	Rare	Moderate	Low	Rare	Moderate	Low			Likelihood assessed on modelling that has been undertaken and assessed as not being an issue.
46	End use - irrigation quality water	Hydraulic load insufficient for extended wet weather	Water	Overwatering of receiving environment	E	120 kL irrigation storage and buffer tank (total approximately 200 kL) Sandy soils, do not water log easily	Good	Aquacell (Design & Operation), NEV (surveillance)	Possible	Moderate	High	Possible	Minor	Moderate	Ensure Stage 2 has adequate wet weather storage to prevent overwater of the receiving environment	16	Modelling indicates Stage 1 does not need wet weather storage Stage 2, has a planned wet weather storage
42	Potable backwash irrigation reuse	Potassium permanganate, sodium bicarbonate	Chemicals	Minimal impact to receiving environment	E				Likely	Insignificant	Low	Likely	Insignificant	Low	Consider use of lime instead of sodium bicarbonate at the WTP	17	
43	Potable backwash irrigation reuse	TDS in backwash water	TDS	Potential impacts to receiving environment	E				Unlikely	Minor	Low	Unlikely	Minor	Low			Rejected TDS <400 mg/L which meets recommended irrigation guidelines
44	Potable backwash irrigation reuse	Cleaning chemicals	Chemicals	Potential impacts to receiving environment	E	Cleaning chemicals discharged to waste plant	Very good	Aquacell (Design & Operation), NEV (surveillance)	Possible	Moderate	High	Rare	Moderate	Low			Maximum likelihood assessed assuming chemicals discharged to environment

Appendix C Water treatment plant backwash calculation

The Narara Water Treatment Plant backwash is proposed to be used for irrigation. Source water for the plant is taken from the dam (see Figure 3-1). The process flow diagram for the system and a summary of peak and average flows for system components, including backwash is shown in Figure 3-3, from which the ratio of backwash to peak flow has been calculated as 0.49.

To ensure that the water treatment plant backwash meets municipal irrigation water quality requirements, a high level analysis of log reduction value requirement has been calculated using the *Manual for the Application of Health Based Targets* (WSA, 2015) and the AGWR (2006).

Log reduction requirements have been calculated using the following equation from the AGWR (2006):

$$Log\ reduction = log_{10}\left(\frac{C \times E \times N}{DALYd}\right)$$

Where:

- C - Concentration of the pathogen in the source water i.e. backwash water
- E - Exposure volume
- N - Number of exposure /year

To calculate the levels of pathogens in the source water, two sets of calculations have been undertaken including assuming a Tier 2 partially protected catchment and Tier 4 unprotected catchment. Log reduction value requirements have been calculated to use this backwash for municipal irrigation based on the above equation and the assumptions detailed in Table C-1 for the two assumed catchment types.

Using the conservative estimate from the Tier 4 unprotected a maximum of 2.5 log reduction requirement value has been calculated, which can be met through end use control barriers (no public access and minimum 30 m buffer zone).

If a Tier 2 partially protected catchment is assumed, which is likely to be the case for the area, no log reduction is required for public health.

Table C-1. Assumptions used in backwash for irrigation LRV requirement calculations[1]

Pathogen	C (pathogens/L)[2]	E (L)[3]	N (/yr)[4]	DALYd[5]	LRV requirement[6]	LRV end use controls [7]
Tier 2 partially protected catchment						
Cryptosporidium	0.005	0.001	50	1.6×10^{-2}	**-1.8**	**3**
Rotavirus	0.016	0.001	50	2.5×10^{-3}	**-0.3**	**3**
Campylobacter	1.6	0.001	50	3.8×10^{-2}	**0.4**	**3**
Tier 4 Unprotected catchment						
Cryptosporidium	5.1	0.001	50	1.6×10^{-2}	**1.2**	**3**
Rotavirus	16.3	0.001	50	2.5×10^{-3}	**2.5**	**3**
Campylobacter	16.3	0.001	50	3.8×10^{-2}	**1.3**	**3**

[1] *WSA 2015, Section 3.2.5 calculation*

[2] *E – exposure volume, sourced from AGWR (2006) Table 3.7 Municipal Irrigation*

[3] *N – number of exposures per year, sourced from AGWR (2006) Table 3.7 Municipal Irrigation*

[4] *AGWR (2006) Appendix 2*

[5] *AGWR (2006) Appendix 2 Box A2.2*

[6] *AGWR (2006) Appendix 2 Box A2.2*

[7] *AGWR (2006) Table 3.5 (No public access and buffer zone)*

Appendix D Critical Control Points

Quality Control Points (QCP) and Critical Control Points (CCP) detailed within the Narara Ecovillage Recycled Water Scheme - Recycled Water Quality Management Plan (Aquacell 2015), are shown in Table D-1, Table D-2, Table D-3, Table D-4, Table D-5 and Table D-6 below. These limits and the monitoring points were not assessed within this workshop but are included for completeness.

Table D-1. QCP1 Influent pH

QCP1	**Influent pH**
Alert	pH ≤ 4.0; pH ≥ 9.5
Critical	-
What	Influent pH
How	Sensor
When	Continuous, Online
Where	Buffer Tank
Who	Aquacell/Automatic
Corrective Actions	

Source: *Aquacell 2015*

Table D-2. CCP1 MBR

CCP1	**MBR**
Critical limits/Alert limits	**Membranes**
Alert	0.2 NTU
Critical	0.5 NTU
Monitoring procedures	
What	Turbidity
How	Sensor
When	Continuous, Online
Where	Filtrate line
Who	Aquacell/Automatic
Corrective actions	
What	MOS recirculation mode
How	Open recirc. valve
When	Immediately if turbidity exceeds 0.5 NTU
Where	Filtrate line
Who	Aquacell/Automatic

Source: *Aquacell 2015*

Table D-3. QCP 2 Bioreactor

QCP2	**Bioreactor, Dissolved oxygen (QCP 2)**
Critical limits/Alert limits	
Alert	< 0.5 mg/l; > 10 mg/l
Critical	
Monitoring procedures	
What	MBR DO
How	Sensor
When	Continuous, Online
Where	Biological tank
Who	Aquacell/Automatic
Corrective actions	

QCP2	Bioreactor, Dissolved oxygen (QCP 2)
What	DO alarm
How	Send to operator
When	Immediate
Where	SCADA
Who	Aquacell/Automatic

***Source**: Aquacell 2015*

Table D-4. CCP 2 UV Disinfection

CCP2	UV disinfection				
	UV RED	UVT	Lamp age	Lamp status	Water Flow
Critical limits/Alert limits					
Alert	55.2 mJ/cm^2	65%	11,000 hours		> 48 L/min
Critical	52.6 mJ/cm^2	60%	12,000 hours	Lamp Fail	> 50 L/min
Monitoring procedures					
What	UV Controller	UVT Monitor	Hour monitor	Lamp monitor	flowmeter
How	UVI Sensor, Flow, UVT	UVT sensor	PLC record and UV unit control module	UV Controller	PLC
When	Continuous, Online	Continuous	Continuous, Online	Continuous	Continuous, online
Where	UV Controller	UV unit	UV Controller and PLC	UV Controller output	Before UV
Who	PLC/ Automatic	PLC/ Automatic	PLC/ Automatic	PLC/ Automatic	PLC/ Automatic
Corrective actions					
What	Treated water is sent to dam				
How	Dump Valve				
When	Immediate				
Where	UV Control module and PLC				
Who	PLC/Automatic				

***Source**: Aquacell 2015*

Table D-5. CCP 3 and CCP4

CCP3, 4	Free chlorine disinfection			
	Residual free chlorine (3)	Water pH (4)	Water temperature (3&4)	Water flow (as for CCP2)(3&4)
Critical limits/Alert limits				
Alert	≥ 4.5 mg/L; ≤ 1.0 mg /L	pH ≥ 8.3; pH ≤ 6.3	≤ 12°C	
Critical	≥ 5.0 mg/L; ≤ 0.75 mg /L	pH ≥ 8.5; pH ≤ 6.0	≤ 10°C	
Monitoring procedures				
What	Free Residual Chlorine (FRC)	pH	Temperature	
How	Sensor	Probe	Thermocouple	
When	Continuous, Online	Continuous, Online	Continuous, Online	
Where			At the end of the	

CCP3, 4	Free chlorine disinfection			
	At the end of the chlorine contact pipe	At the end of the chlorine contact pipe	chlorine contact pipe	
Who	PLC/Automatic	PLC/Automatic	PLC/Automatic	
Corrective actions				
What	Treated water is discharged to sewer	Treated water is discharged to sewer	Treated water is discharged to sewer	
How	Dump Valve	Dump Valve	Dump Valve	
When	Immediate	Immediate	Immediate	
Where	After chlorine contact system	After chlorine contact system	After chlorine contact system	
Who	PLC/Automatic	PLC/Automatic	PLC/Automatic	

***Source**: Aquacell 2015*

Table D-6. QCP and CCP summary of control system response and operator action

QCP/CCP	Control System Response	Operator Actions
QCP1 – Feed pH outside range	Stops flow to biology until pH is within range.	The most likely cause is poor mixing in the feed tank (septic conditions). The operator should contact Aquacell and confirm mixer operation. If there is no mixer operational faults, consider increasing mixing time to increase DO levels. Chemical contamination is another possible cause. Manual pH correction by addition of acid or caustic may be required.
CCP1 – MBR turbidity	The MBR atomically monitors turbidity and will shutdown after a controlled period of recirculation with no improvement.	The operator should contact Aquacell for a detailed investigation. The most likely causes are membrane system leaks (seals or membrane integrity), faulty turbidity readings (due to air bubbles), or biogrowth shedding from pipework.
QCP2 – Bioreactor DO	Control system stops filtering if DO is out of range. Raises alarm.	Efficient operation of the bioreactor relieson correct DO. If this is outside the normal range the operator should investigate and correct the cause. The may be a leaking or failed air line, diffuser, or pipework. The DO probe may not be functioning correctly and need calibration or replacement.
CCP2 UV RED	This includes monitoring of UVI, UVT, flow, lamp status and lamp hours. The plant diverts water to sewer if the UV conditions are not all met.	The relevant parameters that affect UV dose are individually monitored and alarmed to guide the operator response.
CCP3 and CCP4 Chlorine Dosing	Chlorination pH, chlorine residual, and temperature are monitored continuously. The PLC diverts to sewer if the treated water does not meet control limits.	Chlorine residual could be affected by changes in chlorine demand, or flows. Establish stable flows and adjust chlorine dose rate as required. pH outside limits could be due to poor biological conditions or changes in feedwater quality. Contact Aquacell for investigation.

***Source**: Aquacell 2015*

Appendix 4.2.11

aquacell
water recycling solutions

Narara Ecovillage Recycled Water Scheme

Recycled Water Quality Management Plan

30 November 2015

Aquacell Project A0072

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Revision	Date	By	Checked	Document Status	Amendments
NEV_RWQMP_V1	3/1/14	W. Johnson		Draft	
NEV_RWQMP_V2	20/11/15	J. Taylor		Draft	Updated Roles and Responsibilities

Table of Contents

1. Introduction

1.1 Purpose of the RWQMP

This RWQMP forms part of the Infrastructure Operating Plan (IOP) for the Narara Ecovillage (NEV) water scheme. It states the microbial quality objectives for the recycled water scheme and describes elements of the management plan to ensure those objectives are achieved and maintained. The document contains:

- Responsibilities of the recycled water supplier;
- Description of the recycled water process, including composition of the source and end use applications for which the treated water is fit-for-purpose.
- Detailed validation of the treatment processes;
- Detailed process control and monitoring program to ensure the treated water meets the required quality for end use.

1.2 Description of the scheme

1.2.1 Site Description

The NEV site is located on Research Rd, Narara on the NSW central coast. The development will be staged with 60 lots to be released initially, and expanding to around 130 in the future.

A plant layout for the NEV recycled water scheme is shown in Appendix 1. The ultimate design capacity of the system is **60 kL/day**. The biological reactor will be constructed to enable the plant capacity to be ramped up as development occurs.

The recycled water plant proposed will be designed to meet the requirements of the Australian Guidelines for Water Recycling. (Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1), 2006). The guidelines are referred to in this document as AGWR.

Wastewater will be collected from the following sources to the treatment system:

- Home and community centre toilets, showers, hand basins, and laundries.

Recycled water will be supplied for:

- toilet flushing in homes and the community centre
- irrigation of home and community gardens, lawns and landscaped areas.

Any excess water will be used to irrigate an orchard and broad acre area to ensure the water is put to beneficial use.

Water that does not meet the full disinfection requirement, but has passed through the MBR process (biological treatment and UF) will be disposed of by irrigation.

Buffer capacity, equivalent to approximately 6-days storage at maximum design flow, is provided to allow time to deal with breakdowns. If this is insufficient time then pump out of the buffer tanks will be carried out until the plant is operational again.

1.2.2 System Process Design

Referring to Appendix 2: NEV Recycled Water Treatment Plant Process Flow Diagram. The system consists of the following:

- A buffer tank for collection of wastewater from the site
- Pre-screen
- Biological treatment and ultrafiltration zone (together forming the Membrane Bioreactor or MBR).
- Ultraviolet light disinfection
- Chlorine disinfection
- Recycled Water Storage, and Irrigation water storage.
- Irrigation water dam
- Overflows and drains to pumpout (back to buffer tank)
- Sludge collection tank (off-site disposal)
- Chemical neutralisation and recycle tank.

1.3 Management commitment

Narara Ecovillage Co-operative Ltd (the NEV Co-op) will be the owners of the recycled water treatment plant. The NEV Co-op are committed to ensuring the system is maintained and operated in compliance with relevant guidelines, regulations and standards at all times.

The NEV Co-op will subcontract responsibility for the maintenance of the wastewater treatment system to Aquacell Pty Ltd (Aquacell). Aquacell commit to maintain and operate the system in compliance with relevant guidelines, regulations and standards at all times.

2. Roles and responsibilities

NEV as the WICA license holder will be responsible for all aspects of the operation of the scheme and any conditions attached to the license.

To assist with the design, construction, monitoring and maintenance of the scheme NEV will sub-contract specific duties to its experienced third party sub-contractor Aquacell.

A table outlining the various roles and responsibilities of the parties is shown in table 1.

Table 1: Division of roles and responsibilities

Role/ Assignment		NEV	Aquacell
Non-Potable and Sewerage Scheme	WICA License Holder - Network	X	
	WICA License Holder - Retail	X	
Waste Water Treatment Plant	Design		X
	Installation and Commissioning		X

Role/ Assignment		NEV	Aquacell
	Operation		X
	On site testing and monitoring	X	X
	Completing daily site log	X	
	Maintenance – Daily	X	
	Maintenance – Weekly	X	X
	Maintenance - Monthly		X
	Maintenance – 6 Monthly		X
	Asset Management Plan		X
	Infrastructure Operating Plan		X
	Instrument Calibrations		X
	Training		X
	Water sampling and forwarding as per RWQMP	X	
	Management of water quality testing		X
	Review of sampling results and identification of appropriate actions		X
Non-Potable Sewerage Network	Design – scope and specification	X	
	Preparation of tender specification	X	
	Coordination of tendering process	X	
	Construction	X	
	Construction Supervision	X	
	Plumbing in accordance with AS/NZS 3500:2003	X	
	Testing and Commissioning	X	
	Repair and Maintenance of sewerage and non-potable network	X	
Infrastructure Operating Plan	Preparation and approval	X	
	Statutory reporting	X	
	System audit	X	
	Review		X
Incidents and Emergencies	Development of protocols, response actions, responsibilities and communications	X	
	Identification of non-compliances and incidents	X	X
	Statutory reporting of non-compliances and incidents	X	
	Emergency repairs to waste water treatment plant		X
	Emergency repairs to sewerage network	X	
	Coordinating emergency pump out via tanker when necessary	X	
Administrative	Monthly reporting of treatment plant performance to owner		X
	Billing of retail customers	X	

Role/ Assignment		NEV	Aquacell
	Annual reporting as per WICA license requirements	X	
	Audits as required for WICA license	X	

2.1 Supplier

The supplier of recycled water is Aquacell.

2.2 Scheme Manager

The scheme manager is NEV.

2.3 Users

The users are the residents and visitors to the ecovillage.

3. Water quality objectives

Approximately half of the wastewater generated will be treated for reuse. The remainder represents excess water that will be disposed of through irrigation via the wet weather storage dam. Irrigation disposal will also be used for any water that does not meet all the quality requirements for reuse, but is assessed as safe for irrigation. Any water that does not meet the quality requirements either for reuse or irrigation will be recycled back to the buffer tank for reprocessing.

There are therefore two water quality risks to consider; one for water to be reused, and one for irrigation disposal. The pathogen quality objectives for reuse are covered in section 3.1, and those for irrigation disposal are addressed in section 3.2.

3.1 Pathogen quality objectives for reuse

The AGWR requires a risk-based approach to determining the log removal credits required to treat the source water to the appropriate level for reuse. The risks have been assessed on the basis that treated water will be recycled for use in toilet flushing and irrigation around homes and gardens within the ecovillage.

3.1.1 Assumptions

In order to arrive at log reduction requirements for the treatment process, certain assessments must be made regarding exposure to, and possible ingestion amounts of, treated water. The following outlines the assessments made in order to calculate the log reductions necessary.

The possible exposure to treated water at this site:

1. Ingestion from cross connections between the drinking and recycled water systems
2. Aerosol ingestion from toilets
3. Ingestion of water used for irrigation, or ingestion of aerosols from spray irrigation

The risk assessments for each of these exposure routes are detailed in the following sections.

3.1.2 Ingestion from cross connections between the drinking and recycled water systems.

The recycled water system will be distributed to homes via a dual pipe system. Education, signage and labelling will be used to mitigate the risk of cross-connections or inappropriate use of recycled water, however the risk of cross-connection cannot be eliminated. The assumptions provided within table 3.7 of the AGWR have been adopted for the risk calculations.

3.1.3 Aerosol ingestion from toilets

Guidance on typical exposure rates and ingestion volumes for toilet flushing are provided in table 3.3. from AGWR. These figures have been adopted for the purposes of calculating performance targets.

Ingestion of water used for irrigation

The proposed reuse includes irrigation of gardens and lawns around homes and common areas. There is potential risk from ingestion of sprays or accidental ingestion of recycled water. The figures from table 3.3. of the AGWR have been adopted with consideration for both these potential exposures.

3.1.4 Performance Target Calculations

The proposed pathogen removal targets (using sewage as source) to meet the minimum tolerable health risk of 10^{-6} DALY as recommended by AGWR have been determined as follows:

With reference to AGWR Table 3.3 and 3.7, and using the above estimates for ingestion, frequency and population:

Table 3.1: Microbial health-based performance targets calculation

Use	Ingestion (L)	Frequency (/yr)	Total (L/yr)	Log Reduction		
Toilet	0.00001	1100	0.011	Protozoa	Virus	Campylobacter
Cross-connect	1	0.365	0.365	4.9	6.3	5.0
Irrigation – Ingestion of spray when watering	0.0001	90	0.009			
Irrigation – Indirect ingestion through contact	0.001	90	0.09			
Irrigation – Accidental Ingestion	0.1	1	0.1			
			0.575			

The above calculation is based on Appendix 2 of AGWR. Log reduction = log (concentration in source water x exposure (L) x N /DALYd)

Concentration in source water (from AGWR Table A2.1):

- Cryptosporidium is 2000 - Organisms per litre in source water (N) (95th Percentile)[a]

- Rotavirus is 8000 - Organisms per litre in source water (N) (95th Percentile)[a]
- Campylobacter is 7000 - Organisms per litre in source water (N) (95th Percentile)[a]

a – Hazard concentrations in raw sewage (95th percentile from Australian and international data). Numbers of adenoviruses have been used as an indication of numbers of rotaviruses, because of the lack of enumeration methods for rotaviruses. Adenoviruses were used because these were the most numerous of the viruses detected in Australian monitoring of sewage (data from Virginia Pipeline Scheme in South Australia).

N is the number of exposures per year and DALYd is the dose equivalent to a DALY of 10-6. DALYd includes consideration of dosed response and ratio of infection to illness.

Exposure and N data was found in Table 3.3 of "Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1) 2006"

The log reduction number calculated in the above table is as following:

Protozoa Log reduction = log (2000 x 0.575/1.6 x 10-2) = 4.9

Virus Log reduction = log (8000 x 0.575/2.5 x 10-3) = 6.3

Bacteria Log reduction = log (7000 x 0.575/3.7 x 10-2) = 5.0

Notwithstanding the above calculations, the more conservative values from AGWR table 3.8 for dual reticulation, toilet flushing, and garden use have been used, which require 6.5, 5.0, 5.0 for virus, protozoa and bacteria respectively.

Target LRV and treatment train contributions are therefore as follows:

Table 3.2: Treatment plant performance objectives for reuse

	MBR	UV	Chlorination	Total LRV Achieved	Target LRV
Virus	1.9	0.6	4.0	6.5	6.5
Protozoa	3.0	3.0	0	6.0	5.0
Bacteria	3.0	3.0	4.0	10.0	5.0

The treated water from the proposed process train should meet or exceed the target LRV.

3.2 Pathogen quality requirements for Irrigation disposal

Treated water that does not meet the quality requirements for reuse within the community, may still be acceptable for irrigation disposal following an appropriate assessment. This may occur due to equipment failures or out of specification water such as low UV dose or chlorine residual post MBR.

The location of the wet weather storage dam and the irrigation area is shown in appendix 10. This is a non-food crop with no public access during irrigation, and limited or no contact afterwards. Table 3.8 of the AGWR indicates that for irrigation of non-food crops following secondary treatment, with no access during irrigation and a minimum buffer of 30m to the nearest point of public access, the pathogen exposure reduction is 5.0-log.

Applying a pathogen reduction of 5.0-log to the values above (section 3.1.4, table 3.2) reduces the target quality for this form of disposal to 1.5-log virus reduction. However, table 3.8 also indicates a water quality objective of < 10,000 cfu/100mL of *E. coli* , which is approximately 2-log removal based on an E. coli level of 10^6. This water quality can easily be met using the MBR stage alone (biological treatment plus MF/UF), for which the LRV is 1.9-log virus, and 3.0-log bacteria and protozoa. There are further mitigating factors such as storage time in the wet weather dam and extended buffer distances, which have not been included in this analysis.

The LRV required for irrigation disposal is as indicated below in table 3.3.

Table 3.3: Treatment plant performance objectives for irrigation disposal (no reuse)

	MBR	UV	Chlorination	Total LRV Achieved	Target LRV
Virus	1.9	-	-	1.9	1.5
Protozoa	3.0	-	-	3.0	2.0
Bacteria	3.0	-	-	3.0	2.0

MBR treatment is therefore the only unit process required for irrigation quality to be met. If this cannot be achieved, the water will be returned to the buffer tank for reprocessing.

3.3 Chemical

The source water is blackwater from the residential community. There is no industrial component and the potable water supply is of high quality. There are no known chemical inputs, other than the possible inadvertent disposal of small quantities of cleaning fluids and other minor chemicals into the system from time to time. Excessive volume of these solutions can create pH levels harmful to the biomass in the reactor; however the plant monitors the feed pH constantly and will not accept water unless it is within the specified range. No specific water quality targets for chemicals have therefore been determined.

Sodium hypochlorite is the only chemical added to the treated water for disinfection. See Section 5.2 Free Chlorine System Validation, below.

4. System assessment

A HAZOP and Environmental Risk Assessment and Hazard Analysis and Critical Control Point (HACCP) analysis of the NEV scheme has yet to be been completed. These will form Appendices 3 and 4 respectively. The methodology will be in accordance with AGWR and Aquacell's documented risk procedures.

The proposed participants in the HACCP and HAZOP are:

NSW Health: Leslie Jarvis (or delegate)
IPART: Gary Drysdale (or delegate)

NEV Co-op:	Mark Fisher (+ other invitees as required)
Aquacell:	Warren Johnson

5. Compliance with Australian Guidelines for Water Recycling

The table below lists the 12 elements of the framework for managing recycled water quality and use (as per the AGWR) and shows how the scheme will meets the various elements.

Table 5: 12 Framework Elements

Framework element	Activity	Reference Document
Element 1: Commitment to responsible use and management of recycled water quality		
Components: Responsible use of recycled water	The project parties, NEV Co-op and Aquacell, are all committed to the responsible use of recycled water as indicated in section 1.3. The recycled water facility is part of a range of features to achieve sustainability within this development. There is a commitment to ensure correct design installation and management.	Aquacell Recycled Water Policy exists. *IMS Document EM010* Policy statement from NEV-Co-op also confirms commitment to responsible use of recycled water.
Regulatory and formal requirements water	• Approval is being sought from IPART for the installation and operation of the recycled plant. • A Development Application has been lodged with Gosford City Council for the sub-division development as whole, and consent has been recieved.	WICA Application Gosford City Council DA
Engaging stakeholders	• The Narara Ecovillage Co-operative Ltd actively involves all its members in the planning and approval of the development and its infrastructure. The Co-operative operates under Dynamic Governance, which seeks to achieve fair, inclusive, transparent, accountable and creative decision-making processes. A working group of interested members has been involved from the early stages of the project looking at the technical aspects of the project and helping to choose technology options. The NEV has a website which contains information on the proposed development with contact details and invitation for comment and further information.	NEV website NEV Co-op charter
Recycled water policy	• The implementation of a recycled water policy is recommended.	• NEV Recycled Water Policy exists.
Element 2: Assessment of the recycled water system		
Components: Identify intended uses and source of recycled water	Uses are for toilet flushing and irrigation of lawns and gardens. Sewage is collected solely from on-site gravity sewerage system services the households and community buildings.	This RWQMP section 1.2.1.
Recycled water system	• The plant receives sewage from the facility. The water is subject to treatment through a membrane bioreactor, ultra filtration, ultraviolet (UV) disinfection, and chlorination. The treated water is piped to two dedicated storage tanks and distributed for use.	Operations and Maintenance Manual

Framework element	Activity	Reference Document
Assessment of water quality data	As the development is new, there are no existing wastewater quality data available, however published data exists for a similar eco-development at Capo Di Monte in Queensland. This data has been used a guide to the expected wastewater characteristics. The treated water quality will be required to meet the Australian Recycled Water Guidelines (ARWG), and will require a licence under WICA.	This RWQMP, and AGWR
Hazard identification and risk assessment	**Human health** Preliminary hazard identification and risk assessment for human health found that microbial hazards for humans include bacteria, viruses and protozoa. **Environmental performance** A land capability assessment found low risk due to salinity, run-off, chemicals, or nutrients. A HACCP and HAZOP will be conducted and used to identify any potential risks and mitigation strategies. These will be contained in appendix 4.	HACCP and HAZOP Appendices 3 & 4
Element 3: Preventative measures for recycled water management		
Components: Preventative measures and multiple barriers	**Human health** Preventative measures to manage risks to human health include: Membrane filtration, UV disinfection and chlorine disinfection; Pipework (purple and/or with text) and signage at site of use indicating that recycled water is being used; Educational of those on site about appropriate disposal of wastes; Signage at site to alert plumbers to recycled water system and co-ordination of plumbers through site management; Backflow prevention and cross-connection control. **Environmental performance** Preventative measures to manage risks to the environment include:	This RWQMP AS/NZS 3500:2003 Community information provided on Aquacell website and NEV website.

Framework element	Activity	Reference Document
	Education programme for co-operative residents and visitors; Information and open days; Promoting use of environmentally friendly detergents in the toilets and hand basins and avoidance of disposal of chemicals.	Community page on NEV and Aquacell websites (to be added).
Critical control points	Critical control points will be dentified during the HACCP risk assessment. These will likely include: MBR filtrate turbidity; UV Intensity; Free chlorine residual and treated water pH.	HACCP (to be completed) Appendix 4.
Element 4: Operational procedures and process control		
Components: Operational procedures	Operational procedures were identified for all processes and activities associated with the system, including operation of treatment processes and auditing procedures for cross-connections. Documented procedures must be available to operations personnel and for inspection at any time. Operators are proficient and are able to recognize the significance of changes in the recycled water treatment plant and water quality. They are able to respond appropriately according to established procedures.	Operations and Maintenance Manual O+M Manual Aquacell Trouble Shooting Guide (IMS Document OM070*)* Aquacell Work instructions
Operational monitoring	Monitoring includes: Dissolved oxygen in bioreactor (continuous); pH buffer tank (continuous); Turbidity of filtered water (continuous) – critical limits set; UVI, power and lamp failure (continuous) - critical limits set; Free chlorine residual (continuous) - critical limits set; Effluent pH (continuous) - critical limits set.	Section 7 of this RWQMP
Corrective action	Corrective actions include the following: Noncompliance with critical limits results in the system being stopped and/or treated water transfer to storage is prevented. If cross-connections detected, flow to property stopped until repairs completed. Site switches to potable water backup until treated water is of suitable quality for reuse. Water that does not meet specification is sent to subsurface irrigation for disposal, if suitable for this purpose, otherwise it will be returned to the buffer tank.	Section 7 of this RWQMP

Framework element	Activity	Reference Document
Equipment capability and maintenance	Treatment plant and disinfection systems of standard and reliable design. Maintained by qualified supplier.	A service agreement (to be finalised) will exist between NEV Co-op and Aquacell for the maintenance and service of the recycled water treatment system.
Materials and Chemicals	All plumbing and drainage work is conducted in a manner conforming to AS/NZS standard 3500. All chemical used in the plant are obtained from credible suppliers.	The plant design is approved prior to construction. MSDS are supplied for each chemical
Element 5: Verification of recycled water quality		
Components: Recycled water quality monitoring (specifically designed for individual systems, taking into account source of water, end uses and receiving environments)	**Human health** Monitoring of defined parameters is undertaken based on risk assessment and taking into account sources and end uses.	Section 8 of this RWQMP
Application and discharge site monitoring	**Environmental performance** Irrigation system monitored for operation and moisture levels.	Aquacell Service checklist
Documentation and reliability	The sampling plan (location, parameters and frequency) will be determined and agreed to by the relevant authorities. The sampling and testing is performed by an independent, NATA accredited laboratory.	Laboratory NATA certification Records of results
Satisfaction of users of recycled water	Complaints handling policy in place. •	NEV "Complaints Handling and Dispute Resolution Policy"
Short-term evaluation of results •	The customer is supplied with a monthly report regarding the performance of the plant.	Monthly Service Report to NEV Co-op regarding plant operation and performance indicators.

Framework element	Activity	Reference Document
	The Aquacell recycled water engineer and service technician will be in regular verbal and e-mail correspondence with NEV Co-op representatives.	Audit reports are published on Aquacell website. WICA Network Operators Retail suppliers Reporting Manual
Corrective responses	Corrective action depends on the incident. As a minimum, it involves investigation of plant performance records to confirm normal operation, and additional testing to confirm the result and identify the source. If target criteria for environmental parameters are exceeded, preventative measures need to be reassessed and corrective action taken to ensure environmental performance is improved.	Corrective actions are addressed in section 7.1 and 7.2 of this RWQMP
Element 6: Management of incidents and emergencies		
Components: Communication	Noncompliance with approval conditions to be reported immediately to IPART and NSW Health. In the case of an incident or emergency that requires a media response, only the CEO is authorized to make any public comment.	Records of incidents or emergencies kept by Aquacell.
Incident and emergency response protocols	Employees are trained in emergency response and incident protocols. Emergency response procedure described in section 10.	• NEV and Aquacell Incident and Emergency Management Procedures (IMS Document IE010) • RWQMP Section 10 describes responses to Incidents and Emergencies
Element 7: Operator, contractor and end user awareness and training		
Components: Operator, contractor and end user awareness and involvement	Operator of treatment plant to be sufficiently skilled to run the plant and investigate any faults	Technician induction on commencement of employment, operating manuals, supervision from experienced engineers.

Framework element	Activity	Reference Document
	End users are made aware of the restrictions on the use of recycled water and any practice that could threaten human health. Community meetings and NEV websites used as places to disseminate information on the wastewater treatment process and recycled water risks. Contractors inducted to site are told of the presence of dual pipe systems and the precautions required.	NEV and Aquacell websites contain educational material. Induction records for those coming on site to work.
Operator, contractor and end user training	Operator to be aware of approval conditions and instructed on occupational health and safety requirements • NEV and Aquacell have an induction programs for new employees and written procedures for all areas of responsibility. Training needs for individual employees are identified and adequate resources made available during the induction phase. Annual performance reviews identify additional training requirements and set performance targets. Training records are kept. • Any contractors used on site are accredited, qualified and have the appropriate level of training. A site induction includes familiarization with NEV and Aquacell's Safe Work Method Statements (SWMS's), which are site specific. Aquacell maintains a partnership with several contractors to ensure continuity of knowledge and technical expertise.	Site Induction program Annual reviews Contractor induction records. NEV document "Contractor Requirements" NEV and Aquacell SWMS's
Element 8: Community involvement and awareness		
Components: Community consultation	In the NEV Ecovillage development the key stakeholders are the members of the village community. The community consultation process is therefore similar to the stakeholder consultation process described in element 1. This includes community education and a Dynamic Governance process that seeks to involve all the members in decision making.	NEV website NEV Co-op charter
Communication and education	Various documents on the development proposal and activities have been produced to promote public awareness and education. This information is available online through the Department of Justice website. • NEV and Aquacell maintain a site specific community section on the company websites that also contains advice and educational information about sites.	NEV website; NEV Newsletter NEV and Aquacell company websites community page

Framework element	Activity	Reference Document
Element 9: Validation research and development		
Components: Validation of processes	Ongoing investigations into recycled water quality and treatment plant performance to refine assessments. This may enable less conservative critical control points to be adopted or treatment requirements reduced.	Validation according to section 6 of this RWQMP
Design of equipment	The design of the plant is based on well-documented and validated technologies.	Section 6 of this RWQMP
Investigative studies and research monitoring	As the depth of operational knowledge regarding this and similar water treatment technologies increases, so the understanding of the weaknesses increases. This results in better opportunity to be proactive regarding operational control and maintenance of the plant.	This RWQMP will be reviewed in 12 monthly intervals as part of the process of continual improvement.
Element 10: Documentation and reporting		
Components: Management of documentation and records	Design of treatment plant and reticulation system documented; Operating procedures documented; All results to be recorded and stored; Aquacell has developed an in house Integrated Management System (IMS) that is based on the ISO 9000 system, but not yet certified. This is a goal of the company in the future. Included in this RWQMP and the Operations and Maintenance Manual is information pertaining to preventative measures employed, target and critical limits, critical control points, operating and corrective action procedures. These documents, along with the incident and emergency response plans, training programs and reporting protocols ensure that the plant is operating within set limits at all times. The document control system, ensures that only the most current version of any document is available for use. All documents are reviewed on an annual basis.	IOP, RWQMP, Incident and Emergency Management Procedure, (IMS document IE010) Performance reviews, Risk Management Procedure, (IMS document RM030) Aquacell Operations and Maintenance Manual
Reporting	Internal reporting consists of verbal communication between the Aquacell engineer and the site service technician and written reports from the technician to the engineer. The owners of this treatment plant receive a monthly report detailing all operational and performance parameters and the maintenance performed during that month. Non compliance breaches are reported immediately to IPART and NSW Health.	Monthly reporting to NEV Co-op
Element 11: Evaluation and audit		

Framework element	Activity	Reference Document
Components: Long-term evaluation of results	Regular reporting to client on results and maintenance activities. Operational audit performed after 12 months as part of WICA license.	Monthly reports to NEV Co-op External audit reports
Audit of recycled water quality management	Statutory audit after the first 12-months then ongoing at least every 3 years by third party auditor.	Audit reports
Element 12: Review and continual improvement		
Components: Review by senior managers	Performance of treatment plant, customer complaints/satisfaction	A senior review of this plant will be conducted annually in combination with the audits
Recycled water quality management improvement plan	RWQMP reviewed at least annually and more frequently as needed. Any opportunities for improvement identified through staff, customers, or auditors are reviewed and implemented as appropriate.	Improvement actions from audit reports or annual reviews are reviewed and implemented where appropriate.

6. Validation of treatment processes

6.1 Membrane Bioreactor

6.1.1 Challenge test results

Memcor B40N membranes, supplied by Evoqua, have been selected for the MBR in this project. The required log removals for the MBR are 1.9 for virus and 3.0 for protozoa and bacteria (see section 3.0 for details).

A number of challenge studies have been carried out on the B40 membranes in both clean water conditions and in an MBR environment. One study conducted on membranes that were badly compromised after many years of operation with no repairs carried out, was able to demonstrate log removals of 4.75 – 6.23 for F-specific RNA bacteriophage, 5.41-6.70 for *E. coli*, and 3.66 to 5.19 for somatic coliphage (Pettigrew et al, 2010). This highlights the inherent benefits of operating membranes in an MBR environment where the high solids levels tend to plug any defects that may be present or develop over time.

Despite strong data demonstrating significant pathogen reduction across membranes in an MBR environment, the reference study used for the purposes of supporting the claimed pathogen LRV credits was conducted on clean water and is attached as appendix 7 ("Pathogen Removal by Integral and Compromised Siemens Memcor MBR systems" Nov 2010). Clean water represents the worst case, and is a way of establishing the pathogen removal capabilities of the membrane without the benefit of solids present in the water.

This test work was conducted in accordance with the USEPA Membrane Filtration Guidance Manual. Five modules were randomly selected and subjected to challenge testing using MS2 bacteriophage seeded into filtered water. Samples were collected before the start of the filtration cycle and at three points through the filtration cycle. The results showed log reductions ranging from 2.16 to 3.61.

In a separate study to investigate removal of protozoa and bacteria, five B40N modules were tested using the USEPA protocol (Membrane Filtration Guidance Manual) and challenged with *Bacillus subtilis* spores with an average size of around 1 µm. The challenge organism was seeded into carbon filtered potable water and supplied to the modules. Samples were collected before the start of the filtration cycle and at three points through the filtration cycle. The results showed log reductions of *Bacillus subtilis* ranging from 5.8 to 7.3. The report is included as appendix

The above challenge tests confirm the ability of the B40N modules to reject viruses, protozoa, and bacteria at levels well in excess of log credits required for the plant under clean water (worst case) conditions.

6.1.2 Integrity Monitoring –Turbidity

The challenge test work reported is based on clean water conditions with integral modules. Online turbidity monitoring is essential in ensuring the required integrity is maintained during operation.

An extensive study carried out by Evoqua on B40N membrane sought to examine the relationship between integrity (measured by pressure decay rate (PDR) and challenge testing) and turbidity (appendix 9, "Pathogen Monitoring of MBR systems using on-line Turbidity, 2012). A rack of 16 modules with known integrity compromise (LRV 2.7 based on PDR), was subjected to a pressure decay test to cause a temporary spike in turbidity by disrupting any defects that had plugged with solids. The turbidity was monitored following the disruption along with *E. coli*, faecal coliforms, and *C. perfringens*. As expected, there was a spike in turbidity to around 2.6 NTU which coincided with a spike in the presence of pathogens. However, the water quality returned to pre-test conditions (LRV > 6) after 5 minutes of operation. The tests was used to determine a quantitative relationship between turbidity and LRV (measured by pathogen rejection). The result was the following (correlation coefficient of 0.95):

$$LRV = 5.662 - 2.0151 * NTU$$

Using the above with our target LRV of 3.0 the maximum turbidity would be 1.3 NTU. However, it is proposed that we operate the membrane at a more conservative turbidity of 0.2NTU, with an absolute maximum (CCP) of 0.5 NTU. Based on the above, this would achieve an LRV of 6.7, well above the target LRV of 3.0 with a comfortable level of conservatism. This is also consistent with the USEPA Title22 approach for water reuse applications which adopts 0.2 NTU 95% of the time and a maximum of 0.5 NTU 100% of the time.

Based on this analysis is proposed that we set **0.2 NTU as the alarm level, and 0.5 NTU as the CCP maximum**.

6.1.3 Integrity monitoring for viruses

Turbidity monitoring can be applied as described in section 6.1.2 for ensuring the integrity of the membrane is maintained above the required LRV for bacteria and protozoa (3-log in this case), which are particles that are completely rejected by an intact membrane (section 6.1.1). However, virus particles are not completely rejected, and as discussed, the membrane will achieve an LRV of 2.16 for virus when intact. It is necessary to confirm that the required virus LRV (1.9-log) can still be achieved even if there is sufficient membrane bypass through defects for the bacteria and protozoa LRV to drop from complete rejection to an LRV of 3.0.

This can be done by a simple mass balance. The log reduction (LRV) of a particle is defined as the log ratio of concentration in the feed (C_{feed}) to the concentration in the filtrate ($C_{filtrate}$). The filtrate concentration is in turn made up from particles that pass through the membrane (at concentration $C_{membrane}$) and particles that bypasses the membrane through defects or leaks (at concentration C_{bypass}). The concentration in the filtrate can be determined from the flow through the membrane ($Q_{membrane}$) and the flow bypassing the membrane (Q_{bypass}).

$$LRV = \log\left(\frac{C_{feed}}{C_{filtrate}}\right)$$
$$= \log\left(\frac{C_{feed}}{\frac{(Q_{membrane} * C_{membrane}) + (Q_{bypass} * C_{bypass})}{(Q_{bypass} + Q_{membrane})}}\right)$$

Now, since the bypass flow is very low relative to the membrane flow, ($Q_{membrane}$ + Q_{bypass}) is approximately equal to $Q_{memrbane}$. So the above simplifies to:

$$LRV = log\left(\frac{C_{feed}}{C_{membrane} + \left(\frac{Q_{bypass} * C_{bypass}}{Q_{membrane}}\right)}\right)$$

$$= log\left(\frac{1}{\frac{C_{membrane}}{C_{feed}} + \left(\frac{Q_{bypass} * C_{bypass}}{Q_{membrane} * C_{feed}}\right)}\right)$$

Assuming that anything bypassing the membrane has the same concentration as the feed then $C_{bypass}/C_{feed} = 1$. Further, since protozoa are removed completely by an intact membrane and we are monitoring for a minimum 3-log reduction then the ratio $Q_{bypass}/Q_{membrane}$ is 10^{-3}. The results of the virus challenge testing conducted by Evoqua on the B40N module showed a minimum virus log reduction of 2.16 (appendix 7). This represents the virus removal capability of an intact membrane, thus $C_{membrane}/C_{feed} = 10^{-2.16}$.

Substituting into the above,

$$LRV = log\left(\frac{1}{\frac{C_{membrane}}{C_{feed}} + \left(\frac{Q_{bypass} * C_{bypass}}{Q_{membrane} * C_{feed}}\right)}\right)$$

$$= log\left(\frac{1}{10^{-2.16} + (10^{-3} * 1)}\right)$$

$$= 2.1$$

In other words, if the integrity of the membrane for bacteria and protozoa were to drop to an LRV of 3, the virus LRV would drop from 2.16 to 2.1. This is above the virus LRV of 1.9 required, confirming that protozoa control to an LRV of 3.0 is sufficient to ensure the virus LRV target can be met.

The above assumes that virus passage through the membrane does not degrade with time. Experience has shown that in an MBR environment even relatively large defects plug with time, so virus rejection is always much higher in situ than in clean water test conditions (Pettigrew, 2010). The assumption is therefore conservative.

6.2 UV validation

From table 3.2, the UV system is required to achieve pathogen reductions of 3.0-log for both protozoa and bacteria and 0.6-log for viruses.

The UV system must comply with the requirements of the Victoria Department of Health *Guidelines for validating treatment processes for pathogen reduction* (Vic. DH 2013). This requires that the UV systems be validated by a third party in accordance with the requirements of the US EPA *Ultraviolet Disinfection guidance manual for the final long term 2 enhanced surface water treatment rule* (UVDGM)(US EPA 2006).

Table 1.4 of the UVDGM provides the UV dose requirements for pathogens, and is reproduced below.

Target Pathogens	**Log Inactivation**							
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22

Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

A plot of the dose versus log virus inactivation from the data of table 1.4 is shown in figure 6.1. The result is a straight line with a regression coefficient of 0.9992, and a line of best fit indicating:

UV Dose = 40*(log inactivation) + 18.7

Therefore, to achieve an LRV of 0.6 the validated UV dose required is given by:

UV Dose (mJ/cm^2) = 40 * 0.6 +18.7 = **43 mJ/cm^2**

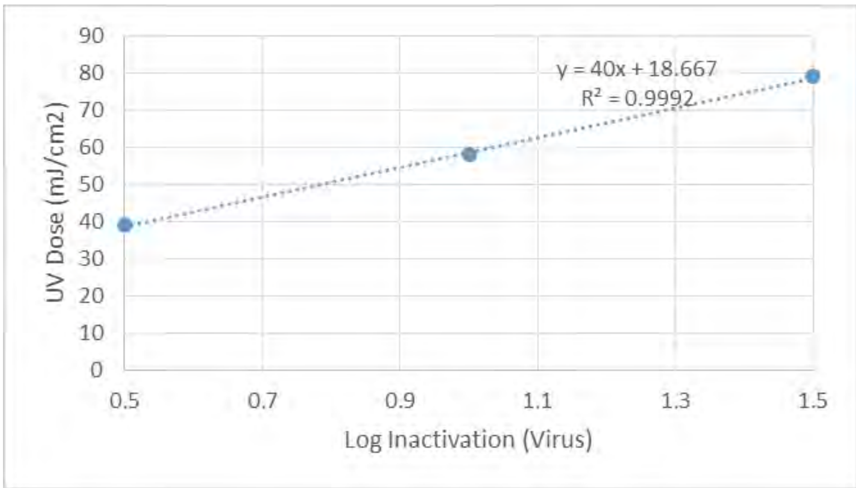


Figure 6.1 – UV Dose versus log inactivation (virus) from table 1.4 (UVDGM).

The protozoa dose requirement for 3.0-log inactivation is **12 mJ/cm^2**. Bacteria are more UV sensitive than protozoa and will therefore be reduced by an amount at least equal to protozoa (e.g. E. coli up to 10 mJ/cm^2 for 4-log inactivation (AwwaRF, 2004)).

The UV reactor must be validated in accordance with the UVDGM at the required operating conditions for NEV. Aquacell have selected a suitable unit, and a confidential validation report has been provided by the manufacturer to Aquacell. Analysis of the data in this report confirms that it meets the USEPA requirements and will achieve a validated dose of 43 mJ/cm^2 at end of lamp life under the conditions shown in table 6.1 below

Table 6.1: UV operating parameters

Operating Parameter	Operating Conditions
Operating Mode	Calculated dose monitoring
Validated UV Dose	≥43 mJ/cm^2 (virus); ≥12 mJ/cm^2 (protozoa)
RED setpoint	52.6 mJ/cm^2
Flowrate	≤ 50 L/min
UVT	≥ 60% at 254 nm
Lamp status	Operating, and hours < 12,000

An analysis of the proposed UV system and validation of the ability to provide the required dose follows.

6.2.1 UV Dose Monitoring

The method of operation chosen for this project to ensure the required UV dose is the calculated dose approach.

The manufacturer of the UV system has had a Validation Study carried out by a third party in order to establish the UV performance in accordance with the requirements of the UVDGM (Carollo (2011)). A confidential copy of the Validation Study has been provided by the manufacturer to Aquacell.

For the calculated dose monitoring approach with the ProLine+ 0027 UV the study determined the relationship between the measured MS2 RED (mJ/cm^2) as a function of lamp output (at optimal water layer), flowrate (gpm) and UV absorbance (UVA) at 254nm, which is presented as equation 1.2/5.14 in the study. This equation is reproduced below as equation 6.1.

$$MS2\ RED = 10^{A} \times UVA^{B \times UVA} \times \left[\frac{S/S_0}{Q}\right]^{[C+ln(UVA)]} \qquad \text{Equation 6.1}$$

Where:
A = 3.6448
B = 6.4947
C = 0.67715
D = -0.0663
Q = Flow (gpm)
UVA = log(100/UVT)
S/S_0 = Relative lamp output, calculated as the ratio of the UV intensity, S (W/m2), to the UV intensity with the lamp operating at maximum power for the given UVT.

The minimum validated UVT is 60% (UVA = 0.22), and the maximum design flow for this project is 50 L/min (13.2 gpm). The validation study provides an example UV system sizing in which the combined end-of-lamp life and fouling factor (S/So) is 0.808 (figure 1.5b, page 1-24). Typical values recommended by the manufacturer for this application are 0.8 for end-of-lamp life and 0.9 for fouling factor. This yields a slightly more conservative combined factor of 0.72 (0.8 x 0.9), which is the value adopted for this project. The predicted RED is then obtained from equation 6.1:

$$RED = 10^{A} \times 0.22^{B \times 0.22} \times \left[\frac{0.72}{13.2}\right]^{[C+D \times ln(0.22)]}$$
$$RED = 52.6\ \text{mJ/cm2}$$

6.2.2 Uncertainty of Validation

To obtain the required disinfection credits the UV reactor must deliver a validated dose (D_{val}) that is equal to, or greater than, the dose specified in table 6.1 of this document (≥ 43 mJ/cm^2 and ≥ 22 mJ/cm^2 for virus and protozoa respectively). The validated dose is given by (UVDGM page 5-42):

$$D_{val} = \frac{RED}{VF} \qquad \text{Equation 6.2}$$

Where VF is the validation factor and RED is the predicted RED from equation 6.1.

The validation factor is determined using:

$$VF = B_{RED} \times \left(1 + \frac{U_{val}}{100}\right) \quad \text{Equation 6.3}$$

Where B_{RED} is the bias factor and U_{val} is the percent uncertainty in the validation.

Combining equation 6.2 and 6.3 yields:

$$D_{val} = \frac{RED}{B_{RED} \times \left(1 + \frac{U_{val}}{100}\right)} \quad \text{Equation 6.4}$$

The UVDGM (page 5-40) states that the U_{val} is a calculated by:

$$U_{val} = \sqrt{U_{IN}^2 + U_{DR}^2 + U_S^2} \quad \text{Equation 6.5}$$

Where U_{IN} is the uncertainty of interpolation using the dose monitoring equation, U_{DR} is the uncertainty of the test microbe dose response, and U_S is the uncertainty of the UV sensors during validation.

The UVDGM states (page 5-41) that U_{IN} is determined from:

$$U_{IN} = \frac{t \times SD}{RED} \times 100\%$$

Where t is the t-statistic at 95% confidence level for the sample size equal to the number of test conditions used to define the dose equation, and SD is the standard deviation of the differences between the measured and predicted RED's. The validation report gives the values for (t x SD) for the ProLine +0027 data as 9.906 mJ/cm^2 (page 1-22). Therefore:

$$U_{IN} = \frac{9.906}{52.6} \times 100\%$$

$$= 18.8\%$$

The UVDGM states (page 5-19) that U_S is defined as the largest difference observed between the duty and reference sensor. This value can be set to zero if it is <10%. The difference between the duty and reference sensors is reported in the validation report and is < 3% (figure 5.5a and figure 5.5b on page 5-10) and, hence U_S is set to zero.

The uncertainty of the UV dose response, U_{DR}, is given by:

$$U_{DR} = \frac{CI}{RED} \times 100\%$$

Where CI is the confidence interval at the specified dose calculated using statistical approaches. The UVDGM states that the value of U_{DR} can be set to zero if the calculated U_{DR} (using the method of Draper and Smith) is less than 15% of the RED at 1-log inactivation. The validation report (table 6.4, page 6-7) indicates that for RED's greater than 20.38 mJ/cm2, the value if U_{DR} is <15%. The calculated RED is 52.6 mJ/cm^2, which is greater than 20.38 mJ/cm^{2}and so the value of U_{DR} can be set to zero.

Combining the values for U_{IN}, U_{DR}, and U_S, and substituting into equation 6.5 yields:

$$U_{val} = \sqrt{U_{IN}^2 + U_{DR}^2 + U_S^2}$$
$$U_{val} = \sqrt{18.8^2 \ + 0 + 0}$$
$$U_{val} = 18.8\%$$

6.2.3 Validated Dose - Virus

The challenge microorganism used in the validation study was MS2 phage which was determined to have a dose sensitivity of between 20 and 22 mJ/cm2/log i (table 6.2, page 6-3 of the validation study). Table G.17 of the UVDGM indicates a bias factor of 1.0 for virus up to 4-log reduction for sensitivity ≤ 25 mJ/cm2/log i. Therefore, a value of 1.0 is adopted for B_{RED}. The RED is 52.6 mJ/cm^2 (section 6.1.1), and U_{val} is 18.8% (section 6.1.2).

Substituting into equation 6.4 yields the validated dose for virus reduction:

$$D_{val} = \frac{RED}{B_{RED} \times \left(1 + \frac{U_{val}}{100}\right)}$$

$$D_{val} = \frac{52.6}{1 \times \left(1 + \frac{18.8}{100}\right)}$$
$$D_{val} = 44.2 \text{ mJ/cm}^2$$

The validated dose of 44.2 mJ/cm^2 is greater than the required dose of 43 mJ/cm^2, therefore the system is capable of delivering the required virus log reduction of 0.6.

6.2.4 Validated Dose - Protozoa

In order to determine whether the UV dose provided is adequate to claim a log reduction of 3.0 for protozoa, and additional calculation of bias factor, B_{RED}, is required. RED bias values are given in appendix G of the UVDGM as a function of UV sensitivity and UVT of the water. The UV sensitivity or the MS2 used in the validation study is determined as between 20 and 22 mJ/cm^2/log i (table 6.2, page 6-3 of the validation study) at a RED of 52.6 mJ/cm^2.

Appendix G, table G.3 of the UVDGM gives RED bias factors for 3.0-log Cryptosporidium down to a UVT of 65%. The Victorian Department of Health *Guidelines for validating treatment processes for pathogen reduction* (Vic. DH 2013), provide guidance in section 9.2.2 for extrapolating the RED bias factor to lower UVT's and is the methodology adopted here. This involves a linear extrapolation of the last two values from the relevant table in appendix G at the challenge UV sensitivity. Figure 6.1 shows a plot of the UVT and RED bias values from table G.3 of the UVDGM for UV sensitivity >20 and ≤ 22 mJ/cm^2.

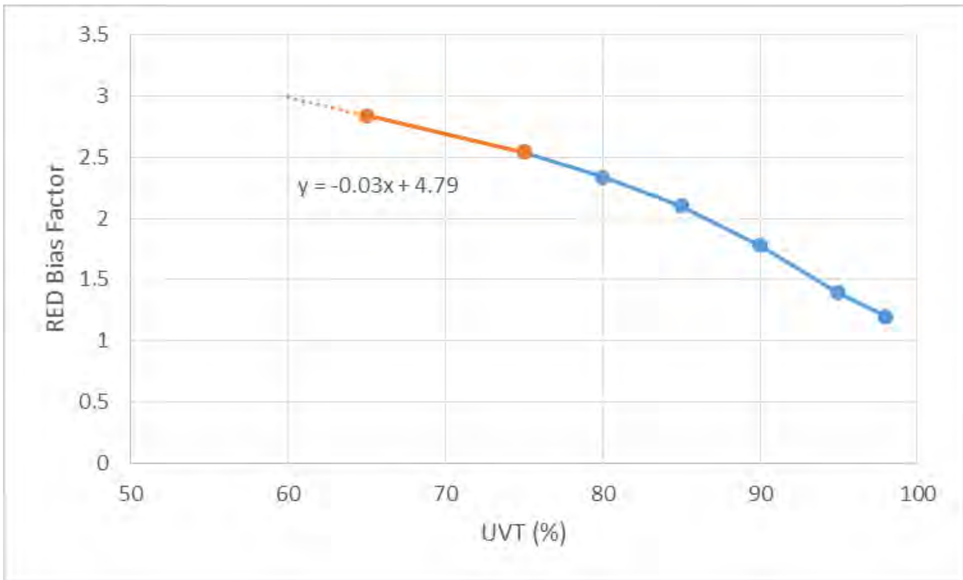


Figure 6.2 – RED Bias factor as a function of UVT from table G.3 UVDGM.

The trendline is a line of best fit for the last two points (75% and 65% UVT) and is shown extrapolated to a UVT of 60%. The RED bias factor at 60% can be calculated from the trendline equation for these two data points and yields an RED bias factor of **2.99**.

Substituting the RED bias factor into equation 6.4 gives:

$$D_{val} = \frac{RED}{B_{RED} \times \left(1 + \frac{U_{val}}{100}\right)}$$

$$D_{val} = \frac{52.6}{2.99 \times \left(1 + \frac{18.8}{100}\right)}$$

$$D_{val} = 14.8 \text{ mJ/cm}^2$$

As the validated dose of 14.8 mJ/cm^2 is greater than the required dose of 12 mJ/cm2, the unit is capable of providing the 3-log protozoa reduction.

6.2.5 UV validation envelope

The UV validation study indicates a validation envelope extending to a UVT of 60% and a minimum flow of 5 gpm (19 L/min) and up to a maximum flow of 52 gpm (187 L/min), and a UVT of 99% (table 1.4 page 1-14 of the validation study).

The design minimum UVT and maximum flow of 60% and 50 L/min respectively are within this validated envelope.

UVT is monitored continuously to ensure it remains at or above 60%, and flow is monitored continuously to ensure it remains at or below 50 L/min.

If the flow drops below the validated minimum flow the UV controller automatically adopts the lowest validated flow for the calculated RED output value. Similarly, if the UVT is above the maximum validate UVT the controller adopts the maximum validated UVT for the calculated RED output value.

6.2.6 UV Intensity Sensor Location

The location of the sensor should be optimal to ensure the most efficient dose monitoring control. The validation study examined three difference sensor locations and determined the optimum sensor location to be at a water layer of 23 mm. The UV sensor will be installed at the optimum location, which is the basis of equation 6.1.

6.2.7 UV Hydraulic Configuration

The UVDGM section 3.6.2 requires that the installation of the reactor have at least 5 pipe diameters of length upstream in addition to the length provided in validation testing. The validation study (figure 1.3b) shows that the validation installation had 8.5" of 2" pipework to the first elbow on the inlet to the UV reactor. The total length required on the installation is therefore 2"x 5 + 8.5" = 18.5" (470 mm). The design provides for approximately 1m of straight pipe upstream which meets this requirement.

6.3 Free Chlorine System Validation

Chlorine disinfection is used to achieve 4-log virus and bacteria inactivation (table 3.2). Table 9 of the Victorian *Guidelines for validating treatment processes for pathogen reduction* (DH, 2013) suggests a critical C-T for 4-log virus inactivation is 22 mg·min/L at pH ≤ 8.5 and temperature ≥ 10 °C, and is the value adopted for this project. Bacteria are more sensitive to chlorine and so a 4-log virus inactivation will also achieve 4-log bacteria inactivation.

The Theoretical Detention Time (TDT) is given as follows:

$$TDT=V/Q$$

Where:
TDT=Theoretical Detention Time (min)
V= minimum volume of chlorinate contact system (L)
Q=peak flow rate (L/min)

Actual detention time (T) is determined by correcting for the impact of potential bypass by the use of a baffling factor (BF) as follows:

$$T=TDT \times BF$$

Where:
T=time that water is contact with chlorine (min)
BF=baffling factor (usually between 0.1 – 1.0)

The design for NEV uses a long length of pipe to achieve the chlorine contact time. The *Guidelines for validating treatment processes for pathogen removal* (DH, 2013) allow the assumption that contact time (T) is equal to theoretical contact time (TDT) provided the length to diameter ratio is ≥40 (section 8.1.3, DH, 2013). That is, baffling factor (BF) equals one. This is the assumption used for NEV.

Using a minimum pipe length (L) of **24 m** at a diameter (d) of **289 mm** (L/d = 83 which is greater than the minimum of 40) the calculated detention time for the NEV plant is determined as follows:

Volume (V) $= \pi * (289/2/1000)^2 * 24$
$= 1.574\ m^3$
Max. Flow (Q) $= 3.0\ m^3/h$ (peak design flow)
$= 0.05\ m^3/min$

TDT $= V/Q$
$= 1.574/0.05$
$= 31$ min

A concentration of **0.75 mg/L** of free chlorine at the end of chlorine contact is set as the minimum, which gives a minimum residence of 29 minutes for C-T of 22 mg·min/L. This is less than the actual residence time provided of 31 minutes, so meets the C-T requirement.

7. Operational monitoring and process control

The following Quality Control Points (QCP) and Critical Control Points (CCP) were determined in a risk workshop (appendix 5).

The QCP and CCP points and responses are outlined below:

Influent buffer tank	MBR	UV	Chlorine Contact	Storage tank
QCP 1	CCP 1 & QCP2	CCP 2	CCP 3 & CCP 4	

An independent third party oversight and review of the validation process, and the CCP's is required prior to recycled water being supplied to the site. This will be conducted post-commissioning and written confirmation of compliance appended to this report.

7.1 Monitoring and corrective actions

QCP1	**Influent pH**
Alert	pH ≤ 4.0; pH ≥ 9.5
Critical	-
What	Influent pH
How	Sensor
When	Continuous, Online
Where	Buffer Tank
Who	Aquacell/Automatic
Corrective Actions	

What	Valve AV-01
How	Close
When	Immediate
Where	Prescreen discharge
Who	Aquacell/Automatic

Influent pH:
The pH meter is located in the buffer tank. If the pH is out of range the plant does not feed and raises an operator alarm. This provides opportunity for the operator to investigate the cause and take appropriate action. This might include manual pH adjustment in the buffer tank, or processing at a reduced flow.

CCP1	MBR Membranes
Critical limits/Alert limits	
Alert	0.2 NTU
Critical	0.5 NTU
Monitoring procedures	
What	Turbidity
How	Sensor
When	Continuous, Online
Where	Filtrate line
Who	Aquacell/Automatic
Corrective actions	
What	MOS recirculation mode
How	Open recirc. valve
When	Immediately if turbidity exceeds 0.5 NTU
Where	Filtrate line
Who	Aquacell/Automatic

Turbidity:

If the turbidity exceeds the critical level of 0.5 NTU the filtrate flow is diverted from treated water to recirculation back to the bioreactor. If after 30 minutes the filtrate turbidity is still > 0.5 NTU, the MBR will go to standby and a "shutdown on high turbidity" alarm will be generated.

Production resumes when the operator resets the turbidity alarm after the cause has been identified and addressed.

QCP2	Bioreactor Dissolved oxygen (QCP 2)
Critical limits/Alert limits	
Alert	< 0.5 mg/l; > 10 mg/l
Critical	
Monitoring procedures	
What	MBR DO
How	Sensor
When	Continuous, Online
Where	Biological tank
Who	Aquacell/Automatic
Corrective actions	
What	DO alarm
How	Send to operator
When	Immediate
Where	SCADA
Who	Aquacell/Automatic

Dissolved Oxygen:
If the dissolved oxygen level in the biology tank is out of range, an alarm is raised to warn the operator.

CCP2	UV disinfection				
	UV RED	UVT	Lamp age	Lamp status	Water flow
Critical limits/Alert limits					
Alert	55.2 mJ/cm^2	65%	11,000 hours		> 48 L/min
Critical	52.6 mJ/cm^2	60%	12,000 hours	Lamp Fail	> 50 L/min
Monitoring procedures					
What	UV Controller	UVT Monitor	Hour monitor	Lamp monitor	flowmeter
How	UVI Sensor, Flow, UVT	UVT sensor	PLC record and UV unit control module	UV Controller	PLC
When	Continuous, Online	Continuous	Continuous, Online	Continuous	Continuous, online
Where	UV Controller	UV unit	UV Controller and PLC	UV Controller output	Before UV
Who	PLC/ Automatic	PLC/ Automatic	PLC/ Automatic	PLC/ Automatic	PLC/ Automatic
Corrective actions					
What	Treated water is sent to dam				
How	Dump Valve				
When	Immediate				
Where	UV Control module and PLC				
Who	PLC/Automatic				

UV dose

The applied UV RED is calculated in accordance with equation 6.1 using the measured flow, UVI and UVT. This is calculated within the UV controller and output as RED to the plant control PLC.

If the UV dose drops below the alert level an alarm is triggered to warn the operator that the UV system is approaching low UV dose limit. The operator can then check unit operation and rectify before UV dose reaches critical level. If critical level is exceeded the UV unit diverts treated water production to the storage dam for irrigation disposal. Return to production requires the UV fault to be rectified for at least 30 minutes. This happens automatically as part of the UV system restart sequence.

UVT

The UVT is continuously monitored and used to determine the applied UV dose from equation 6.1. If the UVT is below the critical level, then an alarm is raised and the unit diverts treated water to sewer. If the UVT exceeds the maximum validated UVT (99%) then the calculated UV dose will use the maximum validated UVT to determine the applied UV dose.

Lamp Status:

Lamp status is monitored continuously by the UV control module. If a lamp failure is detected an alarm output is sent to the PLC and production of treated water to storage is stopped immediately by diverting treated water to sewer. Return to production requires the UV fault to be rectified and diversion of water post chlorine contact for at least 30 minutes. This happens automatically as part of the UV system restart sequence.

Water Flow:
The UV unit has been validated for a flowrate of 50 L/min. The flowrate is controlled by a variable speed drive and the flow is monitored by an inline flow meter to ensure the flow is controlled at the setpoint at all times. However, if the maximum flow is exceeded an alarm is raised and the flow is diverted to sewer until the cause can be identified and corrected.

If flow falls below the minimum flow, then the calculated dose will assume the minimum flow for the purposes of determining the applied dose from the dose equation.

If the flow is outside the alert range an alarm is generated (UV high flow).

Impact of measurement time delay
Delays between the point of measurement and the control system response could occur due to signal transmission time delays, PLC delays including noise filtering on alarms, output response delays and valve opening and closing time. In total this has been calculated as 17 seconds. The system is designed such that the UV system is directly ahead of the chlorine contact system. The recirculation valves to return out of specification water back to the UV break tank are downstream of the chlorine contact system. Therefore, if a UV fault is detected that requires the UV to shutdown, the comparatively long residence time in the chlorine contact systems ensures that no untreated water will be sent to storage.

There is a time delay in starting up the UV in which partially treated water passes through the UV to the chlorine contact tank. Transfer of treated water to storage will be delayed by the PLC following UV start up by an amount of time calculated to be equal to the detention time in the chlorine system at the set flow.

CCP3, 4	Free chlorine disinfection			
	Residual free chlorine (3)	Water pH (4)	Water temperature (3&4)	Water flow (as for CCP2)(3&4)
Critical limits/Alert limits				
Alert	≥ 4.5 mg/L; ≤ 1.0 mg /L	pH ≥ 8.3; pH ≤ 6.3	≤ 12°C	
Critical	≥ 5.0 mg/L; ≤ 0.75 mg /L	pH ≥ 8.5; pH ≤ 6.0	≤ 10°C	
Monitoring procedures				
What	Free Residual Chlorine (FRC)	pH	Temperature	
How	Sensor	Probe	Thermocouple	
When	Continuous, Online	Continuous, Online	Continuous, Online	
Where	At the end of the chlorine contact pipe	At the end of the chlorine contact pipe	At the end of the chlorine contact pipe	
Who	PLC/Automatic	PLC/Automatic	PLC/Automatic	
Corrective actions				
What	Treated water is discharged to sewer	Treated water is discharged to sewer	Treated water is discharged to sewer	
How	Dump Valve	Dump Valve	Dump Valve	
When	Immediate	Immediate	Immediate	
Where	After chlorine contact system	After chlorine contact system	After chlorine contact system	
Who	PLC/Automatic	PLC/Automatic	PLC/Automatic	

Residual Free Chlorine:
If the free residual chlorine level drops below the critical level of 0.75 mg/L or rises above the maximum level of 5.0 mg/L then the treated water is diverted to sewer until the chlorine residual is between 0.75 and 5.0 mg/L. An alarm is raised to make the operator aware that delivery of treated water has ceased due to chlorine residual out of range.

The chlorine residual at distant points in the distribution system will be checked periodically as per the recommendations of the risk assessment (Appendix 5; 6-Distribution and Storage Tanks). Based on the results the chlorine residual target range will be adjusted to ensure a residual is present in the network to control biofilm growth. If there are excessive chlorine levels for irrigation, the plant target free chlorine range can be lowered, providing it remains above the critical level.

Treated Water pH:
If the pH of the treated water measured at the outlet of the chlorine contact pipe drops below the critical level of 6.0 or rises above the maximum level of 8.5 then the treated water is diverted to sewer until the pH is between 6.0 and 8.5. An alarm is raised to make the operator aware that delivery of treated water has ceased due to pH out of range.

Water Temperature:
The chlorine contact system has been designed based on a minimum temperature of 10°C. It is important to ensure that chlorine contact occurs above this temperature so as to ensure effective inactivation of pathogens.

If the temperature of the treated water measured at the outlet of the chlorine contact pipe drops below the critical level of 10°C the treated water is diverted to the dam until the temperature is above 10°C. An alarm is raised to make the operator aware that delivery of treated water has ceased due to temperature out of range.

Water Flow:
The chlorine contact system has been designed based on a maximum flow of 50 L/min. It is important to ensure that the treated water flow remains below this figure so as to ensure effective inactivation of pathogens. The flow is continuously monitored by the PLC. The limits for the chlorine contact system are the same as for the UV as both unit operations are installed in series and the UV system is designed with the same maximum flow.

Impact of measurement time delay
Delays between the point of measurement and the control system response could occur due to signal transmission time delays, PLC delays including noise filtering on alarms, output response delays and valve opening and closing time. This has been calculated as 17 seconds. The design provides for an additional 6 meters of pipework from the measurement point to the diversion valve which provides the required delay for the valve to divert the flow before any non-compliant water is discharged.

7.2 Standard operating procedures

An operations and maintenance manual will be supplied with the system to explain detailed operation. This includes a description of the QCP/CCP's and required operator actions.

A summary of the QCP and CCP's in provided in table 7.1 along with the control response and operator actions. Further details are provided in the operating and maintenance manual.

Table 7.1 – QCP and CCP summary of control system response and operator action

QCP/CCP	Control System Response	Operator Actions
QCP1 – Feed pH outside range	Stops flow to biology until pH is within range.	The most likely cause is poor mixing in the feed tank (septic conditions). The operator should contact Aquacell and confirm mixer operation. If there is no mixer operational faults, consider increasing mixing time to increase DO levels. Chemical contamination is another possible cause. Manual pH correction by addition of acid or caustic may be required.
CCP1 – MBR turbidity	The MBR atomically monitors turbidity and will shutdown after a controlled period of recirculation with no improvement.	The operator should contact Aquacell for a detailed investigation. The most likely causes are membrane system leaks (seals or membrane integrity), faulty turbidity readings (due to air bubbles), or biogrowth shedding from pipework.
QCP2 – Bioreactor DO	Control system stops filtering if DO is out of range. Raises alarm.	Efficient operation of the bioreactor relies on correct DO. If this is outside the normal range the operator should investigate and correct the cause. The may be a leaking or failed air line, diffuser, or pipework. The DO probe may not be functioning correctly and need calibration or replacement.
CCP2 UV RED	This includes monitoring of UVI, UVT, flow, lamp status and lamp hours. The plant diverts water to sewer if the UV conditions are not all met.	The relevant parameters that affect UV dose are individually monitored and alarmed to guide the operator response.
CCP3 and CCP4 Chlorine Dosing	Chlorination pH, chlorine residual, and temperature are monitored continuously. The PLC diverts to sewer if the treated water does not meet control limits.	Chlorine residual could be affected by changes in chlorine demand, or flows. Establish stable flows and adjust chlorine dose rate as required. pH outside limits could be due to poor biological conditions or changes in feedwater quality. Contact Aquacell for investigation.

8. Verification and ongoing monitoring

To provide evidence that the overall system is capable of delivering water of the specified quality, the following verification monitoring plan is proposed. The period of sampling is for 6 weeks.

Table 8a: Verification Monitoring

Influent

Parameter	Units	Frequency	Influent Compliance Value
E. coli	cfu/100mL	Weekly	NA
BOD	mg/L	Weekly	NA
Coliphages	pfu/100mL	Fortnightly	NA
Clostridia	cfu/100mL	Fortnightly	NA

Effluent

Parameter	Units	Frequency	Effluent Compliance Value
E. coli	cfu/100mL	2 times/week	< 1
BOD	mg/L	2 times/week	< 10
SS	mg/L	2 times/week	< 5
pH	NA	Continuous online	6.0 – 9.0
Turbidity	NTU	Continuous online	<2 (95%ile) & 5 (maximum)
UVI	mJ/cm^2	Continuous online	> 65
Residual Chlorine	mg/L	Continuous online	1.0 – 5.0
Coliphage	pfu/100mL	2 times/week	< 1
Clostridia	cfu/100mL	2 times/week	< 1

To provide evidence that the overall system is capable of delivering water of the specified quality on an on-going basis, the following monitoring plan is proposed.

Table 8b: On-going recycled water monitoring

Parameter	Effluent Target	Effluent monitoring frequency
E. coli	< 1cfu/100ml	Weekly

9. Prerequisite programs

For the effective operation of this RWQMP, prerequisite programs that outline detailed procedures and protocols will be provided.

Operations and Maintenance procedures:
An operations and maintenance manual will be drafted for the scheme. Included in the manual are the Standard Operating Procedures, Maintenance Procedures, Calibration Procedures and Chemical Safety Procedures.

Calibration of monitoring instruments:
The calibration of all on-line monitoring instruments will be checked at monthly intervals as part of the monthly servicing of the plant. The calibration of each instrument is logged and maintained on a standard maintenance record.

Organisational quality management:
Aquacell has developed an in-house management system, IMS (Integrated Management System), which is based upon but not certified to ISO9001. This system documents Aquacell's regulatory, risk and organisational procedures and protocols.

Inspections:
The plant is under continuous remote supervision by Aquacell as the contracted operator. Data logging of key parameters is a part of this supervision. Weekly inspections will be conducted by NEV appointed and Aquacell trained individuals. The responsibilities will be clearly delineated in the service agreement. Also in accordance with the service agreement, monthly maintenance including instrument calibration checks are carried out by Aquacell and records maintained. Six-monthly servicing is carried out by Aquacell and records maintained.

10. Incidents and emergencies

NEV and Aquacell maintain a community contact and FAQ section on their websites with procedures relating to the management of emergencies. This will be updated to include the NEV water scheme.

Table 10.1: Incidents and emergencies

Hazards and events that may lead to emergencies	Immediate Response		Corrective Action		Authorities	
	What	Who	What	Who	What	Who
Non-conformance of water with critical limits	If detected by online instrument, plant automatically shuts off supply to treated water storage.	Aquacell	Aquacell diagnose and rectify.	Aquacell	Has non-compliant water been delivered? If yes, Aquacell notify NSW Health and NEV.	Aquacell
Monitoring results outside targets set in Table 8b.	If there are any occurrences of positive results for the ongoing water quality monitoring as described in table 8b, supply of recycled water should be stopped, and the cause investigated. Aquacell to notify NSW Health and Aegis. Aegis to immediately notify the Victorian Department of Health.	Aquacell	Aquacell to investigate cause and rectify.	Aquacell	Aquacell notify NSW Health and NEV.	Aquacell.
Accidents that increase level of contamination in source water	Collection tank continuously monitored for pH. Feed pump disabled when pH outside limits.	Aquacell	Pause production and wait for operator rectification. Production resumed once pH returns to specification.	Aquacell	NA	
Cross-connections	If a cross connection is detected, immediately stop use of treated water, and switch to potable water backup.	NEV	Conduct audit to identify location of cross-connection. Rectify. Preventative measures include signage, labelling, colour-coding, information brochures for plumbers and public. Do not reinstate delivery of treated water until cross connect audit has been completed.	NEV	Should a cross-connection be identified, notify NSW Health and NEV.	NEV
Prolonged power outages	Plant shuts down in a safe state on power failure. Notify Aquacell so that restart procedures and checks can be made and the plant monitored during startup. Potable water backup will provide water needs automatically.	Aquacell	Remote operator log-in. Restart operation on return of power.	Aquacell	NA	
Leakage, spillage, or runoff of recycled water or sewage on site.	For minor contained spills, NEV to respond. Notify Aquacell for repair If treatment plant is responsible.	NEV	Aquacell to action if treatment plant is responsible. Incident report to be prepared and corrective actions implemented	Aquacell	If major spill that contaminates or potentially contaminates the environment also contact EPA.	NEV

11. Employee awareness and training

Both NEV and Aquacell are individually responsible for ensuring its employees and contractors are familiar with the operation of the scheme and aware of the potential consequences of system failures, and of how their decisions can affect the safety of the scheme.

Aquacell will provide an experienced water recycling engineer to monitor the plant. Any staff used on site must be accredited, qualified and have the appropriate level of training.

A site induction will be required for anyone doing work related to this scheme. This will be carried out and recorded by Aquacell, or by those appointed and trained by Aquacell for this purpiose. For plant work this includes familiarization with Aquacell's Safe Work Method Statements (SWMS's) which are site specific. Aquacell maintains a partnership with several contractors to ensure continuity of knowledge and technical expertise.

Aquacell has an induction program for new employees and written procedures for all areas of responsibility (IMS document HR120).

Training needs for Aquacell employees are identified and adequate resources made available during the induction phase. Annual performance reviews identify additional training requirements and set performance targets. Training records are kept.

12. Documentation and reporting

12.1 Documentation

The following records and documents will be maintained by Aquacell as the blackwater recycling plant operator.

- Verification and on-going monitoring results
- CCP monitoring results and analysis
- Plant operation data
- Laboratory testing results and analysis
- Breaches of critical limits and corrective actions taken
- Incidents and emergencies and corrective actions taken
- Inspection and maintenance activities relevant to water quality

CCP results and operation data will be collected by online data acquisition system and kept as electronic copy by the plant operator Aquacell.

Verification results will be collected by Aquacell from a NATA accredited testing laboratory and stored electronically.

A record of any maintenance to the treatment plant will be kept in the plant log book. Any equipment adjusted, repaired, replaced or calibrated will be recorded. Monthly maintenance checks and calibrations are recorded on a monthly maintenance checklist (See Operations and Maintenance Manual).

12.2 Reporting

There will be a monthly report provided to NEV in relation to the operation and maintenance of the blackwater recycling plant by Aquacell.

An annual compliance report will be prepared and submitted to IPART certifying that the licensee has complied with its licence obligations.

12.3 Notifications

Aquacell, as the licence holder will, as soon as practical and within 48 hours, notify NSW Department of Health and IPART should any of the following incidents occur:

- a system failure that may potentially impact on the end users of the recycled water,
- an emergency or an incident that potentially places public health a risk,
- any changes to the RWQMP or operation of the treatment process that may potentially impact on achieving the required microbial criteria.

Notification should include details of corrective and future preventive action.

Contact details for various key entities in the project are listed in the table below.

Entity	**Contact**	**Details**
NSW Health	Environmental health unit	[to be advised]
EPA NSW	[to be advised]	[to be advised]
NEV Co-op	John Talbott, CEO	[to be advised]
Aquacell	Warren Johnson, Technical Manager	Address: 64 Alexander Street, Crows Nest, NSW, 2065 Phone: 02 4721 0545 Mobile: 0428 529 181 Email: warrenj@aquacell.com.au

13. Auditing

The frequency for ongoing audits will be determined by IPART using a risk based approach, but will occur at least every 5-years.

14. Review and improvement

The RWQMP is reviewed and updated annually.

Where improvements to the plant or revisions to operation of the plant are identified, such improvements shall only be implemented with the endorsement of IPART if the improvements or revisions involve altering public health and environment protection measures such as CCPs, corrective actions, relevant monitoring and inspection programs.

15. Commissioning the RWQMP

All operational monitoring, critical alarms and corrective actions within the RWQMP will be tested and verified as part of commissioning.

16. Plumbing

The Building plumbing and drainage system has been designed in accordance with the Water Supply Code of Australia and in accordance with AS/NZS 3500:200.

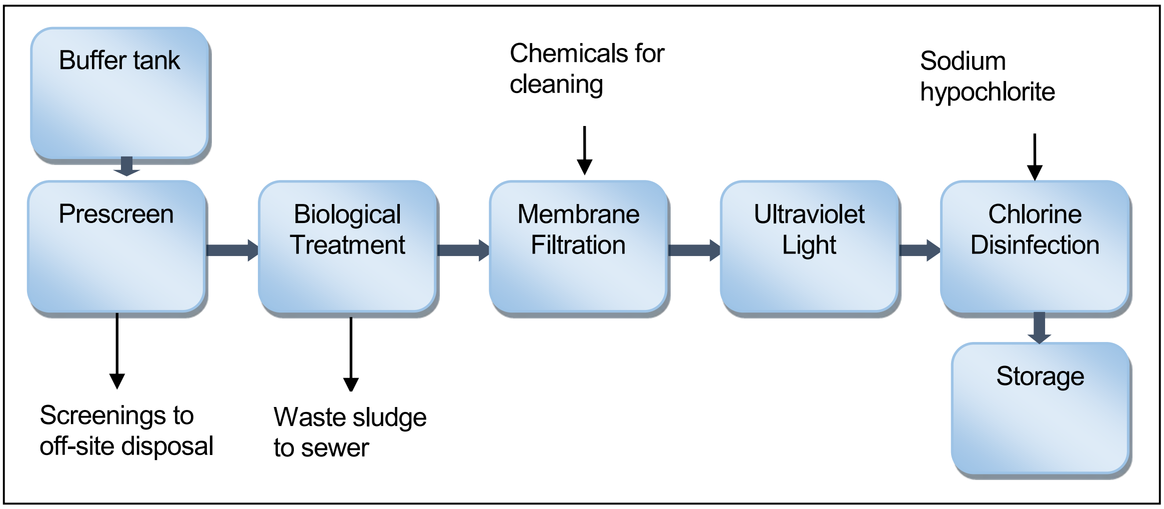
References

1. AWW Research Foundation, *Inactivation of Pathogens with Innovative UV Technologies*, 2004
2. EPA Victoria. 2005. *Guidelines for environmental management: dual pipe water recycling schemes – health and environmental risk management*, publication 1015: State Government of Victoria, Melbourne.
3. Department of Health, Victoria. 2013. *Guidelines for validating treatment processes for pathogen reduction – Supporting Class A recycled water schemes in Victoria*: State Government of Victoria, Melbourne.
4. NRMMC et al . 2006. *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 1)*: Environmental Protection and Heritage Council, the National Resource Management Ministerial Council and the Australian Health Ministers' Conference.
5. Pettigrew, L., Angles, M., Nelson, N. *Pathogen Removal by a Membrane Bioreactor*. Wastewater Treatment, September 2010.
6. USEPA, Membrane Filtration Guidance Manual
7. ASTM D6908-03

Appendices

Appendix 1 General Arrangement Aquacell (pending)

Appendix 2 Simplified Process Flow Diagram



Appendix 3	HAZOP Aquacell (pending)
Appendix 4	Environmental Risk Assessment HACCP (pending)
Appendix 5	Service Checklist Version 1.2 (pending)
Appendix 6	Plumbing Audit (cross connection Audit) (pending)
Appendix 7	Pathogen Removal by Integral and Compromised Siemens Memcor MBR Systems (confidential)
Appendix 8	Validation of Memcor B40N MBR Modules for Protozoa and Bacteria Removal (confidential)
Appendix 9	Pathogen Monitoring of MBR Systems using On-line Turbidity (confidential)